Texas Nutrient Criteria Development Support Project

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Executive Summary

Eutrophication or nutrient enrichment is one of the leading causes of surface water quality impairment in the United States. Eutrophication is a process by which productivity of a water body, as measured by algal biomass, increases as a result of increasing nutrient inputs. These inputs can be due to natural processes but in recent decades they have been greatly supplemented by various human related activities. Cultural eutrophication, or nutrient overenrichment, is the elevated accumulation of algae that is caused by human activities including increased discharges or runoff amounts of nutrients. A variety of impacts may result, including nuisance and toxic algal blooms, depleted dissolved oxygen, and loss of submerged aquatic vegetation (SAV) and benthic fauna. Defining the levels of nutrients that reduce the likelihood of negative impacts is an integral part of development of protective water quality standards.

The adoption of numeric nutrient criteria in state water quality standards for the protection of water quality is currently a high priority for the United States Environmental Protection Agency (EPA). The EPA has mandated that all states develop and adopt numerical criteria for nutrients in all waterbody types including reservoirs, rivers, streams, estuaries, and tidal rivers and streams. The Texas Commission on Environmental Quality (TCEQ) has historically, like most other states, maintained narrative nutrient standards for all waterbody types. The TCEQ has also recently adopted numeric criteria for selected reservoirs, which are being reviewed by the EPA. The next step for the TCEQ is to develop and adopt numeric nutrient criteria for rivers, streams, and estuaries. In this effort, the TCEQ is investigating the types of approaches used by other states as well as the quality and quantity of data available to support these methods. This information would provide helpful insight into approaches that will best suit the available data and guide the gathering of future data. The results of this project provide much of this information needed to complete such an effort.

A comprehensive compilation and review of past and recent water quality data and literature was conducted using existing federal and state water quality databases, interviews with state and federal officials, and a review of online literature using retrieval services available through the University of Houston Clear Lake (UHCL) Alfred R. Neumann Library and popular academic search engines such as Google Scholar. The UHCL library is a full service facility that utilizes and participates in all the major academic bibliographic database services. Document retrieval and duplication services were provided in part by the library. In addition, the EPA online nutrient criteria support web site, NSTEPS was used to compile extensive information on the status of current and planned nutrient criteria for each state. In addition, the EPA and individual state water quality standards web sites were used to identify additional sources of nutrient data and historical information on the status of nutrient water quality criteria. We also obtained data from individual staff employed with various EPA regions and state who are listed in the acknowledgment section of this document.

Candidate water quality data compiled for potential future analyses was obtained from multiple online electronic data available from various data sources including the Texas Water Development Board (TWDB), TCEQ, United States Geological Service (USGS), EPA STORET, National Coastal Condition Assessment, National Lakes Assessment and National Rivers and Streams Assessment. Only sources containing significant amounts of nutrient data including nitrogen (nitrates, nitrites, ammonia nitrogen, total Kjedahl nitrogen (TKN) and total nitrogen), phosphorus (total, reactive (TRP) or orthophosphate, OP), and chlorophyll-a were compiled. Additional variables of interest that may explain patterns in the response and relationships of these variables that were also compiled include streamflow, salinity or conductivity, water temperature, suspended solids (TSS), and turbidity (nephelometric measurements and secchi disk depth). We also reviewed and compiled data organized by U.S. Fish and Wildlife Service (FWS), and University of Texas researchers engaged in past compilations of water quality data for Coastal Bend Bays and Estuaries Program (CBBEP) and Galveston Bay Estuary Program (GBEP). These electronic retrievals were supplemented by additional data and reports obtained through a literature review and direct contact with representatives of the TWDB, TCEQ, USGS, CBBEP, FWS, and University of Texas researchers engaged in past compilations of water quality data for CCBEP and GBEP.

In addition to environmental data compiled for this project we also compiled recent information on current and proposed state numeric nutrient criteria, including nutrient criteria development plans, and recent technical approaches used by various states. A summary and discussion of recent technical studies, available NNC planning documents, and/or recently passed standards containing NNC criteria are included for all states and some territories. In addition, copies of the federal and state planning documents and technical support documents and studies are included in the electronic resource directories created for this project. Peer reviewed journal articles and technical reports dealing with the subject of numeric nutrient criteria development are also included. All of these documents are provided in either PDF or Word format.

The TCEQ database is by far the most comprehensive data set of nutrient data and related parameters located within the state. Other complimentary sets include data collected by the intense monitoring conducted by the TWDB during the 1960’s through 1980’s which was focused on the bays and estuaries and associated with freshwater flow studies. There are however potential limitations in the data compiled from these monitoring programs and past research projects. These potential limitations include 1) lack of consistent and extensive periphyton monitoring in streams and phytoplankton monitoring in estuaries, 2) limited number of total nitrogen measurements and 3) even a less number of paired nutrient (total nitrogen TN and/or total phosphorus TP) and chlorophyll-a samples. In addition, in many cases key parameters such total phosphorus, were reported at less than detection limits.

After a careful review of each states ongoing NNC development program and existing adopted and/or EPA approved or promulgated we can conclude the following. Most states had similar although widely varying in content Nutrient Criteria Development Plan strategies. That is common steps included 1) compilation and review of data, 2) preliminary review of EPA provided ecoregion derived draft NNC for freshwater systems, 3) establishing a priority that focused on development of NNC for lakes/reservoirs first and then streams or rivers next followed by estuaries if applicable or wetlands if land-locked. However, this was not the pattern followed by all states.

The majority of states first attempted to utilize an ecoregion reference condition approach. However, most states recognized the limitation of this method and the need to use more quantitative stressor-response modeling approaches. Very few states or territories used "off the shelf" values provided by EPA in their Ecoregion Nutrient guidance documents and chose to regionalize their approach based on more specific data collected by the state or other agencies (e.g. USGS). They made this decision in most cases because they felt the EPA ecoregion were too spatially coarse and they found that their monitoring data provided better more representative spatial coverage to build their database upon. They also found if they used the EPA ecoregion values they would often classify waterbodies containing little or no anthropogenic sources of stress as being impaired due to "high" values of TP or TN, even though the biological community or "response" variable like chlorophyll-*a* seems to be supporting aquatic life uses.

When possible most states preferred the use of stressor response or causal and effect models based on their own ambient data because they felt that a clear demonstration of cause and effect is much more effective in convincing the public and regulated community that the proposed NNC are reasonable. In addition the use of such representative values could be used to successfully manage and control sources of eutrophication. This also allows investigators and managers to more easily describe the problem causing a reduction in the designated uses of an area or loss of fishing and/or associated human recreational uses. Unfortunately many states lacked sufficient numbers of observations containing paired variables (e.g. chlorophyll-*a* versus nutrients). This limits the ability of these states to use this approach.

Based on our review many states utilized a "weight of evidence approach", utilizing reference condition/ecoregion based approach using state specific data from finer resolution ecoregion level 3 and 4. The "weight of evidence" approach which was often used included a combination of methods which included ecoregion based statistically derived values, stressor-response modeling using paired nutrient values and response variables, usually chlorophyll-*a* (open water or periphyton based) and subsequent development of thresholds using linear regression, quantile regression, breakpoint analysis and in some cases shifts in community composition. In the case of Florida, new consideration for downstream standards was also emphasized in the case of new stream standards that impact streams that eventually flow into lakes or estuaries. Consequently new stream standards may have to be protective of downstream streams that flow into lakes or estuaries.

Although extensive subsequent analyses will be needed several suggestions and observations can be made at this time.

1. Texas like many states lacks a long-term comprehensive database of paired measurements of periphyton biomass and chlorophyll-*a* along with TN and TP, for streams and smaller rivers. This will make it difficult to develop stressor response based NNC for these systems. Additional supplement monitoring and/or special studies may be needed. However, very little data or research has been conducted on larger rivers.
2. EPA in their guidance documents has indicated that the preferred nutrient forms for analysis are TN and TP. Texas has historically not measured TN directly. In addition, the lack of large scale measurements of this parameter or at least TKN and combined NO_x will limit the ability to use TN as a causative variable in statistical ecoregion based NNC methods. It may be possible however to relationships between NO_x and/or TIN (NO_x + NH_3-N) and chlorophyll-*a* for larger rivers and/or estuaries and tidal streams. Also, there is some historical data collected by other agencies which might be useful in constructing historical baseline conditions if the quality of these data is acceptable.
3. For coastal systems, many states utilized an approach that attempted to relate designated uses (e.g. support of fisheries) with existing or past water quality. Texas does possess long-term fisheries database collected by Texas Parks and Wildlife Department, and may want to explore this option as well.

Texas will be challenged in developing standards for freshwater streams and estuaries due to the complex biogeography of our state, which is influenced by natural gradients in climate, rainfall and streamflow. This complexity is illustrated by the hypersaline Laguna Madre containing marine seagrasses to small first order acidic streams in east Texas. For example, development of NNC for estuaries might focus on protection of seagrasses and other designated uses from excessive periphyton growth or phytoplankton shading. In contrast stream systems might require NNC that prevent excessive nuisance periphyton growth. Larger rivers in contrast may require NNC that protect against excessive phytoplankton growth. Each of the unique designated uses of these waterbodies will need to be addressed individually. Therefore a combination of data and analytical tools will likely be needed to develop numeric nutrient criteria. The data contained in the provided databases that were produced and the associated technical and regulatory literature should provide TCEQ with important additional tools and information to complete this task.

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List of Acronyms and Technical Terms

ADEC - Alaska Department of Environmental Conservation

ADEM - Alabama Department of Environmental Management

ADEQ - Arkansas Department of Environmental Quality

Alpha - α- probability of committing a Type I error – probability of rejecting (stating it is false) a null hypothesis (usually status quo), when it is actually true (a “false positive”).

AZDEQ - Arizona Department of Environmental Quality

Beta – β – probability of committing a Type II error - probability of not rejecting a null hypothesis system, when in fact is false (a “false negative”).

BPJ - best professional judgment

CCBBEP - Coastal Bend Bays and Estuaries Program

CDPHE - Colorado Department of Public Health and Environment

Chl-A - Chlorophyll-*a*, chlorophyll-a, chlorophyll a

Chl_{RS}-a - satellite-derived chlorophyll-*a* (a term used in EPA guidance for Florida estuarine nutrient criteria technical guidance document)

cm – centimeter

Compensation Depth or Compensation Point for Photosynthetic Activity – typically defined as the depth at which one percent of the light intensity at the surface remains unabsorbed. The light intensities at the surface and subsurface are measured simultaneously by PAR meter and paired. Equivalent to point that photosynthesis = respiration.

CRP - Clean Rivers Program

CSWRCB - California State Water Resource Control Board

CTDEP – Connecticut Department of Environmental Protection

CWA – Clean Water Act

D - Prefix when placed in front of reported analyte refers to dissolved fraction.

List of Acronyms and Technical Terms Continued

DIN – dissolved inorganic nitrogen = dissolved NH $NO_{2\&3}$ - N   Nitrate and Nitrite as nitrogen

DNREC – Delaware Department of Natural Resource and Environmental Control

DO – dissolved oxygen

DON – dissolved organic nitrogen

EIH - Environmental Institute of Houston

EMAP = Environmental Monitoring and Assessment Program

EPA - United States Environmental Protection Agency

FDEP - The Florida Department of Environmental Protection

GBEP - Galveston Bay Estuary Program

GOMA - Gulf of Mexico Alliance

HAB - Harmful algal blooms

halocline - a steep salinity gradient in an estuary caused by differences in salinity between the bottom and surface layers of water that limits mixing of the two layers (see thermocline and pycnocline).

HGAC - Houston Galveston Area Council

IN – inorganic nitrogen = NH_3-N (ammonia as nitrogen) + NO_2+NO_3 - N   (nitrate plus nitrite as nitrogen)

M - molarity

meq/l – milliequivalents per liter (sometimes written as me/l)

mg/l – milligram per liter

MMI – multimetric index

mw - molecular weight

N – Normality = equivalents/L

List of Acronyms and Technical Terms Continued

NARS – National Aquatic Resource Surveys (Lakes, Reservoir, and Streams includes NLA and WSA)

NAWQA - USGS National Water-Quality Assessment Program

NCA – National Coastal Assessment

NCCA – National Coastal Condition Assessment

NHD - The National Hydrography Dataset

NH_3 – N - Ammonia as nitrogen

NLA - National Lakes Assessment

NNC - Numeric Nutrient Criteria

NOAA - National Oceanic Atmospheric Administration

$NO_x = NO_2$ or NO_3 or $NO_2 + NO_3$

NO_2 -N - Nitrite as nitrogen

NO_3 - N - Nitrate as nitrogen

$NO_{2\&3}$ - N = NOx = $NO_2 + NO_3$ - N = Nitrate and Nitrite as nitrogen

N-STEPS or Nutrient STEPS - Nutrient Scientific Technical Exchange Partnership and Support

NTU - Nephelometric turbidity units

NWA – National Wetlands Assessment

NWSA - National Wadeable Streams Assessment

QA - Quality assurance

QC - Quality control

OP – orthophosphates (see soluble reactive phosphorus)

List of Acronyms and Technical Terms Continued

PAR – photosynthetically active radiation (light in wavelength of is the amount of light available for photosynthesis, which is light in the 400 to 700 nanometer wavelength range).

ppb - parts per billion

ppm - parts per million

ppt = parts per thousand (normally used with salinity measurements)

psu – practical salinity units (approximately equal to ppt)

pycnocline - a steep density gradient in a waterbody caused by differences in temperature or salinity between the bottom and surface layers of water that limits mixing of the two layers (see thermocline and halocline).

Redfield Ratio - or Redfield stoichiometry is the molecular ratio of carbon, nitrogen and phosphorus in phytoplankton or algae. The stoichiometric ratio is C:N:P = 106:16:1 when nutrients are not limiting. In limnology/oceanography often just N:P ratio is used; general rule If N:P > 20, P is considered scarce relative to N and potential P limitation; If N:P<10, N is considered scarce and potential N limitation.

Redfield-Brzezinski nutrient ratio for diatoms is C:Si:N:P = 106:15:16:1

REMAP - Regional Environmental Monitoring and Assessment Program

RIDEM – Rhode Island Department of Environmental Management

RIVPACS - River Invertebrate Prediction and Classification System

RTAG - Regional Technical Advisory Groups

RWQBs - California Regional Water Quality Control Boards

SAB – EPA Science Advisory Board

SAV - submerged aquatic vegetation

SD - secchi disk transparency

SMN - Statewide Monitoring Network (predecessor to SWQM)

List of Acronyms and Technical Terms Continued

thermocline - a steep temperature gradient in an waterbody caused by differences in temperature between the bottom and surface layers of water that limits mixing of the two layers (see halocline and pycnocline).

SRP - soluble reactive phosphorus (consists mostly of OP)

STORET - STOrage and RETrieval EPA database for water quality data

SWQM - TCEQ Surface Water Quality Monitoring Program

SWQMIS TCEQ Surface Water Quality Monitoring Information System

TCEQ - Texas Commission on Environmental Quality

TDS – total dissolved solids

TKN - Total Kjedahl Nitrogen = total organic nitrogen (TON) + ammonia nitrogen

TMDL - Total Maximum Daily Load

TN - Total nitrogen = Organic Nitrogen + Inorganic Nitrogen = TKN + remaining total inorganic nitrogen (usually NO_3 and NO_2)

TON – total organic nitrogen

TSI – Carlson Trophic Index or modification thereof

TSS - total suspended solids

TP - total phosphorus

TPWD - Texas Parks and Wildlife Department

TDWR - Texas Department of Water Resources

TWDB – Texas Water Development Board

TWQB - Texas Water Quality Board

Type I error – probability of rejecting (stating it is false) a null hypothesis (usually status quo), when it is actually true (a “false positive”). See alpha 👌

Type II error - probability of not rejecting a null hypothesis system, when in fact is false (a “false negative”). See beta β

List of Acronyms and Technical Terms Continued

μg/L - micrograms per liter, equivalent to ppb under most conditions

UHCL - University of Houston Clear Lake

USCOE - United States Army Corp of Engineers (also COE)

USDA – United States Department of Agriculture

USGS - United States Geological Survey

WSA – Wadeable Streams Assessment

WQS –Water Quality Standards

Units of Measure and Conversions

1) mg/L ÷ M.Wt. = mmol/L (note g/L ÷ M.Wt. = mole/L = M (Molarity))

2) mmol/L ÷ 1000 = mol/L = M

3) mg/L ÷ Eq.Wt. = meq/L

4) meq/L ÷ 1000 = equiv/L = N

5) mg/L * Z. = meq/L

6) mmol/L * Z = equiv/L = N *where Z = valence and other units defined below*

7) Equivalent concentration of element: compound expressed in terms of its equivalent amount of primary element.

8) cm – centimeter = 0.001 meter

9) cubic meter = m^3 = 1000 liters

10) Eq. Wt = Equivalent weight – weight of ion (sum of the atomic weights of the atoms making up an ion) divided by number of charges associated with that ion.

11) L - liter

12) M - molarity = mol/L = moles substance dissolved ÷ liter solvent (usually water)

13) mmol/L – millimoles per liter

14) moles - gram substance ÷ molecular weight substance

15) meq/l – milliequivalents per liter = 0.001 of an equivalent weight.

16) mg/l milligrams per liter; often used as an equivalent measure to parts per million (ppm) in most waters

17) ml - milliliter

18) mmhos/cm - millimhos per centimeter, equivalent to mS/cm

19) moles - gram substance ÷ molecular weight substance

20) mmoles = mmol = millimoles = 0.001 moles

Units of Measure Continued

21) mS/cm - milliseimens per centimeter, a unit of electrical conductance

22) M.Wt. - molecular weight of compound = mw

23) N – Normality = equiv/L =equivalents/L

24) ppm = parts per million = 1 g solute per 1000 g of solution (normally water) = equivalent to mg/L for most substances

25) ppb = parts per billion

26) salinity (‰) = psu (practical salinity units) = parts of solute per 1000 g of solution (term reserved to describe salt content of marine waters, assuming constant ratio of cations and anions. Constant ratio only down to about to 3 ppt, due to dilution of different ions in freshwater.

27) µg/L - micrograms per liter; equivalent to parts per billion (ppb) for most waters. 1 µg/L = 0.001 mg/L

28) µmhos/cm - micromhos per centimeter, equivalent to mS/1000, measure of conductivity

29) µmol/L = micromole per liter = 0.001 mmol/L

30) µS/cm – microseimens per centimeter, equivalent to mS/1000, measure of conductivity

Introduction

Eutrophication is one of the most important water quality problems in the United States and also one of the most difficult to manage (Bricker et al. 2007; State-EPA Nutrient Innovations Task Group 2009). Part of this problem centers on the incomplete understanding of factors that induce algal blooms. It is well know that eutrophication is a process in which the addition of limiting nutrients (largely nitrogen and phosphorus) to water bodies stimulates algal growth. Excessive nutrient inputs may lead to other more serious problems including harmful algal blooms (HABs), low dissolved oxygen (hypoxia) and loss of submerged aquatic vegetation (SAV) by overgrowth of attached algae. These immediate effects can cause deleterious ecosystem wide changes due to loss of SAV habitat and fish kills in extreme cases(Bricker et al. 2007; Howarth et al. 2000). However, nutrients are also essential to the proper functioning of ecosystems and in the case of estuaries where the major source of nutrient input is freshwater inflows, there is an equivalent effort by scientists who are attempting to define required amounts of nutrients needed to maintain a sound ecosystem .

One of the primary tools recommended by the United States Environmental Protection Agency (EPA) to manage excessive nutrients is numeric nutrient criteria (NNC) (Bricker et al. 2007; State-EPA Nutrient Innovations Task Group 2009). EPA has mandated that all states develop and adopt NNC in all waterbody types (reservoirs, rivers, streams, estuaries, and tidal rivers and streams) and has provided a national strategy to accomplish this goal which was reaffirmed numerous times through 2011 (Grubbs 2001a; Grumbles 2007; Stoner 2011b; United States Environmental Protection Agency 1998). The national nutrient strategy described the approach that EPA would follow in developing nutrient information and working with states to adopt NNC as part of their water quality standards. The strategy resulted in the development of various assessment tools and recognized the current capabilities of states for conducting these assessments at the regional watershed and waterbody levels. The major focus of the strategy was the development of waterbody-type technical guidance documents and ecoregion-specific nutrient criteria . After waterbody-type guidance and candidate nutrient criteria were established, EPA was then supposed to assist states and tribes in adopting numeric nutrient criteria into water quality standards (United States Environmental Protection Agency 2000h; United States Environmental Protection Agency 2001k).

EPA proposed development of State Nutrient Criteria Plans to insure progress is being made toward adoption of State NNC (Grubbs 2001a). EPA proposed that these plans should contains interim milestones including but not limited to data collection, data analysis, criteria proposal, and criteria adoptions consistent with the Clean Water Act. Theoretically this should lead to more streamlined federal approval of proposed criteria since EPA would have been an integral part of the process through its role as technical advisor and reviewer. Many but not all states have developed and revised Nutrient Criteria Development Plans or similar documents. However, progress has been slow and EPA has recently been criticized for not exerting more influence and providing sufficient technical support (United States Environmental Protection Agency 2009a).

The Texas Commission on Environmental Quality (TCEQ) recently adopted numeric nutrient criteria for selected reservoirs throughout the state and is awaiting EPA approval (Texas Commission on Environmental Quality 2010d; Texas Commission on Environmental Quality 2010e).The State of Texas lacks numeric nutrient criteria for waterbodies other than reservoirs. TCEQ does currently consider nutrient controls by 1) applying narrative criteria to address permitted nutrient loadings at sites of concern, 2) developing watershed rules which require nutrient reductions in wastewater discharges in or near specified water bodies, and 3) employing the TCEQ's antidegradation policy to increases in discharge loads of nutrients (Texas Commission on Environmental Quality 2003). The TCEQ also screens phosphorus and nitrate nitrogen and chlorophyll *a* monitoring data as a preliminary indication of areas of possible concern in the Texas Water Quality Inventory under Section 305(b) of the federal Clean Water Act (CWA)(Texas Commission on Environmental Quality 2010b).

The next step for TCEQ is to develop and adopt numerical nutrient criteria for rivers, streams, and estuaries. In this effort, the TCEQ is investigating the types of approaches used by other states as well as the quality and quantity of data available. This information could provide helpful insight into approaches that will best suit the available data and suggest the gathering of future data.

One of the challenges of developing nutrient criteria in any water body is the dual nature of nutrients. Unlike toxic compounds, nutrients are required as essential elements for the normal functioning and growth of plants and other autotrophs. The primary macronutrients that may be limited and can trigger excessive algal growth include nitrogen and phosphorus. However, other essential factors are needed to support plant or algal growth including sufficient light, sufficiently clear water, and in the case of a major group estuarine phytoplankton called diatoms, silica (Bianchi 2007b). The data and information compiled during this project will address many of the information needs listed above. This review will provide TCEQ with the necessary information, tools, and data needed for the important task of numeric nutrient criteria development in lotic and estuarine waterbodies.

Methods

Our project consisted of several major tasks including 1) a compilation and review of historical water quality data in Texas waters, 2) a compilation and review of data obtained from focused monitoring and research studies of nutrients in Texas, 3) a literature review of published data on eutrophication and critical levels associated with detrimental impacts in lotic and estuarine environments, 4) a review of current and proposed federal methods to derive NNC and 5) compilation and review of current and recently proposed state nutrient water quality standards, nutrient criteria plans, and technical support documents and studies from other states and territories of the United States. These reviews focused on the analysis of currently used criteria development methods including related screening and alert levels that have been documented in the scientific literature. These reviews included an evaluation of the method and parameters used by various organizations.

A. Historical Water Quality Data in Texas

Our goal was to compile historical water quality data on targeted variables that may be useful in developing NNC. To accomplish this we contacted the TCEQ Surface Water Quality Monitoring (SWQM) and Water Quality Standards staff to identify candidate water quality variables that have historically used to assess water quality conditions related to nutrient concentrations. In addition, we reviewed various technical reports including EPA numeric nutrient criteria guidance documents, and examined water quality data collected by various state and federal agencies. The primary variables recommended in the literature for NNC development include total nitrogen (TN) (calculated from individual constituents or measured directly), total phosphorus (TP), chlorophyll-*a* (mostly lentic water bodies and/or estuaries), periphyton (streams and rivers), various biological community metrics, transparency/clarity, stream flow, and conductivity/salinity (estuaries)(United States Environmental Protection Agency 2000h; United States Environmental Protection Agency 2000i; United States Environmental Protection Agency 2001k). We however included additional variables monitored by TCEQ and others to assess water quality for potential eutrophic conditions (Texas Commission on Environmental Quality 2010b). Many of these variables have been monitored for many years. It may be possible to develop predictive models or transfer functions between more commonly measured and target variables (Racca et al. 2007). Statistical models could then be used to simulate missing data and test potential relationships with eutrophic indicators.

Examples of candidate variable classes that we attempted to obtain data for are listed in Table 1. The water quality constituents and associated TCEQ parameter codes used during this study are listed in Table 1. The methods used and associated water quality parameter codes may vary between agencies. If provided by the source agency, the laboratory or field methods are listed in the individual databases and included with the database in the same directory. Quality Assurance Project Plans (QAPP) and/or standard operating procedures (SOPS) were obtained and documented when available.

Table 1. List of water quality parameter groups and supporting data for which sources were queried.

Parameter/Variable	TCEQ Method Code	Levels/Methods and Comments	
1) Data Source	NA	Agency or Study, Literature Citation	
2) Physical location a. Name of waterbody b. TCEQ waterbody code	NA	Obtained from TCEQ web page (GIS Layer, TCEQ SWQMIS database)	
c. HUC 10 digit	NA	Obtained from USGS (GIS layer and descriptions)	
3) Type II/II Ecoregion	NA	Obtained from TCEQ web sites (GIS layer and descriptions from EPA web site	
4) TCEQ Station ID		From SWQMIS database	
5) Lat & Longitude		Either calculated from maps (see geospatial data discussion) or provided by agency or publication	
6) River mile/km	NA	Measured from mouth = 0	
7) Date and time (24)	NA		
8) Site description a. waterbody type b. total depth	 a) NA b) 82903	 a) stream, lake, tidal stream, estuary, marine, wetland	
9) Depth of measurement	13850		
10) water temperature	00100		
11) Nitrogen forms TKN NO_{2+3}-N NO_3-N NO_2-N NH_3-N TN calc or measured	 00625 00630 00620 00615 00610 00600	Other nitrogen forms (dissolved or total, chemical form/species and method calculated: measured directly or calculated) documented through parameter codes or verbal description in individual databases or examination of methods used in original articles or documentation.	
12) Phosphorus forms Total phosphorus TP Reactive or Orthophosphate - P	 00665 00671	Other phosphorus forms (dissolved or total, chemical form/species and method calculated: measured directly or calculated) documented through parameter codes or verbal description in individual databases or examination of methods used in original articles or documentation.	
13) Silica (total/diss)	00955/56		
14) chlorophyll-*a* (water) pheophytin in water phytoplankton counts	32211 32218	Spectrophotometric Spectrophotometric	Chl-a measured with spectrophotometer and flourometer (70953). Phytoplankton numbers measured by various methods
15). Periphyton	SM 10300C	Chl- *a*/biomass	1998. Clesceri et al. Standard Methods
16). Dissolved oxygen (DO)	00300		Field
17). Specific conductance, salinity	00094 00480	Field	
18). TSS – total suspended solids	00530		
19). Water clarity/turbidity a. secchi disk/tube b. turbidity (NTU)	 00078 00076		
20). Total alkalinity	00410		
21). pH	00400	Field	
22). Streamflow	00061	Field or gage	
23). Methods lab & field		Chemical analysis/collection method unless described with parameter code	
24) Data quality	QA levels: 3=Agency QAPP program used (EPA, TCEQ, Etc.) 2=QAPP document available, 1=QA described, 0=No documentation provided		
25) Comments	Comment if appropriate (e.g. data collected during a fish kill, red tide or algal bloom);		

We were also originally charged with two additional tasks including 1) evaluating spatial and temporal trends in water quality data and 2) examining potential relationships between stressor (e.g. nutrients) and response variables (e.g. chlorophyll-*a*). However, based on recent discussions and guidance received from TCEQ water quality standards staff we subsequently narrowed our scope to just compiling and evaluating the occurrence of paired data response and causal variables, primarily nutrients (e.g. TN & TP) and chlorophyll-*a*, for evaluation of causal responses. Consequently no in-depth statistical analysis of compiled data was conducted.

An important preliminary step that was needed before data could be used for causal effect analysis was the realignment of the data structure to facilitate future statistical analysis. Most agencies store water quality data in a format which consists of multiple columns (variables) or fields with one field representing the parameter code for individual variables and the second (column) field representing the actual measurement. In some cases there are also a “unit of measurement ” field (e.g. mg/l, μg/L) and other fields representing date, time, location, and depth. The primary task that was needed to prepare data for future analysis needs was to “unstack” the “matched” columns of fields (e.g. parameter code, concentration, and if present “qualifier” and unit fields) and rotate the all data fields, along with associated identifiers into a format which yields rows in the converted spreadsheet or database which represent a single observation consisting of a unique site, date, time, and depth combination along with the results of each variable monitored and reported. An example of this transformation is illustrated below (Figure 1).

Typical Agency Data Structure

Site	Date	Parameter	Units	Value
A	2/.4/09	Temp	C	15
A	2/.4/09	Salinity	psu	2
A	3/9/2009	Temp	C	17
A	3/9/2009	Salinity	psu	9
B	3/10/2009	Tenp	C	18
B	3/10/2009	Salinity	psu	8
B	3/10/2009	Oxygen	mg/l	7
C	7/11/2010	Temp	C	28
C	7/11/2010	pH	su	8

Transformed Data Structure that facilitates regression models

Site	Date	Temp C	Salinity psu	Oxygen mg/l	pH
A	2/.4/09	15	2	*	*
B	3/9/2009	17	9		*
B	3/10/2009	18	8	7	*
C	7/11/2009	28	*	*	8

Figure 1. Typical data transformation applied to raw electronic agency files

Agency Data

The majority of data was obtained from state and federal agency online electronic databases including Surface Water Quality Monitoring Information System (SWQMIS), the United States Geological Survey (USGS) streamflow network, and EPA STORET. Data stored in SWQMIS includes data collected by TCEQ predecessor agencies (Texas Natural Resource Conservation Commission TNRCC; Texas Water Commission TWC; Texas Department of Water Resources TDWR) and recent partner agencies (mainly River Authorities, Houston Galveston Area Council – HGAC, and local governments) who participate in the coordinated monitoring through the Clean Rivers Program (CRP). Monitoring data collected by TCEQ and predecessor agencies and partner organizations have historically been conducted under an agency and EPA approved QAPP. The TCEQ QAPP is listed on their SWQM web site. Field and laboratory methods have historically utilized standard approved water quality analysis procedures approved by EPA and more recently in compliance with the agencies National Environmental Laboratory Accreditation Program (NELAP) (Clesceri et al. 1998; Kopp and McKee 1983a; Texas Commission on Environmental Quality 2008a; Texas Commission on Environmental Quality 2010g).

EPA sponsored monitoring data was obtained from the STORET data center (http://www.epa.gov/storet/dbtop.html). STORET consists of both older legacy data and new data maintained on a new distributed system. "Legacy STORET" is the term used to describe the original (mainframe) STORET database. The STORET Legacy data center is where all data reported to EPA prior to January 1, 1999 is stored. This database cannot be updated and remains static on the EPA's website. The STORET data warehouse (i.e. EPA_STORET modern_database) is an updatable database that contains data provided to the EPA from cooperating federal and state agencies from January 1, 1999 through 2007, which was the most recent data found for the state of Texas. EPA has historically required cooperating agencies who store data in STORET to utilize EPA approved laboratory methods and comply with agency approved QAPP and SOPS (Kopp and McKee 1983b).

EPA has sponsored various probability based regional and national monitoring programs and has made this data available online. This data was collected by the Environmental Monitoring and Assessment Program (EMAP), the Regional Monitoring and Assessment Program (REMAP) and the National Coastal Assessment (NCA) (http://www.epa.gov/emap/html/data/index.html). EMAP data from 1991-1994, R-EMAP studies from 1993-1994, and NCA monitoring from 2000 – 2004 were downloaded from the EMAP web site. Data from the Texas portion of the National Lake Assessment (NLA), and the National Wadeable Streams Survey (NWSS) was also obtained (http://water.epa.gov/type/lakes/lakessurvey_index.cfm , http://water.epa.gov/type/rsl/monitoring/streamsurvey/index.cfm). It was later discovered that data from the regional probability based EPA monitoring programs was also available through the current modern STORET system. Eventually we utilized STORET as our primary resource to maintain comparable data structure. However, it appeared that some of the coastal NCA data was not present on STORET so we also downloaded and retained that data as well. All data downloaded from STORET also provides information on the source of the data, reporting unites and program. Interestingly enough, other than standardized nomenclature STORET does not include the STORET code for each parameter. Instead, the user must download the STORET parameter code table from their web site if you wish to match up the standardized measurement with the appropriate parameter description. As a side note, many of the TCEQ parameter codes actually originated as STORET codes, most likely resulting from the early practice of TCEQ predecessor agencies submitting data to EPA STORET. The NCA, NLA, NWSS, EMAP and REMAP programs all have QAPPs and SOPS which are available on their respective web sites and have been downloaded and included with our database.

Hydrology and water quality data was identified and/or obtained from the USGS National Water Information System: web Interface (http://waterdata.usgs.gov/tx/nwis/nwis) and the National Water Quality Assessment (NAWQA) data warehouse (http://infotrek.er.usgs.gov/apex/f?p=NAWQA:HOME:0). Surface water hydrology and water quality data were obtained from these two USGS data sources. The USGS has standard procedures that have been developed for the analysis of water quality data and hydrological measurements (Gibs et al. 2007a; Gibs et al. 2007b; United States Geological Survey 2006; Wilde 2011a; Wilde 2011b). In addition, many of their methods are based or derived from American Society of Testing and Materials (ASTM) standards. All of their projects and programs require programmatic and project specific QAPPs (http://water.usgs.gov/owq/quality.html).

The Texas Water Development Board (TWDB) provided us with copies of their historical coastal data series (CDS). This data was compiled from the electronic data provided on computer disk (CD) and transcribed from written reports and input into the project Access database that includes data from multiple projects. In addition, estimates of monthly freshwater inflow by estuarine basin were obtained from the TWDB web site (http://midgewater.twdb.state.tx.us/bays_estuaries/hydrologypage.html). Data available through this web page represent fresh water inflows into Texas estuaries. Inflow summaries for the Sabine-Neches Estuary (Sabine Lake), Trinity-San Jacinto Estuary (Galveston Bay), Lavaca-Tres Palacios Estuary (Matagorda Bay), Guadalupe Estuary (San Antonio Bay), Mission- Aransas Estuary (Aransas Bay), and Nueces Estuary (Corpus Christi Bay) are currently available. Monthly and annual flow data beginning in 1941 are provided in these summaries. We downloaded this data and have included this in our comprehensive database. This information may be useful in evaluating numeric nutrient criteria under varying basin hydrology.

Ward and Armstrong Coastal Data Compilations

Dr. George Ward and the Coastal Bends and Bay Estuary Program (CBBEP) assisted us by providing electronic data compiled from his past reviews of water quality data conducted under sponsorship of the Galveston Bay Estuary Program (GBEP) and CBBEP (Ward and Armstrong 1991; Ward and Armstrong 1992a; Ward and Armstrong 1992b; Ward and Armstrong 1997a). These data sets represent comprehensive compilations of the existing data for each watershed for the period preceding mid-1990. We also examined the published documents which describe the data they reviewed and compiled.

University Studies

Additional electronic data from two studies evaluating the influence of freshwater inflow were obtained from Dr. Antonietta Quigg from Texas A&M at Galveston and Dr. Montagna from Texas A&M at Corpus Christi. Dr. Montagna also provided associated published reports based on these data. The focus of Dr. Quigg's study was the influence of freshwater inflow on phytoplankton community structure in Galveston Bay. The data obtained from Dr. Montagna were associated with studies on the influence of freshwater inflow along the lower Texas coast on benthic communities and water quality.

Published Data Sources

We were also asked to conduct a historical review of all nutrient data collected by major studies performed in Texas by other organizations and/or university researchers. To accomplish this task we manually transcribed target water quality variable data from published studies on Texas waterbodies. These reports and journal articles were obtained from internal library holdings, interlibrary loan, internet searches and agency inquiries. Web (e.g. Google scholar) and library searches were done using key words such as nutrients, eutrophication, and algal blooms. This search included published literature and agency publications. In particular we attempted to capture data collected by various agencies and researchers who did not submit their findings to established agency databases. The largest source of published data was the previously mentioned TWDB data set. This data was collected during multiple surveys of coastal estuaries between 1975 to 1989. Although all data and original publications were archived a large proportion of the studies did not contain raw data but instead only summary information. Although useful for illustrating the findings of the study in many cases we were unable to deconstruct these data sets back into original raw data sets. Data from all the published studies within Texas were manually transcribed and entered into an Access database that contained an expanded list of the variable fields listed in Table 1. All literature sources were scanned into PDF format and archived in the EndNote database.

Duplicate Data Sources

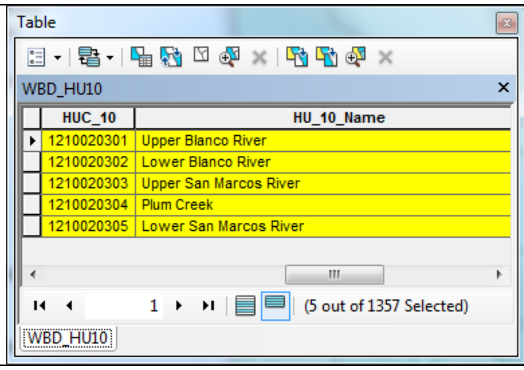
We attempted to limit the amount of duplicative data obtained from various data sources that have been shared between various organizations databases. This typically happened when one agency participated in a collaborative or externally funded monitoring program. For example, we did not obtain any Clean Rivers Program (CRP) data from HGAC or the various River Authorities because we all entities submit their data to the SWQMIS database. However, there were Texas Water Commission (TWC) and Texas Natural Resource Conservation Commission (TNRCC), data in the STORET legacy database, which was also archived in SWQMIS. TWC and TNRCC are predecessor agencies of TCEQ. Whenever possible we deleted obvious duplicate date or not their presence.

Geospatial Data and Data Manipulation

Data collected by TCEQ sponsored programs are collected at established SWQM sites which are georeferenced to TCEQ designated waterbody segment numbers. Any monitoring sites that are added during future studies are generally georeferenced by latitude and longitude and descriptions of their location in relation to landmarks and whether they are located within a TCEQ waterbody segment. This is important since water quality standards may be defined and vary between waterbody segments. However, data collected from other sources sometimes lacked specific site information. Therefore it was necessary for us to georeference new sites and associated data from non-TCEQ databases to TCEQ waterbody segments. This classification would facilitate future data analysis in support of development of NNC. Depending on the source of data the location of sampling sites from other studies ranged from very precise descriptions including latitude and longitude coordinates to general descriptions based on landmarks and/or older hand drafted maps.

For example, some location data associated with older data extracted from TWDB reports were visually adjusted using landmarks when necessary to correct obvious errors. Many of the older TWDB data and other studies were collected back before the advent of GPS technology or with instruments with lower accuracy. Positions were often approximated or surveyed with sextants and associated navigational aids.

The location of the non-TCEQ sampling sites were determined by plotting their location using the overlay functionality in GIS in order to detect the association between these sites and the most likely TCEQ designated waterbody segments. Our analysis showed that some of these sites were not located on or very near major streams which area assigned TCEQ segment numbers. Also, some of the sites are located between major streams and it was not possible to link them to a specific stream segment. It was more feasible to link them to other features however. We chose to link these sampling sites to the major basins in Texas (i.e. 25 TCEQ designated basins including the Gulf of Mexico) and to the USGS Hydrologic Units they are located within. The 10-digit Hydrologic Units have been examined against the TCEQ major streams and it was found that the names of the hydrologic units at this level correspond reasonably to the names of the TCEQ major streams segments. The next screenshots of the attribute tables illustrates the good correspondence between the names of the hydrologic units and the segment names (Figure 2).



Table

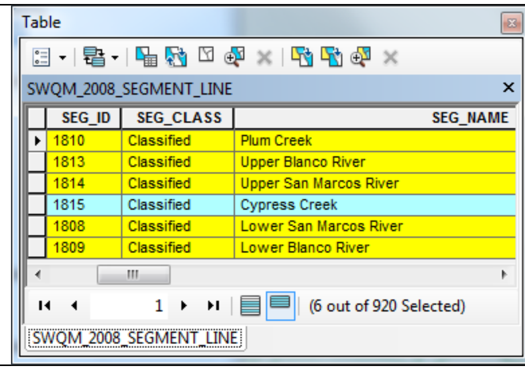
WBD_HU10

HUC_10	HU_10_Name
1210020301	Upper Blanco River
1210020302	Lower Blanco River
1210020303	Upper San Marcos River
1210020304	Plum Creek
1210020305	Lower San Marcos River

(5 out of 1357 Selected)

WBD_HU10

Hydrologic units at 10 digit level in the San Marcos watershed



Table

SWQM_2008_SEGMENT_LINE

SEG_ID	SEG_CLASS	SEG_NAME
1810	Classified	Plum Creek
1813	Classified	Upper Blanco River
1814	Classified	Upper San Marcos River
1815	Classified	Cypress Creek
1808	Classified	Lower San Marcos River
1809	Classified	Lower Blanco River

(6 out of 920 Selected)

SWQM_2008_SEGMENT_LINE

TCEQ major segments in the San March Watershed

Figure 2. Comparison of TCEQ segments and HUC 10 units.

Consequently, the 10-digit Hydrologic Unit Code (HUC10) and the basin number for each site have been added to the databases using the ‘Spatial Join’ function in ArcGIS, which established the spatial relationship between the sampling sites on one side and the basin and hydrologic units on the other side. For example, all sites that are located within the Trinity River Basin will be associated with this basin by giving it basin number 8. Again this was done because we were not able to always associate or assign the appropriate TCEQ segment number with any degree of confidence. Again, the majority of these data were from published reports in which we had to manually input the data into our Access database.

The databases of the sampling sites include the latitude and longitudes values in reference to the North American Datum 1983 (NAD 83), which allowed us to import these data directly from Excel spreadsheets into ArcGIS and then to create shapefiles for these sites. These shapefiles are used with other spatial layers (i.e. TCEQ major streams, Lake and reservoirs in Texas, outlines of major basins in Texas, and the outline of State of Texas) in order create a number of maps in ArcGIS. These maps show the locations of the sampling sites within individual basins as well as at the state level and also report the total number of sites in each map.

In our experience in most cases nutrients and/or chlorophyll and phytoplankton have been collected near the surface. Therefore our compilation focused on paired measurements of the water quality variables collected in surface waters.. Where possible, data from most sources were reformatted such that each line of data includes all associated variables for that collection event (time/date, location & depth combination). Columns or fields represented individual variables (e.g. chlorophyll, total P, etc). This format facilitates statistical analyses between potential causal (e.g. TP and TN) and response variables (e.g. chlorophyll-*a*) including simple correlation and regression analyses and more complex spatial and multivariate models if needed.

B. Compilation and Review of Nutrient Studies

While conducting our literature search for water quality data in Texas we also retrieved articles on the general topic of eutrophication and NNC. These articles included several review papers which were also archived into the EndNote database for use as supporting technical articles. We briefly describe some of the more pertinent studies later in the report. Some of these reports were associated with individual state's efforts to develop NNC and are discussed under those sections of our report as appropriate. They are also in some cases archived with each individual state's regulatory information.

C. Numeric Nutrient Criteria Derivation Approaches

Technical Guidance Documents

We consulted the Tetra Tech N-STEPS web site and EPA Water Quality Standards web page to download the most recent published and EPA supported technical support documents dealing with the topic of NNC development (http://n-steps.tetratech-ffx.com/NTSCHome.cfm , http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/index.cfm, http://water.epa.gov/scitech/swguidance/standards/wqslibrary/index.cfm). These documents are also provided in our bibliography and cited in EndNote. We realize that TCEQ staff is very familiar with current EPA approaches to numeric criteria development. Therefore we only provide a very brief overview of the technical basis and guidance for these proposed methods for NNC. Selected non-EPA review articles and technical literature on "guidance values" and criteria development were also obtained, summarized and briefly discussed.

Status of State Numeric Nutrient Criteria

As established under the Clean Water Act (CWA), water quality standards are the regulations which list designated uses, water quality criteria and an antidegradation policy. Designated uses are the water uses specified in water quality standards for each water body. The CWA requires that the uses are to be achieved and protected, even if they are not currently being attained. The standards are established to protect public health and welfare and enhance water quality in a state. Water quality standards including numeric criteria are normally adopted by state regulation. They are then reviewed and if acceptable to the EPA approved by that agency. After formal review if the EPA does not approve the standards, then EPA is mandated to take over the process and set standards for state waters in a process known as promulgation. Failure by the state or EPA to implement the requirements of the CWA subjects the EPA to the possibility of citizen law suits to enforce the provisions of the Act similar to recent lawsuits associated with the State of Florida.

The Nutrient Scientific Technical Exchange Partnership and Support (N-STEPS) web site maintained by EPA contractor Tetra Tech, and the EPA water quality standards web page were initially queried to obtain information and web links to individual state water quality agency sites (http://n-steps.tetratech-ffx.com/NTSCHome.cfm , http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/index.cfm , http://water.epa.gov/scitech/swguidance/standards/wqslibrary/index.cfm, http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/progress.cfm). Recent (as of 20008-2011) summary data and reports were obtained from these web sites on the status of state NNC approved by EPA. Several recent publications that provide a summary of the current status of state adopted and/or EPA approved water quality standards in 2008, 2010 and 2011 were also reviewed for pertinent data (Laidlaw 2010b; Thomas 2011; United States Environmental Protection Agency 2008b). These documents are archived in the EndNote bibliographic database provided as part of this study. These summary documents are placed in the state NNC summary directory that is listed in Appendix 1.

We also conducted independent internet web searches using popular search engines. The terms “nutrient criteria”, “nutrient standards”, “nutrient plan”, and the state name were used to locate additional information on the status of recently proposed and/or state adopted NNC, nutrient criteria development plans, technical support documents, and related studies. We downloaded both existing and recently proposed standards and nutrient criteria develop plans if available for each state. In addition, any published and posted studies that were conducted in support of NNC development were also downloaded for review.

To insure important State NNC documents or information were not missed we also attempted to contact individual state agency staff responsible for water quality standards, using supplementary internet and telephone interviews. The names and contact information of these individuals were obtained through the N-STEPS and EPA water quality standards web pages and/or by searching their State agency web page. Finally, we also attempted to contact staff in each EPA Region responsible for or engaged in NNC development. Each state respondent was asked to describe their current NNC, whether EPA had approved it, proposed NNC, whether they had a nutrient criteria development plan, and whether there were any published scientific study results available for distribution. Agency staff was requested to send copies of any NNC documents and supporting material we may have missed. Electronic copies of all documents (state standards, technical support documents, and associated studies) were placed in individual state directories that are listed in Appendix 1. In addition, a review and status of each state’s NNC was compiled in several tables for quick review.

A summary of each individual state’s NNC development efforts was compiled. We also present brief descriptions of each states NNC status and approach used. Certain states that have been very activity in NNC development are discussed in more detail. For example, most recently in the State of Florida, EPA as a result of a lawsuit, has developed NNC for freshwater systems and is in the process of promulgating marine criteria. When available we obtained individual states nutrient numeric criteria development plans. For multiple states we also provide verbatim excerpts of their standards for review. The information provided in this review should not be considered exact duplicates of their standards. Although we made every effort to obtain the most recent versions of state NNC and EPA approval status as of May 31, 2011, we encourage the reader to consult the official agency web page for updated information which we have provided. As noted before we compiled each states standards and nutrient criteria development plans along with technical studies and placed them in individual file directories for future use by TCEQ staff as needed.

Results

Numerous data sources including published articles, government reports and regulations, and electronic data were reviewed and compiled for this project. Water quality data for Texas waterbodies was extracted from these sources, reformatted to facilitate construction of predictive statistical models, and placed in various database files. The locations of these files and/or directories are provided in Appendix 1. The electronically available data from specific agencies were organized into agency/study specific Excel spreadsheet databases. Data extracted from published reports and/or peer reviewed literature was manually transcribed and input into an Access 2007 database.

In addition to construction of water quality databases, we also acquired and compiled a collection of over 930 technical reports, regulatory guidance documents and peer reviewed journal articles. These documents were obtained from original electronic (Word, HTML, PDF) versions or by scanning paper copies into PDF format. These documents were stored under their respective state, federal agency, or subject directories and cross referenced and cited within EndNote. The EndNote database, which also functions as an add-in within Microsoft Word, can be used to quickly locate these published articles by key words (e.g. state, subject, title and author. Another important feature of the EndNote software, if the provided directory structure is maintained intact on the user's computer, is the functional hot-links within EndNote which allows the user to quickly search, find, and then open the source document. The user can if working within Microsoft Word, insert the citation into a written report as well. To aid in this effort, articles directly pertaining to federal guidance and individual state NNC development were organized by federal and state directories (Appendix 1).

Water Quality Data and Literature Synthesis

The primary use of the data and technical information that we have compiled will be to support future development of numeric nutrient criteria for lotic waters (streams and rivers) and estuaries (tidally influenced streams and open water estuary and marine systems). Consequently, we focused our efforts on the compilation of the data for these waterbody types. However, additional data on reservoirs was also compiled since recent regulatory events in Florida have highlighted approaches that must consider protection of downstream standards including lakes (United States Environmental Protection Agency 2010g). A total of 1,500,977 monitoring records originating from 23,517 sites were identified and compiled from various data sources (Table 2). A monitoring record represents an occurrence of at least one target parameter listed in Table 1. Usually there was more than one parameter per line, since we counted the number of records after we had reformatted the original data provided to us, and combined or collapsed all single variable rows (observations) into rows containing all data from each variable (column), per unique combination of date, time and depth. We counted unique monitoring sites per sampling program. However, there was some overlap of sites between sampling programs and their associated databases (e.g. SWQMIS and USGS TWIS). In other words the 23,506 sites do not necessarily represent unique sites since some may have been sampled at multiple times by different agencies or projects. These data are archived in individual electronic databases and can be located by following the directory path as follows: TCEQ Nutrients Project > Sub Directory: Environmental Data (Appendix 1). The title of each subdirectory if self explanatory and most data are provided in Excel format with the exception of data extracted from published articles which were input into an Access database.

Agency Data

The majority (52%) of these observations and sites (30%) were records obtained from the TCEQ and its predecessor agencies. The TCEQ SWQMIS program maintains the most comprehensive nutrient and Chl-*a* data both temporally and spatially within Texas. The SWQMIS database contained data records from all waterbody types extending from 1968 to 2010. During this time period extensive collections were in every waterbody type. However, very few samples were collected from either freshwater or estuarine wetlands or the offshore marine (Gulf of Mexico) waters (Table 2).

The distribution of the TCEQ monitoring network overall and for streams and estuaries is depicted in a series of maps in Appendix 2 (Figures A2.1-A2.28). Individual PDF versions of these maps generated to depict the overall distribution of monitoring networks or studies are archived in our database under > Electronic Data Sets > SubLevel2: Maps of Environmental Data Used (Appendix 1). The distribution of monitoring sites reflects the history of water quality assessment in Texas. The majority of sites were located in areas with heavy urbanization or lower in the watershed in higher order rivers and estuaries. Very few sites were located outside the estuaries in the Gulf of Mexico, i.e. true marine sites. Therefore there are limited data to describe the nutrient levels in the Gulf of Mexico (Figure A2.28).

Another major source of freshwater water quality and/or hydrology data was the data collected and archived by the USGS within the National Water Information System (NWIS). This also included special studies, and special programs under the National Ambient Water Quality Assessment (NAWQA) program (Table 2, Appendix 3, Figures A3.1 to A3.41 and Table A3.1). In some cases data obtained from routine USGS water quality monitoring programs extend back to 1951.

Table 2. Electronic data sources containing various forms of nutrients (N, P, Si) and/or response variables (chlorophyll-a) and associated modifier variables (flow, turbidity, salinity) compiled during this study. Data does not include USGS gage sites containing only streamflow data.

Source	QA level	Waterbody	Total Records	No. Sites	Data Start Date	Data End Date
Montagna and Li 2010	1	Coastal/ Estuarine	3,409	49	1/28/1987	10/27/2010
TCEQ SWQM	3	Texas (all)	787,134	6,939	2/4/1968	8/25/2010
	3	Canals	5,968	117	5/12/1969	5/11/2010
	3	Freshwater Wtlnds	1	1	6/2/1998	6/2/1988
	3	Lakes	36	1	8/20/1997	8/3/2005
	3	Freshwater Streams	275,379	3,923	2/4/1968	8/25/2010
	3	Ponds	57	12	7/28/1994	10/15/2002
	3	Reservoirs	310,892	1,169	9/6/1968	8/5/2010
	3	Springs	1,160	32	11/5/1975	3/18/2010
	3	Tidal Streams	77,552	513	9/23/1968	7/20/2010
	3	Estuaries	111,941	1,145	4/17/1969	7/26/2010
	3	Oceans	4,148	26	5/21/1969	6/22/2010
Quigg 2011	2	Coastal/ Estuarine	143	8	2/19/2008	6/14/2010
USGS	3	Texas (all)	51,056	821	6/18/1959	3/2/2011
TWDB CDS	3	Coastal/ Estuarine/Tidal Rivers	65,890	45	11/301960	7/29/1989
USGS NAWQA	3	Texas (Freshwater)	274,422	70	10/1/1991	2/23/2011
Ward and Armstrong	3	Coastal/ Estuarine	215,662	13,897	1/11/1950	1/29/1996
NCA/EMAP/ REMAP Coastal Studies	3	Coastal/Estuarine/ Tidal Rivers/Marine	2,689	601	7/9/1991	9/9/2004
Modern STORET	3	(592) Freshwater Streams, (654) Reservoirs	1,246	96	1/7/1999	10/18/2007
Legacy STORET	3	Freshwater Streams (19,631), Reservoirs (25,142), Tidal Streams (186), Estuaries (45,920), Marine (1,038)	91,957	980	2/4/1968	7/20/1998
TWDB Hydrology	3	Monthly time step freshwater inflow to estuaries = modeled + gaged	7,369	11	1/1/1941	12/31/2009
		OVERALL TOTAL	**1,500,977**	**23,517**	**1/1/1941**	**3/2/2011**

QA levels: 3=Agency QAPP program used (EPA, TCEQ, Etc.) 2=QAPP document available, 1=QA described, 0=No documentation provided

[1] A total of 3,989 legacy STORET sites were identified but only 980 contained data not found in SWQMIS.

[2] Access literature database statistics are not included in this tally which 708 additional sites, 4,746 records).

The Texas Water Development Board (TWDB) provided several types of data from the various monitoring and research programs they have administered. The majority of water quality data was obtained from their intensive coastal studies of water quality and freshwater inflow which occurred during the 1960’s through 1989. This data is archived in the Coastal Data Systems (CDS) platform (Texas Water Development Board) (Table 2, Appendix 4 Figure A4.1).

In addition to this electronic data we also secured hard copies of final reports associated with these same estuarine studies (Hahl and Ratzlaff 1970; Hahl and Ratzlaff 1972; Hahl and Ratzlaff 1973; Hahl and Ratzlaff 1975). However, there were other data collected during past freshwater investigations that were not archived in electronic format (Hughes and Leifeste 1965; Hughes and Rawson 1966; Kunze 1969; Kunze 1971; Leifeste et al. 1971; Leifeste and Hughes 1967; Leifeste and Lansford 1968; Mendieta 1974). When electronic data was not found in the CDS archive we manually transcribed information from the associated reports and placed these in the Access database (Appendix 1). As it turned out, all of the marine studies were electronically archived in the CDS databases, whereas all the freshwater studies were not. Although there was no need to transcribe the coastal water quality data, the TWDB reports associated with this data did provide additional information on methodology and location of monitoring sites that was not easily obtained form the electronic database. Taken together the reports and electronic data provide sufficient information on the approach and scope of these studies.

A significant source of older data collected by the predecessor agencies (TWC and TNRCC) to the TCEQ, and other agencies, are stored in the legacy STORET database (Table 2, Appendix 6, Figures A5.1 -A5.3). The electronic data includes mostly duplicative data shared with the SWQMIS. The majority (75%) of the data consists of historical monitoring data collected by the TWC or TNRCC (Table 2). These duplicative TCEQ data include information obtained from 1968-1998. We counted 46,848 duplicate observations in STORET from TNRCC/TWC during this period.

Approximately 50%, 20%, and 1% of the sites were classified as estuarine/tidal creeks, freshwater streams/rivers and marine respectively. The majority of sites were located in watersheds surrounding the Dallas-Fort Worth, Houston, Beaumont-Port Arthur, San Antonio and Austin metropolitan areas (Figure A5.1). The majority of coastal sites were located in the Galveston Bay, Corpus Christi Bay and upper Laguna Madre (A5.3).

Several other unique data sources reported in these tables include historical data compiled from the EPA's National Aquatic Resource Surveys (NARS) including the National Lakes Assessment (NLA), National Wadeable Streams Assessment (NWSA), and National Coastal Assessment (NCA), REMAP and EMAP surveys (Table 2, Appendix 6 Figures A6.1 to A6.5; Appendix 7 Figure A7.1). These studies were conducted usually once during an annual period and may have been repeated over a 1 to 5 year cycle. They usually have large spatial coverage across a state or region but sparsely cover any particular area or watershed. For most of these studies within Texas, TCEQ was an active participant but did not archive the data in SWQMIS (C. Kolbe pers. comm.). We therefore provide the data extracted from the national EPA online archives for these projects. We found out later while examining these data that they are actually archived in two locations, including the NCA/EMAP archives and modern STORET database. Therefore there are some duplicative entries for coastal NCA/EMAP data. We did take this into account and did not count these sites and collections twice in Table 2. Similarly, it appeared that STORET contained all the EPA sponsored National Lakes (NLA) and Wadeable Streams (WSA) assessment data, so we did not present this data twice. The modern STORET data compiled from EPA also contained some duplicative data from the

Texas Water Commission (now TCEQ) records, which is not presented in the summary table (Table 2). It should be noted that the EPA has sponsored two additional recent studies in Texas including the NCCA (National Coastal Condition Assessment) in 2010 and the NWA (National Wetland Assessment) in 2011, which is currently underway. Neither program currently has data available for public distribution. Both programs will have additional nutrient and/or chlorophyll-*a* data once released.

Ward and Armstrong Coastal Data Compilations

Multiple data sets were compiled by Drs. Ward and Armstrong (Table 2, Appendix 8, and Figure A8.1). As described earlier, the database constructed for Galveston and Corpus Christi Bays contained duplicative "TCEQ" data for the period between the late 1960's to early 1990's (Ward and Armstrong 1992a; Ward and Armstrong 1997a). In addition, duplicative data from the TWDB is found within the TWDB CDS, the TWDB literature sources, and the Ward and Armstrong databases. In the Corpus Christi area, other than the historical SWQM data (historically referenced as SMN Statewide Monitoring Network) there were very few studies conducted by other groups that generated high quality nutrient data. This was due to various reasons including 1) poor quality assurance and documentation of methods, 2) uncertainty on the use of detection limits, 3) potential erroneous nitrogen data (nitrites) during 1967-68 and 4) possibly transcription errors and inaccurate estimation of salinity values. The only study that appeared to have collected data with documented methodology was the study coded MSI-NB which was conducted by Dr. Terry Whitledge, who was affiliated with the University of Texas at Port Aransas during the period of these studies.

In the Galveston Bay watershed, there was considerably more water quality data pre-1990 (Ward and Armstrong 1991). The authors compiled water quality data from 26 separate data collections programs, They also reviewed the data for obvious transcription errors and rejected or deleted data with obvious errors including missing time, date and location fields. Based on a review of their report there appears to be several sources of historical nutrient and primary producer data in Galveston Bay. This included the state SMN (Stream Monitoring Network) which was managed by Texas Department of Water Resources (TDWR) and Texas Water Quality Board (TWQB). These agencies were predecessor agencies of the TCEQ. These data were obtained in digital form from the respective agencies by the investigators and then reformatted and checked for errors prior to data analysis. During the 1970 through 1985, many special studies including nutrient bioassays, were actually conducted to establish predictive relationships between algal growth and nutrients (T and P) levels. The most important historical study during this period was the Galveston Bay Project (GBP). The GBP was a comprehensive study of the system conducted by the TWQB, which involved monthly sampling at a network of fixed stations for the period 1968-1972. The authors stated during this period quality assurance documentation was often lacking but use of standard laboratory and EPA approved test methods were being practiced at all agency support labs (Ward and Armstrong 1992b; Ward and Armstrong 1997a). The authors further stated that the TDWR and later the Texas Water Commission (TWC), both predecessor agencies of the TCEQ, did not have any formal QAPP through early 1990's and had very little documentation in terms of formal field methodology.

(Ward and Armstrong 1992a) described another important series of studies conducted in Galveston Bay during the period of 1975 to 1989 by the TWDB. These studies were part of a system of coastwide surveys conducted to characterize freshwater inflow and circulation effects on water quality and salinity. This data, archived as the Coastal Data Series (CDS) was also obtained independently from the TWDB and extracted from their reports. Numerous sites were monitored on a bimonthly or quarterly schedule. Paired measurements of nitrogen (TKN, nitrates), TP, and chlorophyll-*a* were made during this period. Some level of quality assurance and quality control (QA/QC) was practiced and standardized laboratory procedures were used (Ward and Armstrong 1991). The TWDB data was obtained in digital form. Additional water quality data was collected at multiple tributaries at USGS gage sites. Multiple university studies were also conducted throughout Galveston Bay by local agencies and university researchers. However, many of these studies lacked formal QAPP or standard methods. The authors concluded that much more data existed prior to 1980 in Galveston Bay, but a large amount of this had been lost due to poor archiving practices and investment in data management. They also stated that based on their reviews nitrate and phosphorus levels had been declining in Galveston Bay, although overall total inorganic nitrogen was increasing (Ward and Armstrong 1992a).

University Studies

The two academic researchers that have conducted extensive studies along the Texas coast had considerable data on nutrients and chlorophyll-*a* data both temporally and spatially. The data provided by Dr. Paul Montagna from Texas A&M at Corpus Christi, who was formerly affiliated with the University of Texas Port Aransas where much of the data collection took place in part, contained considerable information on south Texas estuaries extending back to 1987 (Table 2, Appendix 9 Figures A9.1). The recent studies conducted in Galveston Bay by Dr. Antonietta Quigg, contained spatially intense data from recent studies. Dr. Quigg's study was conducted for TCEQ under a state QAPP. Although not extending over a long period of time it is one of the few studies that provide intensive spatial coverage during fluctuating freshwater inflow conditions (Table 2, Appendix 9 Figures A9.2).

Published Data Sources

In addition, multiple data sets were extracted from published studies conducted in Texas. Currently a total of 119 published papers including government agency and academic studies were utilized for data extraction. These data were placed in an Access database that is provided with this report. A total of 238 publications were assembled that pertain to nutrient criteria and nutrient impacts. A total of 89 of these papers pertain to nutrient criteria and 149 pertain to nutrients in general. All of these publications are available in PDF format and fully searchable using the EndNote database that was provided.

These data extracted from published literature contain 4,746 individual records from 708 additional sites. Individual data points with corresponding location, date, time and depths were recorded and plotted on a map for reference (Appendix 10 Figure 10.1). These reports include data collected by various agencies including the Texas Water Development board and academic studies. In cases where individual data were lacking summary data are reported and noted. Data from these studies ranged from 1930 to 2006. This included data from 3790, 1069, 2633, and 36 records containing information on -NO_3, -PO_4, SiO4 and chlorophyll-*a* levels respectively. All other forms of nutrients were generally present in less than 50 samples.

In addition to the general data compilations approximately an additional 150 regulatory documents including water quality standards, nutrient criteria development plans and associated studies and reports were organized by state and placed in a directory for further use by TCEQ investigators. The majority of these original documents area available in PDF format as well.

Description of Electronic Data

The data sources that were compiled contained extensive information on water quality that may be useful for TCEQ staff engaged in nutrient criteria development. The TCEQ data set contained > 550,000 individual records for water temperature, conductivity, salinity, pH, and dissolved oxygen (Table 3). Over a million records exist overall for these parameters. Interconversion of salinity and conductivity values is possible so the ability to augment the amount of observations containing either variable is possible.

The majority of EPA guidance documents and methodology stress the use of total nitrogen and total phosphorus. Total nitrogen is seldom measured directly and instead derived from the relationship of $TN = TKN + NO_2\text{-}N + NO_3\text{-}N$. Using this relationship we supplemented the amount of TN values either measured directly or reported independently in the respective database. The calculated values that we generated by our post-processing of the data are presented as a separate variable in each database. The total number of TN and other forms of nitrogen values was much higher in freshwater streams in comparison to estuarine waters (Table 4). USGS data is another significant source of TN data for freshwater system (primarily riverine), while the TWDB and Ward compilation serve as another major source of nitrogen data for estuarine and tidal stream sources. Very few measurements were made in the Gulf of Mexico.

Table 3. Compilation of in-situ water quality meter and turbidity measurements from all electronic data sources. Numbers in cells refer to number of separate measurements of each variable that was recorded in each database.

Source	Waterbody	Flow (cfs)	Temp (C)	Spec Cond (uS)	Salinity (ppt)	DO (% Sat)	DO (mg/L)	pH	Secchi Disk (m or in)	Turbidity (NTU or JTU)
Montagna and Li 2010	Coastal/ Estuarine	--	2,703	2,662	2,703	2,129	2,678	2,588	955	--
TCEQ SWQM	Texas (all)	91,922	669,776	626,129	152,541	--	624,337	586,692	129,624	--
	Canals	411	5,449	5,483	2,360	--	5,411	5,165	1,575	--
	Freshwater Wtlnds	--	1	1	--	--	1	1	--	--
	Lakes	13	30	30	--	--	24	30	16	--
	Freshwater Streams	89,665	220,170	208,689	19,908	--	204,661	184,490	57,342	--
	Ponds	--	41	38	--	--	41	--	--	--
	Reservoirs	593	294,715	290,225	19,298	--	291,433	285,622	40,501	--
	Springs	258	751	809	--	--	458	672	65	--
	Tidal Streams	972	68,267	66,529	33,029	--	66,779	60,063	14,994	--
	Estuaries	10	76,597	50,634	75,650	--	51,958	47,443	14,716	--
	Oceans	--	3,755	3,691	2,296	--	3,571	3,206	415	--
Quigg 2011	Coastal/ Estuarine	--	138	135	138	138	138	103	--	--
USGS	Texas (all)	2,560	48,987	50,032	--	--	47,775	49,559	--	--
TWDB CDS	Coastal/ Estuarine/Tidal Rivers	698	54,311	48,413	13,869	37,872	51,386	41,412	10,956	17,657
USGS NAWQA	Texas (all)	271,847	35,330	36,620	--	2	2,373	2,461	--	403
Ward and Armstrong	Coastal/ Estuarine	--	139,564	--	142,254	--	112,845	66,049	10,698	41,842
NCA & EMAP & REMAP	Coastal/Estuarine/Tidal Rivers/Marine	--	1,337	--	1,331	--	1,113	1,315	546	--
Modern STORET	(592) Freshwater Streams, (654) Reservoirs	32	693	675	--	--	621	785	54	129
Legacy STORET	Freshwater Streams (19,631), Reservoirs (25,142), Tidal Streams (186), Estuaries (45,920), Marine (1,038)	589	94,202	84,485	46,262	--	64,681	25,387	1,455	3,551
TWDB Hydrology	Monthly time step freshwater inflow to estuaries - modeled + gaged	7,369	--	--	--	--	--	--	--	--
	Grand Total	**367,648**	**1,047,041**	**849,151**	**359,098**	**40,141**	**907,947**	**776,351**	**154,288**	**63,582**

Table 4. Compilation of various nitrogen forms from all data sources. Numbers in cells refer to number of separate measurements of each variable that was recorded in each database. Calculated constituents are noted in each respective database and stored in a separate variable field.

Source	Waterbody	N-NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	NO3+NO2 (actual or calculated, mg/L)	TKN (actual or calculated, mg/L)	TN (actual or calculated, mg/L)
Montagna and Li 2010	Coastal/ Estuarine	3,409	3,409	3,409	2,862	--	--
TCEQ SWQM	Texas (all)	188,559	128,509	70,041	176,116	106,491	133,916
	Canals	1,204	817	353	1,403	442	540
	Freshwater Wtlnds	1	1	--	--	--	--
	Lakes	16	7	--	13	15	3
	Freshwater Streams	107,809	73,979	39,117	101,929	60,666	75,117
	Ponds	5	--	--	--	7	4
	Reservoirs	40,662	31,768	20,464	42,673	29,568	40,967
	Springs	483	254	51	645	350	348
	Tidal Streams	21,155	11,786	5,670	16,497	7,848	11,625
	Estuaries	16,479	9,405	4,222	12,333	7,318	5,074
	Oceans	745	492	164	623	277	238
Quigg 2011	Coastal/ Estuarine	143	36	36	143	--	140
USGS	Texas (all)	--	--	--	--	--	29,995
TWDB CDS	Coastal/ Estuarine/Tidal Rivers	13,067	14,982	15,278	4,305	8,467	3,648
USGS NAWQA	Texas (all)	68	--	58	58	1,841	380
Ward and Armstrong	Coastal/ Estuarine	20,751	21,230	7,502	1,495	22,971	1,495
NCA & EMAP & REMAP	Coastal/Estuarine/Tidal Rivers/Marine	930	930	930	844	--	318
Modern STORET	(592) Freshwater Streams, (654) Reservoirs	97	214	5	4	9	88
Legacy STORET	Freshwater Streams (19,631), Reservoirs (25,142), Tidal Streams (186), Estuaries (45,920), Marine (1,038)	4,325	11,765	--	2,763	2,736	32
TWDB Hydrology	Monthly time step freshwater inflow to estuaries - modeled + gaged	--	--	--	--	--	--
	Grand Total	**231,349**	**181,075**	**97,259**	**188,590**	**142,515**	**170,012**

Nutrient information was reported by the different monitoring programs using various units of measurement including total and dissolved fractions, and as original units (e.g. NH_4 ammonium) or standardized to elemental composition (e.g. NH_3-N). For purposes of summarization we have combined these units in the summary tables presented. Therefore unless we state otherwise we use the terms broadly in the discussion below. For example, unless otherwise specified, "nitrates" include both nitrates and nitrate-nitrogen. The original units are however, retained in the original databases. These units of measure can be easily converted using stoichiometric relationships described in the "Units of Measurement" section of this report using the given temperature, pH, and conductivity data that was almost always collected at the same time.

Total phosphorus and orthophosphates were the two major forms of phosphorus reported Table 5. The occurrence of collections for TP and other forms of nitrogen values was higher in freshwater streams in contrast to estuaries (Table 4). Phosphorus is seldom considered limiting in high salinity estuarine and marine waters. USGS data is another source of TP data, while the TWDB and Ward and Armstrong database is another major source of nitrogen data for coastal waterbodies. Chlorophyll-*a* was collected more frequently in freshwater systems (Table 5).

The number of paired measurements of N, P, and chlorophyll-*a* occurred much less frequently than individual variables (Table 6). This suggests that there may be a limitation on the number of sites containing sufficient data to develop predictive models of nutrients versus chlorophyll-*a*. The number of collections available for evaluation of these relationships will depend on the final segmentation scheme by the end user analyst.

In addition to the electronic sources of data there were other sources of environmental data including nutrients and chlorophyll-*a* that were extracted from published reports (Table 7). A total of 94.2% of these (23,067) were from published TWDB reports, while the other records were from eight other sources and categories including various miscellaneous authors. Although there were numerous observations collected on total silicates, there were few matching data available from any source on chlorophyll-*a* (Table 7). Once again, this additional data may be limited in use for any user interested in attempting to utilize paired variable sets for construction of empirical models relating causal (e.g. nutrients) variable and response (e.g. chlorophyll-*a*) variables.

Table 5. Compilation of various phosphorus forms and other chemical constituents from all data sources. Numbers in cells refer to number of separate measurements of each variable that were recorded in each database.

Source	Waterbody	TSS (mg/L)	OP (mg/L)	TP (mg/L)	Total Alkalinity (mg/L)	TOC (mg/L)	Chl-*a* (S or F)[1], mg/L)	SiO4 or SiO2 (mg/L)
Montagna and Li 2010	Coastal/ Estuarine	--	--	--	--	--	2,341	3,409
TCEQ SWQM	Texas (all)	211,359	131,592	185,763	133,220	3,413	124,284	--
	Canals	1,374	1,015	1,205	1,064	42	760	--
	Freshwater Wtlnds	1	1	1	1	--	1	--
	Lakes	16	3	16	3	3	16	--
	Freshwater Streams	121,699	69,554	106,844	71,377	1,060	65,582	--
	Ponds	5	4	7	5	4	5	--
	Reservoirs	47,253	35,846	42,365	35,146	760	33,750	--
	Springs	449	379	414	130	32	121	--
	Tidal Streams	21,783	11,942	18,117	11,743	605	10,272	--
	Estuaries	17,653	12,340	16,040	13,233	905	13,241	--
	Oceans	1,126	508	754	518	2	536	--
Quigg 2011	Coastal/ Estuarine	--	--	140	--	--	50	--
USGS	Texas (all)	--	--	43,445	--	--	--	36,259
TWDB CDS	Coastal/ Estuarine/Tidal Rivers	--	9,041	13,795	698	8,621	4,558	4,441
USGS NAWQA	Texas (all)	--	2,290	2,216	2,291	1,401	--	1,836
Ward and Armstrong	Coastal/ Estuarine	62,471	4,505	19,290	2,669	12,355	10,487	3,818
NCA & EMAP & REMAP	Coastal/Estuarine/ Tidal Rivers/Marine	929	930	318	--	--	914	319
Modern STORET	(592) Freshwater Streams, (654) Reservoirs	75	11	95	2	2	54	129
Legacy STORET	Freshwater Streams (19,631), Reservoirs (25,142), Tidal Streams (186), Estuaries (45,920), Marine (1,038)	1,480	11,443	4,422	4,697	639	721	128
TWDB Hydrology	Monthly time step freshwater inflow to estuaries - modeled + gaged	--	--	--	--	--	--	--
	Grand Total	**485,189**	**159,812**	**269,484**	**143,577**	**26,431**	**143,409**	**50,339**

[1] S = spectrophotometric, F = flourometric chlorophyll-*a* measurements

Table 6. Number of collections with paired measurements of the primary response variable chlorophyll-*a* and at least one form of the various nutrient forms (N and P) and associated modifier variables (e.g. flow, temperature, salinity). Flow not considered for coastal waterbodies.

Source	Waterbody	Routinely Monitored Paired Parameters: Flow, Temp, Cond/Sal, NO3+NO2, NO3, OP, Chl-*a*	Literature Recommended Nutrient Forms and Paired Parameters: TN, TP, Chl-*a*, Cond/Sal, Temp	Notes
Montagna and Li 2010	Coastal/ Estuarine	1,680	2,085	Flow and OP lacking; Other paired parameters do not include TN or TP
TCEQ SWQM	Texas (all)	9,009	38,980	
	Canals	12	78	
	Freshwater Wtlnds	--	--	
	Lakes	--	--	
	Freshwater Streams	8,788	19,962	
	Ponds	--	--	
	Reservoirs	106	15,938	
	Springs	1	53	
	Tidal Streams	97	2,774	
	Estuaries	5	171	
	Oceans	--	4	
Quigg 2011	Coastal/ Estuarine	35	135	Routinely monitored parameters do not include flow, OP, or Chlor-a (when Chlor-a included, value = 45)
USGS	Texas (all)	2,340	24,264	Routine paired parameters do not include NO3+NO2, NO3, OP, or Chlor-a; Other paired parameters do not include Chlor-a
TWDB CDS	Coastal/ Estuarine/Tidal Rivers	2,199	187	Routine paired parameters did not include flow or NO2+NO3
USGS NAWQA	Texas (all)	58	377	Paired routine parameter count did not include NO3 and Chl-*a*, not in database; OP, alkalinity, and SiO2 were filtered forms. Both paired key parameter counts contain estimated values
Ward and Armstrong	Coastal/ Estuarine	801	801	Routine paired parameters do not include flow or OP (Only 5 paired measurements with OP)
NCA & EMAP & REMAP	Coastal/Estuarir	27	46	No flow data, however all stations (except 1) are in tidally influenced segments
Modern STORET	(592) Freshwater Streams, (654) Reservoirs	0	0	Modern STORET, contains National Park Service, EPA, State of Okalhoma border waters, and NLA and NWSA, multiple reporting units, dissolved and total fractions. Statistics based on NCA coastal sites excluded.
Legacy STORET	Freshwater Streams (19,631), Reservoirs (25,142), Tidal Streams (186), Estuaries (45,920), Marine (1,038)	560	3,549	Legacy STORET, contains National Park Service, EPA, National Forest Service, COE, State of Oklahoma, Texas Department of Health
TWDB Hydrology	Monthly time step freshwater inflow to estuaries - modeled + gaged	--	--	Data consists of monthly gaged and modeled inflows into estuaries.
	Grand Total	**16,709**	**70,424**	

Table 7. Summary of additional water quality data extracted from published reports and peer reviewed literature including sources of data and parameters extracted (CRP – Clean Rivers Program; USDA – U.S. Department of Agriculture; NPS – National Park Service; Other – various authors).

Parameters	CRP	EPA	NPS	OTHER	TCEQ	TPWD	TWDB	USDA	USGS	Grand Total
Count of Flow_(cfs)				8			3,151		14	3,173
Count of Temperature_(C)				93			1,015		14	1,122
Count of Specific_Conductance_(uS)	15	24	2	249	22	3	4,406	1	24	4,746
Count of Salinity_(ppt)				88			67			155
Count of pH	15	24	2	249	22	3	4,406	1	24	4,746
Count of DO_(mg/L)				67			978		7	1,052
Count of DO_(%sat)							911			911
Count of Turbidity_(NTU)										
Count of SS_(mg/L)									10	10
Count of NH4_(mg/L)				34			157			191
Count of DNH4_(mg/L)				43			18		15	76
Count of NO3-_(mg/L)				59			3,848			3,907
Count of NO2-_(mg/L)				43			169			212
Count of DNO3-_(mg/L)									1	1
Count of NO2+NO3_N_(mg/L)				15			41			56
Count of DNO2-_(mg/L)									15	15
Count of D_NO2+NO3_N_(mg/L)									14	14
Count of TKN_(mg/L)							24		13	37
Count of DTKN_(mg/L)									13	13
Count of DIN_(mg/L)							21			21
Count of DON_(mg/L)							4			4
Count of TN_(mg/L)				**8**						**8**
Count of OP_Lab_(mg/L)							21			21
Count of PO4_(mg/L)				34			1,035			1,069
Count of DOP_(mg/L)									15	15
Count of TP_(mg/L)				**8**			**24**		**15**	**47**
Count of DP_(mg/L)									**15**	**15**
Count of DOC_(mg/L)							1			1
Count of TOC_(mg/L)							25			25
Count of DSiO2_(mg/L)							100			100
Count of DSi_(mg/L)		2	2	14	2		23		1	44
Count of TSiO4_(mg/L)				19			2,613			2,632
Count of Chl-a_(Flour)							**9**			**9**
Count of Chl-a_(Spec)_(ug/L)				**36**						**36**
Total	**30**	**50**	**6**	**1,067**	**46**	**6**	**23,067**	**2**	**210**	**24,484**

Nutrient Criteria Approaches

Background Information

The role of nutrients in aquatic ecosystems is complex. The addition of excess nutrients to a water body can cause a multiple cascade of effects from the microbial level to the top trophic level (Schmitz 1996). There is a considerable body of knowledge on the general relationship on nutrients and food webs but, except for lakes, it is less common to find quantitative relationships between nutrient levels and specific effects (Lee et al. 1978; Tetra Tech 2004). This is due in part to the differences between natural systems, where similar nutrient concentrations may cause different responses due to the influence of non-nutrient factors, such as streamflow, shading, sediment loads, turbidity, and salinity/conductivity (Tetra Tech 2004). However, detection and documentation of quantitative relationships between limiting nutrients and endpoints such as dissolved oxygen or chorophyll-*a*, is considered one of the most useful approaches for development of NNC. These quantitative relationships are important because they can be used to develop predictive models between a desired level of a system response (such as dissolved oxygen or chlorophyll-*a* levels) and a specific nutrient level. These relationships can be established for a specific water body type within a geographic region, or for a group of water bodies based on similar geomorphology, hydrology and climate. These relationships can be used to develop in turn this nutrient level or range of concentrations that can be translated into a NNC.

In order to understand what is needed to develop protective NNC it is first useful to gain an understanding of nutrient cycling in freshwater, estuarine and marine systems and factors that lead to conditions of eutrophication. It is important to understand these nutrient cycles in order to develop scientifically defensible NNC and subsequently any management tools including TMDLs (United States Environmental Protection Agency 1999). Understanding the relationship of nutrient sources, availability, and associated impacts on plant growth is an essential step in developing NNC. For example, development of NNC for nutrients that are not normally limited within a waterbody would help little in do little not help restore healthy ecosystem functioning. For example, phosphorus is seldom a limiting nutrient in estuarine or marine systems in contrast to freshwater systems.

Literature Derived Numeric Nutrient Screening Levels

In addition to providing citations to existing and proposed federal technical guidance on NNC development approaches we also conducted a review of the recent published literature. In some cases these studies were conducted in support of an individual state's or multi-state/regional NNC development strategy. In these cases we may also briefly revisit this study under the individual state's NNC description. If these studies have been covered under the federal NNC technical guidance (e.g. basis for technical guidance) we did not cover it again in detail again. However, most of these studies that we cite were intended to develop generic approaches that could be used across a broad spectrum of conditions and waterbodies (Table 8). In addition, we have also included several literature reviews we felt summarized several of more pertinent studies and/or compiled data from large geographic regions. Even though some of these regions do not include Texas, they illustrate methodology that could be used in NNC within Texas.

Related to the issue of NNC development is the classification protocol used to group similar waterbodies. As previously mentioned EPA has provided a matrix for classifying freshwater rivers and streams in their criteria guidance documents that States can further refine (United States Environmental Protection Agency 2000a; United States Environmental Protection Agency 2000b; United States Environmental Protection Agency 2000c; United States Environmental Protection Agency 2000d; United States Environmental Protection Agency 2000e; United States Environmental Protection Agency 2000f; United States Environmental Protection Agency 2001a; United States Environmental Protection Agency 2001b; United States Environmental Protection Agency 2001c; United States Environmental Protection Agency 2001d; United States Environmental Protection Agency 2001e; United States Environmental Protection Agency 2001f; United States Environmental Protection Agency 2001i). Similar systems are however still being developed for estuarine systems. Within the Gulf of Mexico several articles and reports have been published that provide some guidance and/or data for classifying estuaries based on hydrological and geomorphological attributes (Engle et al. 2007; Hagy III et al. 2008; Solis and Powell 1999). Another source of data that might be useful in classifying estuaries is the freshwater inflow estimates provided by the Texas Water Development Board.

Table 8. Literature derived numeric nutrient screening levels and classification methods.

Method	Parameter	Waterbody Type	Concentration	Frequency/Spatial Coverage	Citation
Statistical, weight of evidence	Chl-A (authors also used numeric dissolved oxygen levels, and spatial and temporal coverage of macroalgae, SAV and algal blooms)	Estuary	High > 20 µg/L Based on 90th percentile in an annual cycle Medium 5-20 µg/L Low 0-5 µg/L	Frequency: Episodic Periodic Persistent Spatial Coverage High > 50% Moderate 25-50% Low 10-25% Very Low 0-10%	(Bricker et al. 2007)

Method	Parameter	Waterbody Type	Concentration	Frequency/Spatial Coverage	Citation
Empirical relationship Log of mean and maximum monthly Chl-A (mg/m^3) and nutrients (mg/m^3), and mean days of accrual d_a (periods between high flows) using multiple regression and resulting nomograph; $Log_{10}Chl\text{-}A_{(mean)}$ = -0.926+1.152 $Log_{10}d_a$ + 0.462 $Log_{10}SRP$ R^2=0.488 $Log_{10}Chl\text{-}A_{(max)}$ = -2.946+4.285 $Log_{10}d_a$ – 0.929$(Log_{10}d_a)^2$+ 0.504 $Log_{10}DIN$	Benthic algae, Chl-A, TN and TP	Freshwater streams (New Zealand Trout Streams	Used (Dodds et al. 1998) values of 60 mg/m^3 = µg/L TP for oligo-mesotrophic, and 200 mg/m^3 for meso-eutrophic boundary in trout streams	Mean monthly soluble nutrients (DIN and SRP)	(Biggs 2000a; Biggs 2000b)
Empirical: Log (mean Chl-A) = -3.22360+2.82630 log(TN) - 0.431247 $(log(TN))^2$ +0.25465 log (TP), R^2 = 0.430 Log (max Chl-A) = -2.70217 +2.78572 log(TN) – 0.43340$(log(TN))^2$ +0.30568 log(TP), R^2 = 0.354	Benthic algae, Chl-A, TN and TP	Montana streams and other streams	Assume nuisance level of mean Chl-A periphyton levels = 100 mg/m^2 and maximum Chl-A = 150 mg/m^2 Estimate TN = 350 µg/L; TP = 30 µg/L	Monthly, seasonal	(Dodds et al. 1997) Cited in Dodds et al. 1997: Chl-A levels from: (Welch et al. 1988) and (Horner et al. 1983)

Method	Parameter	Waterbody Type	Concentration	Frequency/Spatial Coverage	Citation
Statistical distribution of sites	Benthic algae, Chl-A, TN and TP	Montana streams and other streams	Oligotrophic - Mesotrophic boundary Mean benthic Chl-A (mg/m^2) = 20 Max benthic Chl-A (mg/m^2) = 60 TN = 700 µg/L TP = 25 µg/L Mesotrophic-Eutrophic boundary Mean benthic Chl-A (mg/m^2) = 70 Max benthic Chl-A (mg/m^2) = 200 TN = 1,500 µg/L TP = 75 µg/L	Monthly, seasonal	(Dodds et al. 1998)
Empirical model Log (mean Chl-A) = 0.155 + 0.236 log (TN) + 0.443 log (TP), $R^2 = 0.40$ Log (max Chl-A) = 0.714 + 0.372 log (TN) = 0.223 log (TP), $R^2 = 0.31$	Benthic algae, Chl-A, TN and TP	Expanded USGS stream data set	Assume nuisance level of mean Chl-A periphyton levels = 100 mg/m^2 Estimate TN = 304µg/L; TP = 42 µg/L	Monthly, seasonal	(Dodds et al. 2002) (Creager et al. 2006) (Welch et al. 1988) and (Horner et al. 1983)
Empirical relationships with Periphyton – summary table 9.1	Benthic alagae, Chl-A v.s TP, TN and TSS	Multiple studies summarized	variable	variable	(Azim et al. 2005)
Trophic classifications of lakes and reservoirs – Table 13.18	TP, TN, Chl-A, Secchi disk	Multiple studies summarized	Annual	Variable	(Wetzel 2001)

Method	Parameter	Waterbody Type	Concentration	Frequency/Spatial Coverage	Citation
Estuarine Classification Methods					(Engle et al. 2007; Hagy III et al. 2008; Solis and Powell 1999)
Estuarine Seagrass Criteria	Nutrients, light, epiphytes Tables 3.1-3.3; 7.1-7.2	Various studies reviewed	Various	Field and laboratory studies	(United States Environmental Protection Agency 2009c)
Stream Literature Review	Nutrients, periphyton	Various studies, VA and adjacent states	Various	Various	(Virginia Water Resources Research Center 2006)
Lake Literature Review	Nutrients, chlorophyll, secchi disk	Various studies, VA and adjacent states	Various	Various	(Walker et al. 2007)
Conceptual model, based on field data tidal creeks and rivers	Nutrients, chlorophyll	Eastern seaboard, tidal creeks and rivers	10-70 ug/L Chl-A; 20 to 500 ug/L N and P various forms	Field studies	(Paerl 2009)
Conceptual model freshwater vs. marine systems					(Smith et al. 2006)
Stream Literature Review	Nutrients, periphyton	Various studies	Various	Various	(Zheng and Paul 2010)
Wetlands Literature review	Nutrients, periphyton	Various studies	Various	Various	(Bressler and Paul 2010)
Assorted stream nutrient studies and criteria development approaches by W.K. Dodd and colleagues	Nutrients, periphyton	Various studies	Various	Various	(Dodds 2003; Dodds 2007; Dodds et al. 1998; Dodds and Oakes 2004; Dodds et al. 2002; Dodds et al. 1997; Dodds and Welch 2000)
Weight of evidence approach for large rivers	TP, NO_3, TN, Chl-A	New York State	Compared and combined methods to derive criteria	Compared Chl-A (water column), diatoms, and macroinvertebrates vs. nutrient loading NO_3 and TP and TN	(Smith and Tran 2010)

Method	Parameter	Waterbody Type	Concentration	Frequency/Spatial Coverage	Citation
General reference estuarine chemistry and nutrients					(Bianchi 2007a)
General reference Gulf of Mexico estuarine chemistry and nutrients					(Bianchi et al. 1999)
Algae assemblages in relation to nutrient levels	Taxonomic composition of periphyton and phytoplankton in freshwater	Lakes and rivers	Varied		(Bellinger and Sigee 2010)
Breakpoint Analysis	TN, TP, Chl-A periphyton (Caskey)	Streams (Indiana – Caskey)	≈10-170 ug/m2 Chl-A; 0.02 to 0.40 mg/L TP; 0.25 to 11.25 mg/L TN		(Caskey et al. 2010b; Crain and Caskey 2010)
General reference on estuarine nutrient cycling, edited book	Chl-A, SAV, TN, residence time	Various estuaries review	Provides cases studies including levels of nutriens and Chl-A associated with seagrass decline		(Nielsen et al. 2010)
Article on European methods to classify trophic condition of eustaries	TN, DO state	Various estuaries in Europe	Problem area defined as levels exceeding 28 µM TN with bad levels exceeding > 61 µM	50% of time threshold	(Topcu et al. 2009)

Federal Technical Guidance and Roles

Numerous technical guidance documents have been produced over the last 14 years by the Environmental Protection Agency (EPA) that deal with the topic of development of numeric nutrient criteria. We have compiled the pertinent technical support literature, federal guidance documents, state adopted and proposed water quality standards, nutrient criteria plans, and related scientific studies. Data from various sources were also compiled and archived for later use by TCEQ. Some general guidance provided on the EPA sponsored Nutrient STEPS (N-STEPS) web site (http://n-steps.tetratech-ffx.com/nutrient-supportLiterature.cfm) in regards to development of nutrient criteria is listed below.

All states have been encouraged through several EPA memorandum and guidance documents to develop a strategy to develop NNC. This normally takes the form of a Nutrient Criteria Development Plan. The name of each state's plan and final form varies but essential elements were normally incorporated in each plan. The elements are listed below.

Elements of Good Nutrient Criteria Development Planning[1]

"These elements were developed from information provided by EPA, but do not represent EPA policy. Rather, they are recommended steps based on experience generated over the last 5 years of nutrient criteria development. A good nutrient criteria development plan should contain:

1. A specific list of parameters for which criteria will be set.

2. A rationale for key parameters (e.g. Nitrogen (N), Phosphorus (P), Chlorophyll-a (Chlor-a), submerged aquatic vegetation (SAV), total suspended solids (TSS), turbidity as measured by nephelometric turbidity units (NTU) or Secchi depth (SD) that will not be included in the plan.

3. The type of criteria (numeric or qualitative with a numeric translator) that will be developed.

4. The approach being used for nutrient criteria development.

5. The order of priority by waterbody type for numeric nutrient criteria development.

6. A discussion of how those priorities were determined.

7. Classification schemes used for waterbody types.

8. How criteria will be applied: statewide, ecoregional, subecoregional, or other.

[1] Nutrient STEPS (N-STEPS) web site (http://n-steps.tetratech-ffx.com/nutrient-supportLiterature.cfm)

9. The approach for waters shared across political boundaries.

10. The status of current data availability and adequacy, and a discussion of how data gaps will be filled.

11. A date-specific schedule for major milestones (with mention of uncertainties).

12. Mention of administrative steps required for adoption into water quality standards.

13. The schedule and process for review and plan revisions."

The role of the federal government in regards to numeric criteria development in support of standards is outlined in past and recent guidance documents and strategies. In order to expand and update guidance in the area of nutrient assessment and control, the EPA held a National Nutrient Assessment Workshop (see Proceedings of the National Nutrient Assessment Workshop: December 4-6, 1995, EPA 822-R-96-004). In response to this workgroup effort, EPA developed a peer reviewed national nutrient criteria strategy.

The major elements of this strategy included:

1) Use of a regional and waterbody-type approach for the development of nutrient water quality criteria.

2) Development of waterbody-type technical guidance documents (i.e., documents for streams and rivers; lakes and reservoirs; estuaries and coastal waters; and wetlands) that will serve as "user manuals" for assessing trophic state and developing region-specific nutrient criteria to control over enrichment.

3) Establishment of an EPA National Nutrient Team with Regional Nutrient Coordinators to develop regional databases and to promote State and Tribal involvement.

4) Development by EPA of nutrient water quality criteria guidance in the form of numerical regional target ranges, which EPA expects States and Tribes to use in implementing State management programs to reduce over enrichment in surface waters, i.e., through the development of water quality criteria, standards, NPDES permit limits, and total maximum daily loads (TMDLs).

5) Monitoring and evaluation of the effectiveness of nutrient management programs as they are implemented.

Since then EPA has produced multiple guidance documents to support development of numerical criteria for nutrients focusing on two causal or "stressor" variables nitrogen, phosphorus, one or more "response" variables such as chlorophyll-*a* and/or one "modifier" variable turbidity. However, the EPA recognized that regional patterns in geology, vegetative communities, climate, and resulting streamflow combine within watersheds and ecoregions to produce different relationships between these variables. Consequently, EPA has recommended various approaches but always considering the unique geography and local conditions. In recent years due to law suits EPA has also been placed in the position of drafting nutrient criteria without initial submittal by the state through the federal promulgation (e.g. State of Florida).

EPA has issued various types of guidance starting in the early 2000's. This involved the issuing of technical guidance documents for development of criteria in lakes and reservoirs, rivers and streams, estuaries and coastal waterbodies and wetlands (Table 9).

Table 9. Numeric nutrient criteria guidance documents produced by EPA during 1998 to 2010.

Year	Event
1998	National Nutrient Strategy: Created national and regional nutrient criteria program; emphasized science and creating technical capacity (United States Environmental Protection Agency 1996).
2000-2010	Published Technical Guidance Manuals
2000	Rivers and Streams (United States Environmental Protection Agency 2000h)
2000	Lakes and Reservoirs (Gibson et al. 2000)
2001	Estuaries and Coastal (United States Environmental Protection Agency 2001j)
2007	Wetlands (United States Environmental Protection Agency 2008a)
2000-2001	Published Ecoregion Nutrient Recommendations (TP, TN, Chl-A, Secchi disk)(United States Environmental Protection Agency 2000a; United States Environmental Protection Agency 2000b; United States Environmental Protection Agency 2000c; United States Environmental Protection Agency 2000d; United States Environmental Protection Agency 2000e; United States Environmental Protection Agency 2000f; United States Environmental Protection Agency 2001a; United States Environmental Protection Agency 2001b; United States Environmental Protection Agency 2001c; United States Environmental Protection Agency 2001d; United States Environmental Protection Agency 2001e; United States Environmental Protection Agency 2001f; United States Environmental Protection Agency 2001g; United States Environmental Protection Agency 2001i; United States Environmental Protection Agency 2003c)
2009-10	Draft Empirical approaches for nutrient criteria derivation (United States Environmental Protection Agency 2010d; United States Environmental Protection Agency 2010h)
2010	Stressor-Response Approaches developed (United States Environmental Protection Agency 2010j)

These methods outlined in these guidance manuals have been used to derive lentic, lotic and marine nutrient criteria directly or modified to utilize additional state and site specific data. In some cases, a combination of these methods, have been used to derive criteria. The "empirical approaches guidance document" was reviewed by the Science Advisory Board" (SAB). This method basically outlines a variety of statistical methods that can be used with data sets potentially exhibiting stressor response relationships to define and develop NNC. The guidance focused on model selection, variable selection and selection of endpoints for NNC development. However, the SAB provided an unfavorable review of this document and stated that EPA should address these concerns before the guidance document is released. They cited that EPA failed to include sufficient alternative models and guidance on how these approaches can be used with other methods to actually prove causal mechanisms, in other works the present statistical models alone do not necessarily provide sufficient evidence for proving causal mechanisms. The "Stressor-response" guidance document is the final EPA document that was published that deals with the development of stressor response models (United States Environmental Protection Agency 2010j).

Many of the approaches used by the various proposed methods outlined in these EPA methods are summarized on the N-STEPS web site including discussions of various statistical and modeling approaches http://n-steps.tetratech-ffx.com/statisticalTool-tools.cfm). It is assumed that TCEQ staff is familiar with the use of these methods and will determine which method is most appropriate for the data set utilized.

Table 10. Major approaches recommended by EPA and/or used by states to develop numeric nutrient criteria or screening levels including narrative criteria.

Method/Approach	Description	Comments	Citation
Best Professional Judgment	NNC Based on expert opinion on system of interest.	Seldom used alone, but rather in coordination with other methods including technical literature, and statistical based or stressor response methods	
Literature Derived	Based on past research in similar systems. Multiple literature and research can be used.	May be difficult to use if system studied is not representative of waterbody where NNC is being developed. In addition, some literature derived values require additional causal or independent variables that may not be available if predictive equations are used. Can be very useful for establishment of reference values or values to compare output from other methods.	See Table 8

Method/Approach	Description	Comments	Citation
Reference Condition (e.g. Ecoregions) – Streams, Lakes and Reservoirs.	Approach uses data collected at sites including reference, or "least impacted," sites within the same ecoregion. Waterbodies shares many of the same physical, chemical, and biological attributes. Recommended ecoregion reference site method selects either the 25th percentile of nutrient concentrations from all waters, or the 75th percentile of the nutrient concentrations of reference sites only - Recommended Lake Variables: TN, TP, Chl-A, SD, DO, TOC, Macrophyte density - Recommended Stream Variables: TN, TP, Chl-A, Turbidity (NTU) or SD; optional periphyton Chl-A mg/m^2 (Supplemental ecoregion support documents with matching forms of N and P).	1) May be difficult finding & establishing least impacted site in same ecoregion. 2) Data may be lacking to support analysis. 3) EPA did produce nutrient data for various ecoregions (some may be missing in TX). 4) May be feasible in some parts of TX were SWQM or other programs have monitored water quality 5) Currently focused on use of TN and TP. Most Texas monitoring programs have not collected TN. 6) Very little periphyton monitoring data exists for Texas streams.	(Gibson et al. 2000; United States Environmental Protection Agency 2000h) including ecoregion specific guidance documents
Breakpoint Analysis	Statistical method used to detect "shifts" in relationship between variables, denoting potential response threshold Related method focused on species composition analysis = TITAN	Fairly easy to use. Numerous software packages becoming available. Some such as TITAN must be obtained from authors	(Caskey et al. 2010a; King 2009)
Modeling including TMDL (back calculation of NNC from TMDL loading)	Various water quality models utilizing either statistical or mechanistic relationships between hydrological and between water quality variables are used to "back-calculate" necessary loads and concentrations that are protective of designated uses, including associated dissolved oxygen levels, turbidity or chlorophyll-*a*.	Depending on complexity of model, it may be hard to gather all data for individual variables. Has been used in the Chesapeake Bay for control of nutrients to protect for use by SAV and reduced likelihood of hypoxia (United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2010b). Advocated by several states as a possible approach e.g. Florida Tampa and Sarasota Bay for protection of SAV	(United States Environmental Protection Agency 2004; United States Environmental Protection Agency 2007; United States Environmental Protection Agency 2010b; United States Environmental Protection Agency 2010c)

Method/Approach	Description	Comments	Citation
Stressor-Response Relationships	Mostly linear and non-linear models relating change in response variable (e.g. chlorophyll-*a*) to stressor. Based primarily on empirical relationships between variables in the field. Several modified approaches including quantile regression, break point analysis (see below), and various transformations .	Strong preference by EPA and most states when possible. Method providing strongest empirical evidence of impairment of uses if associated with designated uses. Major limiting factor is the frequent lack of matching appropriate response and casual variables (e.g. TN, TP and chlorophyll-*a*). Some states have also found that the predictive ability of models is enhanced by inclusion of both nutrient forms (TN and TP) as well as supplementary variables (e.g. flow, turbidity, tides etc).	Preferred method by EPA and most states. Requires long-term monitoring database and gradient in level of both stressor and response variables that spans potential site conditions. (United States Environmental Protection Agency 2010j)
Multiple lines of evidence (e.g. modeling + empirical, reference condition); often referred to as "*weight of evidence*"	Combination of methods used including 1) literature derived, 2) monitoring based empirical models relating nutrients to periphyton and plankton chlorophyll-*a* and biomass, modeling, and use of designated uses and 3) ecoregion/statistical method to guide appropriate endpoint level selection.	Approach recommended for California rivers and streams and estuaries. Drawbacks: 1) data is often limited to test empirical relationships in regards to periphyton response in freshwater; 2) endpoint definition in estuaries still unclear. Other states have recommended this approach for freshwater systems.	(Creager et al. 2006; Sutula et al. 2007b) State of California

Overview Status of Numerical Nutrient Criteria Development - States

The status of each states progress toward developing nutrient criteria was obtained by a comprehensive review of each state and U.S. territories current water quality standards and nutrient criteria development plans, if available. This included reviewing documents obtained from state and EPA water quality standards program offices, and contacting both EPA Regional Water Quality program staff, and individual states water quality standards staff within the appropriate state agency. This task was aided by the availability of several recent published reports and presentations that review the status of state adopted and EPA approved NNC from 2008 through 2011(Laidlaw 2010b; Thomas 2011; United States Environmental Protection Agency 2008b). Over 400 regulatory documents including water quality standards, nutrient criteria development plans and associated studies and reports were organized by state and placed in a directory for further use by TCEQ investigators (Appendix 1).

According to recent EPA reports, a total of 29 states still do not have any <u>federally approved</u> numeric nutrient criteria (NNC) as of early 2011 (Laidlaw 2010b; Thomas 2011; United States Environmental Protection Agency 2008b)(Figure 3 and Table 11). However some states during 2010 and 2011 did adopt NNC that were subsequently federally approved including Texas, Alabama and North Carolina, reducing this number to 26. The types of NNC vary between states and include various combinations of "causative variables" including nitrogen and phosphorus, in flowing waters, lakes and reservoirs and estuaries (Figure 4-Figure 6).

Some states have state adopted NNC that are under review by EPA. In some cases such as Maine, state adopted NNC were subsequently removed for further review when EPA did not act upon or did not approve them. The state of West Virginia also rescinded their previously passed state NNC for lakes and reservoirs. Some states, such as New York, continue to use narrative criteria that often utilize numeric "screening values" or "translators" to evaluate selected classes of waterbodies (http://www.dec.ny.gov/chemical/23853.html). These translator values are provided in technical guidance manuals or "*Technical and Operational Guidance Series*" (TOGS). Most of these state "screening values" are based on statistical distributions which utilize an extreme percentile (e.g. 75-95th percentile) values to flag high or low values. In some cases these are based on historical evaluation of ecoregion "reference sites" but in other cases a state has utilized all data collected for a respective waterbody type. The period of record evaluated ranges between 5 to 7 years typically and is often contained in combined assessment (e.g. 305b and 303d) reports. These screening values are used to evaluate compliance with narrative water quality standards and evaluate the need for TMDL development. Recently, numeric screening values based on causal mechanism models have been developed (Creager et al. 2006; Sutula et al. 2007b).

Due to a third party lawsuit the EPA promulgated standards for the State of Florida which included NNC for lakes, streams and canals (United States Environmental Protection Agency 2010l; United States Environmental Protection Agency 2010m; University of Florida IFAS Extension 2010). Estuarine/marine criteria are also scheduled to be developed by EPA for Florida by November 2011. The Florida case is discussed in more detail later in the report. The State of Florida had previously invested extensively on the development of both freshwater and estuarine NNC. While some of those documents were circumvented by the federal process they remain nonetheless available for review. Some of the elements and approaches recommended during the state process were in fact incorporated into the federal process. Also, there has been a recent request by the State of Florida to assume the normal adoption process of NNC (Florida Department of Environmental Protection 2011b). The state of NNC development from both a legal and scientific standpoint is very dynamic and it is likely to remain so in the future. Several states will likely NNC in the near future. Frequent consultation with of the official EPA web site, N-STEPS and individual states is encouraged in order to gather the most frequent information. Table 12 summarizes each state's current status in regards to NNC and is provides links with each section of the report dealing with the specific state.

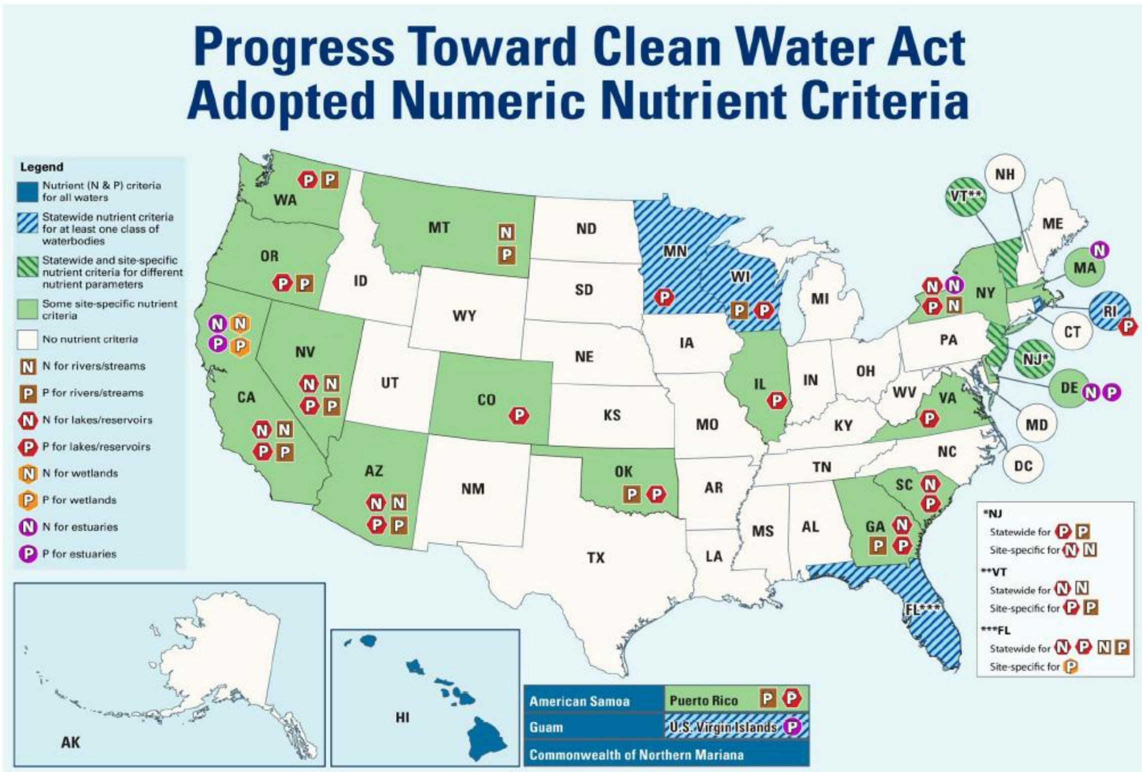


Figure 3. Status of state adopted and federally approved numeric nutrient criteria (NNC) in 2011. Recent data obtained from state agency documents confirm that Alabama and North Carolina possess site specific approved NNC for selected lakes and reservoirs, and Texas has recently obtained EPA approval for chlorophyll- *a* for reservoirs. These are not shown on this map. Source: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/progress.cfm

Table 11. Number of states with adopted and federally approved numeric nutrient criteria by year and waterbody type. Modified from: (Thomas 2011; United States Environmental Protection Agency 2008b). Recent data obtained from state agency documents confirm that Alabama and North Carolina possess site specific approved NNC for selected lakes and reservoirs, and Texas has recently obtained EPA approval for chlorophyll-*a* for reservoirs.

Numeric Nutrient Standards Status by Year	4 Parameters 4 Waterbody Types [1]	1+ Parameters + Entire Waterbody Types [2]	1+ Parameters Selected Waters [3]	No Numeric Criteria [4]
1998	0	6	7	37
2008 (2011)	0	7 (9)	18 (20)	25 (23)
2008 Numeric Nutrient Standards Status by Waterbody Type	4 Parameters 4 Waterbody Types [5]	1+ Parameters 1+ Entire Waterbody Types [6]	1+ Parameters Selected Waters [7]	No Numeric Criteria [4]
Lakes/Reservoirs (2011)	0 (1)	6 (7)	13 (15)	31
Rivers/Streams (2011)	0	5 (6)	9	36
Estuaries (24 eligible States)	0	3	7	14
Wetlands	0	0	4	46

1) Adopted numeric criteria for all four parameters for all waterbody types.
2) Adopted numeric criteria for one or more parameters for at least one entire waterbody type.
3) Adopted numeric criteria for one or more parameters for selected waters in one or more 4) waterbody types.
4) Has not adopted numeric criteria.
5) Adopted numeric criteria for all four parameters for the entire waterbody type.
6) Adopted numeric criteria for one or more parameters for the entire waterbody type.
7) Adopted numeric criteria for one or more parameters for selected waters in a waterbody type.

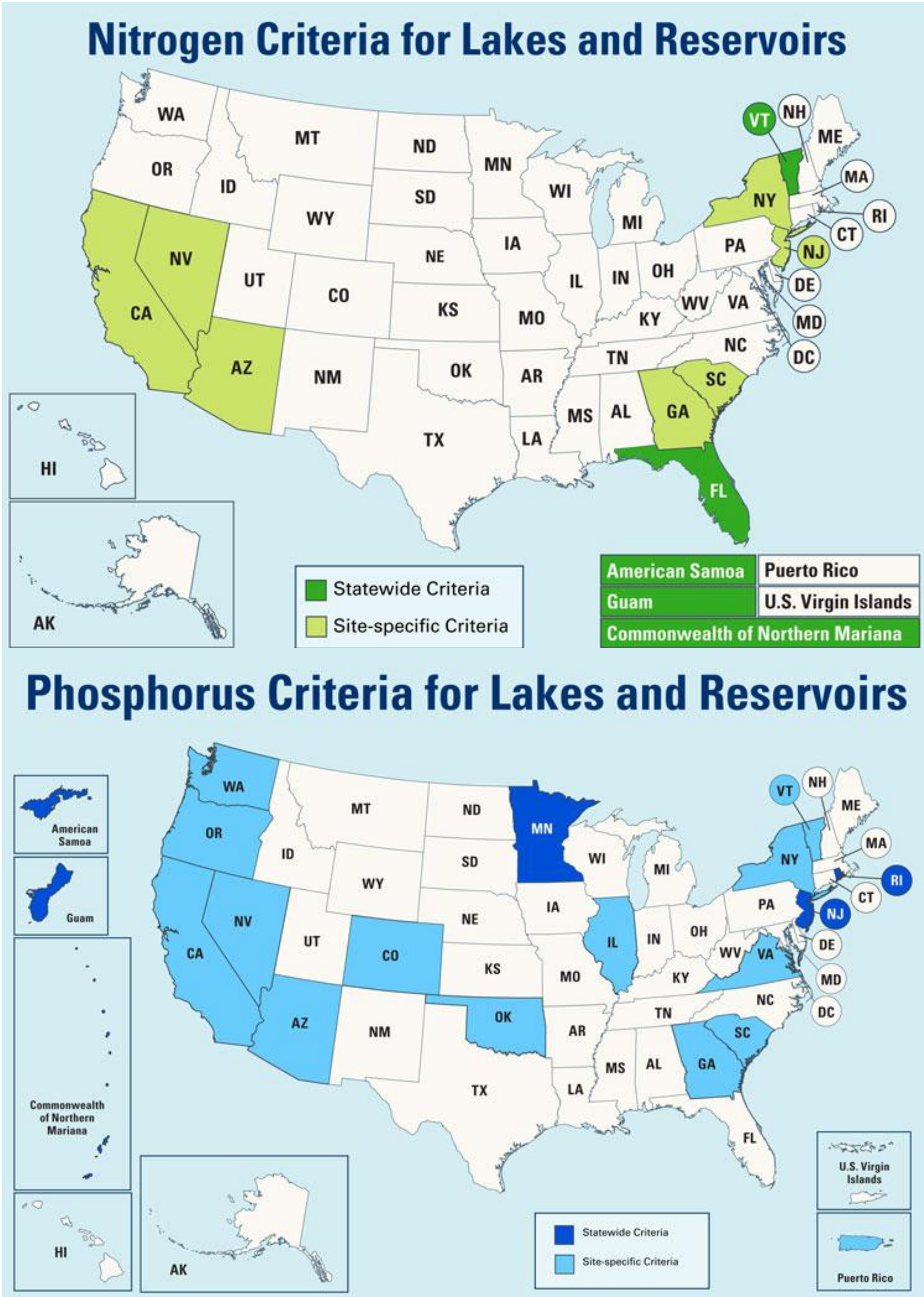


Figure 4. Status of state adopted and federally approved numeric nutrient criteria (NNC) for nitrogen and phosphorus in lakes and reservoirs in 2011. Recent data obtained from state agency documents confirm that Alabama and North Carolina both possess site specific EPA approved NNC for selected lakes and reservoirs, which is not shown on this map.
Map source: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/progress.cfm

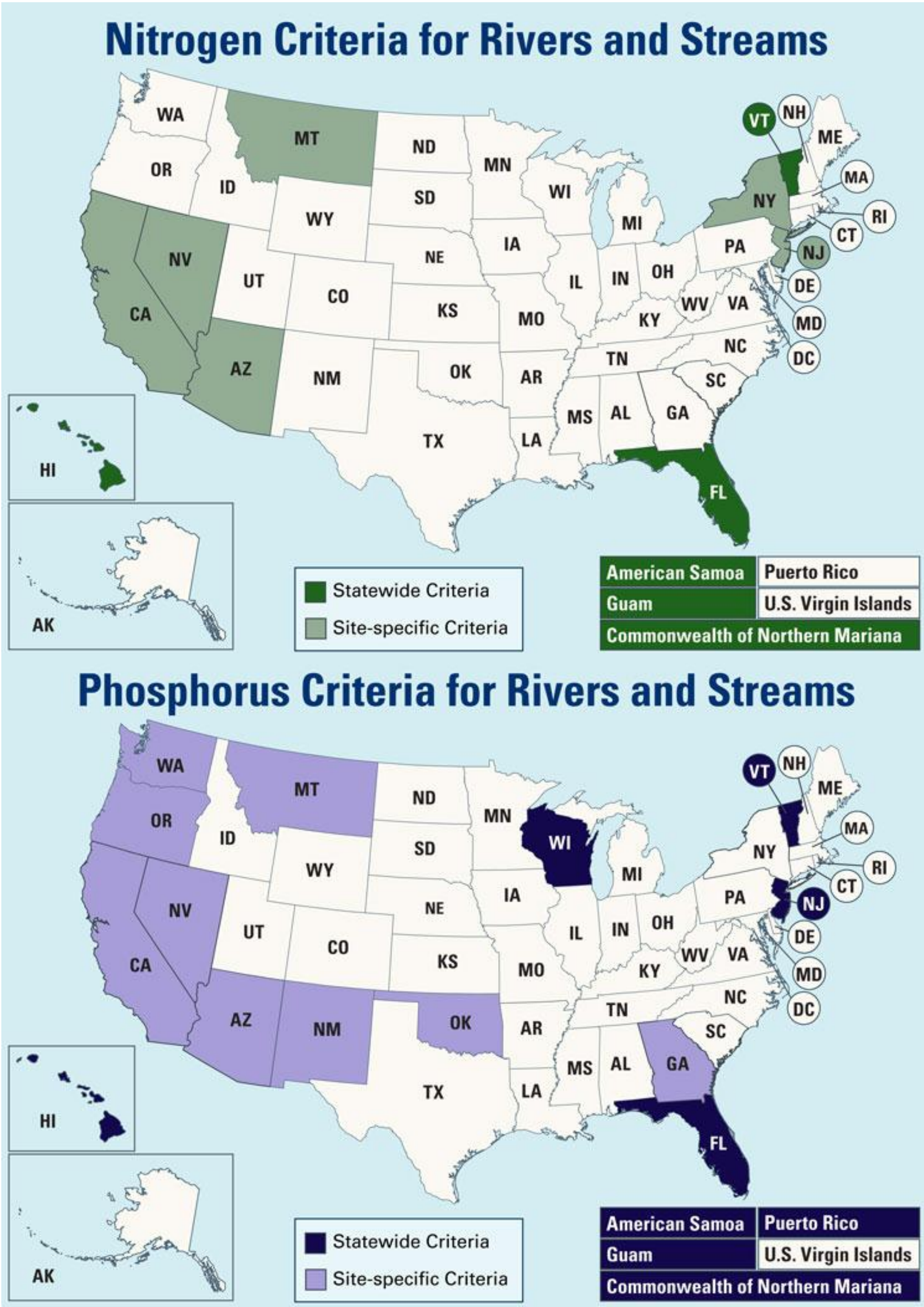


Figure 5. Status of state adopted and federally approved numeric nutrient criteria (NNC) for phosphorus and nitrogen in rivers and streams in 2011. Map source: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/progress.cfm

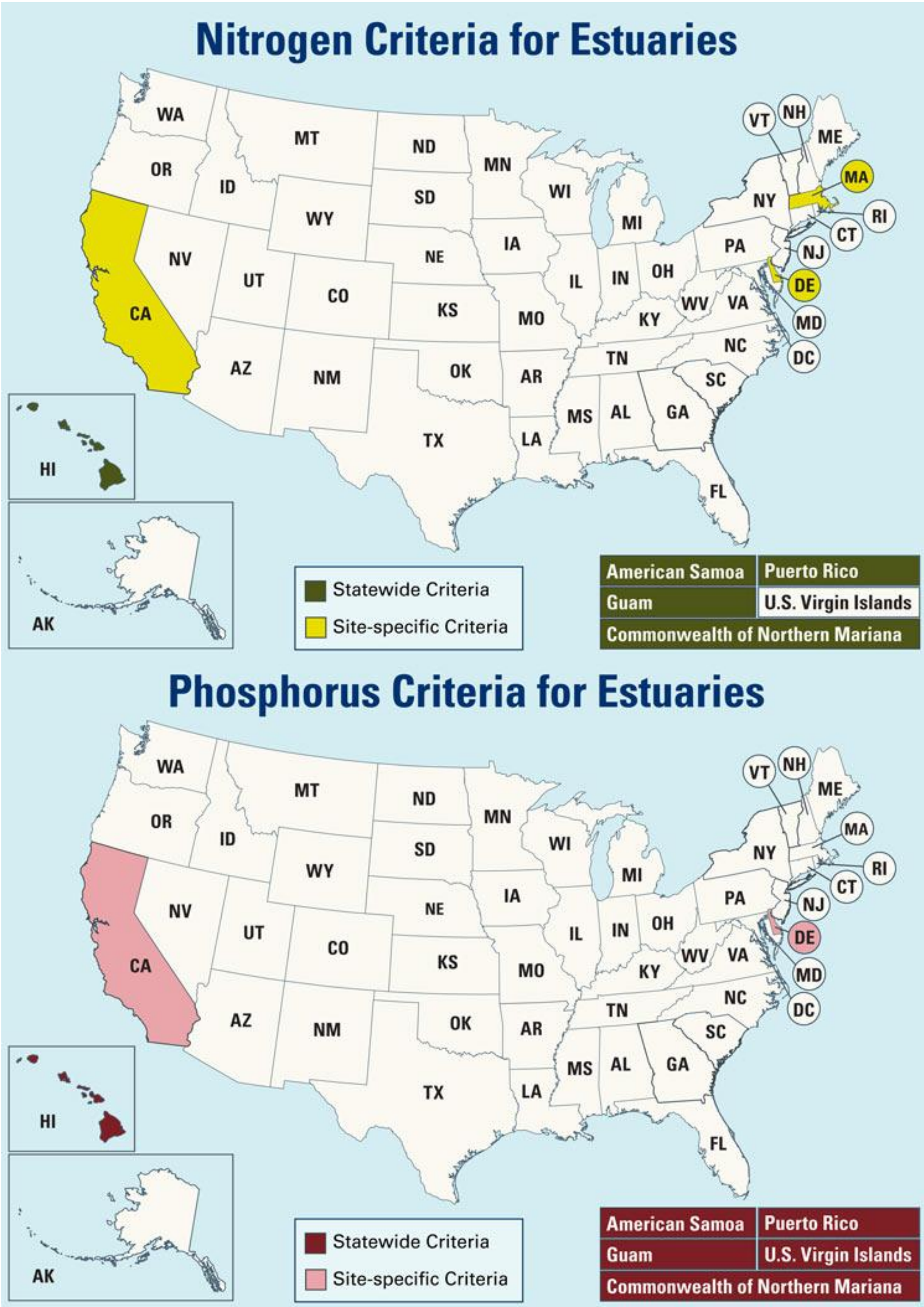


Figure 6. Status of state adopted and federally approved numeric nutrient criteria (NNC) for phosphorus and nitrogen in estuaries in 2011. Map source: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/progress.cfm

Table 12. Description of state adopted and/or federally approved numeric nutrient criteria. Code: * = under consideration but not adopted by state, ○ = state adopted but not federally approved, ● = federally approved, ▲= federally promulgated and approved (i.e. derived by EPA not state). BPJ – best professional judgment. FW = freshwater; SW = marine/estuarine. Note all states had some form of a Nutrient Criteria Development Plan.

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Alabama (pg 109)	○● Selected Major Lakes and Reservoirs	○● Chl-A	BPJ (best professional judgment), literature & empirical/statistical	-State adoptions starting in 2001 to most recent revision in 2011. -EPA approval in 2002 through 2006. - NNC = Mean monthly Chl-A values during growing season (April-October) range between 6 to 20 µg/L depending on reservoir and location. - Approved Nutrient Plan 2007
Alaska (pg 119)	* Lakes * Reservoirs	* Chl-A * TN * TP	* Regional Ecoregion Reference Waterbody	Alaska does not currently have NNC (Alaska Department of Environmental Conservation 2011) Alaska is currently in the process of developing regional nutrient criteria for the Matanuska - Susitna Valley (Alaska Department of Environmental Conservation 2006). In the development of a regional nutrient criterion ADEC will utilize previously collected data for development of regional lake criteria (Lomax 2008). Nutrient Plan referenced in several documents but was not listed on web page. Formally requested Plan from staff, but never received.

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
American Samoa (pg 119)	○● Lakes ○● Rivers ○● Estuary/Marine ○● Wetlands	○● N&P, Clarity (all waterbody ○● Chl-A	Methods used to formulate standards unknown although some TP values appear to be similar to proposed values in (United States Environmental Protection Agency 1986)	Maximum single values below: <u>Freshwater:</u> TP 150 µg/L TN 300 µg/L Light penetration 65 feet (50% of time) <u>Bays: (3 categories)</u> TP 15-30 µg/L TN 135-200 µg/L Light penetration 65-130 feet (50% of time) Chl-A 0.5-1.0 µg/L Marine: (2 categories) TP 11-15 µg/L TN 115-130 µg/L Light penetration 130-150 feet (50% of time) Chl-A 0.18-0.25 µg/L
Arizona (pg 119)	○ Selected Lakes ○ *Selected Lakes ○* Selected Rivers	○ *Rivers: TP and TN ○ *Lakes: TP and TN See Table 12	Literature review/BPJ – Lakes	2008 Nutrient Criteria Plan 2009 State WQS revised and adopted Narrative Lake Criteria – some lakes with numeric guidance values -NNC for other lakes -Standards under review by EPA -Current 2002 Standards still in effect for CWA purposes.

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Arkansas (pg 123) .	* Selected lakes	*TP, TN, Chl-A, SD	Weight of Evidence Approach using ecoregion reference sites and empirical evidence of impairment: For rivers: Saline River Pilot Study – three tiered study: 1) screening of data based on statistical distribution (25^{th} and 75^{th} percentile); tier 2 site visit, tier 3 more intensive data collection. Used various indicators, biota and Chl-A unable to develop draft NNC for streams. For Lakes: Beaver Lake Study – Growing season chlorophyll-*a* = 8 µg/L; annual average SD transparency – 1.1 meters; nutrient "targets" <u>not criteria</u> recommended for TP (40 µg/L) and TN (0.4 mg/L) (Arkansas Department of Environmental Quality 2010).	-2006 Nutrient Criteria Plan, updated 2010 (Arkansas Department of Environmental Quality 2002; Arkansas Department of Environmental Quality 2006; Arkansas Pollution Control and Ecology Commission 2010; Colorado Department of Public Health and Environment 2004; Colorado Department of Public Health and Environment Water Quality Control Commission 2006). -No state or federally approved NNC -Narrative Criteria only for all waterbodies Studies underway as authorized under nutrient criteria plan. a) Pilot Saline River stream studies utilizing three tiered study plan – failed to find major differences in nutrient impaired and least disturbed sites (response variables). b) For lakes ADEQ used "Weight of Evidence Approach": 1) Pilot Studies of Beaver Lake, 2) evaluation of surrounding state's NNC for lakes, 3) EPA ecoregion, 4) Hydrologic Plunge Point analysis, 4) statistical analysis of reference lakes and Beaver Lake, 5) Empirical loading relationships, 6) Dynamic modeling and 7) frequency of attainment

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
California (pg 128)	● Selected Lakes ● Selected Rivers ● Selected estuaries *Selected wetlands	● Selected Lakes: TN,NO_3+NO_2-N, NO_3, TP, OP, OP ● Selected Streams: TN,NO_3+NO_2-N, NO_3, TP, OP, OP Estuaries: TN, TP and SD Wetlands: TN, TP and SD See Table 15	Unknown, many standards in place since 1997-98. TP appear to be similar to values in (United States Environmental Protection Agency 1986). Recent technical guidance documents produced (Creager et al. 2006; Sutula et al. 2007b). Proposed NNC development approach for lakes, reservoirs, rivers and streams based on: 1) Perceived support of beneficial uses estimated from monitoring data and site conditions, which is based in part on 2) documented empirical relationships between causal (e.g. TN or TP) and threshold values of response variables (e.g. hypoxia, algae density) documented in literature and/or agency studies and 3) statistical and mechanistic models; and 4) using thresholds and relationships between response and causal variables and modeling tools are then used to back-calculate and establish TN and TP nutrient targets using empirical models.	California water quality managed by network of Regional Water Quality Boards, with a regional approach to promulgation of water quality standards. Most recently State of California and EPA contracted with Tetra Tech to develop conceptual framework for development of NNC for Estuaries and Streams and Lakes. Methodology relied heavily on 1) relationship of designated uses and observed nutrient distributions 2) development and identification of literature derived predictive relationships between nutrients and response variables and 3) estimation of threshold levels of causal variables (e.g. TN and TP) that would cause undesirable impacts on designated uses. Previous studies and models were relied upon (Biggs 2000a; Dodds et al. 1998; Dodds et al. 2002)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Colorado (pg 142)	● ○ Selected Lakes /Reservoirs	TP, Chl-A Mean Chl-A and/or TP depending on reservoir; seasonal – generally summer/growing season (July-Sept or Oct; one reservoir Mar-Nov). Usually 1 in 5 year allowable exceedance frequency Chl-A = 4.0 -18.0 µg/L, summer average, TP = 0.0074- 0.035 mg/l, summer average Plus matching narrative criteria for TP, SD and dissolved oxygen for some reservoir	Current reservoir NNC based on long-term site specific studies and modeling of nutrients and algal growth. (Lewis 2005) conducted study evaluating periphyton response to nutrients in mountain streams and lakes. Used ecoregion and stressor response approach used. Recommended criteria based on interannual summer median: Lakes: TP – 10 µg/L DIN – 350 µg/L Streams, Rivers, Wetlands TP 100 µg/L DIN 700 µg/L NOTE: only weak periphyton response in streams noted. Recently, CDPH recommended use of quantile regression to establish criteria nutrients vs. benthic index in rivers and streams. Used regression methods to establish relationship between nutrients and Chl-A, harmful algal blooms (HABs) and high pH (Colorado Department of Public Health and Environment Water Quality Control Commission 2010b) and (Colorado Department of Public Health and Environment Water Quality Control Commission 2011a)	Higher lake TP (32 mg/l) values not approved by EPA during 2010 review ((EPA Region 8 2011). Nutrient criteria plan 2002 (Colorado Department of Public Health & Environment 2002). Colorado Nutrient Criteria Concept Paper describes most recent approach used by state (Colorado Department of Public Health and Environment Water Quality Control Commission 2010a) Draft statewide NNC June 30, 2011(Colorado Department of Public Health & Environment Water Quality Control Commission 2011) – (CDPH) Lakes/reservoirs TP – 20-80 µg/L, TN – 40-850 µg/L Chl-A 5 - 20 µg/L depending on size and cold or warm-water status, seasonal average with specified exceedance frequency (1 in 5 years, mixed surface layer). Rivers and Streams TP – 110-160 µg/L, TN – 400-2000 µg/L Chl-A 150 mg/m^2 depending on cold or warm-water status, 5 year median not to exceed levels. Proposed NNC submittal delayed till March 2012 (Colorado Department of Public Health & Environment 2011a).

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Common-wealth of N. Mariana (pg 150)	● Lakes, Reservoirs, Rivers, Streams, Estuaries and Wetlands	●The following concentrations (mg/L) shall not be exceeded. Class AA marine 0.20 mg/L NO_3-N 0.40 mg/L TN 0.025 mg/L OP 0.025 mg/L TP 5 mg/L TSS Class A Marine 0.50 NO_3-N 0.75 mg/L TN 0.05 mg/L OP 0.05 mg/L TP 40 mg/L TSS Class 1 FW 0.75 mg/L TN 0.10 mg/L OP 0.10 mg/L TP 5 mg/L TSS Class 2 FW 1.50 mg/L TN 0.10 mg/L OP 0.10 mg/L TP 40 mg/L TSS See Table 16	●Unknown – adopted in 1998, no nutrient workplan available. TP values appear similar to values cited in (United States Environmental Protection Agency 1986)Pacific Island Chain with little freshwater.	● Approved 2004 (Division of Environmental Quality 2005; United States Environmental Protection Agency 2008b)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Connecticut (pg 151)	none	none	TMDL back-calculated loading levels and are being used by default to derive waterbody specific TP screening criteria or goals Long Island Sound TMDL for dissolved oxygen is being used to derive nitrogen control strategies and generate default TN loading values and resulting numerical screening criteria or goals. Empirical derived Lake Trophic levels based on TP, OP, TN, Chl-A, SD, and NO_3-N are used as numerical translators or screening levels to evaluate attainment of narrative criteria. See Table 19 and Table 20	No proposed or adopted state or federally approved NNC. Currently "Lake Trophic levels" are used as numerical translators of narrative nutrient criteria (State of Connecticut Department of Environmental Protection 2011). Nutrient Criteria Development Plan and support documents available (Becker and Dunbar 2009; Connecticut Department of Environmental Protection 2005)
Delaware (pg 162)	● Selected tidal rivers and streams and Chesapeake Bay	● DIN, DIP, TSS and SD	● NNC derived from empirical studies derived to support SAV and from TMDL studies of Chesapeake Bay (United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2010b).	●EPA Approved all NNC; Nutrient Criteria Development Plan in effect (Delaware Department of Natural Resources and Environmental Control 2004; State of Delaware 2004).
District of Columbia (pg 164)	●Tidal and estuarine waters only	● Seasonal (July 1 through September 30) segment average chlorophyll-a NNC of 25 µg/L. Seasonal (Apr - Oct) secchi disk depth of 0.8 m.	● NNC derived to support SAV from the TMDL based Chesapeake Bay standard (United States Environmental Protection Agency 2010b).(United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2010b)	● All NNC EPA approved (District Department of the Environment 2010).

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Florida (pg.165)	●Ever-glades ○ Fenholloway R. ▲ inland lakes and rivers	● Everglades: < long-term geometric mean of 10 ppb, but not lower than natural levels ○ Fenholloway R. – PAR activity not decreased > 44.3% from back ground conditions given annual avg. compensation depth of at least 0.66 meters ▲ see Table 25 and Table 26 *For estuarine systems FDEP and EPA recommended the following variables: salinity, temperature, nutrients (TN, TP, NO_x), DOC, (TSS), Secchi depth, color, and chlorophyll-a, SAV * Chl-A 11 µg/L Tampa Bay threshold value TMDL	● Everglades criteria – stressor-response studies in Everglades (Florida Department of Environmental Protection 2009b) ○ Technical support document for Fenholloway River provided (Florida Department of Environmental Protection 2010}). The Estuarine Coastal and Ocean Model, calibrated using extensive field data, was used to predict a natural conditions scenario describing the expected compensation depth and chlorophyll-*a* in the area affected by the proposed SSAC (Hydroqual. 2009). Preliminary endpoints and criteria generated that would still support native phytoplankton and SAV. ▲The adopted freshwater criteria used two primary approaches: reference stream/ecoregion – streams and stressor-response (United States Environmental Protection Agency 2010a) – See Table 25 and Table 26 * FDEP concluded that since a direct comparison between any two specific estuaries is difficult, the “EPA reference waters” approach appears to be less practical than the “dose-response” approach in estuaries (Florida Department of Environmental Protection 2009c) * FDEP is drafting numerous estuary specific NNC proposals using reference conditoin, TMDL, stressor-response methods. See Table 31 * Use TMDL Chl-A threshold as a criteria to derive TN and TP via regression models	● Approved Everglades criteria – 2006 (Florida Department of Environmental Protection 2010a) ○ Adopted Fenholloway River -2010 (Note: not a direct nutrient criteria, but included in review due to the transparency standard potentially being useful in future NNC ▲ Promulgated inland freshwater standards – 2011 (United States Environmental Protection Agency 2010a) * FDEP is drafting numerous estuary specific NNC proposals. See Table 31 * EPA is drafting federally promulgated NNC for estuaries and south Florida waterbodies (Carleton et al. 2010)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Georgia (pg.275)	●Selected reservoirs/lakes ●Selected river/stream	●Table 57 selected lakes and rivers *Table 58 literature proposed values	●Unknown but TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979). * Table 58 – literature review	● Selected lakes and rivers * Estuarine criteria – third party proposed for estuaries.(Risse and Tanner 2009) Nutrient Criteria Development Plan available (Georgia Department of Natural Resources 2006).
Guam (pg. 281)	●Lakes ●River ●Estuary ●Wetlands All statewide	●OP(SRP) - 0.025-0.10 mg/L varying with designated use ●NO_3-N – 0.1-0.50 mg/L varies with designated use ●NTU <0.5 or < 1.0 NTU over ambient conditions Table 59	● Unknown. but original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979).	● Approved NNC (Guam Environmental Protection Agency 2001)
Hawaii (pg. 283)	●○ Rivers ●○ Estuaries	Table 60-Table 66	●○ Unknown, but original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979).	○● State adopted and federally approved (Hawaii Department of Health 2009)
Idaho (pg.286)	None	None	No proposed NNC. Evaluating multiple approaches in Nutrient Criteria Development Plan. Currently assembling data and conducting various lines of investigation (percentile reference waterbody, regression models etc)	No NNC. EPA approved Nutrient Criteria Development Plan (Idaho Department of Environmental Quality 2007)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Illinois (pg.289)	○ Lake Michigan ○ Lakes > 20 acres	L. Michigan not to exceed: NO_3-N 10 mg/L TP 7.0 mg/L Lakes > 20 acres not to exceed: 0.05 mg/L TP	No proposed NNC. Unknown origin of original L. Michigan NNC. Most likely original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979) Studies currently underway.(Markus et al. 2005; Morgan et al. 2006)	Only site specific Lake Michigan NO_3-N and TP NNC and Lakes/Reservoirs > 20 acres TP criterion. Nutrient Criteria Plan available (Illinois Environmental Protection Agency 2006)
Indiana (pg. 290)	○ Lake Michigan	○TP monthly average 0.03 mg/L Daily max – 0.04 mg/L	Unknown origin of original L. Michigan NNC. Most likely original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979). Recent stream studies provide candidate NNC (Selvaratnam 2010b).(Caskey and Frey 2009; Caskey et al. 2010b; Selvaratnam 2010b) See Table 67	Only site specific Lake Michigan TP NNC (Indiana State 2007). Nutrient Criteria Plan available (Indiana Department of Environmental Management 2008)
Iowa (pg. 292)	None	None	Nutrient plan written, research being conducted on nutrient levels, methodology. TAC assisting in review of work products.	No NNC (State of Iowa 2011) Nutrient Criteria Development Plan (Iowa Department of Natural Resources 2006)
Kansas (pg. 293)	No NNC * lakes /reservoirs	No NNC *10 µg/L chlorophyll-*a* lakes	No NNC. Nutrient Criteria Development Plan in effect * KDHE white paper on proposed drinking water reservoir standard (not for support of aquatic life). Based on stressor response models, breakpoint analysis of existing data.(Dodd et al. 2006; Kansas Department of Health and Environment 2011)	No NNC. Draft stage on chlorophyll-*a* NNC (Kansas Department of Health and Environment 2011)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Kentucky (pg.295)	No NNC	No NNC	No NNC. Nutrient Criteria Development Plan in effect. Considering various approaches. Prefer stressor-response relationship approach. For streams prefer use of community structure versus periphyton biomass. Numerous confounding factors will make NNC development for lakes and large rivers difficult.	No NNC. (Kentucky Department for Environmental Protection 1995) Nutrient Criteria Development Plan (Kentucky Department for Environmental Protection 2007)
Louisiana (pg. 301)	No NNC	No NNC	No NNC. Approved Nutrient Criteria Development Plan. Considering stressor response and ecoregion based approach.	No NNC (Louisiana State 2011) Approved Nutrient Criteria Development Plan (Louisiana Department of Environmental Quality 2006a)
Maine (pg. 303)	No NNC * Streams Lakes – loading limits based on nutrient screening levels.	No NNC * Streams Note: screening levels used in lakes based on protection of loading from new development	No NNC * Proposed NNC for streams not adopted by state under review Table 72 and Table 71	Proposed NNC for streams and lakes postponed due to EPA concerns (Danielson 2009a; Danielson 2009b; Maine Department of Environmental Protection 2010). Lake "criteria" based on loading target values used to control non-point source pollution. Table 68-Table 70

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Maryland (pg. 323)	Clarity (Chesapeake Bay), tidal bays and Chl-A for reservoirs Table 73-Table 75	Chesapeake Bay and Tidal bays - Table 74 and Table 75 Reservoirs – Not to exceed arithmetic mean (30 day moving average) of 10 µg/L during May 1-Sept 30 growing season; also DNE 90th percentile of 30 µg/L.	TMDL – estuarine clarity NNC for Chesapeake Bay Unknown – reservoir (http://www.mde.maryland.gov/programs/Water/TMDL/Water%20Quality%20Standards/Pages/Programs/WaterPrograms/TMDL/wqstandards/index.aspx)	State adopted and EPA approved latest version 2010 (http://www.mde.maryland.gov/programs/Water/TMDL/Water%20Quality%20Standards/Pages/Programs/WaterPrograms/TMDL/wqstandards/index.aspx);(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_md.cfm).
Massachusetts (pg. 327)	N estuaries Table 77	Table 77	State is evaluating data availability and methods for development of NNC in freshwater (Massachusetts Department of Environmental Protection 2004; Zimmerman and Campo 2007). Methods include TMDL back calculation, ecoregion based and stressor response.	NNC for estuaries only (Massachusetts Department of Environmental Protection 2007). Nutrient Criteria Plan available (Massachusetts Department of Environmental Protection 2004).
Michigan (pg. 337)	None	No NNC Table 78	No NNC. Current planned approach focused on several approaches including stressor response, ecoregion reference based, and use of translators to convert narrative nutrient criteria for lakes and rivers ((Michigan Department of Environmental Quality 2006a).	No NNC (LeSage and Smith 2010). Nutrient Criteria Development Plan (Michigan Department of Environmental Quality 2006a; Soranno et al. 2008)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Minnesota (pg.337)	●Lakes Table 79-Table 83	● Lakes: TP Chl-A Secchi disk	● Lakes. Methods outlined in Nutrient Criteria Development Plan and individual plans for rivers and streams. Lakes – weight-of-evidence approach (combination of reference- and effect based approaches, user perception data, and literature review); Rivers -- effect-based approach for medium and large rivers where appropriate and defensible (Heiskary 2008; Heiskary et al. 2010; Heiskary and Wilson 2008; Minnesota Pollution Control Agency 2008c).	NNC for lakes - (Minnesota Pollution Control Agency 2008a; Minnesota Pollution Control Agency 2008b). Nutrient Criteria Development Plan and additional specialty plans for lakes and rivers - (Heiskary et al. 2010; Heiskary and Wilson 2008; Minnesota Pollution Control Agency 2008c)
Mississippi (pg. 341)	None	None	None. Numerous studies underway or being proposed for coastal waters through Gulf of Mexico Alliance. Also see: (Heiskary and Wasley 2010)	No NNC presently (Mississippi Department of Environmental Quality 2007). Nutrient Criteria Plan Available (Mississippi Department of Environmental Quality 2010).
Missouri (pg. 342)	None	None	None. Recent and past studies have focused on defining statistical distribution of streams and defining stressor response relationships (Author ; Missouri Nutrient Criteria Technical Team 2010a; Missouri Nutrient Criteria Technical Team 2010b; Osborn)	No current NNC. (Missouri Department of Natural Resources 2010). Nutrient Criteria Plan Available. (Missouri Department of Natural Resources 2005; Missouri Department of Natural Resources 2009) with focus on streams.
Montana (pg. 342)	○Selected Rivers and streams. Table 84-Table 86	○TN, TP and chlorophyll-*a* - periphyton	○ Various methods used. Ecoregion/Stressor Response (Dodds et al. 1997; Montana Department of Environmental Quality 2008b; Paul 2008; Suplee et al. 2008; Suplee et al. 2007)	EPA approved NNC (Montana Department of Environmental Quality 2008a) and Nutrient Criteria Development Plan (Suplee 2002).
Nebraska (pg. 344)	* State only for selected lakes Table 88	*See section Table 88 TP, TN, Chl-A	*See section. Table 88. Ecoregion reference approach used in part (Frankforter et al. 2003; Nebraska Department of Environmental Quality 2008)	*State Adopted & Proposed standards only, EPA has deferred action on NNC (Nebraska Department of Environmental Quality 2009a; United States Environmental Protection Agency 2010e). Nutrient Criteria Development Plan very brief (Nebraska Department of Environmental Quality 2008).

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Nevada (pg. 344)	○Some lake & river: Table 89- Table 162	○Lakes N, P, Chl-A, clarity; ○Rivers N, P, and Clarity. See section: Table 89	○See section: Table 89 - Table 162. Numerous site specific criteria have been developed for this state. Ecoregion based and/or stressor response method used (Nevada Division of Environmental Protection 2004; Nevada Division of Environmental Protection 2007; Nevada Division of Environmental Protection 2008; Nevada Division of Environmental Protection 2009a; Nevada Division of Environmental Protection 2009b; Nevada Division of Environmental Protection 2009c; Pahl 2007; Tetra Tech Inc. 2002a).	State adopted and EPA approved NNC for statewide and site specific NNC for various rivers and streams within Nevada since at least 2007 depending on waterbody. Also, the state has an active 2009 Nutrient Criteria Development Plan. http://www.leg.state.nv.us/nac/nac-445a.html http://ndep.nv.gov/bwqp/stdsw.htm (Nevada Division of Environmental Protection 2004; Nevada Division of Environmental Protection 2007; Nevada Division of Environmental Protection 2008; Nevada Division of Environmental Protection 2009a; Nevada Division of Environmental Protection 2009c; Nevada Register of Administrative Regulations 2011; Tetra Tech Inc. 2002a).

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
New Hampshire (pg. 392)	No NNC	No NNC	None. Under Nutrient Criteria Development Plan, New Hampshire is conducting Periphyton nutrient studies to determine if stress-response relationship can be detected and quantified. Field work primarily that will be completed during 2011, and report issued in 2012 (Unknown 2010)	New Hampshire has a Nutrient Criteria Development Plan (Unknown 2010). NHDES using the reference waterbody/ecoregion approach found that regionally derived numeric nutrient thresholds based on EPA recommended frequency distribution approach lower than those derived by individual states; NH - 0.009 – 0.015 mg/L. Their best initial best estimate of low end of range of numeric TP is 0.020 – 0.035 mg/L and based on 75th – 90th percentile of assessment waterbody units (AUs) without known dissolved oxygen impairment. The NHDES assumed that the upper end of TP numeric threshold is equal to their sister state New York State derived biological response estimate (0.065 mg/L) until additional data becomes available. Therefore NHDES is currently assuming the best estimate of interim freshwater criterion = 0.030 mg/L TP.
New Jersey (pg. 393)	○Lake and ○River, ○Estuary	Lakes: Max 30 day avg: 10-15 NTU; Max 30 day 30-50 NTU; NTE 10 NTU; NTE 2 mg/L NO3-N For TMDL lakes: NTE 0.05 mg/L TP, seasonal average of 10-20 µg/L TP	Method used to derive original NNC unknown.	State adopted and federally approved NNC. Current Nutrient Criteria Plan is dated 2002. However recent presentations suggest that New Jersey is conducting updated research.

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
New Mexico (pg. 393)	○River (8 watersheds)	In any single sample: Total phosphorus (as P) will be less than 0.1 mg/L.	Method used to derive original NNC unknown but original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979). * Proposed methods will involve multiple approaches including the three general approaches for criteria development as discussed in the EPA Guidance manuals including (1) identification of reference sites for each waterbody class based on best professional judgment or percentile selections of data plotted as frequency distributions, (2) use of predictive relationships, and (3) application and/or modification of established nutrient/algal thresholds(New Mexico Environment Department 2006). SWQB stated that they will explore the use of the different approaches as needed for different waterbody types.	State adopted and federally approved 2005. Current water quality standards approved 2011.(New Mexico Environment Department 2011; New Mexico Water Quality Control Commission 2005) State adopted and federally approved Nutrient Criteria Development Plan (Lemon 2011; New Mexico Environment Department 2006).
New York (pg 399)	Lakes, River tributaries, Lake Ontario, Erie and Lake Champlain	○●TP Lakes: NTE 20 μg/L Lake Erie/Ontario; NTE 10-15 for Lake Champlain; by regions NTE 10-54 μg/L	Unknown origin of some of the current regulations for NNC in current standards. Some based on TMDL backcalculation of causal variables. (http://water.epa.gov/scitech/swguidance/standards/wqslibrary/ny_index.cfm)(New York Department of Environmental Conservation 1998; New York Department of Environmental Conservation 2008b) Documentation provided for research of new potential NNC in Nutrient Criteria Development Plan.	Guidance values for TP for statewide use and site specific TP criteria(New York Department of Environmental Conservation 1998; New York Department of Environmental Conservation 2008b). New York has an existing ambient water quality guidance value of 20 μg/L for phosphorus established for classes A, AA, A-S, and B waters for which the letter "P" (ponds, lakes and reservoirs) appears in their Water Index Number (state classification system), excluding Lake Champlain. New York has a long history of using "guidance values" listed in their Technical and Operational Guidance Series (TOGs) to interpret narrative criteria

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
North Carolina (pg. 410)	●Lake, River and Estuary: Chl-A ○Lakes, Rivers, Estuaries clarity	Trout waterbodies: >10 acre lakes and streams/rivers Chl-A 15 µg/L 10 NTU Non-trout waterbodies: Chl-A 40 µg/L Lake 25 NTU Stream 50 NTU Estuaries Chl-A 40 µg/L NTU 25 or ambient	Unknown, but believed to be derived from ecoregion approach (North Carolina Department of Environment and Natural Resources 2005; North Carolina Division of Water Quality 2004).	NNC Currently adopted and approved. (North Carolina Department of Environment and Natural Resources 2007)
North Dakota (pg. 413)	NNC lacking	NNC lacking	None proposed, current Nutrient Criteria Development Plan describes multiple approaches including ecoregion reference site and stressor response methods (Deutschman 2007)	NNC not yet proposed. Nutrient criteria development plan in effect. (Deutschman 2007; North Dakota Department of Health 2011)
Ohio (pg. 439)	NNC lacking	NNC lacking	None proposed, current Nutrient Criteria Development Plan describes several approaches including ecoregion reference site and stressor response methods. Also, several technical support documents available describing methods for lakes, streams and rivers. (Miltner 2011; Miltner 2010; Ohio Environmental Protection Agency 1999; Ohio River Valley Water Sanitation Commission 2002; Skalski and Anderson 2010)	NNC not yet proposed. Nutrient criteria development plan and several support documents are available. (Miltner 2011; Miltner 2010; Ohio Environmental Protection Agency 2010b; Ohio River Valley Water Sanitation Commission 2002; Skalski and Anderson 2010)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Oklahoma (pg. 440)	Sensitive Water Supply Lakes (n=92) Scenic Rivers (n=6) Lakes Eucha and Spavinaw	The State of Oklahoma does have NNC for selected lakes, reservoirs, streams and rivers (Oklahoma Department of Environmental Quality 2010; Oklahoma Water Resources Board 2010)(http://water.epa.gov/scitech/swguidance/standards/ criteria/nutrients/states_ok.cfm, http://www.owrb.ok.gov/quality/standards/standards.php)Table 171. Oklahoma recently adopted new water quality standards and implementation rules that impact	Technical basis for 2008 Standards (Mike Bira pers.com.) and Oklahoma Water Quality Standards web site. (Clark et al. 2000) – Sensitive Lakes TP (Downing et al. 2001) – Scenic Rivers TP Chl-A and TP water quality modeling Lake Eucha and Spavinaw	EPA approved (2008 Standards) 2011 New Standards adopted by State, pending EPA approval. New NNC related implementation procedures Nutrient Plan approved in 2006 (Oklahoma water Resources Board 2006)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Oregon (pg. 456)	● Lakes, Rivers, Estuaries – Chl-A ○Reservoirs – Chl-A ○ Lakes, Rivers - P	See section Table 172 Reservoirs/Lakes >10 acres; average values based on 3 samples during 3 months. For stratified lakes: 0.08 mg/L Chl-A For non-stratified lakes, estuary, rivers/stream = 0.015 mg/L Clear Lake watershed = TP 9.0 mg/L during May1-Sept 30, 2 year median Williamette Yamhill River – 70 µg/L median May 1 to Oct 31.	Unknown, but original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979).	See section. Could not find approved NNC development plan. State approved and EPA adopted NNC for Chl-A and TP present. (Oregon Department of Environmental Quality 2007) Oregon is currently reviewing numeric turbidity criteria for possible adoption. However, turbidity criteria appear to be primarily focused on reducing excessive turbidity due to non-point source runoff or dredging that would reduce periphyton production or benthic spawning fish (Oregon Department of Environmental Quality 2010)
Penn-sylvania (pg. 462)	No NNC adopted	None	No NNC. However various approaches proposed in recent studies outlined in (Brown 2007; Paul and Zheng 2007). See also Table 173	Nutrient Criteria Plan published in 2004 (Pennsylvania Department of Environmental Protection 2004) No current NNC http://www.portal.state.pa.us/portal/server.pt/community/drinking_water_and_facility_regulation/10535 (Pennsylvania Department of Environmental Protection 2006)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Puerto Rico (pg464)	○Lakes/Reservoirs ○Streams/Rivers ○Estuarine	○ TIN – NTE 5.0 mg/L in estuaries/marine waters ○ TP, TP shall not exceed 1 mg/L upstream of drinking water reservoirs or estuarine waters except by permission of board. ○ clarity, estuarine/marine waters – NTE 10 NTU; all other (reservoirs, streams and wetlands) NTE 50	Unknown. Original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979).	NNC approved by EPA 1983; Recent EPA approved standards 2010 (Commonwealth of Puerto Rice Environmental Quality Board 2003; Commonwealth of Puerto Rice Environmental Quality Board 2010b). Puerto Rico has an approved Nutrient Criteria Development Plan which was originally released in 2008 and updated in 2010 (Commonwealth of Puerto Rice Environmental Quality Board 2010a; Commonwealth of Puerto Rico Environmental Quality Board 2008)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Rhode Island (pg. 467)	• P - lake	Table 175-Table 177 Average Total Phosphorus shall not exceed 0.025 mg/L in any lake, pond, kettlehole or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria, except as naturally occurs,	Unknown. Original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979). However, current plans to develop NNC for rivers and streams and other parameters for lakes are outlined in the current Nutrient Criteria Development Plan(Rhode Island Department of Environmental Management 2007b). Several approaches were recommended including 1) Statistical/Ecoregion methods with and without reference sites and 2) Development of Stressor-Response Models and 3) supplemental Best Professional Judgment (BPJ). We did not observe any reference to development of NNC for estuarine or marine waters.	No currently proposed NNC. Nutrient Criteria Development Plan available (Rhode Island Department of Environmental Management 2007b)

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
South Carolina (pg. 467)	○Lakes – N,P, Chl-A, clarity ○Rivers, Estuary, Wetlands - clarity	Table 178 <u>TP, Chl-A, TN</u> NNC applicable to lakes >= 40 acres (*3 ecoregions; range provided*). TP shall not exceed 0.02 – 0.09 mg/L, Chl-A shall not exceed 10-40 µg/L, and TN shall not exceed 0.35 – 1.50 mg/L. <u>Turbidity:</u> *For Trout Waters* Not to exceed 10 (NTUs) or 10% above natural conditions & existing uses are maintained. *Other freshwaters* NTE 50 NTUs (25 NTU lakes) & existing uses are maintained. Shellfish Harvesting Waters NTE 25 NTUs provided existing uses are maintained	Modified Ecoregion Approach used for lakes. Currently considering similar approach for rivers and estuaries (South Carolina Department of Health and Environmental Control 2007). In addition, development of stressor-response models.	Current NNC for lakes federally adopted. No new NNC proposed. (South Carolina Department of Health and Environmental Control 2008).

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
South Dakota (pg. 472)	No NNC developed	No NNC	None described. No nutrient criteria development plan.	No NNC approved, adopted or proposed
Tennessee (pg. 478)	○ Lakes – Chl-A	18 µg/L Chl-A mean based on compositve of monthly measurements form April –Sept.	Unknown for current reservoir. Ecoregion based and stressor response methods being considered for remaining waterbodies (Tennessee Department of Environment and Conservation 2007b). Classification based on Wadeable, Non-wadeable streams and lakes/reservoirs. Also state uses "nutrient translator values" to convert narrative nutrient to numerical values.	State adopted and federally approved NNC for selected reservoirs only. No other NNC adopted or approved Nutrient Criteria Plan available(Tennessee Department of Environment and Conservation 2007b)
Texas (pg. 483)	○ Reser-voirs	○ Chl-A Median of monitoring data will not exceed NNC for Chl-A. Range depending on reservoir: (5.00-53.05 ug/L) for	Various approaches considered, ecoregion, TSI, stressor response (Lower Colorado River Authority 2009; Texas Commission on Environmental Quality 2008b; Texas Commission on Environmental Quality 2009; Texas Commission on Environmental Quality 2010a; Texas Commission on Environmental Quality 2010c; Texas Commission on Environmental Quality 2010f; Texas Parks and Wildlife Department 2007). Final approach used involved historical sampling data and NNC set at the upper parametric prediction interval (Texas Commission on Environmental Quality 2010h). Recent studies involving whole stream and mesocosm level community studies of stream periphyton versus nutrient loading and concentrations have been conducted under EPA funding using stressor response approach and TITAN type analysis (King et al. 2009; King and Winemiller 2009).	NNC adopted by State in 2010 for selected reservoirs, recently EPA approved in 2011 ((Flores 2011; Texas Commission on Environmental Quality 2010h; Texas Commission on Environmental Quality 2011).

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Utah (pg.484)	None	None	Nutrient criteria development plan available (Miller 2005). Plan proposed to use a combination of stressor response and state refined ecoregion based approach for lakes and streams. Current activities include stream macroinvertebrate-response and nutrient models, lake Chl-A – diatom, nutrient models; site specific cost studies; Use of models (QUAL 2K), nutrient specific biological indicators – J. Ostermiller pers. com.	There is no NNC in this state. A nutrient criteria development plan is available (Miller 2005; Utah Department of Environmental Quality 2009)(http://www.rules.utah.gov/publicat/code/r317/r317-002.htm)(Utah Department of Environmental Quality 2011).
Vermont (pg.489)	●Lake – N, clarity ○Lake,P ●River N,clarity ○ River P	Table 181 Lakes/Ponds – 5.0 mg/L $N0_3$-N Streams 0.2 to 5.0 mg/L NO3-N based on base flow and elevation; 10-20 NTU annual average flow for rivers and lakes	Unknown, current NNC present in 1998, Original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979). Proposed criteria see section Table 182-Table 183	Nutrient criteria plan in place and proposed NNC is being reviewed by EPA (Laidlaw 2010a; Vermont Department of Environmental Conservation 2006a; Vermont Natural Resources Board 2008).
Virgin Islands (pg. 497)	●Estuary	●NTE TP 50 µg/L ●clarity not to be reduced below 1 meter secchi disk	Unknown but original TP values most likely derived from (United States Environmental Protection Agency 1986) and/or (Organisation for Economic Co-Operation and Development 1982; Vollenweider 1979). Ecoregion and stressor response methods described in Nutrient Criteria Development Plan for future modification and consideration of N control and refinement of P criteria and possible inclusion of chlorophyll-a. Focus on protection of coral reefs and recreational use (United States Virgin Islands Department of Planning and Natural Resources 2010b).	NNC approved June 2010. TP shall not exceed 50 µg/L in any waters (United States Virgin Islands Department of Planning and Natural Resources 2010a). Applicable to class B and C waters.

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Virginia including (Chesapeake Bay Regional) (pg. 501)	○ Lakes - P, Chl-A ○ Estuary: Chl-A, clarity (Chesapeake Bay TMDL)	Table 185-Table 191	Multiple approaches used. TMDL for Chesapeake Bay (United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2010b), Ecoregion and stressor response. Citations to selected technical support documents: (Garman 2009; Garman 2007; Rowe 2006; United States Environmental Protection Agency 2004; Virginia Academic Advisory Committee 2010; Virginia Department of Environmental Quality 2005a; Virginia Department of Environmental Quality 2005b; Virginia Water Resources Research Center 2006; Walker et al. 2007; Zipper 2009)	Approved NNC and Nutrient Criteria Development Plan (Virginia Department of Environmental Quality 2006; Virginia State Water Control Board 2011). Currently no other proposed or state only adopted NNC.
Washington (pg. 515)	○ Lake and River - P	Table 192-Table 193 In addition sections of Spokane River The average euphotic zone concentration of TP shall not exceed 25 mg/L during the period of June 1 to October 31.	Ecoregional method used to develop current lake criteria. Ongoing proposed work for flowing water and estuaries appears to utilize a combination of TMDL approaches using dissolved oxygen and/or pH as endpoints, that would explore nutrients as possible causative agents (Washington State Department of Ecology 2004)	NNC for TP in lakes adopted by state and approved by EPA(Washington State Department of Ecology 2006) No other criteria proposed or adopted only by state.

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
West Virginia (pg.520)	*Lake – P, *Chl-A (state standard only – rescinded in 2010)(Laidlaw 2010a; West Virginia Department of Environmental Protection 2009; West Virginia Department of Environmental Protection 2010)	*Previous recommended and adopted NNC Table 195. Recommended NNC for West Virginia Lakes and Reservoirs. Source:(Hansen et al. 2006).	Current recommended and previously used approaches include TMDL derived, regional ecoregion, and stressor response (Hansen et al. 2006; Laidlaw 2010a; Rowe 2006; West Virginia Coal Association et al. 2006; West Virginia Department of Environmental Protection 2009; West Virginia Nutrient Criteria Committee to the Environmental Quality Board 2004).	State standard for lakes adopted then later rescinded, never approved by EPA (West Virginia Department of Environmental Protection 2009). Some suggestion of consideration of TMDL derived 310 µg/L TP 30 day average NTE standard for Greenbrier River (Laidlaw 2010a) Confirmation of proposed NNC for Greenbrier River located in West Virginia state water quality web site but no mention of these specific TP criteria were observed (West Virginia Department of Environmental Protection 2010).

State (section page number below)	Water Body Type(s) Covered	Parameters/ Frequency	Method/Approach[1]	Approval Status
Wisconsin (pg.525)	○●Lakes and Reservoirs ○●Rivers and Streams	TP 75 µg/L Streams 100 µg/L rivers 30-40 µg/L reservoirs 15-40 µg/L Lakes 5 µg/L L. Superior 7 µg/L L. Michigan	Various used including ecoregion and stressor response (Robertson et al. 2006; Robertson et al. 2008; Unknown 2006; Wang et al. 2007; Wisconsin Department of Natural Resources 2007)	State adopted and federally approved NNC for TP (Wisconsin Department of Natural Resources 2010) Nutrient Criteria Plan in effect (Unknown 2006; Wisconsin Department of Natural Resources 2007)
Wyoming (pg.528)	None	NNC lacking	None	No NNC in current water quality standards.

[1]Compiled from state regulations, agency staff interviews, state and federal online data sources, and in part from: (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/progress.cfm and http://n-steps.tetratech-ffx.com/)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/progress.cfm) (Laidlaw 2010b; Thomas 2011; United States Environmental Protection Agency 2008b).

We present a short synopsis of each states existing, recently state adopted, and proposed numeric nutrient criteria, and whether federal approval has been granted. In addition, we have noted which states have NNC plans and any pertinent funded studies. The amount of information present for any particular state varies with the amount of recent activity and complexity of state issues. For some states there is extensive new information while others have limited information or have adopted NNC many years ago. In addition, we provide summary information on the waterbodies that NNC apply to and classification schemes that have been used to develop these. Many states have multiple classes of water beyond the standard lentic, lotic, wetlands and estuarine/marine, and a variety of designated uses creating a complex tiered water quality standards program. In addition, some states are fragmented into regional authorities with individual authority over water quality standards promulgations (e.g. California). Due to the resulting complexity and specific technical "jargon" used by various agencies throughout the United States to address their unique geography we have tried to present a range of examples to illustrate various approaches used by States in recent years to develop numeric criteria. In recent cases where numeric nutrient criteria were established before 2005, some states are considering modification of nutrient standards based on new data. The methodology used to develop the original numeric standards is often obscure or unavailable. For many of these states a synopsis of their existing standards is presented instead. Much of this information is taken from a (Laidlaw 2010b; Thomas 2011; United States Environmental Protection Agency 2008b) and individual review of state water quality standards or plans and environmental regulatory literature. In some cases due to their unique nature (e.g. Pacific Islands) and lack of similar waterbody types in Texas, we provide a very limited assessment of their NNC program. In other cases due to time limitations we provide only a very brief overview of some states.

Alabama

The majority of information on current and proposed NNC within Alabama was obtained from online data sources and interviews with Mr. Lynn Sisk from the Alabama Department of Environmental Management (ADEM). Currently Alabama has adopted and EPA approved NNC for reservoirs (Alabama Department of Environmental Management 2010b). In addition Alabama has adopted a Nutrient Criteria implementation Plan (Alabama Department of Environmental Management 2009). Like many states Alabama elected to evaluate and develop NNC for reservoirs first and is in the process of developing NNC for streams, rivers and estuaries.

Alabama Reservoirs

Alabama has adopted and EPA has approved NNC for reservoirs starting in 2005 and continuing through 2011 (L. Sisk pers. comm.). This consists of numeric chlorophyll-*a* criteria for all but 4 of its major reservoirs (L. Sisk pers. comm.)(Alabama Department of Environmental Management 2010a; Alabama Department of Environmental Management 2010b)(ADEM Administrative Code Reg. 335-6-10-11 www.adem.state.al.us). The criteria are applied at specific locations and are expressed as a growing season mean. The growing season is defined as April through October except in the Tennessee River basin where it is April through September. The regulations do not specify an exceedance frequency but Alabama's Water Quality Assessment and Listing Methodology states that there shall not be more than 2 exceedances in a six year period to demonstrate full use support. However, an exception is made if the exceedance is due strictly to hydrologic conditions such as floods or droughts. The chlorophyll-*a* criteria was adopted in 2005 and approved by EPA in 2006 (Alabama Department of Environmental Management 2010b).

In developing numeric nutrient criteria, ADEM prioritized all lakes/reservoirs based on several factors such as public priority, available data, use-impairment status (i.e. 303(d) list), complexity of lake system, and modeling requirements. After careful consideration of these factors, ADEM developed a schedule listed in the Nutrient Criteria Plan (Alabama Department of Environmental Management 2009). According to ADEM, the schedule was and is primarily driven by the available water quality data for each lake and the timeframe it will take to gather additional data and complete development of water quality models where necessary. As of November 2009, Alabama has established nutrient criteria in the form of chlorophyll-*a* criteria for 29 lakes and reservoirs.

While developing nutrient criteria for reservoirs, ADEM's objective was to determine nutrient levels that are protective of the beneficial uses for each waterbody. Due to the large diversity in geographic and climatic conditions and significant variability in dam operations between reservoirs, ADEM used best professional judgment to develop nutrient criteria on a lake-specific basis rather than on a more aggregate basis such as an ecoregional approach. ADEM claimed that the lake-specific approach captured the large variability inherent in man-made reservoirs, where Chl-*a* concentrations are typically affected by such factors as reservoir depth, reservoir retention time, and scheduling of power generation.

During the criteria development process for reservoirs, historical data was studied to provide an overall perspective of the condition of each reservoir. This information was analyzed to determine trends in trophic conditions, the degree to which reservoir conditions remain stable over time, and whether any impairment has occurred due to nutrient over-enrichment. From this data, nutrient levels (expressed as seasonal means of chlorophyll a concentrations) were targeted that correlated with reservoir conditions that support the designated beneficial uses. The historical data depicted the diversity of reservoir conditions in Alabama, from lakes that are naturally oligotrophic-mesotrophic, to lakes that tend to be more eutrophic in nature.

ADEM recognized that using an ecoregion reference condition approach to establish nutrient criteria in reservoirs can be limited due to the fact that there is uncertainty regarding what constitutes "natural" conditions in a man-made waterbody. Therefore, in developing nutrient criteria, ADEM selected to analyze historical ambient data on an individual reservoir basis to determine if each reservoir continues to support its designated uses. If so, the nutrient concentrations that have historically corresponded to that reservoir's use support are evaluated to determine a chlorophyll a target specific to that reservoir. This same approach is used regardless of the reservoir's trophic state (i.e. eutrophic, oligotrophic, or mesotrophic). Thus, the intent is that the selected chlorophyll a criteria values are specifically associated with a condition of full use support in each respective reservoir, taking into account the factors unique to various trophic conditions.

Data were analyzed to determine the ranges of chlorophyll a and total phosphorus concentrations historically occurring in each reservoir. To maintain nutrient levels within the ranges associated with full use-support conditions, best professional judgment is used to derive criteria values that "cap" each reservoir system with protective chlorophyll-*a* concentration. In establishing chlorophyll-*a* targets, the variability occurring within the growing season was taken into account. The cooler months are generally less productive and lower chlorophyll a values are usually recorded, while the warmer months are generally more productive with higher values typically recorded.

To determine what constitutes healthy conditions in various types of reservoirs and how trophic gradients relate to use attainment, ADEM utilized research conducted by Dr. David Bayne and his students and colleagues at Auburn University. Their research examined how the quality of fisheries correlated to varying trophic conditions in Alabama reservoirs. The study assessed the potential impacts of reverse eutrophication and nutrient reduction on reservoir fisheries and calculates target levels of primary production that provide both quality fishing and satisfactory water clarity for other recreational users, while protecting all aquatic communities. Their research *("Compatibility between Water Clarity and Quality Black Bass and Crappie Fisheries in Alabama"; American Fisheries Society Symposium 16:296-305. 1996*) provided substantial evidence that fish biomass and sport-fish harvesting are positively correlated to algal production in reservoirs (Maceina et al. 1996). The authors concluded that based on empirical relations in 32 major impoundments in Alabama, chlorophyll-a concentrations greater than 15 mg/m^3 = (15 μg/L) would generally result in water transparencies less than 120 cm, which may be less appealing to nonangling reservoir users. They proposed that in southern U.S. reservoirs, reductions in chlorophyll-*a* concentrations to 10-15 μg /L will not necessarily be detrimental to black bass and crappie fisheries, and will likely improve water clarity.

The research conducted by Dr. Bayne and others demonstrated that the size, growth rates and condition of certain species of sports fish are generally higher in eutrophic than in oligo-mesotrophic reservoirs. Their study, along with case studies of reservoirs in other regions, raised the concern of ADEM that the reversal of eutrophication and improvement in water clarity in some reservoirs can be deleterious to its warm-water sports fisheries by reducing fish production and biomass (Ney 1966). ADEM believed that when establishing nutrient criteria it is vital to set water quality standards that adequately consider all the beneficial uses of the reservoir including fishing and swimming. Therefore ADEM was cautious in developing NNC to insure these did not cause an undesirable shift in fish species. They hypothesized that if historically a reservoir had supported all of its uses, including high-quality fisheries and other aquatic communities, NNC should be targeted to preserve these reservoir conditions.

ADEM considered the typical hydraulic regime and flow characteristics of each reservoir as other key factors to be considered during criteria development. The relationship between water quality, biomass accumulation, and hydraulic residence time (or retention time), which is the average amount of time required to completely renew a reservoir's water volume, was taken into account when establishing their chlorophyll-*a* criteria. For example, reservoirs associated with "run-of-the-river" dams typically have small hydraulic head, limited storage area and short retention times and are considered less susceptible to eutrophication. In contrast, reservoirs associated with larger dams such as flood storage or hydroelectric dams, are more likely to have longer retention times and a higher risk of becoming eutrophic at the same level of nutrients. ADEM confirmed these theories locally through sponsored studies conducted by Dr. Bayne.

According to ADEM, Dr. Bayne examined the relationship between reservoir-water retention times and phytoplankton algae production on Weiss Lake during the summer of 2001. Dr. Bayne, along with Auburn University professor Dr. Mike Maceina, assessed the potential water quality effects on Weiss Lake of the draft Coosa River water-sharing agreement between Alabama and Georgia. Their study showed that reservoirs with typically short retention times, such as reservoirs on the Coosa River, were more susceptible to hypereutrophic effects and higher chlorophyll-*a* concentrations when retention times were increased even moderately. Historical data showed that higher chlorophyll-*a* concentrations in Weiss Lake had consistently corresponded to longer retention times. Hydrologic models utilized in their study indicated that longer retention times in the reservoir would likely increase phytoplankton algal production and biomass accumulation, keeping all other factors constant. This condition would be most acute during drought periods.

While developing reservoir NNC ADEM considered downstream transport of nutrients and the processes by which nutrient uptake occurs in streams. They stated that during constant loading scenarios, nutrient concentrations generally tend to decrease in a downstream direction. This attenuation occurs as nutrients are absorbed by microorganisms and plants (biotic uptake) or as they adsorb onto sediment particles (abiotic uptake) and settle out of the water column. Thus, in developing NNC, the chlorophyll-*a* targets were set so that along certain stretches of river, each successive downstream reservoir had a lower criteria value. Their approach took into account natural processes that determine nutrient concentrations and theoretically should be protective of downstream water quality.

NNC Chlorophyll-*a*

ADEM ultimately elected to use chlorophyll-*a* as the primary indicator of cultural eutrophication. The term "cultural eutrophication" was used to differentiate between over-enrichment caused by human activities and natural nutrient loading from soils and parent materials indigenous to each watershed. Chlorophyll-*a* criteria serves as the primary tool used by the Department to protect the designated uses of lakes and reservoirs from nutrient over-enrichment. Chlorophyll-*a* was selected as the candidate

NNC response variable because it is widely accepted among limnologists and agencies as an effective surrogate for estimating the primary production response to nutrient loading. Chlorophyll-*a* is also relatively easy and inexpensive to collect and analyze.

Chlorophyll-*a* criteria were established based on a "growing-season" basis, which is defined as April through October for all reservoirs in Alabama with the exception of the mainstem reservoirs in the Tennessee River basin. These reservoirs have a defined growing season of April through September. The chlorophyll-*a* criteria are represented as the mean of samples (taken as photic-zone composites) collected monthly during the growing season. Ultimately chlorophyll-*a* criteria for each reservoir were selected using historical data and best professional judgment, recognizing the seasonal variations that occur.

The NNC for chlorophyll-*a* criteria was selected to protect the designated uses in the majority of the area of each Alabama reservoir. However, specific "compliance" monitoring locations were established within each reservoir. Therefore criteria values were not intended to be applied as lake-wide averages or as chlorophyll-*a* concentrations that shall be maintained at all locations within the lake at any given time. Instead ADEM believed that when appropriate, criteria would be established at additional stations to recognize changing limnological conditions and to provide protection of existing uses in the majority of the reservoir.

Due to the non-uniform, complex nature of mixing of water in reservoir embayments and their connection to water quality in associated tributaries, ADEM found it difficult to derive a single criterion value that was protective of an entire reservoir including side bays and tributaries. To address this issue, ADEM has continued routine monitoring of water quality in embayments as a part of their water quality monitoring program. They utilize this monitoring data to determine the degree to which nutrients may be affecting designated use support and, where appropriate (i.e. where designated uses are threatened or impaired), they can adopt future criteria for these areas to protect those designated uses. Until NNC are developed for embayments, ADEM will evaluate their status using established narrative criteria.

The chlorophyll-*a* criteria is used by ADEM to assess reservoir conditions (i.e. trophic state) and to determine use-support status (i.e. 303(d) listing and 305(b) reporting). The chlorophyll-*a* criteria is also used as a water quality target for Total Maximum Daily Load (TMDL) development. For example, when a reservoir is determined to be nutrient-impaired (i.e. exceeding Chl-A criteria), ADEM will conduct analyses to determine the required pollutant load reductions (i.e. TP and/or TN loads) necessary to achieve the lake-specific chlorophyll-*a* criteria.

ADEM did not believe it was necessary to develop numeric criteria for other nutrient indicators including total phosphorus (TP), total nitrogen (TN), or Secchi depth (SD). The significance of these variables and their relation to nutrient loading will continually be evaluated as new data is collected. While chlorophyll-*a* provides a reliable depiction of primary production levels and thus gives a fairly accurate assessment of nutrient conditions in a waterbody, it is uncertain how effective the other parameters are in assessing nutrient over-enrichment. For example, because there is such variability in how each waterbody responds to nutrient loading, it is difficult to determine what concentrations of TP and TN correlate to undesirable levels of primary production. Also, ADEM argued that establishing meaningful relationships between causal and response variables is often problematic. Low concentrations of TP, for example, can correlate to both low and high phytoplankton biomass levels; the latter occurring when originally high TP (this would only occur with dissolved phosphorus) concentrations are significantly reduced as excessive nutrients are assimilated within the growing phytoplankton biomass. ADEM utilizes Algal Growth Potential Tests (AGPT) on each reservoir to determine if the limiting nutrient is phosphorus, nitrogen, or a combination of both. The Department continues to measure TP and the nitrogen series concentrations as a part of its routine reservoir monitoring program. ADEM claims that data collected through 2008 has not revealed significant relationships between growing season average chlorophyll-*a* concentrations and mean TP or TN concentrations (Alabama Department of Environmental Management 2009).

Streams and River NNC Activities

ADEM recently contracted with Auburn University to evaluate available water quality, biological, and habitat data collected in the Tallapoosa River basin in 2010 and previous years (Auburn University Center of Excellence for Watershed Management 2010). Ultimate goal: To assist the Alabama Department of Environmental Management develop numerical nutrient (P and N) criteria for wadeable streams. The primary tasks and objectives of this project include:

1) Analysis and quantification of any statistical relationships between water chemistry & physical data, selected biota, environmental data (light, vegetative cover, geological features, etc.) based on specific stream monitoring data collected or approved by ADEM.

2) Determination of numeric levels at which N and P nutrients are beneficial and at what levels they become detrimental to aquatic biota and designated stream use in the Tallapoosa River Basin based on the analysis of data provided by ADEM or other research data.

3) Recommending alternative methods that may be used if numeric values cannot be determined from available data analysis.

ADEM hired contractors to accomplish these tasks using data compiled and digitally archived from a variety of sources including much prior research and volunteer monitoring data from Auburn University and the Alabama Water Watch Program. Any data gaps will be identified and suggestions made to correct these gaps. Existing data will be analyzed and recommendations made to collect additional data as needed to address data gaps. The ultimate goal is to develop legally defensible numerical nutrient (P and N) criteria for wadeable streams that will be acceptable to EPA. This project is scheduled to be completed by the end of 2011. ADEM is expecting to propose numeric nutrient criteria for wadeable streams in the Tallapoosa River basin sometime in 2012 (Alabama Department of Environmental Management 2009). ADEM's goals for developing and adopting nutrient criteria for Alabama's rivers and streams are as follows:

1) Develop and adopt nutrient criteria that support the beneficial uses designated for rivers and streams and that protect these waters from potential adverse effects associated with over-enrichment.

2) Restore and maintain the chemical, physical, and biological integrity of rivers and streams.

3) Maintain the diversity and uniqueness of Alabama's rivers and streams.

ADEM states that these goals will be difficult to achieve. The proposed approach requires a significant amount of resources and an adequate quantity of collected data. ADEM stated that based on previous water quality studies on streams that were considered impaired from over-enrichment, they found little, if any, correlation between nutrient loading and response variables. They believed that because fluctuations in primary production levels are the result of natural processes involving complex interactions of numerous factors, it is often difficult to relate concentrations of chlorophyll-*a* or periphyton coverage to a single nutrient parameter (N or P) alone. Many other physical and chemical factors other than nutrient loading can lead to fluctuations in algal biomass, including riparian shading, meteorological conditions (shading), water clarity, precipitation, stream velocity, substrate type, stream depth and resulting SAV, periphyton, and floating algae.

ADEM is considering the "reference condition approach" such as that described in the U.S. Environmental Protection Agency's publication, *Nutrient Criteria Technical Guidance Manual (Rivers and Streams)* (United States Environmental Protection Agency 2000h). As previously described, this approach uses data collected at a reference, or "least impacted," site that are found within the same ecoregion or bioregion as the targeted waterbody or that shares many of the same physical, chemical, and biological attributes. ADEM is evaluating the use of Level IV Ecoregions as an *a priori* classification method to facilitate program planning and development of reference conditions. This approach should help ensure that factors potentially affecting biotic communities are monitored. ADEM felt that analysis of this data might facilitate the determination of whether biotic communities differ significantly between Level III and IV Ecoregions or if some of these Ecoregions can be lumped into bioregions.

In the reference condition approach, an upper percentile of the reference data is used to derive the numeric criteria (United States Environmental Protection Agency 2000h). Although this method employs a statistical component, it has a major shortcoming in that it does not necessarily establish a definitive link between nutrient concentrations and levels of impairment and it is primarily applicable to wadeable streams. The method does not provide information regarding the waterbody's capacity to assimilate nutrient loads. Without this type of information, it is difficult to determine if a derived numeric criterion will be under- or over-protective. Thus, there is a credible risk that a waterbody may be listed as impaired even though its designated uses are being attained.

ADEM stated that it believes an "effects-based" approach is better suited for nutrient criteria development in streams and rivers (Alabama Department of Environmental Management 2009). However the agency concluded that time constraints and resource limits will likely require the use of a reference condition approach as an alternative. However, they will attempt to document and utilize cause-and-effect relationships between nutrient concentrations and response variables, such as primary production during final development of NNC. If ADEM cannot find a meaningful relationship between these variables for a waterbody, they stated that they will utilize the reference approach recommended by EPA.

While developing nutrient criteria for streams and rivers, the Department expects to first target those stream segments currently identified as being impaired due to excess nutrient enrichment. They felt that TMDL studies will generate a significant amount of data, including computer modeling, which can potentially provide insight into how the waterbody and its aquatic ecosystems respond to different nutrient concentrations. ADEM anticipated that this type of approach combined with data collected at appropriate reference sites, will provide sufficient information for development of NNC.

A complicating factor in developing nutrient criteria for rivers and streams identified by ADEM was the limitation of assessment methods that can effectively monitor biological impairment from nutrients (Alabama Department of Environmental Management 2009). ADEM is considering adding periphyton assessment to their biological monitoring as a response indicator to nutrients. ADEM has conducted studies to evaluate three different algal bioassessment techniques to determine which provides the most effective indication of nutrient enrichment. The three bioassessment methods evaluated include periphyton biomass as chlorophyll a, diatom community assessment, and a field-based rapid periphyton survey. These methods were tested at 20 stream segments with known or suspected impairment from nutrient over-enrichment as well as at 14 ecoregion reference sites for comparison. To provide the most complete characterization of water quality conditions, habitat quality and macroinvertebrate and fish communities were also assessed at the reference and study reaches.

The preliminary results of their studies suggested that periphyton chlorophyll-*a*, total chlorophyll-*a*, and percent coverage of suitable substrate (CSS) can effectively indicate water quality problems associated with nutrient enrichment. Correlation between reference reaches was variable but may improve as additional data are collected and the method and delineation of ecoregions are further refined. They determined that periphyton as chlorophyll-*a* was significantly correlated ($p = 0.05$; $r = 0.88$) with average total phosphorus (TP) concentrations. The correlation between the CSS method and average TP was not as strong ($p = 0.02$; $r = 0.64$). In addition, several macroinvertebrate and fish bioassessment metrics were correlated with mean total phosphorus and nitrogen concentrations. ADEM anticipates that these correlations will become better defined as more appropriate reference conditions are developed.

ADEM has set up a priority list of rivers and streams to develop NNC. The following list shows the expected sequence of nutrient criteria development in rivers and streams in Alabama, however the development process could proceed simultaneously in some of the following waterbodies.

1) Waterbodies with EPA-approved nutrient TMDLs
2) Waterbodies designated as Outstanding National Resource Water
3) Waterbodies with the Outstanding Alabama Water designated use and ecoregional reference waterbodies
4) Waterbodies contributing significant nutrient loads to reservoir embayments as indicated from embayment monitoring data
5) Other rivers and streams as data and resources allow

ADEM revised its Rivers and Streams Monitoring Strategy in 2005 in part to provide stressor-response data that can be used to develop nutrient criteria. It is based on the two relationships depicted in Figure 4. The Strategy plans biological monitoring activities along a full disturbance gradient to produce a dataset representing both the full stressor gradient and the full biological condition gradient. The biological and chemical datasets that the ADEM is building will allow ADEM to use an iterative, weight of evidence approach to adopt the most appropriate numeric criteria for wadeable streams and rivers.

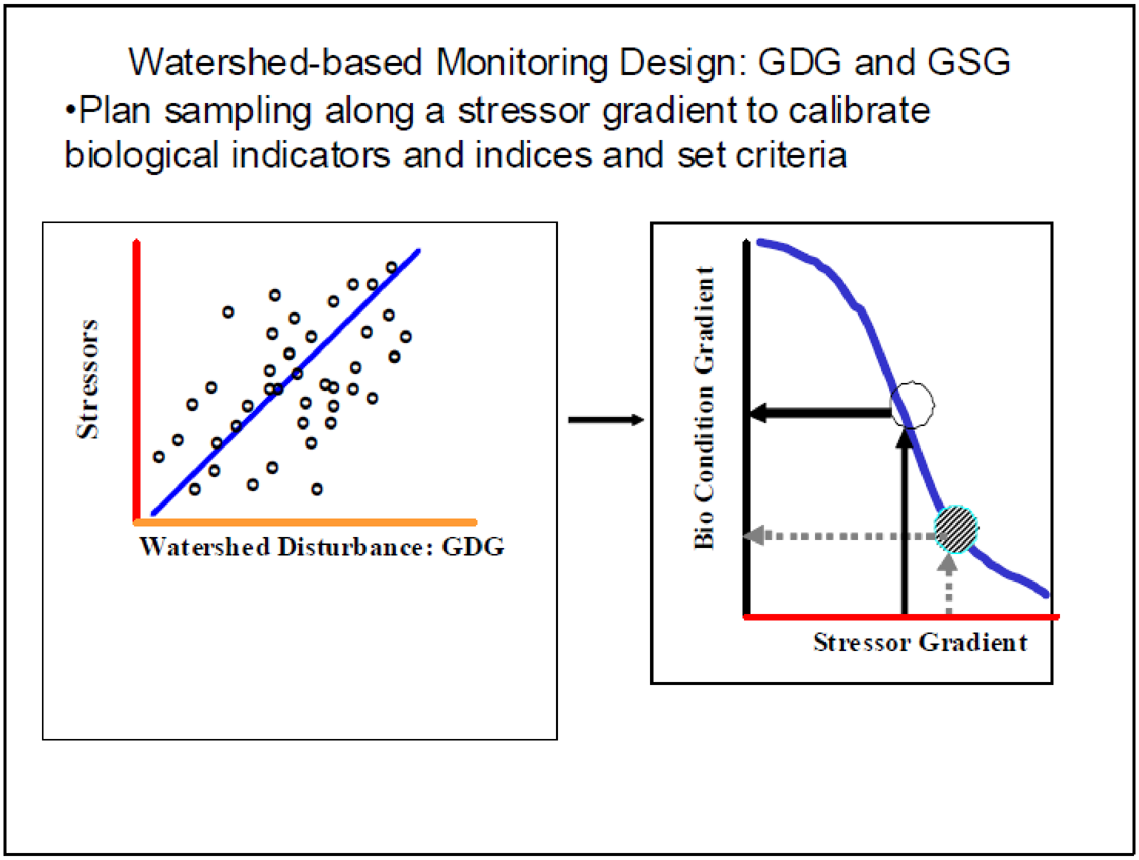


Figure 7. Watershed-Based Monitoring Design From: (Alabama Department of Environmental Management 2009).

Estuarine and Marine NNC Activities

ADEM is participating in a study funded by NOAA funds through the Mississippi Department of Environmental Quality (MSDEQ) to gather data in Weeks Bay in Baldwin County Alabama (Alabama Department of Environmental Management 2009; Alabama Department of Environmental Management 2011). This study is in response to the Gulf of Mexico Alliance (GOMA) – Nutrient Reduction Priority Implementation Team (PIT) – Action 1. Information gathered from that study will be used to calibrate a water quality model for Weeks Bay that will be used to explore the relationship between nutrients (TN, TP) and various response variables (e.g. Chl-A) in a small estuary. Sampling for this project began in February and will continue through November 2011.

Alaska

Alaska does not currently have NNC (Alaska Department of Environmental Conservation 2009; Alaska Department of Environmental Conservation 2011)(Table 12). Alaska does have an EPA approved Nutrient Criteria Plan (Alaska Department of Environmental Conservation 2004). ADEM has adopted a strategy to first develop NNC for lakes, then rivers and finally estuaries and wetlands. The plan called for investigating lakes in urban areas around Anchorage, some lakes near agriculture in the Matsu Valley, and some pristine lakes in the Matsu-Susitna Valley (Alaska Department of Environmental Conservation 2006). The Matsu is the only place in Alaska with any agriculture activity of significance. These studies were carried out by the University of Alaska (Stockwell and Whitledge 2009). In the development of a regional lake nutrient criterion ADEC will utilize previously collected data for development of regional lake criteria (Lomax 2008). According to ADEC officials they have very limited data on nutrient levels in their waters because most of them are only accessible by aircraft (C. Reese pers. comm.). Nutrients are a lower priority for ADEC because Alaska has few anthropogenic sources for nutrients such as agriculture of industrialization. Alaska's water quality issues are often vastly different than those in most other states. Human caused eutrophication of waters is not a major documented problem in Alaska (C. Reese pers. comm.).

American Samoa

American Samoa has extensive NNC for all waters of the territory (Table 12)(American Samoa Environmental Protection Agency 1999; American Samoa Environmental Protection Agency 2005; Vaouli et al. 2010). The NNC are provided in Table 12. These NNC were first adopted in 1998, with the most recent water quality standards revision occurring in 2010 (United States Environmental Protection Agency 2008b). We were unable to determine the rationale for these values, since we were not able to locate the original technical documentation and there was no nutrient criteria plan available. However the values were all given in "not to exceed a single criteria value" term and were specific to waterbodies types including freshwater, bays, nearshore marine and offshore marine. The only exception was the light penetration criteria which referred to a 50th percentile time frequency. The variables used in each water body were TP, TN and light penetration. In addition chlorophyll-*a* was adopted for all waters except freshwater bodies. The most restrictive levels were generally offshore marine, while the most liberal were in the freshwater category.

Arizona

According to the EPA, Arizona has had NNC for selected rivers, streams, lakes and reservoirs and designated uses since 1998 (United States Environmental Protection Agency 2008b). This included TN, nitrate, TP and turbidity. The State of Arizona began the process of developing additional nutrient criteria in 2002 when the Arizona Department of Environmental Quality (AZDEQ) submitted a Nutrient Criteria

Development Plan to EPA. The plan focused on the development of nutrient criteria for lakes and reservoirs as a first priority. AZDEQ suggested the development of a matrix of lake endpoints that would provide the basis for interpretation of the narrative nutrient standard. AZDEQ also established lake and reservoir categories or classes, such that individual water bodies would be evaluated within a context of watershed attributes, land uses, climatology, morphology, and management practices.

AZDEQ subsequently created five functional lake classes: deep, shallow, igneous-based, sedimentary-based, and urban. Lake classes were derived using statistical analysis of lake and watershed characteristics from 70 lakes and reservoirs in Arizona. A subset of 50 lakes and reservoirs was used to derive threshold ranges. According to AZDEQ, they evaluated these thresholds using a scientific literature review process of literature and policies adopted by other states (Arizona Department of Environmental Quality 2008). For each class and each applicable designated use, AZDEQ developed a matrix of threshold values expressed as ranges for chlorophyll-*a*, Secchi depth, TN, TKN, TP, percent blue-green algae, and total count of blue-green algae. Dissolved oxygen (DO) and pH standards were added as relevant and supportive endpoints.

In 2008, the ADEQ drafted implementation procedures for narrative criteria for selected reservoirs, which were eventually adopted by the state in 2009 (Arizona Department of Environmental Quality 2008; Arizona Department of Environmental Quality 2009; Laidlaw 2010a). A lake or reservoir is considered attaining the narrative nutrient standard if the mean of all parameters fall below respective threshold ranges in Table 13 (except for Secchi depth, in which case, the result must all be above the threshold range) extracted from (Arizona Department of Environmental Quality 2009). Under the adopted standard ADEQ will further determine compliance with the narrative nutrient standard in lakes by one of the following four ways listed below:

1. The mean chlorophyll-*a* result is at or above the upper value in the target range for chlorophyll-*a* for the lake category prescribed in Table 13.

2. The mean chlorophyll-a result is within the target range for chlorophyll-a for the lake category prescribed in Table 13, and the mean blue-green algae result is at or above 20,000 per milliliter or the mean blue-green algae count is 50 percent or more of the total algae count.

3. The mean chlorophyll-*a* result is within the prescribed range for the lake category and there is other evidence of nutrient-related impairments. ADEQ will consider the following factors when applying this weight-of-evidence approach:

   a. Exceedances of dissolved oxygen or pH standards;
   b. Fish kills or other aquatic organism mortality attributed to exceedances of dissolved oxygen or pH, or to ammonia or algal toxicity;
   c. Secchi depth is below the lower threshold value for the lake category;
   d. The concentration of total phosphorus, total nitrogen, or TKN exceeds the upper value in the range prescribed for the lake category in Table 13.

4. The lake is a shallow lake with a mean depth of less than 4 meters and submerged aquatic vegetation covers more than 50% of the aerial extent of the lake bottom and there is a greater than 5 milligram per liter swing in diel (24-hr) dissolved oxygen concentration measured within the photic zone.

Table 13. Proposed water quality standards for Arizona lakes and reservoirs. Source: 2009 Arizona Water Quality Standards.

NUMERIC TARGETS FOR LAKES AND RESERVOIRS										
Designated Use	Lake Category	Chl-*a* (µg/L)	Secchi Depth (m)	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Total Kjehldal Nitrogen (TKN) (mg/L)	Blue-Green Algae (per ml)	Blue-Green Algae (% of total count)	Dissolved Oxygen (mg/L)	pH (SU)
	Deep	10-15	1.5-2.5	70-90	1.2-1.4	1.0-1.1				
	Shallow	10-15	1.5-2.0	70-90	1.2-1.4	1.0-1.1				
FBC and PBC	Igneous	20-30	0.5-1.0	100-125	1.5-1.7	1.2-1.4	20,000			6.5-9.0
	Sedimentary	20-30	1.5-2.0	100-125	1.5-1.7	1.2-1.4				
	Urban	20-30	0.5-1.0	100-125	1.5-1.7	1.2-1.4				
A&Wc	All	5-15	1.5-2.0	50-90	1.0-1.4	0.7-1.1			7 (top m)	
A&Ww	All (except urban lakes)	25-40	0.8-1.0	115-140	1.6-1.8	1.3-1.6		<50		6.5-9.0
	Urban	30-50	0.7-1.0	125-160	1.7-1.9	1.4-1.7			6 (top m)	
A&Wedw	All	30-50	0.7-1.0	125-160	1.7-1.9	1.4-1.7				6.5-9.0
DWS	All	10-20	0.5-1.5	70-100	1.2-1.5	1.0-1.2	20,000			5.0-9.0

FBC = "Full-body contact (FBC)" means the use of a surface water for swimming or other recreational activity that causes the human body to come into direct contact with the water to the point of complete submergence.
PBC = "Partial-body contact (PBC)" the recreational use of a surface water that may cause the human body to come into direct contact with the water, but normally not to the point of complete submergence (for example, wading or boating). The use is such that ingestion of the water is not likely and sensitive body organs, such as the eyes, ears, or nose, will not normally be exposed to direct contact with the water.
A&We = "Aquatic and wildlife (ephemeral) the use of an ephemeral water by animals, plants, or other organisms, excluding fish, for habitation, growth, or propagation.
A&Ww = "Aquatic and wildlife (warm water)" the use of a surface water by animals, plants, or other warm-water organisms, generally occurring at an elevation less than 5000 feet, for habitation, growth, or propagation.
A&Wedw = "Aquatic and wildlife (effluent-dependent water) the use of an effluent dependent water by animals, plants, or other organisms for habitation, growth, or propagation.
DWS = "Domestic water source (DWS)" the use of a surface water as a source of potable water. Treatment of surface water may be necessary to yield finished water suitable for human Consumption

The EPA has yet to approve the lake criteria outlined in the 2009 water quality standards as of May 2011, and therefore portions of the previous 2002 Arizona water quality standards remain in effect for Clean Water Act purposes. The 2009 standards cannot be used for assessment of permits until an implementation plan is finalized (Susan Fitch pers. comm. - fitch.susan@azdeq.gov).

The state adopted 2009 nutrient criteria also contained updated NNC for selected streams and rivers based on percentiles generated from new historical data of streams and rivers (Table 14). Arizona's NNC for streams and rivers including the upper portions of some reservoirs consist primarily of nitrogen and phosphorus limits expressed in (mg/L) and defined in terms of 90th percentile values. A minimum of 10 samples, each taken at least 10 days apart in a consecutive 12-month period, are required to determine a 90th percentile. Not more than 10 percent of the samples may exceed the 90th percentile value listed for each stream.

Table 14. Current state adopted NNC stream standards for Arizona. Concentration in mg/l. From AZDEQ 2009 water quality standards.

	Surface Water	Annual Mean	90th Percentile	Single Sample Maximum
1.	Verde River and its tributaries from the Verde headwaters to Bartlett Lake			
	Total phosphorus	0.10	0.30	1.00
	Total nitrogen	1.00	1.50	3.00
2.	Black River, Tonto Creek, and their tributaries that are not located on tribal lands:			
	Total phosphorus	0.10	0.20	0.80
	Total nitrogen	0.50	1.00	2.00
3.	Salt River and its tributaries above Roosevelt Reservoir, excluding Pinal Creek, that are not located on tribal lands:			
	Total phosphorus	0.12	0.30	1.00
	Total nitrogen	0.60	1.20	2.00
4.	Salt River below Stewart Mountain Dam to its confluence with the Verde River:			
	Total phosphorus	0.05		0.20
	Total nitrogen	0.60		3.00
5.	Little Colorado River and its tributaries above River Reservoir in Greer; South Fork of Little Colorado River above South Fork Campground; and Water Canyon Creek above Apache-Sitgreaves National Forest boundary:			
	Total phosphorus	0.08	0.10	0.75
	Total nitrogen	0.60	0.75	1.10
6.	Little Colorado River at the crossing of Apache County Road No. 124:			
	Total phosphorus			0.75
	Total nitrogen			1.80
7.	Little Colorado River above Lyman Lake to above the Amity Ditch diversion near crossing of Arizona Highway 273 (applies only when in-stream turbidity is less than 50 NTU):			
	Total phosphorus	0.20	0.30	0.75
	Total nitrogen	0.70	1.20	1.50
8.	Colorado River at the Northern International Boundary near Morelos Dam:			
	Total phosphorus		0.33	
	Total nitrogen		2.50	
9.	Oak Creek from its headwaters at 35°01'30"/111°44'12" to its confluence with the Verde River at 34°40'41"/111°56'30" and the West Fork of Oak Creek from its headwaters at 35°02'44"/111°54'48" to its confluence with Oak Creek at 34°59'14"/111°44'46".			
	Total phosphorus	1.00	1.50	2.50
	Total nitrogen	0.10	0.25	0.30
10.	No discharge of wastewater to Show Low Creek or its tributaries upstream of and including Fools Hollow Lake shall exceed 0.16 mg/L total phosphates as P.			
11.	No discharge of wastewater to the San Francisco River or its tributaries upstream of Luna Lake Dam shall exceed 1.0 mg/L total phosphates as P.			

The other values (annual mean and single sample maximum) are screening values. In addition, one of the rivers listed requires sampling for standards evaluation only when turbidity (NTU) levels are below a certain level. The citations for various studies used to develop these standards were provided by Susan Fitch AZDEQ (Arizona Department of Health Services 1981a; Arizona Department of Health Services 1981b; Arizona Department of Health Services 1985a; Arizona Department of Health Services 1985c) (Arizona Department of Health Services 1985b). However, the AZDEQ did not provide us with these old studies and they were not posted on their web site.

Arkansas

Data on the current status of Arkansas NNC were obtained from published reports and agency publications and from information provided by the Arkansas Department of Environmental Quality (ADEQ) water quality standards staff member Tate Wentz (wentz@adeq.state.ar.us). Arkansas currently does not possess any state adopted and/or EPA approved NNC (Arkansas Pollution Control and Ecology Commission 2010; Thomas 2011). However, Arkansas does have a nutrient criteria development plan and has conducted studies to obtain information to develop NNC. In addition, draft proposed NNC have been developed for reservoirs (Tate Wentz, ADEQ pers. comm.). ADEQ does have narrative nutrient criteria. The pertinent narrative nutrient criteria language from their current regulations states:

"Materials stimulating algal growth shall not be present in concentrations sufficient to cause objectionable algal densities or other nuisance aquatic vegetation or otherwise impair any designated use of the waterbody. Impairment of a waterbody from excess nutrients are dependent on the natural waterbody characteristics such as stream flow, residence time, stream slope, substrate type, canopy, riparian vegetation, primary use of waterbody, season of the year and ecoregion water chemistry. Because nutrient water column concentrations do not always correlate directly with stream impairments, impairments will be assessed by a combination of factors such as water clarity, periphyton or phytoplankton production, dissolved oxygen values, dissolved oxygen saturation, diurnal dissolved oxygen fluctuations, pH values, aquatic-life community structure and possibly others. However, when excess nutrients result in an impairment, based upon Department assessment methodology, by any established, numeric water quality standard, the waterbody will be determined to be impaired by nutrients.
All point source discharges into the watershed of waters officially listed on Arkansas' impaired waterbody list (303d) with phosphorus as the major cause shall have monthly average discharge permit limits no greater than those listed below".

Arkansas's Nutrient Criteria Development Plan that was originally published in 2006 and most recently amended in 2010 (Arkansas Department of Environmental Quality 2006; Thomas 2011). A combination of two approaches suggested by EPA (Grubbs 2001b) and modified to fit ADEQ's nutrient criteria development approach were utilized to meet the following objectives:

1) Develop numeric nutrient criteria that fully recognize localized conditions to protect specific designated uses using EPA's Technical Manual.

2) Develop a scientifically defensible methodology utilizing:

a. Causality-based studies to identify quantitative relationships
b. Empirical approaches
c. Appropriate conceptual and statistical models
d. Appropriate spatial and temporal scales

The Plan called for the three tiered assessment approach for rivers and streams and targeted studies of selected reservoirs and lakes.

Arkansas has conducted a pilot study on the Upper Saline River Watershed to test the methods for developing nutrient criteria for Arkansas' river/streams (Arkansas Department of Environmental Quality 2006; Arkansas Department of Environmental Quality 2010). In addition, Beaver Lake, a large drinking water source for Northwest Arkansas, served as a pilot study area for development of nutrient criteria for Arkansas' lakes/reservoirs (FTN Associates 2008). ADEQ plans that after completion of the pilot studies and verification of assessment methodologies, they will continue assessments with priority being assigned to waterbodies based on screening flags obtained from monitoring data, such as dissolved oxygen, percent oxygen saturation, TP, and N.

Findings from the ADEQ Pilot Study on the Upper Saline River have been recently published (Arkansas Department of Environmental Quality 2010). The purpose of ADEQ's pilot study was to test and refine methodologies outlined in the State of Arkansas Nutrient Criteria Development Plan within the upper Saline River watershed, with the final objective of developing standard methods to establish statewide numeric nutrient criteria for Arkansas's streams and rivers.

The Saline River watershed study utilized a three-level (levels I-III) approach to evaluate the ecological conditions of each site (Arkansas Department of Environmental Quality 2010). Level I assessments involved gathering and organizing water quality data and establishing standards (25th and 75th percentiles for each variable) against which site-wise water quality parameters could be compared. ADEQ utilized the following sampling design for potential nutrient impacted and least-disturbed sites. For Level I assessments ADEQ calculated the 25th and 75th percentiles of the past ten years' worth of data from ADEQ's water quality database of roving and ambient water quality monitoring sites. Data collected outside of the critical season were excluded from these calculations as stipulated by their state water quality assessment regulation (APCEC Regulation No. 2.). The following water quality parameters and associated criteria were used to assess the data:

1. Dissolved oxygen less than water quality standard (6 mg/L) (ADEQ Reg. 2.505)

2. The 25th and 75th percentiles of the following parameters measured were reviewed:

   - Total Kjeldahl nitrogen (TKN)
   - Nitrite + nitrate-nitrogen (NO2+NO3-N)
   - Ammonia as nitrogen (NH4-N)
   - Total phosphate as phosphorus (TP)
   - Ortho-phosphate as phosphorus (OP)
   - Total organic carbon (TOC)
   - Turbidity
   - Total dissolved solids (TDS)
   - Total suspended solids (TSS

Level I assessments were used to characterize water quality trends for each ecoregion and summarize sites that may potentially require additional field assessments. Sites that exceeded the 25th and 75th percentile in three or more of the above parameters were included as candidates for Level II assessment.

ADEQ selected sample sites for their Level II assessment based on adherence to the standards established by the Level I assessment. Sites where water quality conditions fell into or below the 25th percentile were chosen by ADEQ to represent least-disturbed conditions. Sites that exceeded the 75th percentile, as well as dissolved oxygen and turbidity standards set by APCEC Regulation No. 2, were also included as candidates for Level II sampling as nutrient enriched sites. Level II assessments were used to characterize the water quality conditions of 25th and 75th percentile sites. These assessments involved performing in situ water quality and instream habitat assessments, and included 72-hour diurnal dissolved oxygen measurements and water quality sampling during the critical season (when the water temperature exceeds 22^{o} C).

The specific requirements of the ADEQ Level II assessments consisted of a minimum of two site visits to collect the following data:

• Photo documentation
• Percent canopy cover*
• 72-hour diurnal dissolved oxygen
• Bank stability*
• pH
• Riparian habitat*
• Water temperature
• Vegetative protection*
• Potential nutrient sources
• Percentage of algal cover*
• NO_2+NO_3 – N)
• Algal filament length
• Ammonia as nitrogen (NH_{-4}-N)
• Turbidity

• Total Kjeldahl nitrogen (TKN)
• Total phosphate as phosphorus (TP)
• Ortho-phosphate as phosphorus (OP)
• Total organic carbon (TOC)
• Total suspended solids (TSS)
• Total dissolved solids (TDS)
• Periphyton thickness

*These physical measurements were indices that ADEQ estimated in the field based on protocol outlined in (Barbour et al. 1999). According to ADEQ the aquatic life communities, particularly benthic macroinvertebrates and fish, along with coinciding habitat and water quality samples for metals, anions, field and routine parameters were not used to make nutrient evaluations. Instead this information was used to make correlations between water quality and any changes in the macroinvertebrate communities that were not correlated to other factors.

All water quality data, including diurnal data, were collected during the months of June through early October when water temperatures were greater than 22^{o}C. ADEQ determined that potentially nutrient impacted and least-disturbed sites would require a Level III assessment if three or more of the following conditions were observed:

1. Algal cover > 50% in nutrient impacted, or < 50% in least-disturbed
2. Periphyton thickness > 0.5 - 1.0 mm in nutrient impacted, or < 0.5 - 1.0 mm in least-disturbed
3. Algal filament length > 4 inches in nutrient impacted, or < 4 inches in least disturbed
4. pH < 6 su or > 9 su in nutrient impacted, or > 6 su or < 9 su in least-disturbed
5. NO_2 +NO_3 – N greater than the 75th percentile or less than the 25th percentile
6. TP > 75th percentile or less than the 25th percentile
7. OP-P greater than the 75th percentile or less than the 25th percentile
8. 72 hour diurnal dissolved oxygen:

   Dissolved oxygen > 125% saturation in nutrient impacted, or < 125% in least-disturbed

   Dissolved oxygen (mg/L) less than or greater water quality standard of 6.0 mg/L (ADEQ Reg. 2.505)

10. Turbidity greater than or less than water quality standard of 10 NTU (ADEQ Reg. 2.503)

If required the Level III assessments involved intensive physical, chemical, and biological field surveys. This level of assessment required a second sampling of critical season water quality. It also required macroinvertebrate community sampling during the early spring and late fall, and fish community sampling in late summer, at sites that do not substantially dry up during the critical season. They used various biological metrics as response variables in bivariate and multivariate community analyses. They also conducted generalized characterizations of ecological integrity based on each of the above indicators. This included, but was not limited to, sampling of the following parameters:

- water temperature;
- pH;
- dissolved oxygen (mg/L);
- percent canopy;
- and 72-hour diurnal dissolved oxygen, pH, and water temperature (using YSI Data Sondes).

Following the completion of the Level III assessment, the following parameters were considered for use in determining least-disturbed sites (three or more of the following should occur):

1. pH between 6 and 9
2. Dissolved oxygen concentration (mg/L) meets water quality standards (ADEQ Reg.2.505)
3. Dissolved oxygen saturation < 125%
4. Nitrite + nitrate-nitrogen (NO_2 +NO_3 – N) is at or below the 25th percentile
5. Total phosphorus (TP) is at or below the 25th percentile
6. Ortho-phosphate as phosphorus is at or below the 25th percentile
7. Algal cover < 50%
8. Algal filament length < 4 in
9. Periphyton thickness < 0.5 mm
10. Aquatic life

    • Macroinvertebrate community metrics
    • Similarity to ADEQ Ecoregion Fish and Macroinvertebrate Reference Streams

After completion of the pilot study the ADEQ concluded that nutrient concentrations observed during their sponsored study were equal to or less than those of previous studies conducted in the upper Saline River watershed. They found that nutrient enriched sites (75^{th} percentile) exhibited only slightly higher nutrient concentrations than least-disturbed sites (25^{th} percentile), and mostly lacked significant differences among the aquatic biota. They believed this was due to the small sample size of their study which prevented the identification of concentration thresholds for nutrients using aquatic life. They further concluded that the results of this study indicate that the use of weight-of-evidence and the classification of 75th percentile sites based on water quality in streams with low level nutrient concentrations were inappropriate for the Saline River. ADEQ recommended that future nutrient criteria studies in Arkansas must utilize large ecoregion specific datasets encompassing an array of nutrient concentrations in order to develop specific nutrient criterion.

For lakes and reservoir NNC development ADEQ also contracted with FTN Associates who utilized a "Weight of Evidence Approach" during their studies to develop draft NNC. These studies included:

1) Pilot Studies of Beaver Lake,
2) Examination of surrounding state's NNC for lakes and reservoirs,
3) Evaluation of EPA recommended ecoregion criteria for lakes and reservoirs,
4) Evaluation of Hydrologic Plunge Point analysis as an ecoregion classification method,
5) Conducting statistical analysis of reference lakes and Beaver Lake,
5) Utilization of empirical loading relationships,
6) Conducting Dynamic modeling and
7) Evaluation of frequency of attainment for various candidate indicators.

Based on the Beaver Lake and associated lake/reservoir studies ADEQ upon receiving input from FTN Associates, recommended candidate NNC of:

- a growing season chlorophyll-*a* of 8 μg/L;
- an annual average secchi transparency of 1.1 meters;
- recommended nutrient "targets", not criteria, of TP (40 μg/L) and TN (0.4 mg/L) (Wentz pers. comm.)(FTN Associates 2008).

The ADEQ plans to utilize the information and approaches developed during these studies to develop NNC during the next round of water quality standards revision.

California

Water quality in California is governed by the Porter-Cologne Water Quality Control Act (California Water Code § 13000 et. seq.)(Bureau of Land Management 2011a). This state law created a unique state water quality management infrastructure which assigns overall responsibility for water rights and water quality regulation to the State Water Resource Control Board (CSWRCB) and directs the nine statewide Regional Water Quality Control Boards (RWQCBs) to develop and enforces water quality standards within their boundaries. Regulation of water quality and development of water quality control plans (which include numeric criteria) within the State of California is a complex system which involves both the CSWRCB and the 9 RWQCBs which develop water quality plans for their regions.

The implementation of numeric nutrient criteria in California involves the individual implementation of water quality control plans for areas administered by the appropriate RWQCB. Depending on the Regional Water Quality Control Plan, selected NNC may have been promulgated for some or many waterbodies within the state region. Historically, the exact form of the NNC would vary and included a variety of parameters including NO_3+NO_3-N, secchi disk transparency, TN, TP, NO_3-N, OP, and turbidity (NTU). Almost all NNC were developed between 1995 and 1998 when the original nutrient criteria plans were developed (United States Environmental Protection Agency 2008b). All of these have been approved by the EPA. The specific numeric nutrient criteria are listed in for each RWQCB below (Table 17). Five RWQCBs do not currently possess any NNC.

From 1999 through 2000 the EPA Region IX RTAG evaluated the feasibility of using the ecoregion reference approach for development of NNC. This included initial evaluation of EPA proposed criteria for streams and rivers in this region while concurrently sponsoring additional pilot studies. In 2000 the EPA Region IX Regional Technical Advisory Group (RTAG), which included EPA and representatives from each Region IX state, reviewed the findings of a pilot study using the original Level III ecoregions to evaluate draft default 304(a) criteria for rivers and streams. The resulting comparison tables for TP, TN suggested that if the EPA reference ecoregion based values were adopted, that a large number of probably un-impaired water bodies would be misclassified as impaired. In the meantime, during 2001 the CSWRCB created the State Regional Board Technical Advisory Group (STRTAG) to work in parallel with the RTAG and assume responsibility for nutrient criteria development for California and to better coordinate the activities of the individual Regional Boards. The RTAG and STRTAG responded to this potential for misclassification by adopting a resolution to pursue an USEPA approved alternative to development of nutrient criteria (Creager et al. 2006).

Prior to 2002, California did not have any type of Nutrient Criteria Plan or guidance document (United States Environmental Protection Agency 2008b). However, the STRTAG working with the RTAG produced, through a contract with Tetra Tech a document entitled "*Work Statement - The Development of Nutrient Criteria for Ecoregions within: California, Arizona, and Nevada*" or "Region IX Nutrient Work Plan" in 2002 (Tetra Tech Inc. 2002b). This document has served as de-facto Nutrient Criteria Plan for California until recently.

The goal of the work outlined in the "Region IX Nutrient Work Plan" was to develop a scientifically defensible approach to determine nutrient criteria in California, Arizona and Nevada (Tetra Tech Inc. 2002b). The Work Plan described activities within five primary task areas. The task areas included 1) data collection; 2) categorization of waterbodies and development of regionalization units; 3) criteria parameter evaluation; 4) development of criteria and data collection recommendations; and 5) support for and interaction with stakeholder groups (RTAG and STRTAG)(Figure 8). As a result of implementation of this Work Plan various pilot studies and data analyses were conducted and white papers outlining different technical approaches produced. The pilot studies evaluated the feasibility of using ecoregional and sub-ecoregional approaches employing a landscape stratification strategy. Many of the pilot study reports are available in pdf format in the accompanying project database supplied with this report. A complete listing of all the EPA Region IX RTAG sponsored studies, including project reports is available at (http://rd.tetratech.com/epa/) (Butcher 2004; Creager et al. 2006).

Table 15. Description of EPA adopted numeric nutrient criteria in California by Regional Water Quality Board.

Regional Water Quality Control Board	Effective Date	Description of Criteria
RWQCB 1 (North Coast)	Not applicable	No NNC
RWQCB 2 (San Francisco Bay Region)	Not applicable	No NNC
RWQCB 3 (Central Coast)	Not applicable	No NNC
RWQCB 4 (Los Angeles)	2/25/95	NO_3+NO_2-N criteria for select waterbodies
RWQCB 5 (Central Valley)	9/15/98; amended 10/15/03	NTU – turbidity for selected lakes, rivers and estuarine delta; max 5 NTU in some recent waters
RWQCB 6 (Lahontan)	10/94	1) Secchi depth in specific waters (streams, lakes, reservoirs, and rivers). 2) Specific to Fallen Leaf Lake and Lake Tahoe in Lahontan Region Chl-A, N, P, and clarity 3) TN, TP, Nitrate-N & orthophosphate in specific waters in Lahontan Region (lakes, rivers, streams and reservoirs). 4) Eagle Lake specific in Lahontan Region for Chl-A. 5) Bridgeport Reservoir – annual average state target levels = 0.5 mg TN/L and 0.06 mg TP/L. The corresponding 90^{th} percentiles targets are 0.8 mg TN/L and 0.1 mg TP/L
RWQCB 7 (Colorado River Basin)	Not applicable	No NNC
RWQCB 8 (Santa Ana)	Not applicable	No NNC, although state screening targets for selected lakes are set at 0.1 mg TP/L and 0.75 mg TN/L based on 25% percentile levels.
Regional Water Quality Control Board 9 (San Diego)	3/12/97	TN, TP, and secchi depth numeric criteria for selected estuaries, rivers, lakes and wetlands. 0.05 mg/L TP for streams at entry to reservoirs, otherwise 0.1 mg/L 0.025 mg/L TP in reservoir, not to be exceeded 10% of time.

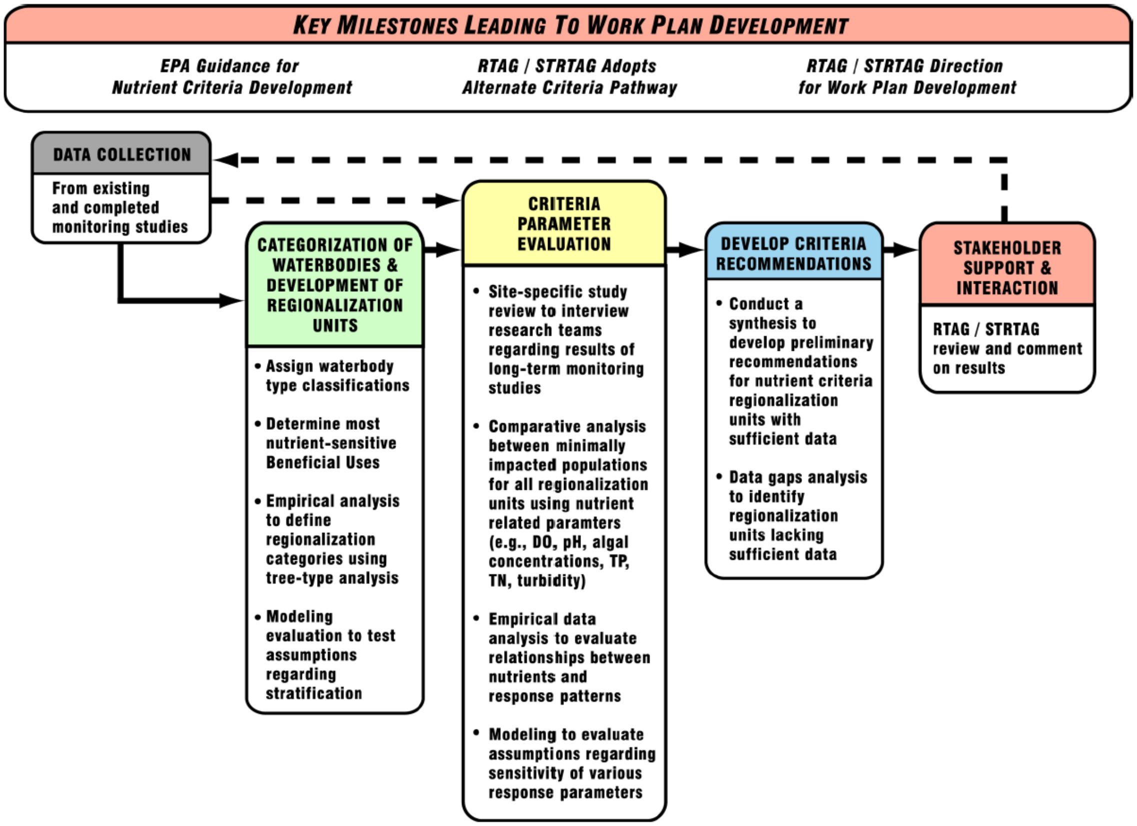


Figure 8. Flow diagram illustrating key project steps for nutrient criteria development used by the State of California SRTAG and EPA Region IX RTAG. From: (Tetra Tech Inc. 2002b).

As a result of this process two technical guidance documents entitled "*Technical Approach to Develop Nutrient Numeric Endpoints for California*" and "*Technical Approach to Develop Nutrient Numeric Endpoints for California* were produced under the direction of the EPA Region IX and the CSWRCB " (Creager et al. 2006; Sutula et al. 2007a). These reports provide technical guidance and approaches to develop numeric nutrient endpoints (NNE) values that could be used to ultimately produce NNC for rivers, streams, lakes, reservoirs and estuaries. These two documents therefore effectively serve as the current California Nutrient Criteria Plan. The reports highlight data gaps and research recommendations critical for their development.

Approach to Development of California Freshwater Waterbodies

The framework that was promoted for development of NNC in freshwater systems is based on the evaluation of risk of observing negative effects as measured by water quality indicators and associated beneficial uses due to elevated nutrients (Figure 9). It stresses the use of causal "models" based on plausible mechanisms by which nutrients can affect beneficial uses through impacts on *intermediate* factors (Creager et al. 2006). Development of NNE and NNC would be used to subsequently reduce nutrient loadings to levels that minimize the risk of impairing designated aquatic life uses. CSWRCB reasoned that if the nutrients present, regardless of actual concentration, have a low probability of impairing uses, then water quality standards will likely be met.

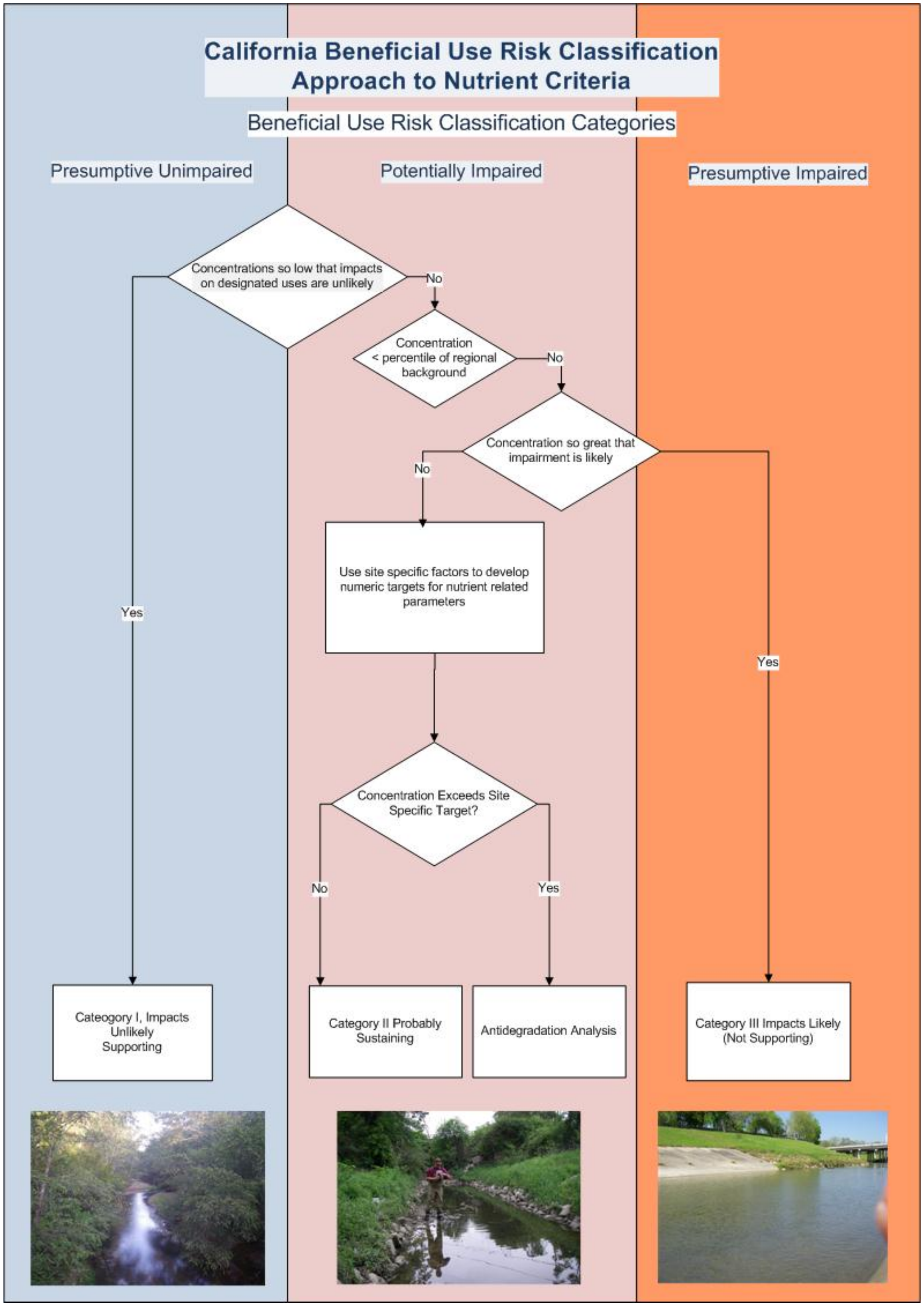


Figure 9. Beneficial use risk categories and the nutrient criteria assessment process proposed for the State of California. Diagram adapted from (Creager et al. 2006; Sutula et al. 2007b).

The State of California has a total of 19 beneficial use categories including 7 human use classes (e.g. hydropower, navigation), 4 public health classes (e.g. shellfish harvesting, municipal/domestic water supply, contact recreation) and 8 ecological classes (e.g. cold water fishery, fish migration)(Creager et al. 2006; Sutula et al. 2007b). The beneficial uses that were evaluated included ecosystem characteristics that the State of California desired to protect. This included various uses including protection of populations of cold water fisheries (COLD), occurrence of unaesthetic algal mats (recreational swimming = REC), or algal-derived taste and odor problems in finished drinking water (drinking water = MUN).

The authors pointed out that some states have addressed nutrient criteria development through direct measures of exposure, that is setting target concentrations of nutrients applicable to a class of water bodies while other states have focused on intermediate measures or indicators (e.g. chlorophyll-*a*)(Creager et al. 2006). However, they point out that reliance on measures of exposure along (e.g. nutrient concentration targets) present problems because the amount of nutrients that a waterbody can assimilate without impairment of uses varies widely, depending on a large number of contributing factors. In addition, it is often difficult to identify and/or isolate the specific stressor (e.g. nutrients) that is causing the impact on the beneficial use or final dependent variable of interest (e.g. cold water fishery), due to the complex interactions with other potential causal variables (e.g. toxic compounds, overfishing etc)(Creager et al. 2006). It is therefore necessary to understand conceptual mechanisms and plausible pathways by which elevated nutrients can impact designated uses and utilize intermediate measures of effect, such as the response variable “algal biomass” which although influenced by other factors, may however be easier to evaluate due to our ability to statistically control or “filter” out other factors (e.g. shading, salinity etc).

(Creager et al. 2006) argue that it is very rare that nutrients alone impair beneficial uses. Rather, they cause indirect impacts through algal growth, low DO, and so on, that impair uses. These impacts are associated with nutrients, but result from a combination of nutrients interacting with other factors. Appropriate nutrient targets for a waterbody should take into account the interactions of these factors to the extent possible. For instance, the nutrient concentration that results in impairment in a high-gradient, shaded stream may be much different from the one that results in impairment in a low-gradient, unshaded stream. Instead of setting criteria solely in terms of nutrient concentrations, it is preferable to use an analysis that takes into account the risk of impairment of uses. Conceptually this is similar to the allocation procedure for Biochemical Oxygen Demand (BOD), under which BOD loads are controlled to achieve acceptable levels of indirect impacts on Dissolved Oxygen (DO), rather than to meet an arbitrary concentration criterion for BOD in the receiving water.

According to the authors, the intermediate response measures or variables appear to be more generically applicable (Creager et al. 2006). For example, it may be possible to find a given level of periphyton biomass that is injurious to support any fishery within a state, even if the level of nutrients that cause this impact may vary between watersheds due to site-specific conditions. The drawback to the use of intermediate indicators alone is that they are more difficult to predict and do not provide a direct indication of what nutrient loads may be appropriate without a site-specific analysis. Therefore the proposed approach for California NNE relied on both measures of exposure and intermediate measures or indicators, which takes advantage of the strengths of each approach. Specifically, the setting of targets relied primarily upon intermediate indicators assigned to ensure support of a designated use; however, the target is then translated into a corresponding measure of exposure to nutrients through a procedure that takes into account the modifying factors that influence the response of one waterbody from another. For instance, suppose that a given aquatic life use in a lake or reservoir will be supported if growing season mean chlorophyll-*a* concentration is held to 25 μg/L or less (an intermediate indicator). This can be converted into a corresponding target nutrient concentration and subsequently load (a measure of exposure) by a procedure that adjusts for key factors (such as hydraulic retention time, depth, volume, latitude, and so on) that influences the response to the nutrient load within the lake. Therefore, the nutrient criteria framework needs to contain, in addition to nutrient concentrations, targeting information on secondary biological indicators such as benthic algal biomass, planktonic chlorophyll, dissolved oxygen, dissolved organic carbon, macrophyte cover, and clarity. These secondary indicators provide a more direct risk-based linkage to beneficial uses than the nutrient concentrations alone.

Streams and Rivers

The recommended NNC development approach for lakes, reservoirs, rivers and streams included several key steps including the: 1) the analysis of the current status of water quality and watershed condition and whether existing levels of nutrients appear to support of designated beneficial uses, 2) review and documentation of literature derived empirical relationships between causal (e.g. TN or TP) and threshold values of response variables (e.g. hypoxia, algae density) and 3) development of additional statistical and mechanistic models 4) establishment of beneficial use risk categories (BURC) based on literature, predictive models, and expert input, and 5) estimate appropriate response variable (e.g. dissolved oxygen, nuisance algae) levels that would increase the risk of adverse conditions not supportive of existing aquatic life uses (e.g. hypoxia, algal blooms) using thresholds and relationships between response and causal variables and modeling tools including the BATHTUB and the Benthic Biomass Predictor models, (Creager et al. 2006). Subsequently, empirical models and/or other mechanistic model including QUAL2K can be used to concurrently derive TN and/or TP NNE and ultimately NNC. Previous empirical studies and models that relate causal variables (e.g. nutrients) and intermediate measures of effect (e.g. algal chlorophyll-*a*) that influence beneficial uses were evaluated (Biggs 2000a; Dodds et al. 1998; Dodds et al. 2002). Multiple equations based on empirical relationships that were examined for potential use in development of predictive models are shown below. These regression relationships were developed by (Dodds et al. 1997) and (Dodds et al. 2002) for development of nutrient criteria to address nuisance growth of benthic algae in streams, using data from Montana and elsewhere.

Equations 1and 2 (Dodds et al. 1997)

Equation 1) log (mean Chl-A) = -3.22360+2.82630 log(TN) -0.431247 $(\log(TN))^2$ +0.25465 log (TP), R^2 = 0.430

Equation 2) log (max Chl-A) = -2.70217 +2.78572 log(TN) – 0.43340$(\log(TN))^2$+0.30568 log(TP), R^2 = 0.354

Equations 3and 4 (Dodds et al. 2002)

Equation 3) log (mean Chl-A) = 0.155 + 0.236 log (TN) + 0.443 log (TP), R^2 = 0.40

Equation 4) log (max Chl-A) = 0.714 + 0.372 log (TN) = 0.223 log (TP), R^2 = 0.31

Ultimately, they were not able to use these equations directly with existing data from California, but only to confirm and compare predicted responses using these formulas with similar models generated from limited data sets on response (e.g. Chl-A) and causal (e.g. TN and TP). The two data sets that were selected were RWQCB 6 and EMAP data. Using these data they generated a predictive model with an even lower R^2 value of 0.20. The regression equation is listed below.

Equation 5). log (mean Chl-A_ = 0-3.20+2.94 log(TN)-0.512 (log(TN))2 +0.0914 log (TP)

Comparison to the Lahontan RWQCB and EMAP data suggested that the equations proposed by Dodds et al. (1998) and (2002), were qualitatively reasonable for predicting mean and maximum potential growth of benthic algae in California streams in the absence of severe light or scour limitation. However, the Dodd's statistical relationships were quite weak, with R^2 values less than 0.50. They believed this reflected the influence of light and scour limitation on plant/algal chlorophyll-*a* levels. They cited studies in New Zealand, by (Biggs 2000a) which demonstrated that the predictive ability of empirical regression equations could be substantially improved (from an R^2 of less than 0.40 to levels greater than 0.70) by including a stream flow variation called "accrual". As defined by the authors mean days of accrual was determined as the average time between flood events >3X the median flow during the study period, which was calculated as [(1/(mean frequency of events per year >3X the median flow X 354 d)](Biggs 2000a).

In addition to empirical models, (Creager et al. 2006) evaluated simulation models as another line of evidence for the estimation of benthic algal or periphyton growth potential in streams. They argue that while a variety of models have been developed to simulate periphyton, the majority are too complex or too site-specific to be useful for initial scoping. Recently, a benthic algal component has been incorporated into a revised version of the QUAL2E water quality model, known as QUAL2K (Chapra and Pelletier 2003). This simple parametric model can be adapted to provide initial estimates of benthic algal responses to availability of light and nutrients, and can be adjusted to achieve general agreement with the empirical relationships developed by (Dodds et al. 2002; Dodds et al. 1997). They indicated that QUAL2K provides a simple method and

scoping document to assess predictions of benthic algal density. Initially when they compared the predicted values of chlorophyll-*a* between Dodd's equations and the QUAL2K output the values diverged considerably. The inability of the model to directly deal with the amount of available nutrients was considered to be the primary reason for this difference. However, after optimization against Dodd's models the QUAL2K model produced predicted ranges of TN and TP that result in maximum chlorophyll-*a* levels which were more correlated with Dodd's model predictions.
(Creager et al. 2006) pointed out that nutrients occur naturally, and vary in relationship to geology, soils, and land use/cover. They further elaborated that if nutrient concentrations are too low this may also impair certain beneficial uses. In other words, a minimum level of nutrients is needed to maintain sufficient productivity to support key elements and functions of an ecosystem. Therefore, they argued that it would make little sense to set a nutrient criterion that is lower than natural background for a specific waterbody, as determined through application of ecoregional statistical criteria. However, for many of the biological indicators associated with nutrients there is no clear scientific consensus on a target threshold that results in impairment.

To address the problem of not having existing clear target thresholds, the State of California proposed to classify water bodies into the three Beneficial Use Risk Categories (BURCs) illustrated in Figure 9 (Creager et al. 2006). The California NNE approach proposed preliminary numeric targets (BURC boundaries) for each of the secondary indicators using literature sources and expert input from the Regional Water Quality Boards. A summary of many of the studies used in developing the endpoint recommendations are included in their report and is also included in our Table 8 (Creager et al. 2006). They believed that most of these values should not change very much from region to region within California. Thus, benthic algal biomass levels that impair the spawning beneficial use are considered to be similar for different parts of the state. Beneficial Use Risk Category I water bodies were not expected to exhibit impairment due to nutrients; BURC III water bodies have a high likelihood of exhibiting impairment due to nutrients; and BURC II water bodies may require additional information and analysis (Creager et al. 2006). They believed that this three-tiered approach was better than binary meet/does not meet criteria approach. For a given beneficial use designation, the BURC I/II boundary represents a level below which there is general consensus that nutrients will not present a significant risk of impairment. Conversely, the BURC II/III boundary represents a level that is sufficiently high that there is consensus that risk of use impairment by nutrients is probable. Within BURC II, additional water body-specific cofactors may be brought into the analysis to determine an appropriate target. Permitting discharges to waters that remain within BURC II after additional analysis would require an antidegradation or reasonable potential effect analysis.

Lakes and Reservoirs

The majority of the technical support document focused on development of NNE for streams and rivers with only a brief review of current California NNC for lakes and reservoirs, and attempts and approaches used to develop NNC in other states (Creager et al. 2006). Therefore the majority of the description that is summarized in this report focuses on the methods examined to develop NNE for flowing waters. The authors summarized that development of NNE for reservoirs must take into account several factors including growing season, type of reservoir and fishery (e.g. warmwater versus coldwater), residence time, and depth of the mixed surface layer or epilimnion. The report then reviews the status of existing NNC for various reservoirs in California. As a baseline each RWQCB cites the same narrative criteria: "waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growths cause nuisance or adversely affect beneficial uses". However, none of the RWQCB has defined a quantitative limit for nuisance growth although some regions have set average chlorophyll-*a* values as targets (Table 15). The authors describe some of the approaches used by other states including Michigan, North Carolina and Oregon. Several states like Michigan have used the Carlson Trophic State Index, based on secchi depth transparency, chlorophyll-*a* and total phosphorus data, to differentiate between oligotrophic, mesotrophic, eutrophic and hyper-eutrophic lakes. In general oligotrophic lakes are defined as lakes capable of supporting cold water fish because they are minimally productive and maintain high dissolved oxygen levels due to the lack for high levels of algae and reduced diel fluctuations in dissolved oxygen. Eutrophic lakes in contrast have high levels of aquatic productivity and generally support warm-water fish, which are not as sensitive to low dissolved oxygen. Lakes experiencing nuisance algal blooms are termed hypereutrophic. The authors stated that the Michigan criteria for summer mean chlorophyll-*a* for cold water fish is < 3 µg/L. The warm water fish criteria is < 40 µg/L (Creager et al. 2006). Proposed NNC for other states ranged between 10 to 33 µg/L of chlorophyll-*a* depending on thermal stratification.

The authors state the USEPA ecoregion regression approach when applied to California showed that the range of 25th percentile values of chlorophyll-*a*, that is the proposed targets for each ecoregion, ranged between 0.9 to 4.4 µg/L. However only four of the 12 ecoregions in the state have at least four data points with which to determine the chlorophyll- *a* criteria. Data from 2 ecoregions resulted in suggested chlorophyll-*a* criteria less than 3 µg/L. All four ecoregions have data with 25th percentile values less than 5 µg/L. Therefore the suggested criteria derived using the EPA ecoregion approach is similar to values derived by Michigan for similar waterbodies (Creager et al. 2006). The authors however point out that the matching chlorophyll-*a* concentrations varied little over the range of nutrient levels encountered suggesting a lack of a strong response by primary producers over the range of nutrients observed (Creager et al. 2006). The authors discussed other variables that may be needed to establish NNC and/or evaluate the response of primary producers to nutrients. This included cyanobacteria density, transparency or secchi depth, dissolved oxygen, macrophyte density, pH, dissolved organic carbon (DOC) and trihalomethane production. None of these alone however can be used to establish NNC.

In summary, the California NNE approach for rivers, streams, lakes and reservoirs is based on lines of evidence that incorporate natural background conditions; the status of risk cofactors (e.g., habitat integrity, flow); and the relationship between secondary indicator response variables (e.g., chlorophyll a, clarity, DO, and pH maximums). The CA NNE approach also produced spreadsheet modeling tools to evaluate various nutrient concentration targets to achieve the desired condition for secondary indicators. The CA NNE approach required a good understanding of the individual waterbody being evaluated and consideration of all lines of evidence. Secondary indicator targets would be converted to nutrient concentration targets appropriate for assessment, permitting, and the calculation of TMDLs by using simulation models for biological responses described in the technical guidance document (Creager et al. 2006). They stressed that relatively simple tools could provide initial targets, although site-specific refinements may be needed for individual waterbodies. Description and documentation for use of simplified tools are included as appendices in their report. The program file names are 1) CA_NNE_Benthic_Biomass_Predictor_V12 and 2) CA_NNE_BATHTUB_V11. According to the authors these software products are available from Tetra Tech.

The nutrient targets that were estimated using the modeling approaches and/or empirical equations were subsequently compared with reference nutrient levels in different regions in California. Nutrient concentration targets derived from secondary indicators could be used if they are not lower than background levels in that region. The authors indicated that depending on the designated use, user perceptions, availability of data, and the economic impact of the decision, other, more detailed and site-specific tools may be needed for translating secondary indicator targets to nutrient concentration targets. However, it may be necessary to make modifications to limit the potential for downstream impacts. Nutrient criteria may require reach-specific limits on upstream concentrations consistent with TMDL allocations. Achieving nutrient reductions to control downstream impacts may require more stringent restrictions in upstream reaches than would be otherwise necessary for uses within those reaches alone. For instance a stream entering a reservoir may need lower nutrient numeric endpoints upstream, not to protect against upstream secondary impacts but to protect against impacts within the reservoir. This approach was taken in the recent federally promulgated Florida NNC which will be discussed later.

The author's state that one of the major lessons learned from several years of pilot studies is that no single approach for the development of NNC will be suitable for all the diverse water bodies within California. They believed that the proposed risk-based approach is the most flexible and viable method and will provide solutions to most issues associated with NNC development in California.

Estuaries

Similar to the approach taken for freshwater systems the RTAG and STRTAG contracted with Tetra Tech to develop a conceptual framework for development of NNC for estuaries (Sutula et al. 2007b). Although no explicitly stated in their guidance document it is likely that approaches developed for estuarine waters would be used for marine offshore state waters as well. Development of methodology relied heavily on addressing three information needs including:

1) defining the relationship of designated uses and observed nutrient distributions

2) development and identification of literature on derived predictive relationships between nutrients and response variables and

3) estimation of threshold levels of causal variables (e.g. TN and TP) that would cause undesirable impacts on designated uses.

In order to develop this methodology the authors of the guidance document recommended the development of a set of estuarine NNE tools, including:

1) a classification scheme that groups estuaries according to factors that control their biological response to nutrient loading,

2) development of risk-based indicators of biological response that can provide quantitative measures of the status of beneficial uses relative to nutrient loads;

3) identifying thresholds that define beneficial use risk categories (BURCs), which provides a framework for regulatory decisions based on quantitative assessments of impairment; and

4) developing modeling tools that link biological response indicators to watershed nutrient loads.

The conceptual framework for development of NNE in estuaries is based on previously described approach and guidance developed for streams and lakes by Tetra Tech and sponsored by the SWRCB and US EPA Region IX (Creager et al. 2006). The resulting framework was founded, similar to the freshwater approach, on the concept that biological response indicators are better suited to evaluate the risk of beneficial use impairment, rather than using pre-defined nutrient limits alone that are less likely to result in mitigation of eutrophication for a particular water body. The proposed approach was considered to provide a more realistic assessment of actual impairment, versus an approach that relies on nutrient concentration data alone.

The California NNE framework for estuaries was based on three organizing principals:

• Biological response indicators provide a more direct risk-based linkage to beneficial uses than nutrient concentrations alone.

• A weight of evidence approach with multiple indicators will produce NNE with greater scientific validity.

• For many of the biological indicators associated with nutrients, no clear scientific consensus exists on a target threshold that results in impairment.

Based on their review they found no clear scientific consensus on a target thresholds associated with impairment for many of the biological indicators of eutrophication. To address this problem, the California NNE framework, similar to the freshwater framework, classified water bodies into the same three Beneficial Use Risk Categories (BURC) used in the freshwater framework (Figure 9)(Creager et al. 2006; Sutula et al. 2007b). For a given beneficial use designation, the BURC I/II boundary represented a level below which there is general consensus that nutrients will not present a significant risk of impairment. The BURC II/III boundary represented a concentration that is sufficiently high that there is expert consensus that risk of use impairment by nutrients is probable. Within BURC II, additional waterbody-specific cofactors may be brought into the analysis to determine an appropriate nutrient target. Ultimately, the goal was to propose preliminary NNE targets (i.e. BURC thresholds) for each of the biological response indicators using literature sources, monitoring data, and expert opinion. Within the framework these values were allow to vary based on California ecoregion specific factors. Similar to the freshwater approach it was intended that the final BURC thresholds for each biological response indicator would be converted to nutrient concentration targets appropriate for assessment, permitting, and TMDLs by using a range of modeling approaches (e.g. simple load-response models, complex dynamic simulation models for biological responses) for estuaries. The authors state that depending on the use, data availability, and economic impact of the regulatory decision, more detailed and site-specific tools may be appropriate for translating secondary indicator targets to nutrient loading targets.

The creation of a toolkit to support development of NNE was approached through a set of four discrete steps, each with an inherent set of data requirements:

1. Development of a definition and classification scheme

2. Selection of biological response variables

3. Development of numeric nutrient endpoints

4. Creation of TMDL tools

There were several data gaps and steps that needed to be addressed before thresholds for Beneficial Use Risk Categories for secondary indicators could be established for estuarine waters in California. A list of the highest priority data gaps, technical and policy issues that were identified during the course of this project was compiled by Tetra Tech and provided to EPA Region IX, the SWRCB and the RWQCBs. They concluded that a total of 14 tasks needed to be accomplished in order to develop NNE for California estuaries (Sutula et al. 2007b). These tasks are listed below and described verbatim.

1) Adopting, for the purposes of nutrient criteria development, a uniform definition of “estuary” across all regional boards.

2) Generating a comprehensive list of estuaries, using the “uniform” definition of estuary

across all regional boards and performing statistical analysis to confirm appropriate classification of each estuary and determine whether ecoregions must be considered for this classification.

3) Developing conceptual models of nutrient cycling for each estuarine class, including the sources, sinks, mechanisms for transformation, and links with biological response.

4) Collecting continuous data sets (2-5 yrs) of nutrient loading and selected biological response indicators (DO, SAV, macroalgae, phytoplankton etc.) in several index systems representing a range of eutrophication for each of the estuarine classes. These data would: 1) assist in defining the "critical condition" for indicator measurement, 2) assist in determination of numeric endpoints by providing a range of reference conditions, and 3) provide a dataset to explore the development of load-response models.

5) Conducting research to clarify the relationship between biomass of primary producer communities, sediment oxygen demand, and surface water DO.

6) Evaluating the impacts of macroalgal blooms on benthic macroinvertebrates and investigating to what extent any impact may affect food availability to fish and birds

7) Investigating mechanisms controlling the production of toxins in harmful algal blooms.

8) Investigating the environmental factors that promote toxic harmful algal blooms. This includes: 1) the relative importance of anthropogenic versus natural sources of nutrients (upwelling), 2) the importance of atmospheric deposition and 3) what physical factors (upwelling, river discharge, etc.) create conditions suitable for HAB formation.

9) Conducting historical studies that 1) help to establish a range of values of the biological response indicators at a time period when an estuary was unimpacted, and 2) establish connections between historical land use, nutrient loads, and indicators of biological response.

10) Exploring the developing of regression models of load and response for estuarine classes with existing data. Once selected, it would be necessary to validate the regression models with additional monitoring in index systems. For those classes where adequate data do not exist, the collection of continuous data on nutrient loads, DO, SAV, macroalgae, phytoplankton and HABs would be necessary.

11) Establishing an internet-based clearinghouse for applicable conceptual models, watershed loading and estuarine water quality models, and supporting studies by estuarine class.

12) Conducting a literature review to identify ranges in rates for key biogeochemical processes (nitrification and denitrification, benthic nitrogen fixation, sediment nutrient flux, primary producer uptake, storage and transformation of nutrients, etc.) for each

estuarine class and identify key data gaps; conduct studies to address data gaps, including studies that establish how rates vary along an eutrophication gradient for each estuarine class.

13) Conducting studies to characterize the relative importance of nutrient sources that are typically under-characterized, such as atmospheric deposition or groundwater inputs.

14) Develop watershed loading and estuarine water quality models in open source code, such that the modeling approaches can be improved over time by collaboration and data sharing.

In conclusion, like many other states the progress towards development of NNC in California estuaries lags behind the methodology for streams and lakes. This is in part due to the inherent complexity associated with estuarine waters and lack of extensive monitoring programs and associated data needed to evaluate the influence of nutrients on response variables including primary producers and beneficial uses. It is likely that their state will arrive at NNC for freshwater systems prior to estuarine and marine waters.

Colorado

Colorado's water quality standards and regulations are codified in Regulation No. 31 of the Colorado Code of Regulations (C.C.R.) at Title 5 C.C.R. 1002-31 (Basic Standards and Methodologies for Surface Water)(http://www.cdphe.state.co.us/wq/index.html) (Colorado Department of Public Health & Environment 2011a). The Colorado Department of Public Health and Environment (CDPHE), Water Quality Control Division (CWQCD) is the agency responsible for managing surface water quality in Colorado (http://www.cdphe.state.co.us/wq/index.html). The CWQCD regulates the discharge of pollutants into the state's surface and ground waters and enforces the Colorado Primary Drinking Water Regulations and is responsible for monitoring and reporting on the quality of state waters. The Colorado Water Quality Control Commission (CWQCC) is the administrative agency responsible for developing specific state water quality policies, in a manner that implements the broader policies set forth by the Colorado Water Quality Control Act. The CWQCC adopts water quality classifications and standards for surface and ground waters of the state, as well as various regulations aimed at achieving compliance with those classifications and standards. Information on the State of Colorado's nutrient criteria development efforts was obtained from various state and EPA online sources including an interview with Blake Beyea, who serves in the CWQCD Standards Unit of the CDPHE. The CWQCC is responsible for adopting water quality standards for surface water and ground water in Colorado. These standards, including use classifications, narrative and numerical standards, and antidegradation provisions are set forth in specific Commission regulations (http://www.cdphe.state.co.us/op/wqcc/Standards/Standards.html). Current and pending state approved water quality standards are published online at http://www.cdphe.state.co.us/op/wqcc/Standards/RegsCurrent/RegsCurrent.html and http://www.cdphe.state.co.us/op/wqcc/Standards/RegsDelayed/RegsDelayed.html .

The State of Colorado is hydrologically divided into seven major river basins: Arkansas, Rio Grande, San Juan, Colorado, Green, Platte, and Republican Rivers. The CDPHE has further divided the seven major river basins into four major administrative watersheds: the Arkansas/Rio Grande, the Upper Colorado, the Lower Colorado, and the South Platte Methods (Colorado Department of Public Health & Environment 2011a). Basin and waterbody specific water quality criteria for each of these basins is outlined in individual basin specific regulations
(http://www.cdphe.state.co.us/op/wqcc/Standards/RegsDelayed/RegsDelayed.html).

Colorado's designated uses for waterbodies consist of two broad categories including "outstanding waters" and "use-protected waters". Outstanding waters designation is applied to certain high quality waters that constitute an outstanding natural resource. No degradation of outstanding waters by regulated activities is allowed. A "use-protected waters" designation is applied to waters with existing quality that is not better than necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water. Classifications may be established for any of Colorado's water bodies except waters in ditches and other manmade conveyance structures, which are not classified (Bureau of Land Management 2011b). There are a total of 6 use classifications used by the State of Colorado. They are listed below.

AG Agriculture . These surface waters are suitable or intended to become suitable for irrigation of crops usually grown in Colorado and which are not hazardous as drinking water for livestock.

ALCW1 Aquatic Life Cold Water-Class 1. These are waters that (1) currently are capable of sustaining a wide variety of cold water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions.

ALCW2 Aquatic Life Cold Water-Class 2 These are waters that are not capable of sustaining a wide variety of cold water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.

ALWW1 Aquatic Life Warm Water-Class 1 These are waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions.

ALWW2 Aquatic Life Warm Water-Class 2 These are waters that are not capable of sustaining a wide variety of warm water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.

DWS Domestic Water Source These surface waters are suitable or intended to become suitable for potable water supplies.

RPC Recreation Primary Contact These surface waters are suitable or intended to become suitable for recreational activities in or on the water when the ingestion of small quantities of water is likely to occur.

RSC Recreation Secondary Contact These surface waters are suitable or intended to become suitable for recreational uses on or about the water which are not included in the primary contact subcategory, including but not limited to fishing and other streamside or lakeside recreation.

Lakes and Reservoirs

Currently Colorado does not have statewide NNC. Site specific NNC are limited to selected reservoirs including Chatfield Reservoir, Cherry Creek Reservoir, Bear Creek Reservoir, Standley Lake, and Dillon Reservoir (Colorado Department of Public Health & Environment 2011b). The current NNC for these reservoirs are listed in (Colorado Department of Public Health and Environment Water Quality Control Commission 2011b; Colorado Department of Public Health and Environment Water Quality Control Commission 2011c). These reservoir criteria are listed and summarized in Table 12. Currently, reservoir NNC exists for Chl-A and TP. The assessment thresholds to determine non-attainment of standards varies with reservoir. The NNC for Dillon Creek Reservoir and other lakes in the same drainage was set as a summer (July through October) TP value of 0.0074 mg/l TP. The Chatfield Reservoir assessment thresholds were a summer (July through September) Chl-A level of 11.2 µg/L, with a 1 in 5 year allowable exceedance frequency and a TP = 0.035 mg/l, summer average, with a 1 in 5 year allowable exceedance frequency. The Cherry Creek Reservoir assessment threshold was a summer (July through September) means Chl-A level of 18 µg/L, with a 1 in 5 year allowable exceedance frequency

Big Dry Creek Segment 2 (Standley Lake): Assessment Thresholds
Chl-A = 4.4 µg/L, Mar-Nov average, 1 in 5 yr allowable exceedance frequency

Bear Creek Reservoir Assessment Thresholds mean
Chl-A = 10 µg/L, TP 32 µg/l July-September average, 1 in 5 yr allowable exceedance frequency

Standley Lake Chl-A 4.0 µg/l plus narrative criteria for TP, SD and dissolved oxygen used by agency staff.

Most criteria either used a depth (upper 3 meters) or mixed surface layer definition for assigning vertical location of were samples were taken. It should be noted that the Bear Creek Reservoir TP criteria of 32 mg/L was not approved by EPA during 2010 review (EPA Region 8 2011).

The State of Colorado has been working on development of statewide NNC prior to formal adoption of the Nutrient Criteria Development Plan in 2002 (Colorado Department of Public Health & Environment 2002). At that time little monitoring data existed for rivers and streams that could be used to develop NNC. In contrast Colorado had already developed NNC for some lakes and reservoirs. This included 5 reservoirs which had Chl-A and/or TP standards. According to the CWQCD, the NNC had been developed based on long-term intensive site specific watershed assessments, and modeling of relationships between nutrient concentrations and algal growth.

One of the first steps proposed for developing NNC for streams and rivers was to develop a database of parameters integral to assessing the effects of nutrients on lotic systems (Colorado Department of Public Health and Environment 2002). This included data from outside agencies, universities and published literature. The CWQCD proposed collaborating with a Utah State University Dr. Chuck Hawkins, who had been funded by EPA to develop RIVPACS type predictive models of stream biological site conditions and physical and chemical attributes including nutrients at 823 reference sites in Oregon, Washington and California (Colorado Department of Public Health & Environment 2002).

The RIVPACS modeling approach was developed in the United Kingdom by Center for Ecology and Hydrology (http://www.ceh.ac.uk/products/software/RIVPACS.html)(Wright et al. 2000). Minimally impacted freshwater river and stream sites are sampled to collect information on physical characteristics, water quality and macroinvertebrates. First, the reference sites are classified into a series of site groups, based only on the macroinvertebrate fauna. Then the relationships between the environmental features and the faunal characteristics of the "reference" site groups are defined, which are used to develop predictive models of benthic macroinvertebrates in the absence of environmental stressors. These relationships are standardized for a variety of physical habitat and flow regimes. The predictive statistical models relate macroinvertebrate assemblages and metrics to a range of water quality variables. These models are then validated against a variety of previously un-surveyed sites including impaired sites.

The final validated RIVPACS model enables the user to estimate the macroinvertebrate community expected at high quality sites from the information on their environmental and physical features. By measuring these environmental features for a new site, the user can then predict the macroinvertebrate fauna you would expect to find at the site if it was also of high quality. Expected fauna for a site is referred to as its “biological reference condition” (Wright et al. 2000). If a macroinvertebrate sample is then taken at the new site, using the same standard protocol as for the reference sites, the observed fauna can be compared with the “expected or predicted” fauna and discrepancies between the two can be used to assess the biological condition or "ecological status" of that stretch of river. The expected and observed values for various biotic indices are then compared using Environmental Quality Indices (EQI). These are values derived from the ratio of Observed:Expected metric scores. The higher the EQI value the closer the observed benthic fauna matches that “expected” at the site in the absence of any environmental stress. The RIVPACS approach incorporates many of the features of the EPA ecoregion approach has many of the features of the EPA Ecoregion approach

One of the critical needs at the time was the need to attempt to relate nutrient criteria to designated waterbody uses (Colorado Department of Public Health and Environment 2002). Some of the steps the CDPHE felt necessary in relating nutrient criteria to uses include the following:

- Establish system for determining “expected conditions” in relation to nutrients and algae
- Determine regional expectations for nutrients and/or algae that reflect attainment of uses or unimpaired conditions
- Determine narrative standards for regional expectations where numeric standards can’t be derived
- Define designated uses with respect to algae in streams

At the time EPA had suggested that states take three possible approaches for setting criteria:

1. Identification of reference reaches for each stream class based on best professional judgment or percentile selections
2. Use of predictive relationship (e.g. trophic state classifications, models, biocriteria)
3. Application and/or modification of established nutrient/algal threshold (e.g. Nutrient concentrations thresholds or algal limits from published literature).

At that time Colorado anticipated using an “expected conditions” based approach as the primary focus for developing nutrient criteria in rivers and streams. In contrast they anticipated that nutrient criteria for lakes will be based on predictive relationships determined through predictive models (Colorado Department of Public Health and Environment 2002).

Studies were later conducted to evaluate response of stream periphyton to nutrients in mountain streams and lakes (Lewis 2005). The authors used a combination of methods including the ecoregion reference stream and predictive stressor response models. Based on this study the author recommended NNC based on interannual summer median values of each parameter. For reservoirs this resulted in recommendations of 10 µg/L TP and 350 µg/L DIN. The recommended criteria for streams, rivers, and wetlands were 100 µg/L TP and 700 µg/L DIN. He did not however find a strong statistical relationship between periphyton and nutrients in the streams that he studied.

More recently, CDPHE recommended the use of quantile regression to establish predictive relationships between nutrients and multimetric benthic biological indices (MMI) in rivers and streams (Colorado Department of Public Health and Environment Water Quality Control Division 2010a; Colorado Department of Public Health and Environment Water Quality Control Division 2010b). The agency had used regression methods to establish statistical relationship between nutrients (stressor variables) and Chl-A, harmful algal blooms (HABs) and high pH (response variables). During this effort the agency introduced the term “Observable Biological Potential” or OBP. Theis OBP described the decline in biological condition as a function of increasing nutrient concentrations. . They used Colorado’s macroinvertebrate multi-metric indexes (MMIs) to represent the biological condition on the vertical axis, while the nutrient concentration is on the horizontal axis. Quantile regression (using the 90th quantile) on log transformed data is used to draw the line that represents the OBP (Figure 10). The criterion is then estimated by locating the concentration at which the OBP is expected to be 5% below the reference condition. The "anchor point" for the 5% decline is the 85th percentile concentration for the set of reference sites.

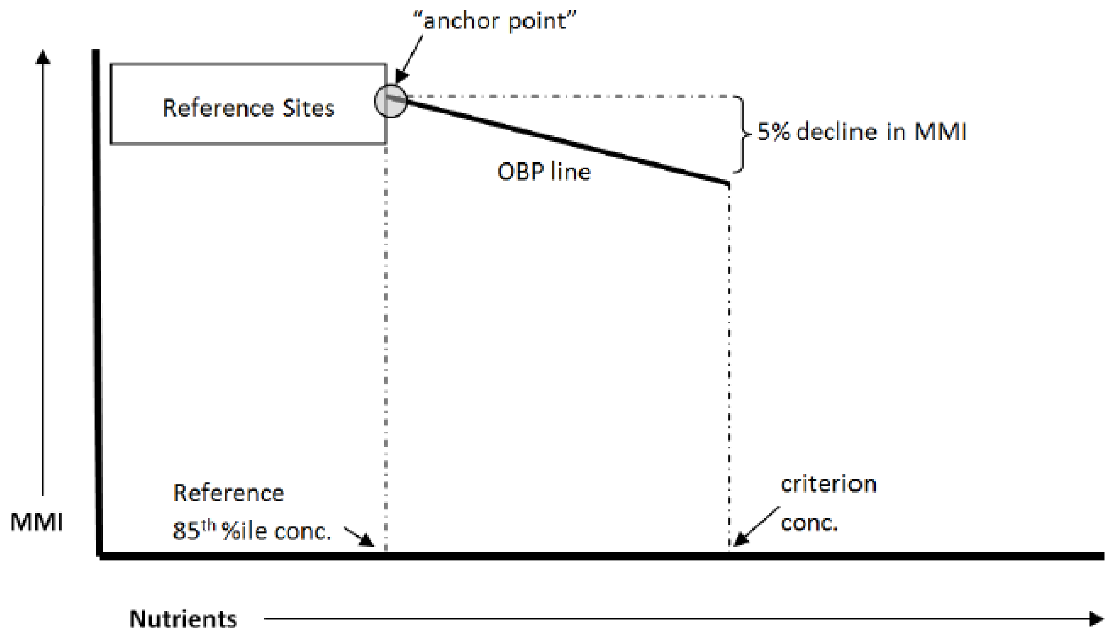


Figure 10. Method of estimating observable biological potential (OBP). From: (Colorado Department of Public Health and Environment Water Quality Control Division 2010b).

Recently the CDPHE CWQCD produced a paper entitle *"Colorado Nutrient Criteria Concept Paper"* which describes the most current approach and strategy that will be used Colorado to develop NNC (Colorado Department of Public Health and Environment Water Quality Control Division 2010a). This concept paper sets forth the agency's current thinking regarding a proposal for adoption and implementation of numerical nutrient criteria, that was advanced for consideration in at the June 2011 CWQCC rulemaking hearing regarding the Basic Standards and Methodologies for Surface Water, Regulation #31 (Basic Standards). This document was intended to provide transparent documentation regarding the CWQCD's thinking as their joint work group process progresses, and could be revised based on further discussions and/or analyses.

The CWQCD was also in the process of developing a nutrient criteria proposal for lakes and reservoirs that attempted to balance potentially competing interests such as clarity for swimming versus, and fisheries productivity. They focused on algal abundance (chlorophyll-*a* concentration) as the response variable since it has a higher likelihood of directly impacting classified uses. The proposed summer average total nitrogen and total phosphorus values were derived using chlorophyll/nutrient relationships developed for Colorado lakes and reservoirs. The relationship was based on the long-term trophic condition that was consistent with the desired balance of uses. The agency stated that a separate chlorophyll concentration threshold may also be proposed to avoid nuisance algae blooms.

The CWQCD also defined a separate approach for a human health nutrient criterion development for "high quality water supply" lakes and reservoirs to reduce the formation potential for disinfection byproducts (DBPs)(Colorado Department of Public Health and Environment Water Quality Control Division 2010a). DBPs are known to cause cancer and are regulated under the Safe Drinking Water Act. DBPs are formed when organic carbon in the water is subjected to disinfection (e.g., using chlorine). DBP formation potential has been found to be correlated with Chl-A levels in source water in the State of New York (Colorado Department of Public Health and Environment Water Quality Control Commission 2010a). Data from Colorado lakes and reservoirs were used to adapt the predictive relationship that was developed for New York lakes. The proposed criterion would be in the form of a summer average chlorophyll level and applied only on a site-specific basis.

Rivers and Streams

The CWQCD is also in the process of developing a nutrient criteria proposal for rivers and streams based on levels necessary to protect the aquatic life use. The macroinvertebrate community is being used as the surrogate for the aquatic life use. The health of the macroinvertebrate community is measured using a multimetric index (MMI) developed by their agency that incorporates taxa richness, community composition, pollution tolerance, and ecological function. The MMI was developed to discriminate between minimally disturbed sites and those with significant anthropogenic influences (Colorado Department of Public Health and Environment Water Quality Control Commission 2010a). The data collected by the CWQCD showed that the health of the macroinvertebrate community as determined by the MMI declines as nutrient concentrations increase. The CWQCD derived the relationship between MMI scores and nutrient concentrations using a method called quantile regression (Cade and Noon 2003). This method estimates the conditional quantiles of a response variable (e.g. Chl-A) distribution in the linear model that provides a more complete view of possible causal relationships between variables in environmental processes. Very often there may be a weak or no predictive relationship between the mean and the response variable (y) distribution and measure predictive factors (X). Yet there may be stronger, useful predictive relationships with other parts of the response variable distribution. The CWQD's proposed approach is based on the assumption that a five percent decline in aquatic life condition from minimally disturbed sites in Colorado as measured using the MMI is acceptable. The proposed criteria would is based on median total nitrogen and total phosphorus concentrations.

The CWQCD is also proposing a Chl-A criterion for the protection of recreational use in rivers and streams based on user surveys conducted in other states. In these surveys, 150 mg/m^2 of Chl-A, based on a sample of attached algae, was identified by users as the threshold between what is an acceptable level and what is undesirable for recreation because attached algae are too abundant. The final proposed criteria would be in the form of mg/m^2 Chl-A from attached algae.

The CWQCD originally projected that during their June 2011 rulemaking the hearing will consider the adoption of numerical criteria for phosphorus and nitrogen, for different categories of state surface waters, to be included in their basic statewide standards. These numerical criteria would then be considered for adoption as site-specific water quality standards in the subsequent rounds of water quality standard-setting hearings for each river basin. The agency further indicated that the statewide criteria themselves would not be self-implementing, that is they would not be used as the basis for discharge permit requirements prior to the adoption of segment-specific standards in individual river basins.

On June 30, 2011 the CWQCD drafted NNC for phosphorus, nitrogen and Chl-A for consideration of adoption by their administrative agency CWQCC (Colorado Department of Public Health & Environment Water Quality Control Commission 2011). The following values were considered.

The proposed NNC for lakes and reservoirs were TP – 20-80 µg/L, TN – 40-850 µg/L, and Chl-A 5 - 20 µg/L depending on size and whether a waterbody is classified as cold or warm-water. The compliance value would be based on a seasonal average of values obtained from the mixed surface layer and based on a specified exceedance frequency of 1 in 5 years.

The proposed NNC for rivers and streams were TP – 110-160 µg/L, TN – 400-2000 µg/L and Chl-A 150 mg/m^2 depending on whether a waterbody is classified as cold or warm-water. These compliance values would be based on a 5 year median "not to exceed level".

In addition, the agency proposed under the statewide regulation #31 that it would commit to a plan for proposal of numeric WQS during each river basin reviews after May 31, 2022. Ultimately the CWQCC delayed NNC submittal till March 2012 (Colorado Department of Public Health & Environment 2011a). Prior to this the CWQCD would continue to research and fine tune proposed NNC with an effort to define values that maintain existing water quality and uses while reducing uncertainty on what is ultimately attainable.

Commonwealth of the Northern Mariana Islands

The Commonwealth of the Northern Mariana Islands (CNMI) consists of two geologically distinct island chains located at 145º E, between 14º – 21º N in the Pacific Ocean (Bearden et al. 2008). The CNMI has two classes (AA and A) for marine water use and two classes (1 and 2) for fresh surface water use. All fresh surface water bodies in the CNMI (wetlands, intermittent streams, and perennial streams) are Class 1, meaning that these waters should remain in their natural state with an absolute minimum of pollution from any human-caused source. There is one lake, several perennial streams and just a few isolated wetlands and intermittent streams. Wetlands and perennial streams comprise less than 5% of the land.

The majority of the coastal marine waters in CNMI are classified as Class AA, which means that these waters should remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-related source or actions. The classified ecological uses protected in these waters are the support and propagation of marine life, conservation of coral reefs and wilderness areas. Human uses include oceanographic research, aesthetic enjoyment and compatible recreation inclusive of whole body contact (e.g. swimming and snorkeling) and related activities. Class A waters are only found near the two largest oceanic sewage outfalls and the ports of the CNMI. Class A waters are protected for similar uses as Class AA waters with the exception of conservation of coral reefs, oceanographic research and whole body contact. Only recreation in these waters of a limited body contact nature is supported. The CNMI adopted NNC in 1998 (United States Environmental Protection Agency 2008b). These NNC include nitrogen, phosphorus and turbidity (TSS)(Division of Environmental Quality 2005). The following NNC are currently in effect. The following concentrations (mg/L) shall not be exceeded.

Table 16. Federally approved numeric nutrient criteria adopted within the Commonwealth of the Northern Mariana Islands. The following concentrations represent maximum values that shall not be exceeded.

Parameter	Class AA Marine	Class A Marine	Class 1 Freshwater	Class 2 Freshwater
NO_3-N	0.20 mg/L	0.50 mg/L	Not applicable	Not Applicable
TN	0.40 mg/L	0.75 mg/L	0.75 mg/L	1.50 mg/L
OP	0.025 mg/L	0.05 mg/L	0.10 mg/L	0.10 mg/L
TP	0.025 mg/L	0.05 mg/L	0.10 mg/L	0.10 mg/L
TSS	5 mg/L	40 mg/L	5 mg/L	40 mg/L

Connecticut

Information on the State of Connecticut's efforts to develop NNC was obtained from several online sources including the Connecticut Department of Environmental Protection (CTDEP) web site, the EPA nutrient criteria web site, and the N-STEPS internet site (http://www.ct.gov/dep, http://n-steps.tetratech-ffx.com/NTSChome.cfm, http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ct.cfm). In addition Ms. Mary Becker who is a staff member of the CTDEP provided useful information on the current status of Connecticut NNC development.

Connecticut has classified it's waterbodies into five use categories. These groups are listed below.

Class AA: The designated uses for these surface waters include existing or proposed drinking water supplies; habitat for fish and other aquatic life and wildlife; recreation; and water supply for industry and agriculture.

Class A: The designated uses for these surface waters are habitat for fish and other aquatic life and wildlife; potential drinking water supplies; recreation; navigation; and water supply for industry and agriculture.

Class B: The designated uses for these surface waters are habitat for fish and other aquatic life and wildlife; recreation; navigation; and industrial and agricultural water supply.

Class SA: The designated uses for these surface waters are habitat for marine fish, other aquatic life and wildlife; shellfish harvesting for direct human consumption; recreation; industrial water supply; and navigation.

Class SB: The designated uses for these waters are habitat for marine fish, other aquatic life and wildlife; commercial shellfish harvesting; recreation; industrial water supply; and navigation.

Connecticut published a nutrient criteria development plan that was formally released in 2005 (Connecticut Department of Environmental Protection 2005). According to EPA this plan was never mutually agreed to by EPA Region 1 ((United States Environmental Protection Agency 2008b). To this day Connecticut water quality standards (WQS) only contain narrative criteria for total phosphorus in certain waters, but no specific numeric criteria for either causal (e.g., phosphorus, nitrogen) or response (e.g., chlorophyll-*a*, Secchi depth transparency) nutrient variables.

The historical strategy that Connecticut has taken was to develop nutrient criteria appropriate to local conditions that protect designated uses of waters, specifically aquatic life support and recreation. NNC were to take into consideration the natural trophic state or tendency of a waterbody, absent of human influence (i.e., forested watershed), as determined from land use and empirical models. For both lakes/reservoirs and rivers/streams Connecticut initially used a site-specific approach. Criteria development in these waters focused on chlorophyll a, transparency and algal/plant communities as response (assessment) variables. Phosphorus, which had been identified as the limiting nutrient in Connecticut lakes would be addressed as a causal (management) variable when waters are found to exceed established criteria for response variables. Connecticut did not focus initial efforts on the development of NNC for nitrogen in freshwater since nitrogen was being managed throughout the state under the Long Island Sound Total Maximum Daily Load (TMD). The majority of freshwater streams flow into Long Island Sound. Development of nitrogen criteria for fresh waters would be considered at a future date, should progress made during the implementation of the Long Island Sound TMDL prove to be non-protective of freshwater designated uses (Connecticut Department of Environmental Protection 2005).

At the time of the publication of the Nutrient Criteria Development plan the CTDEP, had recently developed TMDLs for nutrients in four eutrophic lakes. Work was also being conducted with USGS to identify timing and sources of nutrient loading in a major watershed for appropriate TMDL development. All of these waters are considered impaired for either primary contact or aquatic life use or both due, at least in part, to excessive algal blooms. For the lake TMDLs, nutrient loads were calculated from several mass balance and land use models, which incorporate coefficients for nonpoint and point source contributions. At the time Connecticut expected to identify the model(s) and relevant variables that provide(s) the most appropriate nutrient criteria values for a natural trophic state or reference condition (Connecticut Department of Environmental Protection 2005).

An important decisions that CTDEP made during the mid-2000's was their decisions to not to implement the EPA recommended ecoregion based criteria, which were based on a simple percentile approach (Connecticut Department of Environmental Protection 2005; Gibson et al. 2000; United States Environmental Protection Agency 2000h; United States Environmental Protection Agency 2001g). EPA recommended two ways of establishing a reference condition (of a causal or response variable). One method is to choose the upper 25th percentile (75th percentile) of a reference (unimpaired population of waterbodies). This is the preferred method. The 75th percentile is preferred by EPA because it is likely associated with minimally impacted conditions, will be protective of designated uses, and provides management flexibility. When reference lakes are not identified, the second method is to determine the lower 25th percentile of the population of all waterbodies within a region to attempt to approximate the preferred approach. According to CTDEP they felt that this method automatically established that 75% of an ecoregion's waters are impaired (i.e., exceed nutrient criteria), and does not clearly link nutrient levels to protection of designated uses. Further, they argued that although the EPA ecoregion criteria were developed at reasonable geographic scale (ecoregion III level) they do not account for many important waterbody characteristics and local conditions, such as lake origin, retention time, depth or watershed size, which may be just as important and influence trophic condition more so than other factors. Connecticut recommended an alternative approach to NNC development for major waterbody types (lakes, rivers, estuaries) which is described below.

Natural Lakes

The agency developed a classification system involving ranges of TP, TN, Chl-A and Secchi depth transparency (SD) to describe lake trophic categories. This system was based on studies conducted by (Frink and Norvell 1984)(Table 1). However, these ranges did not constitute formal NNC for lake water quality. These values were and continue to be used as a guideline for the purpose of determining consistency with narrative criteria in their existing water quality standards (WQS). The screening values are used to compare the existing trophic condition of a target lake is compared to the "natural" (i.e. absent significant human impacts) lake. The original ranges of TP, TN, Chl-A and SD appear in Table 17 below (Connecticut Department of Environmental Protection 2005). In addition to water column data, the trophic state of a lake was determined by the percentage of the surface area covered by macrophytes.

Table 17. Total P, total N, chlorophyll a and Secchi depth criteria for six lake trophic categories as originally proposed in the 2005 Connecticut Nutrient Criteria Development Plan.

Category*	Total P (ug/L)	Chlorophyll a (Summer)	Secchi Depth (Summer)
Oligotrophic	0-10	0-2	6+
Oligo-mesotrophic	10-15	2-5	4-6
Mesotrophic	15-25	5-10	3-4
Meso-eutrophic	25-30	10-15	2-3
Eutrophic	30-50	15-30	1-2
Highly Eutrophic	50+	30+	0-1

* Macrophyte information is reviewed in conjunction with water column data to classify shallow waters with significant macrophyte productivity. If macrophyte growth is 75-100% of the waterbody area and dense, the lake is classified as highly eutrophic regardless of water column data. If macrophyte growth is 30-75% of waterbody area and dense, the lake is classified as mesotrophic when water column data indicate oligotrophy and classified as eutrophic when water column data indicate a mesotrophic or eutrophic condition. Based on: (Connecticut Department of Environmental Protection 1998) and (Frink and Norvell 1984) Cited in: (Connecticut Department of Environmental Protection 2005).

CTDEP stated that it would rely on a variety of ongoing empirical studies to further refine and develop lake and reservoir criteria (Connecticut Department of Environmental Protection 2005). The CTDEP also relied on TMDL study results that provided a template for criteria development. The CTDEP would then evaluate the land use and empirical models used in these TMDLs as well as other models to determine which are the best predictors of natural or reference conditions. In so doing CTDEP would develop and define detailed mechanisms for translating narrative criteria into numeric values. According to CTDEP a numeric expression of the narrative criterion would be the nutrient concentration consistent with achieving and maintaining a lake in its natural trophic condition. For example, if the forested watershed trophic category of a lake is determined by appropriate models to be early or oligotrophic the chlorophyll a concentrations during the critical summer months should be within the range of 2-5 µg/L, and transparency should be 4 – 6meters. CTDEP argued that if the present lake condition falls within these ranges, the present trophic parameter values become the criteria. If the present condition exceeds the ranges for oligo-mesotrophic, then the lake is listed as impaired, and a target load (TMDL) for phosphorus will be established such that chlorophyll a and Secchi depth will to fall within the ranges for oligo-mesotrophic.

CTDEP stated that ongoing process of revising lake and reservoir standards would have the following components:

1. Determine the forested watershed trophic condition for the lake through land use and empirical models and/or sediment chrysophyte analysis;

2. Determine the present trophic state of the lake based on chlorophyll a, transparency and macrophyte density; and if the present trophic condition is no greater than the forested watershed condition, then the present trophic parameter values will be established as the criteria for that lake. If the present trophic condition is more advanced than the forested watershed trophic condition, the lake will be listed as impaired, and additional modeling will be done to:

3. Determine the present phosphorus loadings to the lake;

4. Determine the phosphorus loadings and in-lake concentration that will be achievable after full implementation of all BMPs and point source reductions, if applicable.
The phosphorus loading and in-lake concentration following full implementation of BMPs and point source controls would be established in a TMDL process as the numeric criteria. However if modeling results indicated that full implementation of BMPs could not restore the lake to forested watershed trophic conditions, the lake would be listed as impaired, and the post-BMP phosphorus load and in-lake concentration would be established as the numeric criteria through a Use Attainability Analysis (UAA). Over time CTDEP hoped it would establish natural trophic conditions for lakes of the State. The development of such meaningful site-specific water quality goals would ultimately help CTDEP direct resources to lakes that are truly impaired and in need of active management. CTDEP hoped that after criteria had been established for a number of lakes on a site-specific basis, that patterns in water quality and associated land use and geomorphology would emerge to allow logical groupings of waters with similar characteristics for assignment of criteria, and that experience with the appropriate models and datasets would facilitate the process (Connecticut Department of Environmental Protection 2005).

To help facilitate data analysis, CTDEP compiled data contained on historic trophic surveys and numerous recent studies into a relational database. This task required a significant effort and was performed by staff as time and resources allowed. The CTDEP monitoring program did have an extensive ambient water quality monitoring database for river and stream data. A comparable data management system for lakes was initiated to facilitate review and analysis of statewide data for nutrient analyses. At the time Connecticut obtained additional federal funding to increase statewide ambient lake monitoring using a probabilistic design. Physical and chemical sampling was planned for each spring following overturn and again in summer after stratification had been established. Chl-A was also be analyzed for the summer sampling. Additionally sediment cores were collected for chrysophyte analysis to determine present and historic trophic condition. At the time CTDEP planned to archive the sediment cores until funding for analysis is secured. It is unclear if this was ever done.

CTDEP would use the outcome of appropriate models, probabilistic lake monitoring, technical reports and studies, and historical trophic studies, to identify key factors that would be helpful in classifying lakes by type and natural trophic states. Table 19 provides a list of the three possible outcomes when a lake is compared to its natural trophic condition under forested watershed conditions, and the resulting criteria. Figure 11 summarizes Connecticut's proposed approach to developing biologically based nutrient criteria for lakes (Connecticut Department of Environmental Protection 2005).

Table 18. Resulting criteria for three categories of lakes after comparison to forested watershed trophic conditions.

Category	Condition	Criteria
Anti-degradation Waters	Current trophic state ~ forested watershed	Existing Load and Concentration
TMDL Waters	Current trophic state > forested watershed ~ post BMP	Post BMP Load and Concentration
UAA Waters	Current trophic state > forested watershed trophic state < Post BMP	Post BMP Load and Concentration

Reservoirs

CTDEQ determined that drinking water reservoirs would be treated as lakes in so far as the natural (reference) trophic condition of the reservoir can be established. However, they acknowledged that some drinking water reservoirs are completely unnatural waterbodies, as are impoundments of large rivers, and would require a different approach to establishing reference conditions. They determined that future analyses would focus on determining the cause of nuisance algal conditions in order to establish appropriate concentrations and loadings of nutrients to bring the waterbody in to compliance with WQS. Criteria may incorporate seasonal and stratification considerations.

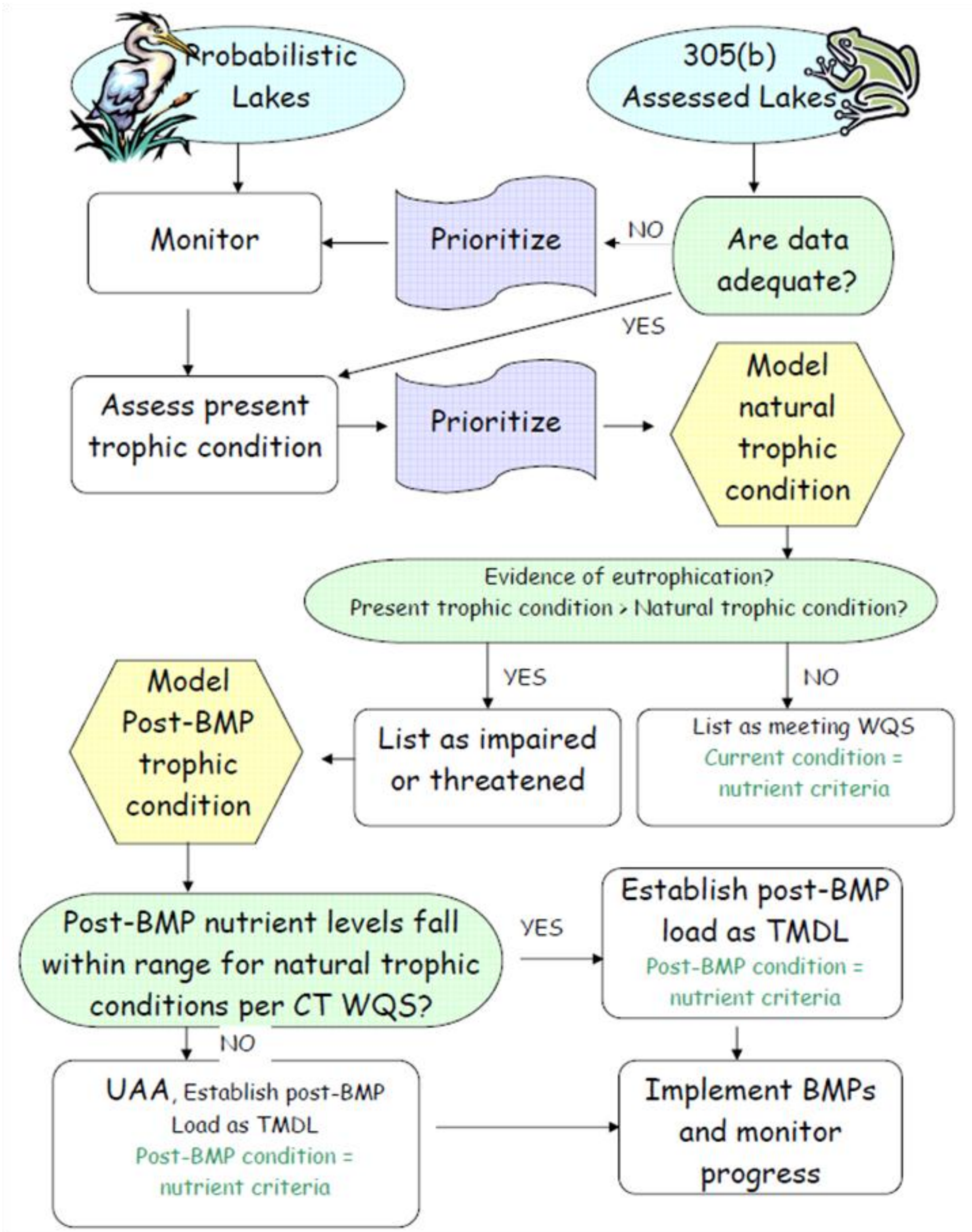


Figure 11. Connecticut's proposed strategy for developing lake numeric nutrient criteria. From: (Connecticut Department of Environmental Protection 2005).

Rivers and Streams

Connecticut planned on utilizing information from these waterbody assessments, modeling efforts and TMDL analyses to develop and refine nutrient criteria for flowing waterbodies with a focus on protecting designated uses (Connecticut Department of Environmental Protection 2005). At the beginning of their efforts CTDEP was not able to detect direct relationship between high nutrient concentrations and biological impairment. At the time CTDEP monitoring staff identified rivers and streams were nutrients appeared to be a potential cause for the biological impairment. However, CTDEP could not establish a clear linkage between a potential stressor and impairment. Rather, elevated nutrients levels had been observed with other potential stressors. Positive identification of causes/stressors for biological community impairment generally required additional further intensive investigations. They also conducted a similar comparison of stream miles with known biological impairments to stream miles in exceedance of the EPA recommended phosphorus criterion. They found that application of the criterion would result in twice as many impaired stream miles. At the time, application of the EPA 304(a) total phosphorus criterion of 31 μg/L for Ecoregion XIV (the ecoregion that encompasses most of Connecticut), would result in 368 of the 1,000 assessed stream miles exceeding criteria. Of those 368 stream miles exceeding this value, 183 miles (about half) were fully supporting for aquatic use as determined by benthic invertebrate community analysis (Connecticut Department of Environmental Protection 2005).

CTDEP concluded that further investigations of nutrients as a stressor in streams having benthic biological community impairment were needed to discern a possible cause and effect relationship. This would involve further statistical correlation analyses between nutrients and impairment, as well as exploration of potential links between impairment and nutrient-related impairing causes such as low dissolved oxygen or excessive algal growth. Beginning in 2002 CTDEP conducted periphyton surveys in streams as part of a statewide probabilistic monitoring program. Analyses of periphyton data included determination of biomass and application of a variety of metrics based on community composition.

Based on previous data and TMDL studies the CTDEP felt that the effects of nutrient enrichment in rivers and streams are more likely to manifest and negatively impact designated uses in impoundments than flowing sections(Connecticut Department of Environmental Protection 2005). The CTDEP felt that by continuing work on problem watersheds long plagued by algal blooms with a focus on remediating river impoundments, where most eutrophic impairments occur they would likely mitigate any nutrient-related impairment of the free-flowing sections. This approach emphasized management of "downstream effects" verses immediate instream effects.

Estuaries Approach

The primary cause of hypoxia in offshore portions of Long Island Sound is excess nitrogen loading, which was being addressed through a TMDL. Given progress on this TMDL and aggressive management of nitrogen in the Sound, Connecticut had not identified a need for additional nutrient criteria development for offshore estuarine waters at this time (Connecticut Department of Environmental Protection 2005). However, Connecticut acknowledge a need to review nitrogen reduction targets in terms of protection of nearshore bays and harbors for submerged aquatic vegetation, eelgrass in particular. Studies at the time suggested that eelgrass demise may be related to nitrogen overenrichment.

Wetlands

CTDEP stated that development of nutrient criteria for wetlands will be considered after methodologies for lakes and rivers have been established and successfully employed (Connecticut Department of Environmental Protection 2005).

Coordination with the Regional Technical Assistance Group (RTAG)

In order to facilitate information and data exchange the CTDEP participated in New England RTAG meetings.

Relationship of Nutrient Criteria to Use Classifications

The two designated uses most impacted by nutrient enrichment in Connecticut are “recreation” and “aquatic life support”. Due to this dual role the potential for conflicts in management of NNC goals are potentially high. For example, recreational uses for lakes in particular must be considered in context of a lake’s natural trophic tendency and the water quality expectations of recreational users. For example, a naturally eutrophic lake having a healthy warm water fishery may offer substantial recreational fishing opportunities, but these same characteristics may make it undesirable for swimming and skiing. A viable NNC development approach must recognize these different acceptable definitions of “designated” recreational uses and consider the public’s water quality expectations.

For programmatic and management purposes at CT DEP, waterbodies are presently grouped by type (e.g., rivers/stream, lakes/reservoirs, and estuaries). The CTDEP felt that future analyses of TMDLs, models and available data may provide sufficient data to support further sub-dividing these groups. For example, impoundments and reservoirs may need to be treated separately from natural lakes.

Recent Changes

At the time of the publication of the Nutrient Criteria Development plan is was Connecticut’s goal to establish numeric criteria for lakes by 2008 and for rivers and streams by 2011. However, this process has been delayed. The State of Connecticut does not currently have state or EPA approved NNC (http://www.ct.gov/dep/cwp/view.asp?a=2719&Q=471444&depNAV_GID=1654)(State of Connecticut Department of Environmental Protection 2011). In preparation for 2011 revisions to the state water quality standards CTDEP had developed several proposed

NNC proposals which were not adopted. For example CTDEP had proposed a phosphorus management implementation plan that would ultimately lead to NNC for TP (Connecticut Department of Environmental Protection 2009). This would be done using a best attainable reference condition approach, Connecticut has developed an implementation procedure that calculates phosphorus loadings associated with best attainable reference conditions within a watershed based on land use characteristics, implementation of source controls and attainment of designated uses, considering loadings of phosphorus from multiple sources including natural and developed land conditions, point and nonpoint contributions and effect of such loadings on downstream waters.

For nitrogen, Connecticut in partnership with the State of New York has established a TMDL to address low dissolved oxygen in Long Island Sound, attributed primarily to increased loadings of nutrients, primarily nitrogen, and other carbon-based pollutants (Connecticut Department of Environmental Protection 2009). The TMDL is based upon a coupled three-dimensional, time variable hydrodynamic/water quality model (LIS 3.0) and provides detailed analysis of the biological and chemical interactions (include nitrogen dynamics) that contribute to increased productivity within the watershed and a commensurate decrease in dissolved oxygen concentrations. Using the model, the necessary load reductions for nitrogen input into Long Island Sound have been identified and are being implemented. Therefore CTDEP has delayed any further development of NNC for nitrogen in rivers and streams, since most of them are tributaries of Long Island Sound and are being addressed indirectly through the TMDL process (Connecticut Department of Environmental Protection 2009).

CTDEP ultimately concluded after further consideration of stakeholder input and further review that there is insufficient information currently available to support adoption of biologically based NNC. The section which described the new NNC approach to the Water Quality Standards (Nutrient Criteria and Implementation Policy) was removed.

The final adopted rules contain the most up to date listing of various trophic classifications for reservoirs (State of Connecticut Department of Environmental Protection 2011) . The ranges of TP, TN, Chl-A and SD associated with each trophic class are presented in Table 19. These values are assessed collectively to determine the trophic state of a lake. In addition to water column data, the trophic state of a lake is determined by the percentage of the surface area covered by macrophytes in accordance the values outlined with Table 20. For the purpose of determining consistency with the WQS, the natural trophic state of a lake is compared with the current trophic state to determine if the trophic state of the lake has been altered due to excessive nutrient input from human sources. Lakes in advanced trophic states which exceed their natural trophic state due to anthropogenic sources are considered to be inconsistent with state WQS.

Since the phosphorus strategy portion of the water quality standards was not approved Connecticut is operating on an interim strategy of developing phosphorus management strategies that should lead to empirical estimates of NNC for TP (Author Unknown 2011; Becker and Dunbar 2009).

Table 19. Connecticut state water quality standards trophic classifications for lakes based on water column attributes. Source:(State of Connecticut Department of Environmental Protection 2011).

Trophic State Based on Water Column Data	Description	Parameters	Defining Range
Oligotrophic	May be Class AA, Class A, or Class B water. Low in plant nutrients. Low biological productivity characterized by the absence of macrophyte beds. High potential for water contact recreation.	Total Phosphorus	0-10 ug/l spring and summer
		Total Nitrogen	0-200 ug/l spring and summer
		Chlorophyll-a	0-2 ug/l mid-summer
		Secchi Disk Transparency	6 + meters mid-summer
Mesotrophic	May be Class AA, Class A, or Class B water. Moderately enriched with plant nutrients. Moderate biological productivity characterized by intermittent blooms of algae and/or small areas of macrophyte beds. Good potential for water contact recreation.	Total Phosphorus	10-30 ug/l spring and summer
		Total Nitrogen	200-600 ug/l spring and summer
		Chlorophyll-a	2-15 ug/l mid-summer
		Secchi Disk Transparency	2-6 meters mid-summer
Eutrophic	May be Class AA, Class A, or Class B water. Highly enriched with plant nutrients. High biological productivity characterized by occasional blooms of algae and/or extensive areas of dense macrophyte beds. Water contact recreation opportunities may be limited.	Total Phosphorus	30-50 ug/l spring and summer
		Total Nitrogen	600-1000 ug/l spring and summer
		Chlorophyll-a	15-30- ug/l mid-summer
		Secchi Disk Transparency	1-2 meters mid-summer
Highly Eutrophic	May be Class AA, Class A, or Class B water. Excessive enrichment with plant nutrients. High biological productivity, characterized by severe blooms of algae and/or extensive areas of dense macrophyte beds. Water contact recreation may be extremely limited.	Total Phosphorus	50 + ug/l spring and summer
		Total Nitrogen	1000 + ug/l spring and summer
		Chlorophyll-a	30 + ug/L mid-summer
		Secchi Disk Transparency	0-1 meters mid-summer

Table 20. Connecticut state water quality standards trophic classifications for lakes based on amount of macrophytes. Source:(State of Connecticut Department of Environmental Protection 2011).

Trophic State Based on Water Column Data	% Water Body Area of Lake Affected by Macrophytes	Lake Trophic State
Oligotrophic	<30	Oligotrophic
	30-75	Mesotrophic
	>75	Highly Eutrophic
Mesotrophic	<30	Mesotrophic
	30-75	Eutrophic
	>75	Highly Eutrophic
Eutrophic	<30	Eutrophic
	30-75	Eutrophic
	>75	Highly Eutrophic

METHODOLOGY: Identify Indicators of Nutrient Enrichment

GIS Analysis of Response Variables that Indicate Nutrient Enrichment

Parameter	High Indication of Enrichment	Medium Indication of Enrichment	Low Indication of Enrichment
Seasonal (April – October) Total Phosphorus Concentrations (mg/L)	> 0.1	0.05 – 0.1	< 0.05
Seasonal (April – October) Chlorophyll a – Periphyton (mg/m²)	> 100	50 - 100	< 50
Seasonal (April – October) Chlorophyll a – Plankton (mg/L)	>30	15-30	<15
Van Dam Trophic State Index – Eutrophentic Species (Presence / Absence)	5 (Eutrophentic)	4 (Meso-Eutrophentic)	< 4

GIS Analysis of Habitat Factors that Affect Biomass Levels

Parameter	Affect Biomass Levels	Do Not Affect Biomass Levels
Dams /Ponded Areas	Present	Absent

Figure 12. Results of GIS analysis of variables and concentrations associated with eutrophication. Source: (Becker and Dunbar 2009)

A geo-spatial modeling analysis was conducted in the various watersheds below facilities discharging phosphorus to assess the level of nutrient enrichment in the river. The goal of the Connecticut interim nutrient management strategy was to achieve or maintain an enrichment factor (EF) of 8.4 or below throughout a watershed. An EF represents the ratio of the total seasonal phosphorus load (April through October) at the point of complete mixing downstream of a National Pollutant Discharge Elimination System (NPDES) discharge to that load calculated for the same location from a fully forested upstream watershed with no point discharges. The total current load includes the current load from the NPDES facility and any additional NPDES facilities upstream plus the load from current land use export. The EF is calculated using the equation below.

$$\text{Enrichment Factor (EF)} = \frac{\text{Total NPDES Load}\left({}^{\text{lbs}}/_{\text{day}}\right) + \text{Land Cover Load}\left({}^{\text{lbs}}/_{\text{day}}\right)}{\text{Forested Condition Load}\left({}^{\text{lbs}}/_{\text{day}}\right)}$$

The goal of an 8.4 EF represents an empirical threshold at which a significant change is seen in stream algal communities indicating highly enriched conditions and impacts to aquatic life uses (Author Unknown 2011). The analysis was conducted using stream algae collected in rivers and streams throughout Connecticut under varying enrichment conditions. The approach targeted the critical 'growing' season (April through October) when phosphorus is more likely to be taken up by sediment and biomass because of low flow and warmer conditions. During winter months aquatic plants are dormant and flows are higher providing constant flushing of phosphorus through aquatic systems. Therefore it is less likely chance that it will settle out into the sediment. Limiting the phosphorus export from industrial and municipal facilities offers a targeted management strategy for achieving aquatic life designated uses within a waterbody.

Delaware

The State of Delaware Water Quality Standards Program is managed by the Delaware Department of Natural Resource and Environmental Control (DNREC) (http://www.dnrec.state.de.us/DNREC2000/Divisions/Water/WaterQuality/Standards.htm).

Current designated uses for waterbodies in Delaware include the following 9 categories:

1. Public Water Supply
2. Industrial Water Supply
3. Primary Contact Recreation (Swimming)
4. Secondary Contact Recreation (Wading)
5. Fish Aquatic Life and Wildlife
6. Cold Water Fish
7. Agricultural Water Supply
8. ERES Waters (Waters of Exceptional Recreational of Ecological Significance)
9. Harvestable Shellfish Waters.

Delaware has very few NNC in the most recent version of their water quality standards (Delaware Department of Natural Resources and Environmental Control 2004) (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_de.cfm). These NNC were approved by EPA and are limited to selected inland bays and estuaries in selected waterbodies. These waterbody specific NNC are listed below.

For tidal portions of the stream basins of Indian River, Rehoboth Bay, and Little Assawoman Bay, the NNC needed to support the submerged aquatic vegetation (e.g. eelgrass *Zostera marina*) growth season (approximately March 1 to October 31) include average maximum levels for dissolved inorganic nitrogen or DIN (NH_3-N + NO_3-N +

NO_2-N) of 0.14 mg/L as N, dissolved inorganic phosphorus (equivalent to dissolved acid hydrolysable P) of 0.01 mg/L as P, and total suspended solids of 20 mg/L.

Delaware has also adopted dissolved oxygen and secchi disk criteria for tidally influenced tributaries of Chesapeake Bay. This is in part due to the multi-state Chesapeake Bay TMDL which resulted in an adjustable back-calculated de-facto numeric nutrient criteria (United States Environmental Protection Agency 2010b). The NNC for water clarity and narrative criteria for chlorophyll-*a* were developed for the Nanticoke River from the upstream-most limits of the City of Seaford to the Maryland State Line and Broad Creek from the upstream-most limits of the Town of Laurel to the confluence with the Nanticoke River. During the period of April 1 to October 31 the minimum seasonal averaged secchi depth shall be 1.0 m. In addition concentrations of chlorophyll-*a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in ecologically undesirable consequences. This includes reduced water clarity, low dissolved oxygen, food supply imbalances, proliferation of species deemed potentially harmful to aquatic life or humans or aesthetically objectionable conditions or otherwise render tidal waters unsuitable for designated uses.

Delaware does have an approved Nutrient Criteria Development Plan (State of Delaware 2004). It should be noted that the report is issued as final but is still entitled "draft" on the EPA nutrient criteria web site and by EPA reports (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/de_ncp_0002_120104.pdf), (State of Delaware 2004; United States Environmental Protection Agency 2008b). We were unable to find this report on the State of Delaware web site or obtain clarification on status of this report.

Delaware promulgated Water Quality Standards in July 2004 that included narrative and numeric nutrient criteria for waters of the State. The numeric criteria for tidal portions of Delaware's Inland Bays (Indian River, Rehoboth Bay, and Little Assawoman Bay) are average levels of 0.14 mg/l-N for dissolved inorganic nitrogen and 0.01 mg/l –P for dissolved inorganic phosphorous. These criteria are applicable during the growth season (March 1 through October 31) and were established to promote the re-establishment of submerged aquatic vegetation (SAV) and protect existing SAV resources. In the 2004 triennial review, the Department promulgated revised dissolved oxygen, chlorophyll-a, and clarity criteria for waters in the Chesapeake Bay drainage basin to implement guidance recommendations made by the EPA through the Chesapeake Bay Program. The Chesapeake guidance documents do not address nutrients specifically, but use dissolved oxygen and chlorophyll-a as surrogate indicators of nutrient over-enrichment (United States Environmental Protection Agency 2010b). This approach is more fully described in the multi-state regional Chesapeake Bay section of this report.

District of Columbia

Numeric nutrient criteria is limited to tidal waters in the District of Columbia and is primarily related to the adoption and ongoing modification of the Chesapeake Bay criteria for DC's Potomac River section and the tidal Anacostia River per their 2010 triennial review of water quality standards (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_dc.cfm)((District Department of the Environment 2010; United States Environmental Protection Agency 2010b). These NNC are limited to chlorophyll-*a* and water clarity.

The designated uses of District of Columbia waters include those listed below.

Primary contact recreation ………………............................... A
Secondary contact recreation and aesthetic enjoyment .... B
Protection and propagation of fish, shellfish, and wildlife C
Protection of human health related ....……... D
to consumption of fish and shellfish
Navigation …..…………………… E

All tidal waters are classified as class C waters in addition to other designations. To support class C designated uses, the seasonal (July 1 through September 30) segment average chlorophyll-*a* NNC of 25 µg/L is applied to all tidal waters. In addition a nutrient related turbidity standard consisting of a seasonal (April 1 through October 31) secchi disk depth of 0.8 meters applies to all tidal waters (District Department of the Environment 2010). These values were derived from the TMDL based Chesapeake Bay standard (United States Environmental Protection Agency 2010b) that will be discussed later under that section. These values are associated with a dissolved oxygen standard for the protection of fish and wildlife in tidally influenced waters which is defined as:

February 1 through May 31	
7-day mean	6.0 mg/L
Instantaneous minimum	5.0 mg/L
June 1 through January 31	
30-day mean	5.5 mg/L
7-day mean	4.0 mg/L
Instantaneous minimum	3.2 mg/L (4.3 mg/L @ temperatures > 29C)

Florida

The State of Florida has recently undergone extensive revisions to their water quality standards due to federal promulgation of numeric nutrient criteria (Florida Department of Environmental Protection 2011c; Migliaccio et al. 2011; Obreza et al. 2011; United States Environmental Protection Agency 2010g; United States Environmental Protection Agency 2010i; United States Environmental Protection Agency 2010l) (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients /states_fl.cfm; http://www.dep.state.fl.us/water/wqssp/nutrients/). The official water quality standards for Florida consists of a mixture of recent federally promulgated NNC and the most recent state water quality standards adopted by the Florida Department of Environmental Protection (FDEP)(Florida Department of Environmental Protection 2010a; United States Environmental Protection Agency 2010l). Due to this dual process we have provided a brief overview of the current existing uses and waterbody classification and then describe the existing state adopted and/or federally approved or promulgated standards. Finally we provide a description of some of the past and current technical approaches used by the State of Florida and/or EPA to develop proposed and/or adopted NNC.

Background

The state of Florida has a wide diversity of waterbody and associated habitat types including freshwater springs, lakes, reservoirs, freshwater streams, coastal streams, inland wetlands, and coastal wetlands (*Spartina* dominated, mangroves), seagrass beds, freshwater submerged grass beds, and coral reefs, estuarine and offshore waters. In addition, the Everglades represent a unique complex of freshwater wetlands and open water that is considered separately in Florida water quality standards. The current stated adopted and federally approved Florida water quality standards regulations recognizes 5 classes of uses (Florida Department of Environmental Protection 2008). These are listed below.

Class I Potable Water Supplies

Class II Shellfish Propagation or Harvesting

Class III Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife

Class IV Agricultural Water Supplies

Class V Navigation, Utility and Industrial Use

Based on our review of their water quality standards, nutrient criteria, both narrative and numeric are typically developed and applied to protect Class III waters and associated uses.

Historical Development of Numeric Nutrient Criteria

The Florida Department of Environmental Protection (FDEP) formally started the process of developing NNC with the production of their original 12 page "Nutrient Criteria Development Plan" which was submitted to EPA in 2002 and received mutual agreement in 2004 (Florida Department of Environmental Protection 2002a), (http://www.dep.state.fl.us/water/wqssp/nutrients/). In 2004, the current site specific NNC for total phosphorus for the Everglades Protection Area was adopted by the state and approved by the EPA (Florida Department of Environmental Protection 2010a). Prior to recent federal promulgation of NNC, the Nutrient Criteria Development Plan had been revised and mutually accepted by EPA and Florida in 2007 (Florida Department of Environmental Protection 2007).

On January 14, 2009, EPA formally determined that numeric nutrient criteria should be established on an expedited schedule. The 24 page 2007 Nutrient Criteria Development Plan was superseded by the 2009 plan which was considerably larger (129 pages) and adopted by the State of Florida. This revised plan reflects the FDEP's current approach to NNC development, and their attempt to meet the expedited schedule. The 2009 Nutrient Criteria Development Plan was not agreed to by EPA due to a pending lawsuit by Earthjustice against the EPA for failure to produce NNC in Florida (Florida Department of Environmental Protection 2009c; Migliaccio et al. 2011). Earthjustice which represented multiple private organizations, believed the state adoption and federal approval process was moving too slow and had filed a lawsuit against the EPA in 2008. In the lawsuit, Earthjustice claimed that there had been an unacceptable delay by the federal government in setting limits for nutrient pollution. They claimed that the EPA had previously determined that numeric nutrient criteria are necessary as described in the Federal Clean Water Act, and further argued that the EPA was obligated to promptly propose these criteria for Florida. EPA settled the lawsuit by issuing a "necessity determination" letter to FDEP that it was necessary for the federal government to propose and promulgate numeric nutrient standards for lakes and flowing waters by January 2010 and for estuarine and coastal waters by January 2011 in Florida (Grumbles 2009; Migliaccio et al. 2011). This process was delayed until November 14, 2010 at which time EPA signed the final rule called "*Water Quality Standards for the State of Florida's Lakes and Flowing Waters*"(Obreza et al. 2011). The rule was published in the federal register on December 6, 2010 and will become effective on March 6, 2012, except for a section of the rule related to implementation of site specific alternative criteria, that is effective as of February 4, 2011 (United States Environmental Protection Agency 2010g).

On 8-5-2010 the State of Florida revised their water quality standards (Florida Department of Environmental Protection 2010a). FDEP adopted new nutrient related numeric criteria for transparency on the Fenholloway River and associated downstream estuarine bay system. These changes have not been approved by the EPA to our knowledge.

In March 2011, EPA released a Memorandum that detailed the eight most crucial elements EPA believes are necessary for all State water quality standards programs to effectively manage nutrient pollution (Stoner 2011a). In response, the Florida Department of Environmental Protection (DEP) filed a petition with EPA on April 22, 2011, requesting that EPA rescind its January 2009 “Necessity Determination” letter and associated promulgated rules (Beason and Hayman 2011). In their petition FDEP argued that Florida had comprehensively addressed the eight elements outlined in the 2011 Memorandum, and that EPA would not have issued its original “Necessity Determination” letter if it had evaluated Florida’s programs against the new eight elements criteria. FDEP requested a response to this request by May 22, 2011. A summary of how FDEP believed Florida had met these 8 elements is quoted verbatim below (Florida Department of Environmental Protection 2011b). More complete information on how FDEP responded to the eight items listed is found in the actual petition (Beason and Hayman 2011).

FDEP Response to 8 Elements (Florida Department of Environmental Protection 2011b).

1. Prioritize Watersheds for Nitrogen and Phosphorus Loading Reductions.

FDEP has identified its high priority waters and established nutrient load reduction targets for most major waters. (Example: Significant reductions documented in the Everglades, Tampa Bay, etc.)

2. Set Watershed Load Reduction Goals Based Upon Best Available Information.

Nutrient reduction goals have been established for the high priority waters, and more continue to be set annually. (Example: 135 adopted nutrient TMDLs).

3. Ensure Effectiveness of Point Source Permits in Targeted/Priority Sub-Watersheds.

Florida has made significant reductions in nutrient loading from NPDES point source dischargers. (Example: Eliminated most surface water discharges, greatly increased reuse, and high level treatment.)

4. Agricultural Areas - target most effective, innovative practices.

According to FDEP Florida has one of the country’s most comprehensive agricultural source control program. (Example: Best Management Practices on over 8 million acres of farm land.)

5. Stormwater and Septic Systems.

FDEP stated that Florida was the first to implement a comprehensive stormwater treatment program, and has a system for management of septic systems. (Example: Florida is 1 of 13 States with specific post-development stormwater treatment requirements.)

6. Accountability and Verification Measures.

FDEP stated that Florida has the most extensive monitoring and assessment program in the country. (Example: Over 30% of the nutrient water quality data in EPA's national water quality database are from Florida.)

7. Annual Public Reporting of Implementation Activities and Biannual Reporting of Load Reductions and Environmental Impacts Associated with Each Management Activity in Targeted Watersheds.

DEP stated that it regularly monitors and documents pollutant load reductions in a variety of reports. (Example: Annual Basin Management Action Plan reports, Basin Assessment Reports, Estuary Reports, etc.).

8. Develop Work Plan and Schedule for Numeric Criteria Development.

FDEP argued that it had followed a "mutually agreed upon" (EPA and DEP) nutrient criteria development plan since 2002. FDEP's petition requested EPA to suspend further action on numeric nutrient criteria in Florida, in order to allow FDEP to reinitiate its own rulemaking.

To our knowledge the EPA has yet to officially respond to the request. Based on recent discussions with FDEP staff, the state is still awaiting an official response from EPA (Charles Kovach - FDEP pers. comm.). In the meantime the FDEP has continued to work on the development of water quality standards, and an alternative plan that will satisfy the technical requirements of the recent federal ruling. It is uncertain what the final outcome will be.

The evolution of NNC development in Florida has therefore involved two major processes including ongoing state efforts and the most recent federal promulgation. Both processes have involved the use of multiple technical approaches with input from expert panels including state, federal and university scientists. Although the EPA has taken the lead in NNC development in Florida there was a significant amount of work done prior to this action which resulted in numerous technical reports and some limited past and current NNC development activities in other locations in Florida including the Everglades and Fenholloway River. We have included a short discussion and description of recent state and federal efforts taken to develop NNC in Florida along with information on the technical approaches used and appropriate literature citations.

Past Approaches and Existing State Approved Nutrient Criteria

Nutrient Criteria Development Plan 2002

In May 2002, the FDEP published the "*State of Florida Draft Numeric Nutrient Criteria Development Plan*" (Florida Department of Environmental Protection 2002a). This document outlined the State of Florida's conceptual framework for eventual development of NNC. At that time the FDEP envisioned using the EPA guidance for development of NNC using regional ecoregion adjusted data derived from minimally impacted sites for both streams and lakes (Gibson et al. 2000; Grubbs 2001b; United States Environmental Protection Agency 2000h). At that time EPA considered TN and TP to be "causal variables", while chlorophyll-*a* and water clarity (secchi depth) were considered "response variables" and early indicators of waterbody nutrient over-enrichment. At the time Florida did not believe the Level III ecoregion data used to formulate recommended EPA criteria for lakes and streams was sufficient to reflect localized variability. Therefore they planned to utilize local data collected by FDEP and conduct preliminary analyses based on ecoregions previously delineated by their biocriteria program. They felt that Level IV ecological regions defined in past studies for Florida would be used to classify data and regionalize if necessary NNC. In addition, FDEP anticipated using designated uses (e.g. navigation, potable water etc) as a subcategory within each waterbody type (e.g. stream, lake etc.) for formulation of NNC.

The FDEP planned to compile necessary data for formulation of NNC by 1) entry/upload of existing sample data to federal and state STORET databases, 2) acquisition of third party (e.g. local and county government, universities, etc) nutrient data and 3) and collection of additional data through targeted sampling efforts to address information remaining needs. They anticipated additional federal funding would be provided to do this. It should be noted that based on information advertised on the FDEP web site, Florida appears to have a very extensive water quality monitoring database, both spatially and temporally. This is due to a relatively long period of ambient monitoring.

Before the 2002 Nutrient Plan was released the FDEP had already started managing several projects that may be useful in developing NNC. These projects included: 1) characterization analyses of nutrient data from lakes, 2) paleolimnological analyses of sediment cores and 3) development of stream diatom populations indices. FDEP anticipated funding additional research projects focused on obtaining data for implementation of methods outlined in the EPA technical guidance manuals.

The FDEP planned on examining and utilizing nutrient loading targets, and resulting ambient nutrient concentrations calculated from TMDL studies as a method to derive site specific NNC. EPA Region IV had agreed to accept this as a method or approach to derive site specific NNC (Florida Department of Environmental Protection 2002a). Similarly FDEP anticipated evaluating and/or utilizing chlorophyll-*a* targets adopted for Tampa Bay by the National Estuary Program.

To assist FDEP in these efforts a Technical Advisory Committee (TAC) was assembled to meet regularly and advise the agency. A timeline was developed for compilation of data, analysis and rule formulation by 2005.

Nutrient Criteria Development Plan 2007

During September 2007 the FDEP updated the "*Numeric Nutrient Criteria Development Plan"* (Florida Department of Environmental Protection 2007). FDEP updated information on progress made towards adoption of NNC and results of ongoing research in support of development of methods to derive NNC. Several projects that were funded by FDEP were used to evaluate potential methods for derivation of NNC. These projects included:

1. Paleolimnological characterization of pre-disturbance water quality in two Florida lake regions

2. Sediment deposited algal pigment profiles in the Florida paleolimnological study lakes.

3. Development of stream diatom population indices for Florida streams

4. Comparison of nutrient criteria approaches for Florida lakes with recommendations for lake TN, TP, chlorophyll–*a*, and secchi depth criteria

5. Another paleolimnological study with further resolution on the lakes in studies 1 and 2 above.

FDEP concluded that for some of these approaches, while good for a specific waterbody, were too time consuming and cost intensive to apply at a subregional scale or larger. However, FDEP felt these studies provided important information on causal and response aspects of waterbody nutrient status.

FDEP continued to support the concept of using TMDLs as a tool for development of site specific numeric nutrient criteria which might supersede future regional criteria if appropriate. FDEP was also exploring the development of NNC for adoption into their state water quality standards as a methodology for identifying impaired waters. As such the NNC would serve both to protect healthy well-balanced natural populations of organisms from the effects of excess nutrients and help identify waters impaired by nutrients.

The TAC continued to meet and assist FDEP in development of NNC. However, progress had been slow due to the complexities associated with assembling and verifying data that would be used in development of NNC. The agency supported the extension of the TAC through at least 2009 to assist in the ongoing criteria development process. The TAC had previously considered analysis of data on the EPA recommended causal (TN and TP) and the response (Chlorophyll-*a*) parameters. The TAC also considered the

FDEP derived bioassessment methods, along with the Stream Condition, Lake Condition, and Lake Vegetation Indices. Additionally, FDEP started using a rapid periphyton survey methodology for streams in early 2007 and initiated the development of phytoplankton and periphyton indices for lakes and streams, respectively.

Based on the guidance provided during TAC discussions in 2006, FDEP staff conducted a pilot study to develop nutrient criteria for streams in the Florida Peninsular bioregion using the reference streams approach. The FDEP developed and utilized an extensive multi-step evaluation of potential reference sites to assure that the reference sites used in the derivation of nutrient thresholds for the Lake Okeechobee tributaries truly represented minimally disturbed conditions. This multi-step evaluation included 1) screening for sites using a Landscape Development Intensity Index (LDI) score, 2) screening sites based on the state's 303(d) list of impaired waters, 3) verifying surrounding land-use using high resolution aerial photographs, 4) obtaining input from local FDEP district biologists knowledgeable of the area, 5) conducting a statistical outlier analysis, and 6) an conducting extensive field evaluations of a large number of the remaining waterbodies containing reference sites.

A key issue of the Lake Okeechobee pilot study was the selection of the appropriate percentile to use for the numeric criterion. FDEP reviewed the technical guidance provided by (United States Environmental Protection Agency 2000h) for development of river and stream NNC. This EPA guidance states that "it is reasonable to select a higher percentile (i.e., 75(h percentile) as the reference condition, because reference streams are already acknowledged to be in an approximately ideal state for a particular class of streams." Another interpretation is the range of nutrient concentrations observed at reference sites is considered to represent nutrient levels expected in areas with minimal human influence. FDEP agreed that using an upper percentile distribution of the reference site population would yield an ecologically justifiable, inherently protective criterion. Case studies in the EPA guidance document, as well as other literature presented at various federal and state nutrient criteria workshops suggested percentiles in the 75th to 95th range would be suitable and represent optimally functioning systems. FDEP suggested that selecting a percentile at the upper end of the distribution (i.e., 90th to 95th percentile) as a criterion appropriately establishes the range of nutrients characteristic of these biologically healthy sites, and results in only 5 to 10 percent of these biologically healthy reference sites from being misidentified as impaired (Florida Department of Environmental Protection 2007).

Based on the 2007 Nutrient Criteria Development plan FDEP intended to continue the validation of its selected reference sites before adoption of numeric nutrient criteria (Florida Department of Environmental Protection 2007). Specifically, FDEP planned to investigate whether there are biological thresholds at and below the reference percentile thresholds (i.e., 75th and 90th). The objective of the expanded validation efforts will be to confirm that healthy well-balanced aquatic biological communities are maintained at or below the selected numeric thresholds. The FDEP expected that the biological demonstrations will likely include both the existing SCI for macro invertebrates as well as periphyton in streams, and macrophytes and phytoplankton in lakes. (Fore 2005) cited in (Florida Department of Environmental Protection 2007) developed a Lake Vegetation Index (LVI) to assess the biological condition of aquatic plant communities in Florida lakes. FDEP also planned to begin work on the development of a periphyton index for Florida streams during the last quarter of 2007.

Although Florida had made significant progress towards the development of numeric nutrient criteria using the reference site approach, they stated in their Nutrient Criteria Development Plan that they wished to continue investigations into alternative approaches that more directly link nutrient levels to biological responses. To this end, FDEP planned on using its extensive biological database and assessment tools to explore response based thresholds. Additionally, potential thresholds of biological response will be examined during development of the stream periphyton index. Ultimately, these alternative approaches may serve as the sole basis for Florida's NNC or the information may be coupled with the reference sites to form the basis for a “weight-of-evidence” approach.

After completion of TAC activities and, prior to submittal of potential draft NNC to the Environmental Regulation Commission (ERC), FDEP will hold rule development workshops, draft rule text, and allow for review and revisions. The ERC is an unpaid citizenry board, which, in exercising its authority, considers scientific and technical validity, economic impacts, and relative risks and benefits to the public and the environment of all proposed rules and standards related to environmental resources. It is anticipated that ERC activities can be completed in a timeframe of twelve months, barring major dissent. The FDEP has limited influence on the time schedule of the ERC's process of approval of such rules is limited, making the establishment of a firm completion date for nutrient criteria adoption difficult.

FDEP initially used Level IV ecological subregions as a starting point for regionalization efforts necessary to establish nutrient criteria. FDEP had previously analyzed stream reference site macroinvertebrate community patterns in all nine ecological subregions north of Lake Okeechobee (Florida Department of Environmental Protection 2007). The data indicated the presence of four distinct bioregions, within which there were similar biological community composition and structure, Similar patterns of relatively homogeneous groupings in the peninsula versus the panhandle have been observed in wetlands macrophyte, algae, and invertebrate data (Lane et al. 2003). Lake macrophyte (for percent invasive species) and invertebrate (based on ecoregion, pH, and color) indices also utilize a similar bioregion scheme (Fore 2005), (Gerritsen et al. 2000) cited in (Florida Department of Environmental Protection 2007). At the time FDEP was evaluating the potential of using ecological subregions collapsed into biological regions as the basis for future nutrient criteria groupings. FDEP considered using bioregions for organizing nutrient data for NNC development based on the theory that observed biologically similar communities will have analogously similar responses to nutrient concentrations. They stated that current biological data suggest bioregions are the most defensible approach to establish appropriate protection of biota. However, these bioregions were derived based on macroinvertebrate assemblage patterns, which may not be entirely indicative of homogeneous response to nutrients. FDEP and its consultants were at the time evaluating bioregions based on stream periphyton assemblages. They stated that if the evaluations reveal significantly different biological regions then the nutrient spatial classifications will be adjusted accordingly.

FDEP and the TAC were also evaluating various scientifically defensible methods or sub-regionalization of known naturally high phosphate areas in the central peninsula and north-central Florida (Weaver 2006) cited in (Florida Department of Environmental Protection 2007). In this Peninsula bioregion pilot study, the FDEP was using a statistical outlier analysis method to exclude these naturally high phosphate areas. At the time FDEP intended to evaluate other methods to explicitly sub-regionalize these areas.

In order to support ongoing FDEP nutrient criteria development the agency had also embarked on efforts to identify data sources and develop tools to facilitate data transfer and entry and upload into EPA STORET and Florida STORET (Florida Department of Environmental Protection 2007). FDEP's was also in the process in the process of implementing watershed approach to monitoring to gather new data within watersheds to supplement existing data. An important component of these efforts was coordination of monitoring programs on shared lakes and streams with bordering states in support of development of nutrient criteria.

Like many states FDEP initially prioritized waters for development and adoption of regional numeric nutrient criteria based on the availability of EPA guidance documents; that is, 1) lake and river stream guidance were available first, followed by 2) estuaries and coastal waters, and finally 3) wetland guidance. Additionally, site specific numeric nutrient target development has been driven by TMDL development schedules, including a number of nutrient TMDLs for specific waterbodies, to be completed in accordance with the consent decree between EPA Region IV and EarthJustice. Regional nutrient criteria development and the site specific TMDL efforts are highly integrated in Florida, and information and experience gained in each effort has been and will continue to be used to refine the other. Methods being developed by FDEP to derive draft regional nutrient criteria have been used by FDEP to develop recommended TMDL thresholds for specific water bodies. Conversely, site specific targets developed via the TMDL process will be evaluated for potential regional application or possible consideration as site specific nutrient criteria for given water bodies, particularly for estuaries and coastal waters.

FDEP staff continued to work with the TAC on nutrient criteria development. In addition FDEP staff served and/or participated on numerous regional and national nutrient criteria related meetings, workshops, and conferences (e.g., Region 4 RTAG, 2006 All States meeting, and Gulf of Mexico Alliance).

As previously stated the FDEP had set up a prioritized schedule for development of NNC in their 2007 Nutrient Criteria Development Plan (Florida Department of Environmental Protection 2007). The state of Florida identified lakes and streams as its first priority for regional numeric nutrient criteria development and adoption. FDEP had numerous meeting with their nutrient TAC and anticipated having draft NNC by 2010. Florida also contains a large number of artificial canals or highly altered streams. FDEP recognized that the biological communities found within these canals are substantially different from natural rivers and streams due to severe habitat limitation and unnatural hydrologic conditions. It can be reasonably expected that response to nutrients within these systems is different from natural streams. Therefore, FDEP and the TAC had been developing numeric nutrient criteria for canals separately from the natural water bodies. However, FDEP currently expected to use a technical approach very similar to the one under development for streams; that is, one based on a best attainable reference condition. It is currently anticipated that nutrient criteria for canals will be developed following the same schedule as the natural lakes and streams.

FDEP selected estuaries as the second priority because of the site-specific nature of nutrient response in estuaries. FDEP concurs with EPA statements made in their national technical guidance documents that estuaries exhibit unique geomorphology and physical attributes and therefore will require a different approach for NNC development, in comparison to lakes and streams (United States Environmental Protection Agency 2000g). FDEP anticipated that numeric nutrient criteria for Florida's estuaries and coastal waters will be based primarily on site specific efforts, including TMDL related efforts. At the time of the release of the 2007 plan FDEP had not initiated a formal estuary nutrient criteria development process. However, there are numerous and extensive existing activities that have either identified or will in the near future identify nutrient response thresholds. For example, the Tampa Bay Estuary Program (TBNEP) has established Chlorophyll-*a* targets for the different segments of the bay based upon a goal of restoring seagrass beds (Florida Department of Environmental Protection 2007). At the time FDEP was considering initially developing regional response variable nutrient criteria based on site specific thresholds developed for many of the larger coastal systems in the state (e.g., Tampa Bay, Indian River Lagoon, Caloosahatchee, St. Lucie River) and subsequently deriving causal variable criteria based on statistical relationships between these response and the causal variables. FDEP intended to hold an estuary nutrient kickoff meeting by May 2008 with an expanded TAC.

Florida had adopted a numeric phosphorus criterion for the Everglades in 2004 before EPA's draft wetland guidance was released. The FDEP did not plan to initiate development of regional wetland nutrient criteria until after the estuary nutrient criteria are into the rule development phase. The lower priority assigned to wetlands is based on the fact that wetlands are biologically very different from other water body types. Implementation of nutrient threshold research or reference condition evaluations will take some time given the current state of wetland science.

Nutrient Criteria Development Plan 2009

In 2009 FDEP released the most current Nutrient Criteria Development Plan (Florida Department of Environmental Protection 2009c). This Plan was a substantial revision of the 2007 plan. The large (138 page) compilation details the most recent efforts by the State of Florida to develop NNC prior to implementation of the EPA promulgated NNC. The Plan documented FDEP's continued development of NNC for various subregions based on Florida's watershed program needs and the availability and order of EPA guidance documents. FDEP continued to evaluate both ecoregions and bioregions as potential subregionalization bases for numeric nutrient criteria. Florida ecoregions had been previously delineated in the early 1990s as part of Florida's biocriteria development efforts for streams and lakes.

While FDEP planned to develop nutrient criteria that are applicable to specific regions which will serve to prevent impairment, they also took the position that in some cases, the development of Total Maximum Daily Loads (TMDLs) or Pollutant Load Reduction Goals (PLRGs), as described in state laws and rules, may also serve as a mechanism for development of more site-specific nutrient targets that could supersede regional criteria. The FDEP mentioned two examples including the Lake Okeechobee phosphorus TMDL, which established the phosphorus concentration that would address undesirable algal blooms in that system and the Tampa Bay Estuary Program which had adopted chlorophyll-*a* targets for portions of Tampa Bay that were specifically designed to protect and restore seagrass communities within the bay. The FDEP also stated that it intended to develop numeric nutrient criteria for adoption in Chapter 62-302, Florida Administrative Code (F.A.C.), as water quality criteria, and in addition, is exploring the incorporation of numeric nutrient thresholds into their Impaired Surface Waters Rule (IWR) (Chapter 62-303, F.A.C.), which established the state's methodology to identify and verify impaired waters not meeting applicable state water quality standards). The IWR already includes thresholds for response variables that serve as translators for Florida's narrative nutrient standard (a quantification of imbalance of flora and fauna) which are used in addition to consideration of other factors to assess waters for nutrient impairment. However, their IWR does not currently include similar numeric causal (e.g. TN or TP) thresholds for either streams or estuaries.

To assist in the development of numeric nutrient criteria, FDEP continued to utilize the Nutrient Criteria Technical Advisory Committee (TAC). The TAC membership is diverse, consisting of representatives with significant experience in the ecology of specific aquatic systems (lacustrine, riverine, estuarine, and/or palustrine) and the interpretation of water quality data through the use of statistical modeling tools. They include representatives of academic and public institutions, along with individuals possessing significant technical experience who were drawn from industry, agricultural, and environmental groups. The TAC is charged with reviewing the existing knowledge base related to aquatic systems and developing recommendations for submittal to FDEP on NNC. The TAC is supported by FDEP staff assigned to provide data assembly and analysis. The FDEP anticipated that smaller subgroups may need to be formed to consult with other experts in addressing specific waterbody types (e.g., south Florida canals, or estuaries) for which criteria are under development.

Many of the recommendations in the 2009 Plan remain unchanged or are very similar to the 2007 Plan recommendations (Florida Department of Environmental Protection 2007; Florida Department of Environmental Protection 2009c). Therefore we will only highlight substantive changes or additional guidance presented in the 2009 Plan. While FDEP had continued to pursue all scientifically defensible approaches to derive numeric nutrient criteria, they stated that they prefer to base NNC on dose-response relationships.

However, due the challenges associated with identifying statistically significant relationships between nutrient concentrations and biological responses, FDEP is also developing nutrient criteria using a "benchmark distributional approach" that will serve as potential alternative method for NNC development if the statistically sound dose response–based criteria cannot be initially determined. In addition FDEP may require biological confirmation before listing waters as impaired.

Nutrient Criteria Development Plan 2009 – Description of Benchmark Distributional Approach

The nutrient benchmark distributional approach builds on previous methodologies originally developed to quantify human disturbance for biocriteria development. FDEP defined nutrient benchmark sites as only being influenced by low levels of human disturbance, enabling full support of the most sensitive designated uses including support of a healthy, well-balanced population of fish and wildlife. FDEP intended to use the upper end of nitrogen and phosphorus frequency distributions from benchmark sites to define nutrient thresholds. FDEP expects that these thresholds would be reliable for protection of aquatic life in Florida waters.

If the benchmark-based nutrient thresholds are adopted by FDEP, these thresholds would be used to identify waters that are potentially impaired for nutrients. Waters with nutrient concentrations above these thresholds would be placed on Florida's Planning List of potentially impaired waters. These sites would be prioritized for additional monitoring including a biological assessment. If subsequent biological information confirms biological impairment instream at that point, or possibly downstream, and this can be linked to excess nitrogen or phosphorus, FDEP would place the waterbody on the "*Verified List"* of impaired waterbodies and on a planning list for nutrients. If no biological impairment can be found for waterbodies (or downstream of these sites, or if the biological impairment is shown to be due to other factors and not nutrients, then FDEP would not be considered them impaired due to nutrient enrichment.

FDEP believed that a site-specific biological confirmation is required to demonstrate a link between nutrients and adverse biological responses for nutrient benchmark approach–derived criteria. This is because multiple factors can strongly influence the expression of biological responses to nutrients. For example other factors such as limited habitat, hydrology are often more influential on biological impairments than nutrients. The benchmark distributional approach identified nutrient concentrations that are presumed protective because these concentrations are associated with relatively low human disturbance and a healthy instream biological community at that point, and have been shown to be protective downstream as well. The final actual biological thresholds will be site-specific and could occur at concentrations that differ from the previously defined benchmark thresholds.

FDEP's official policy in regards to nutrient criteria was to use technically defensible methods and the most robust dataset feasible to develop protective criteria. They had concluded that there is a lack of data describing biological dose-response relationships for nutrients. FDEP initially pursued a nutrient benchmark distributional approach. However, the FDEP's preference is to develop criteria linked to biological response. Given this preference, FDEP has continued efforts, including initiating studies in 2008, to develop response-based criteria for adoption in their standards. FDEP's ongoing and planned studies in support of NNC development (United States Environmental Protection Agency 2010j). These are listed below and briefly described afterwards.

1) Nutrient Gradient Study

2) Development and Initial Application of the Nutrient Benchmark Distributional Approach.

3) Stressor Identification Study

4) Development of the Stream Periphyton Index

5) Downstream Effects of Nutrients in Selected Florida Rivers/Estuaries (Nutrient Longitudinal Study

6) Nitrate-Nitrite Analysis in Streams/Spring

7) Lake Algal and Macrophyte Response

8) Recreation-Based Nutrient Criteria

9) Application of Benchmark Distributional Approach to Lakes

10) Planned Approach for Estuaries

11) Microcystin Round Robin

Nutrient Criteria Development Plan 2009 – 1) Description of Nutrient Gradient Study

As stated earlier, FDEP's preference was to use biological dose-response relationships whenever possible to develop NNC. EPA in their guidance documents suggests that an observed dose-response relationship should be described by a model (e.g., trophic state classification, regional predictive model, biocriteria), which in turn would link nutrient concentrations to the relative risk of environmental harm (United States Environmental Protection Agency 2010j). FDEP stated that they would continue to work on the development of numeric nutrient thresholds using the benchmark distributional approach as a backup. However, FDEP was actively investigating approaches that more directly link nutrient levels to biological responses.

FDEP had recently designed a study to evaluate the association of adverse biological responses with nutrient concentrations. This study was called the "*Nutrient Gradient*

Study", was initiated in the spring of 2008. The study description which is taken from (Florida Department of Environmental Protection 2009c) is summarized and described verbatim from that report.

The study was specifically designed to provide information necessary to develop nitrogen and phosphorus criteria for streams, although FDEP planned to consider and evaluate chlorophyll and transparency measurements. The study objectives were as follows:

• Collect physical, chemical, and biological data on Florida streams to establish the relationship between nutrient levels and adverse biological responses; and

• Analyze the resulting dataset as one line of evidence in FDEP's effort to establish numeric nutrient criteria.

The study design was based on the premise that changes in the natural nutrient regime can cause shifts in the structure of the biological communities present and ultimately the function of the system. To derive appropriately protective nutrient criteria, this approach related nutrients to ecological health and biological responses. Other factors that can also affect biological health (e.g., cover, flow modification) were measured as co-variables to help determine their relative influence on the biological responses under the observed nutrient regimes. FDEP had their District staff monitor sites throughout the state during spring/summer 2008, and again in the fall/winter of 2008–09. Sampling was to be completed by January 2009. At time of the publication of the 2009 Nutrient Criteria Development Plan, laboratory analysis was still underway and no reports had been published. The following measurements were performed at each site:

• Hydrologic Modification Scoring;
• SCI (Stream Condition Index);
• Habitat Assessment (HA);
• Percent Canopy Cover;
• Rapid Periphyton Survey;
• Qualitative Periphyton Collection;
• Linear Vegetation Survey;
• Meter Readings (dissolved oxygen [DO], specific conductivity, pH, and temperature); and
• Water Chemistry (total Kjeldahl nitrogen [TKN], TP, ammonia, nitrate-nitrite, turbidity, chlorophyll a, color, total organic carbon [TOC], total suspended solids [TSS]).

A majority of the sites were selected from a previous statewide intensive "*Dissolved Oxygen Study*" conducted in 2005 and 2006, and included sites with a variety of Land Development Intensity (LDI) Index scores and nutrient regimes. Additional sites were located near National Pollutant Discharge Elimination System (NPDES) point sources with known nutrient-enrichment issues. Sites were geographically diverse in an attempt to represent as much of the state as possible.

The following two types of sites were sampled:

• Sites located upstream and downstream from high-nutrient point source discharges; and

• Sites located along a nutrient gradient, with low, medium, and high nutrient regimes.

Since the objective of their study was to emphasize the effects of nutrients on biota. FDEP made attempts to minimize or account for confounding factors, such as poor habitat and highly modified hydrologic regime. This especially applied to the sites not affected by point sources. In an effort to reduce the effects of confounding variables, only sites with minimal to moderate levels of habitat or hydrologic modification, as determined by Florida's HA and Hydrologic Modification Scoring, were selected. For the sites upstream and downstream from point sources, the most important factor was to ensure similar habitat and hydrology at the paired sites to emphasize the nutrient influences from the discharge. Habitat suitability (substrate diversity and abundance), flow, and length of inundation were taken into account when deciding appropriate sites to sample. Habitat Assessment (HA) ranking, Hydrologic Modification Score, and Percent Canopy Cover were obtained at all sites to adequately characterize these important variables. FDEP staff also assessed the existing and antecedent flow conditions of each site to insure conditions were appropriate for the purpose of the study.

The FDEP anticipated that this study, together with their existing extensive statewide biological database (SBIO), would provide information to establish causal links between water column nutrient levels and adverse biological responses in plant, algal, and macroinvertebrate communities. Nutrient concentrations associated with "exceptional" or "healthy" biological index scores (SCI, LVI, or SPI) would be statistically evaluated against the nutrient concentrations of sites with "impaired" index scores to determine potential dose-response relationships, including the exploration of responses in individual metrics or attributes. If such cause-effect relationships are discerned, the resulting criteria would include an appropriate margin of safety to ensure the protection of healthy, well balanced aquatic communities. FDEP anticipated that the study would help elucidate the effects of other variables (e.g., habitat, flow, canopy cover) on the expression of nutrients. A concurrently planned study on stressor identification and the development of a statewide stressor identification model will complement this proposed work.

FDEP anticipated that the statistical analysis of the resulting data from the Nutrient Gradient Study would be sufficiently rigorous to detect biological responses to nutrient enrichment. The ability to statistically determine patterns in this data will be dependent on sample size, inherent and lab/method induced variability, the level of significance used, and the desired statistical power (i.e. probability to detect a real difference between groups of a certain magnitude when it is true) to detect differences among groups. FDEP will use the most robust statistical methods appropriate to the data characteristics generated from the study. The agency also intended to investigate relationships between nutrient concentrations and biological response with several statistical tools, including the following:

• Ordinary least squares regression;

• Quantile regression;
• Conditional probability analysis; and

• Change point analysis.

FDEP planned to initially investigate biological responses to nutrient enrichment as univariate functions of either phosphorus or nitrogen, using the statistical tools listed above. However, biological responses to nutrients are complex and influenced by numerous other ecological, hydrological, and biogeochemical factors. FDEP therefore felt that simple univariate models may not be sufficiently rigorous to support numeric nutrient criteria development. Consequently, FDEP also planned to investigate the relationships between stressor (nutrients) and response (e.g. chlorophyll-*a*) along with potential modifier or confounding variables (e.g. flow, shading) using more complex multivariate techniques that allow the analyst to evaluate the influence of factors other than nutrients on biological response. FDEP planned to investigate these relationship using statistical techniques such as the following:

• Multiple regression;

• Classification and ordination;

• Cluster analysis;

• Principle components analysis; and,

• Canonical correspondence analysis.

FDEP felt that once completed this study would fill significant informational gaps in the understanding of stream flora and fauna responses to excess nutrient enrichment. Thus, it will help the state continue to make progress towards the timely adoption of numeric nutrient criteria within the deadlines planned. Specifically, the state anticipated completing sample collection by January 2009 and data analysis and synthesis within an additional four to five months thereafter. FDEP anticipates deriving numeric phosphorus and nitrogen criteria for Florida streams by December 2009, assuming the successful completion of this project. Note, FDEP also stated that if the results from the study are of insufficient statistical rigor to promulgate scientifically defensible criteria, additional sampling and analysis may be needed, resulting in a time extension. FDEP planned to present the results derived from the study to the Nutrient Criteria TAC.

Nutrient Criteria Development Plan 2009 – 2) Description of Development and Initial Application of the Nutrient Benchmark Distributional Approach Study

The FDEP and TAC had discussed the benchmark distributional approach over the course of numerous meetings. The TAC indicated its support for FDEP's proposed application of the overall approach (which includes the option of requiring confirmation of biological impairment and use of the resultant thresholds instead of development of statewide standards and recommended that FDEP needed to provide sufficient documentation substantiating low human disturbance levels and biological health (i.e., supporting the designated use) of the selected benchmark sites. Based on the direction provided during TAC meetings starting in 2006, FDEP program staff conducted a pilot study to develop nutrient criteria for streams in the peninsula bioregion of Florida using the "*Benchmark Distributional Approach"*. To accomplish this FDEP developed and utilized an extensive multi-step evaluation of potential benchmark sites to ensure that the sites used in the derivation of nutrient thresholds for the peninsula bioregion truly represented low levels of human disturbance. This multi-step evaluation included the following screening criteria:

(1) Screening for sites with an LDI (land development intensity) score less than or equal to 2.0;
(2) Screening to exclude waters on the state's 303(d) list of impaired waters;
(3) Verifying surrounding land use using high-resolution aerial photographs;
(4) Obtaining input from district biologists knowledgeable about the area;
(5) Conducting a statistical outlier analysis; and
(6) Carrying out an extensive field evaluation of approximately 10% of the remaining waterbodies (identified by Waterbody Identification number, or WBID2) containing benchmark sites.

The LDI is an estimate of the intensity of human land uses based on nonrenewable energy flow. The application of the LDI is based on the ecological principle that the intensity of human-dominated land uses in a landscape affects the ecological processes of natural communities. The LDI was calculated as the area-weighted value of the land uses within an area of influence. Using the land use coefficients and the percent area occupied by each land use as determined by geographic information system (GIS) land use coverage's developed from high-resolution aerial photographs, the LDI is calculated as follows:

$$LDI_{Total} = \Sigma\ (LDC_i * \%LU_i)$$

where, LDI_{Total} = LDI for the area of influence; $\%LU_i$ = percent of total area of influence in land use i; and LDC_i = LDI coefficient for land use i.

The LDI was specifically designed as a measure of human disturbance. LDI values less than or equal to 2.0 within the 100 m buffer area indicate very minimal levels of human disturbance. Numerous studies and evaluation have demonstrated, across multiple waterbody types and taxonomic groups, that the LDI is an accurate predictor of biological health—i.e., healthy, well-balanced biological systems are much more likely to occur at sites with low LDIs (≤ 2.0) than at higher disturbance levels (Fore 2004) cited (United States Environmental Protection Agency 2010j).

Based on their study the FDEP identified an initial set of candidate benchmark sites in the peninsula bioregion, with available nutrient data of known quality and LDI values less than or equal to 2.0. This set consisted of 379 sites distributed among 155 WBIDs. These candidate benchmark sites will be exposed to further review to demonstrate that they do in fact reflect low levels of human disturbance and are representative of the region.

Nutrient Criteria Development Plan 2009 – 3) Description of Stressor Identification Study

The FDEP like many states has historically focused on water quality as the predominant means for assessing water body integrity (i.e., impairment status). FDEP has developed biological assessment tools (e.g., Florida's SCI, BioReconnaissance [BioRecon], and LVI) and habitat assessment procedures as additional means of identifying impairment, especially related to nonpoint source issues. Although bioassessments are useful in determining biological impairment, they do not identify the cause of the impairment, which is required under the Florida regulations before listing a waterbody as impaired. Currently, a "Best Professional Judgment" approach is used to identify the pollutant of concern. The development of a statistically based model(s) for the identification of impairment causes would improve the effectiveness and defensibility of FDEP regulatory actions. Additionally, identifying the primary causative factors that negatively affect biological resources and indicators would allow FDEP to focus limited resources on mitigating the responsible stressor(s) including nutrients. Therefore, a legally defensible procedure to determine the causative factor(s) is needed. The EPA has developed procedures for stressor identification (e.g., Causal Analysis/Diagnosis Decision Information System [CADDIS]) that are useful only for selected sites after fairly substantial data collection efforts (Frithsen 2011). FDEP plans to build on these stressor identification concepts to develop a more robust generalized statistical model or multiple models (Statewide Stressor Identification Model[s]) that incorporates the major nonpoint source stressors widespread in Florida:

- Hydrologic modification;
- Habitat alteration; and,
- Water quality issues (e.g., nutrients, sediments, and biochemical oxygen demand BOD).

The development of a calibrated statewide model would prevent Florida from having to perform expensive site-specific stressor identification studies at all biologically impaired sites. It is anticipated that the Statewide Stressor Identification Model(s) will allow FDEP to streamline and focus mitigation and restoration efforts by identifying the most pervasive human nonpoint stressors in Florida. The overall approach for this project will involve the assessment and collection of a complex suite of data in order to develop the Statewide Stressor Identification Model(s). FDEP plans to initially to use their currently available assessment tools to measure the algal (periphyton and phytoplankton), invertebrate, and macrophyte community health of streams, and EPA's list of common candidate causes, which include the following:

• Nutrient inputs,
• Flow alterations,
• Sediments,
• Metals,
• DO,
• Temperature,
• Ionic strength, and
• Habitat assessment.

FDEP plans to use multivariate statistical methods to investigate the relationships between all available physical, chemical, and biological data, evaluating the relative influence of each variable on the system. FDEP also planned to develop and pose a series of hypotheses (conceptual models) and then statistically examine the relationship between stressor(s) and responses. An example of a research hypothesis related to nutrients is: *High nutrients, coupled with sunlight and sluggish flow, will lead to excessive periphyton in habitats and reductions in periphyton community and invertebrate health*.

The refined model will be tested at a number of sites to verify the model(s). The tasks associated with this project are anticipated to include but are not necessarily limited to the following:

• Analyze current data;

• Evaluate and modify Stressor Indices as necessary;

• Identify possible conceptual model(s;

• Collect additional data;

• Develop Stressor Identification Model; and

• Validate Model(s): Validate model(s) with an independent dataset and verify by comparing the model(s) output with the output of deterministic stressor identification approaches (e.g., EPA CADDIS).

Once this general model is developed, it can be used to better predict the relationship between nutrient levels and stream health, after adjusting for the other factors influencing aquatic life.

Nutrient Criteria Development Plan 2009 – 4) Description of Development of the Stream Periphyton Index Study

FDEP recently developed and validated a multimetric index based on periphyton samples from Florida streams (the SPI), but the index has yet to be calibrated. Several steps need to be completed before this tool can be used including:

(1) Evaluate algal distributional patterns
(2) Develop gradients of human disturbance
(3) Identify and calculate candidate metrics for stream algae
(4) Test taxa against the Human Disturbance Gradient
(5) Test metric response to human disturbance
(6) Develop multimetric index
(7) Validate results
(8) Conduct power analysis
(9) Calibrate the SPI via the Biological Condition Gradient approach

FDEP anticipated that the resulting SPI will be an extremely useful response variable for determining impairment associated with nutrient enrichment in streams, and it may also be adopted as Biocriteria.

Nutrient Criteria Development Plan 2009 – 5) Description Downstream Effects of Nutrients in Selected Florida Rivers/Estuaries (Nutrient Longitudinal Study)

FDEP initiated a *Nutrient Longitudinal Study* during the summer of 2008 designed to evaluate downstream biological responses to naturally high nutrient levels. Biological responses to excess nutrients can be separated in space and time from actual enrichment sources—i.e., an adverse response to nutrients may occur well downstream from the actual enrichment. FDEP's hypothesis is that within systems with low levels of human disturbance and intact ecological processes, naturally high levels of nutrients can be assimilated into biota and sediments without causing adverse biological responses, including downstream estuaries. The goal of this study was to demonstrate that nutrient concentrations representative of the upper portion of the benchmark site distribution actually support the designated use of downstream reaches.

The objectives of the study Nutrient Longitudinal Study were as follows:

(1) Collect physical, chemical, and biological data throughout the length of selected Florida river/estuary systems to establish the relationship between nutrient levels and adverse biological responses, including the most sensitive (generally downstream) reaches; and

(2) Analyze the resulting dataset as one line of evidence in FDEP's effort to establish numeric nutrient criteria, particularly relating to the protection of downstream waters.

The study focused on relating the effects of nutrients on various biological systems, from upstream to downstream, including the most sensitive areas, which typically are slowly flowing lower reaches or estuaries. Two systems were studied by FDEP including the Waccasassa River and Estuary and the Steinhatchee River and Estuary. FDEP conducted semiannual sampling for aquatic primary producers and water quality parameters. Sampling occurred in summer 2008 and January 2009. The following analyses were performed at sites where appropriate (dependant on salinity, conductivity etc.):

- Water Chemistry (TKN, TP, ammonia, nitrate-nitrite, turbidity, chlorophyll a, color, TOC, TSS) (monthly);
- Meter Readings (DO, specific conductivity, pH, and temperature) (monthly);
- Phytoplankton Community Composition (monthly);
- Microcystin Analyses (if warranted from results of algal ID) (to be determined);
- Stream Condition Index (SCI) (quarterly);
- Habitat Assessment (HA) (quarterly);
- Percent Canopy Cover (quarterly);
- Rapid Periphyton Survey (RPS) (quarterly);
- Qualitative Periphyton Collection (quarterly);
- Linear Vegetation Survey (quarterly);
- Sediment Nutrients (semiannually);
- Sediment Nutrient Flux Experiments (semiannually); and
- Hydrologic Modification Scoring (once).

A full description of the methodology for the various indices are found in the bibliography and original FDEP methods guidance documents cited in the 2009 Plan (Florida Department of Environmental Protection 2009c). Both systems were selected to represent conditions of relatively low human disturbance, especially with respect to nutrient enrichment. The range of nutrient concentrations measured at the Waccasassa River are generally lower than the peninsular benchmark site distribution average, while the Steinhatchee River levels range from near the average to the upper end (90th percentile) of the benchmark site nutrient distribution average.

Since the objective of this study was to emphasize the effects of nutrients on biota, attempts were made to minimize or account for confounding factors during site selection. Habitat suitability (substrate diversity and abundance), flow, and length of inundation were examined when deciding appropriate sites to sample. A Habitat Assessment (HA), Hydrologic Modification Score, and Percent Canopy Cover determination was performed at all sites to adequately characterize these important confounding variables. FDEP technical staff also assessed the existing and antecedent flow conditions of each site to determine that they were appropriate for the purpose of the study. For example, extremely low flows occurred at many sites during the first field sampling period.

FDEP hoped that the results of this study will provide evidence that criteria developed using the *benchmark distributional approach* are protective of downstream waters. The knowledge that biota in downstream waters are sufficiently protected would help in establishing numeric nutrient thresholds or NNC using the benchmark distributional approach. FDEP anticipated that the study would also help to differentiate the influence of other variables (e.g., habitat, flow, canopy cover) on the effects of nutrients. FDEP planned to complete sample collection by January 2009 and expected that it would take six to eight months afterwards to analyze/synthesize the results.

Nutrient Criteria Development Plan 2009 – 6) Description of Nitrate-Nitrite Analysis in Streams/Spring Runs Study

The freshwater springs of Florida springs are highly valued for their aesthetic and recreational qualities including their clarity and cool temperatures. The FDEP has documented increased nitrate-nitrite concentrations in many springs due to increased human populations. Anecdotal evidence assembled by FDEP suggested that this has contributed to the currently observed nuisance plant and macroalgal accumulations in many springs. As a result FDEP evaluated nitrate trends at 22 Florida springs and determined that the mean nitrate-nitrite concentration in the 1960s was about 0.2 mg/L, while the average is currently around 1.0 mg/L. Multiple lines of evidence indicate that reducing nitrate-nitrite concentrations in springs should substantially reduce macroalgal growth rates, which is expected to result in the reduced frequency, intensity and duration of nuisance blooms (Stevenson et al. 2007) *cited in* (Florida Department of Environmental Protection 2009c). Based on the evidence accumulated FDEP concluded that both nitrogen and phosphorus reductions in Florida springs should limit macroalgae species growth and accumulations. Reductions in nutrients to appropriate target concentrations (e.g., nutrient criteria) should lead a reduction of algal growth.

FDEP pointed out that in almost all springs, nitrogen (i.e., nitrate-nitrite) reductions may be the only practical management strategy because natural phosphorus concentrations are generally higher than the levels necessary to constrain algal growth. Results from experimental and in situ studies were used to establish the nitrate-nitrite concentration required to prevent algal community imbalances (i.e., to restrict the growth and accumulations of nuisance macroalgae while preserving native periphyton community structure). The most accurate and conservative experimental results, those from micro-centrifuge tube experiments, suggest that nitrate concentrations less than 0.230 mg/L are needed to slow the growth of *Lyngbya wollei*. Similarly, to reduce the growth of *Vaucheria* under laboratory conditions, nitrate concentrations below approximately 0.261 mg/L would be required(Stevenson et al. 2007) *cited in* (Florida Department of Environmental Protection 2009c). The results of periphyton field surveys conducted at a large number of spring systems indicated that nitrate concentrations would need to be reduced below the observed 0.454 mg/L nitrate-nitrite threshold to reduce the nuisance abundance and cover of *Vaucheria* sp. in Florida springs (Pinowska et al. 2007) *cited in* (Florida Department of Environmental Protection 2009c). FDEP concluded that since the 0.454 mg/L threshold represents the lower range of nitrate concentrations for study sites with excessive algal growth and cover, an appropriate safety margin would need to be applied to turn the threshold into a protective criterion. In addition, FDEP examined approximately 10 years of data obtained from periphytometers deployed in the spring-dominated Suwannee, Santa Fe, and Withlacoochee (north) Rivers. They found that a community "imbalance threshold" (i.e. significant biomass increases and alterations in taxonomic community structure) occurred at approximately 0.441 mg/L of nitrate-nitrite. A margin of safety, derived from an analysis of the variability in the nitrate-nitrite concentrations in this system, resulted in FDEP recommending a final 0.35 mg/L nitrate-nitrite criterion for springs during the ongoing triennial review which started in July 2008.

Nutrient Criteria Development Plan 2009 – 7) Description of Lake Algal and Macrophyte Response Study

FDEP intends to evaluate both algal and macrophyte response thresholds in Florida lakes. Staff conducted a preliminary conditional probability analyses between the lake vegetation index (LVI) and TP and TN concentrations and presented this to the TAC in 2008. The analysis with phosphorus showed that the probability of occurrence of an LVI score less than 37 (the impairment threshold) increased up to a lake TP concentration of approximately 50 μg/L, at which point the probability of impairment leveled off. Similarly, the probability of occurrence of an LVI less than 37 increased with increasing TN concentrations. These preliminary analyses demonstrate a likely relationship between in-lake nutrients and macrophyte community health. Because the paired LVI and nutrient dataset is currently limited, particularly in lakes with TP concentrations above 45 μg/L, FDEP conducted additional surveys and calculated LVIs with paired nutrient samples during the summer and fall of 2008. A subset of lakes previously sampled as part of the state's randomized status and trends monitoring was targeted for LVI and water quality sample collection. Although samples were apportioned across the entire range of nutrient concentrations, priority was given to lakes with TP concentrations between 45 and 200 μg/L in an attempt to reduce the uncertainty (i.e., confidence interval width) by increasing sample size in this range of nutrient concentrations. FDEP had not yet analyzed or presented this data, and was not included in the 2009 Nutrient Criteria Development Plan.

FDEP also intends to evaluate algal responses to nutrients. Initially, the evaluation will be based on relationships between nutrients and chlorophyll-*a* concentration. In addition the evaluation will analyze potential relationships between nutrients and metrics contained in the LVI. These analyses will include the evaluation of regression models as well as conditional probability using ecologically significant thresholds. Conditional probability analysis may include a joint analysis of the probability of exceeding either chlorophyll-*a* or LVI impairment targets. FDEP reasoned that this needs to be done, because any given lake may be either algal or macrophyte dominated. FDEP also mentioned that it may conduct community-based analyses may be done pending the development of a calibrated lake phytoplankton index.

Nutrient Criteria Development Plan 2009 –8) Description of Recreation-Based Criteria Study

The University of Florida Lake Watch Program conducted a study that correlated Florida lake residents' aesthetic perceptions with simultaneously measured nutrient and chlorophyll-*a* data. Based on the study results, residents perceived that lake water was less conducive to swimming and aesthetic enjoyment when chlorophyll-*a* concentrations ranged from approximately 17 to 22 μg/L. FDEP may potentially use such information as a line of evidence when establishing appropriate lake chlorophyll-*a* thresholds. The FDEP has not however pursued any additional studies on this topic.

Nutrient Criteria Development Plan 2009 – 9) Description of Application of Benchmark Distributional Approach to Lakes Study

The majority of FDEP's nutrient criteria efforts up to 2009 had focused on streams. However, FDEP stated that sufficient data and information also existed within the state's database to apply the benchmark distributional approach to lakes. FDEP stated that with this data they have the option of applying this approach to lakes using a process similar to that developed for streams. The stated that the approach would include the same multi-step validation process incorporating land use evaluations (e.g., LDI, recent aerial photographs, and field reconnaissance) coupled with confirmations of healthy biological communities using the LVI. However, at that time because of the successful calibration of the LVI, FDEP felt they were close to developing response-based nutrient criteria for lakes. Therefore, FDEP stated that the benchmark distributional approach will only be pursued as a secondary line of evidence and will be used only to derive NNC if the algal and macrophyte response and recreational-based assessments failed to identify significant relationships with nutrient enrichment.

Nutrient Criteria Development Plan 2009 – 10) Approach to Development of NNC for Estuaries

In the 2009 Plan FDEP described how the complexity of Florida estuaries makes it difficult to develop uniform NNC (Florida Department of Environmental Protection 2009c). They characterized estuaries as dynamic systems, with widely varying water residence times, highly fluctuating salinities, and varying transparency/turbidity levels dominated by riverine derived color and sediment inputs. Due to these factors FDEP concluded that a direct comparison between any two specific estuaries is difficult. Therefore the "EPA reference waters" approach did not appear to be a viable option for estuaries and the more likely approach would be the "dose-response" or stressor-response approach.

FDEP's goals for development of estuarine NNC were to focus on methods that would characterize empirical relationships between nitrogen and phosphorus loads and response variables (e.g. chlorophyll-*a*) that represents the quality of water that supports particular uses. FDEP intended to utilize its existing TAC as well as coordinate with the Florida Oceans and Coastal Council, the Gulf of Mexico Alliance (GOMA), and EPA to help develop nutrient criteria for estuaries and coastal waters. FDEP was considering the need to augment their TAC with additional members possessing expertise in estuarine and coastal systems. FDEP initiated the development of estuarine nutrient criteria at the beginning in 2008 and convened their first estuarine nutrient criteria development workshop (http://www.dep.state.fl.us/water/wqssp/nutrients/tac_archive.htm). The objective of this meeting was to discuss the present state of knowledge on estuarine and marine nutrient dynamics, research needs and availability of monitoring data for Florida's coastal waters, as well as potential numeric criteria derivation methods. FDEP invited scientists who had performed research on selected Florida estuaries and asked that they do the following:

• Describe the system, including the hydrodynamics and sources and fates of nutrients;

• Describe the type, quality, community structure, areal extent, etc., of valued ecological attributes (biological communities), emphasizing those shown to respond to anthropogenic nutrient enrichment;

• Provide scientific evidence quantifying the relationship between anthropogenic nutrient inputs and adverse effects on biological communities; and

• Propose numeric targets needed for system protection or restoration, as well as demonstrate the bases for the nutrient targets.

Information from ten estuary studies was presented at this workshop. According to FDEP about half of the presenters focused on the relationship between nutrient loading (mostly nitrogen) causing excess algal growth (as measured by chlorophyll-*a* production), which resulted in decreased transparency and, consequently, light limitation/stress to SAV.

In some estuaries, this complex relationship was established, while in others, the investigators documented relationships between nutrient loading and SAV directly with little evidence for effects on chlorophyll-*a* levels. However, in some cases no relationship between nutrients and biological attributes could be quantified. In one instance, inorganic nutrients were elevated enough to foster harmful algal blooms (HABs) and concomitant declines in animal food webs, even though chlorophyll-*a* levels were low. Based on the workshop findings FDEP concluded that it appears that Florida estuaries generally fell into one of three groups, as follows:

(1) Estuaries where nutrient dose-response relationships are sufficiently understood to warrant proposing criteria (e.g., Tampa Bay, Perdido Bay, North Indian River Lagoon (IRL), Lower St. Johns River, and potentially Sarasota Bay). In general these systems have historically demonstrated nutrient problems and many were recovering due to management and restoration efforts. FDEP noted that in many of these systems, the strongest relationship between nutrients and SAV response was based on <u>loadings, not concentrations</u>. Since these waterbodies had experienced a wide range of conditions, ranging from a prior eutrophic condition to a non-eutrophic recovered status, time series data from these estuaries would be valuable in helping model dose-response relationships.

(2) Systems where factors other than nutrients appear to be more important in defining biological community structure, making it difficult to propose scientifically supported nutrient criteria. This included the Caloosahatchee, South Indian River Lagoon (IRL),

Pensacola Bay, parts of Florida Bay, and Charlotte Harbor systems. For these estuaries, an alternative approach would be needed. For example peer reviewed linked hydrodynamic water quality models may be useful in defining a particular nutrient regime that should protect the designated uses.

(3) Estuarine systems that currently appeared to be functioning well and non-eutrophic, and consequently where a goal of maintaining current biological community structure and water quality may be more appropriate. In this instance it may be more appropriate to maintain nutrient levels at levels similar to existing levels. Example estuaries included the Apalachicola, Apalachee, St. Andrews, Nassau/Amelia/St. Marys, Tolomato, Guana, Matanzas, and Ten Thousand Islands systems.

FDEP also expressed interest in the approach used by the St. Johns River Water Management District (SJRWMD) for the North IRL. FDEP described this approach which included the following findings:

• SAV was related to a watershed loading via a regression model;

• Transparency depth targets to protect SAV photosynthesis in the IRL ranged from 1.2 to 1.8 m; and

• Turbidity, chlorophyll-*a*, and color targets were based on preventing a transparency reduction of greater than 10%.

Using a computer model, SJRWD estimated total allowable nitrogen load limits for each segment. They estimated that the loading needed to be below 20 kilograms of nitrogen per hectare per year (kg N/ha/yr) (based on water area) to protect SAV (Valiela and Cole 2002) *cited in* (Florida Department of Environmental Protection 2009c) . A critical component of the modeling effort was water residence time.

FDEP pointed out that the EPA National Nutrient Criteria Technical Guidance Manual for estuarine and coastal marine waters recommended that appropriate response variables include chlorophyll-*a*, water clarity and other variables recognized in the scientific literature as responsive to nutrient inputs, including dissolved oxygen, seagrass or other biological components of the estuarine ecosystem (United States Environmental Protection Agency 2001j).

In the 2009 Nutrient Criteria Development Plan FDEP expressed their desire to target nutrient criteria development to protect seagrass habitats, a valued estuarine resource throughout the State that supports particular uses. The scientific literature recognizes that the effects of nutrients on seagrass are well-known, but also that these effects are largely indirect. Elevated nutrient loads are known to enhance both phytoplankton production and growth of epiphytic algae on seagrass leaves. Together with colored dissolved organic matter and suspended particulates, these factors reduce water clarity and light availability for seagrass growth.

In 2009 FDEP was working with EPA to gather the information necessary to develop a Florida-specific estuarine nutrient cause/effect relationships, potentially similar to the (Valiela and Cole 2002) model, but tested against, and potentially adapted to Florida estuaries. FDEP described the following actions that would be undertaken by EPA's Gulf Ecology Division (GED) and/or EPA contractors to meet critical nutrient criteria development needs for Florida estuaries. These included:

• Estuary Delineation. EPA and FDEP were in the process of establishing a common approach to delineating the boundaries of estuaries and their watersheds in the State, and identifying the resulting estuaries for which nutrient criteria could be developed.

• Nutrient Load Estimation. EPA and FDEP, with assistance from USGS, planned to develop a common approach for estimating monthly and annual nitrogen and phosphorus loads to each Florida estuary for a suitable period of record, including loads originating from point and non-point sources, atmospheric deposition, and, potentially, from ground water and oceanic sources. In addition to loads, estimates of freshwater discharge and associated source water nutrient concentrations will be estimated.

• Water Quality Database. EPA and FDEP will evaluate the suitability and representativeness of water quality variables within existing FDEP databases. Priority variables include: salinity, temperature, nutrients (TN, TP, NO_x, etc), dissolved organic matter (DOC), total suspended solids (TSS), Secchi depth, color, and chlorophyll-*a*. Available data on historical seagrass coverage across Florida will also be compiled.

• Empirical Analysis. EPA and FDEP will analyze and evaluate empirical relationships between causal and response variables for each estuary using appropriate computational/statistical methods. The evaluation will include analysis of cause-effect relationships for all Florida estuaries combined, or some subset of estuaries based upon a defined criteria or categorization approach. For example, some Florida estuaries are naturally turbid due to a natural background of colored dissolved organic matter, whereas others lack significant natural turbidity. Moreover, some Florida estuaries naturally lack appreciable seagrass coverage. Efforts to identify and evaluate appropriate response variables that represent desired water quality and support designated uses will ensure that the proposed criteria are protective of all estuarine waters.

FDEP also plans to adopt regional response variable nutrient criteria based on site-specific thresholds developed for many of the larger coastal systems in the state (e.g., Tampa Bay, IRL, Caloosahatchee, St. Lucie) and subsequently deriving causal variable criteria based on statistical relationships between these response variables and the causal variables. However, it should be noted that in many cases such relationships may not exist, as was the case in Sarasota Bay. Under this scenario, FDEP may only propose response variable–based criteria until the relationships are determined on a site-specific basis. As a result of the state's 1987 Surface Water Improvement and Management (SWIM) Act and the National Estuary Program (NEP), efforts to develop nutrient-related thresholds for many of the state's largest estuaries and coastal waters are well under way and are briefly described below.

Tampa Bay

Tampa Bay NEP has established chlorophyll a targets for the different segments of the bay based on a goal of restoring seagrass beds to 38,000 acres within the bay. The bay now supports 28,299 acres of seagrass. The Tampa Bay chlorophyll a targets were established based on the effects of chlorophyll on light attenuation and ultimately on the depth of seagrass occurrence. TN loadings were in turn related to chlorophyll a concentrations, using a three-month lag time during the analysis. Ambient nitrogen concentration was not shown to directly affect light attenuation or seagrass condition.

IRL and Banana River

The IRL/Banana River Lagoon PLRG study set maximum loading targets for TN, TP, and TSS as a function of seagrass depth limits in the lagoon. The PLRG study found strong, negative correlations between watershed loadings of nutrients and TSS and the depth limit of seagrass. EPA proposed a TMDL in April 2007 based on the IRL/Banana River Lagoon PLRG, and FDEP proposed a state TMDL for the main stem of the Indian River and Banana River in fall 2008.

Caloosahatchee and St. Lucie Estuaries

The Northern Everglades and Estuaries Protection Program expanded the Lake Okeechobee Protection Plan (LOPP) requirements to the Caloosahatchee and St. Lucie River watersheds. This legislation created the Caloosahatchee and St. Lucie River Watershed Protection Program, which includes the development of Watershed Protection Plans for both rivers. Each Watershed Protection Plan must include a watershed construction project, a watershed pollutant control program, and a watershed research and water quality monitoring program. Under this legislation, the South Florida Water Management District (SFWMD), in collaboration with coordinating agencies, was directed to develop River Watershed Protection Plans for the Caloosahatchee and St. Lucie watersheds by January 1, 2009. A primary objective of the program to address the Caloosahatchee and St. Lucie Estuaries is to develop “pollutant load reductions based upon adopted total maximum daily loads established in accordance with s. 403.067” (Senate Bill 392, 2007). After the TMDLs are completed, Basin Management Action Plans (BMAPs) will be developed. The TMDL for the St. Lucie estuary was proposed for final agency action on December 31, 2008. A notice of change to correct a minor typographical error in the rule will be published in the Friday, January 23, 2009 issue of the Florida Administrative Weekly. As of January 14, 2009, a draft TMDL for tidal portions of the Caloosahatchee River and Estuary is near completion, and it is anticipated that it will be completed, reviewed, and made publicly available by early February 2009. In addition to the site-specific efforts previously mentioned, FDEP is actively involved in GOMA. It is working with the other Gulf states to develop broader-based strategies for developing nutrient criteria and control programs within the shared waters of the Gulf of Mexico. FDEP had assigned two staff members to directly participate in GOMA. Nutrient criteria–related activities are being coordinated between these staff and FDEP’s

Water Quality Standards Program. An example of these ongoing activities includes a comprehensive session on water quality sampling and quality assurance (QA) that was provided to GOMA staff by the Standards and Assessment Section during the summer of 2008. FDEP recognized that inland water criteria must protect downstream uses, and since estuarine condition is affected by the nutrient loads delivered from upstream, there will be effort made to synchronize these two criteria development efforts.

Nutrient Criteria Development Plan 2009 – 11) Description of Microcystin Round Robin Study

In an effort to initiate the development of a useful response threshold to harmful algal blooms (HABs), FDEP hosted a series of quality assurance (QA) “round robin” lab studies to evaluate the precision and accuracy of laboratory analytical results for microcystins. However, FDEP concluded that because of the moderately large interlaboratory variability associated with these analytical results, further work to achieve consistency between labs was needed to further develop reliable indicators of HABs.

Draft Technical Support Document (TSD): Development of Numeric Nutrient Criteria for Florida Lakes and Streams - Overview

In June 2009 prior to the EPA beginning the federal promulgation effort for Florida freshwater streams and lakes, the FDEP published a draft *Technical Support Document for Development of Numeric Nutrient Criteria for Florida Lakes and Streams (Florida Department of Environmental Protection 2009a)*. This document compiled and synthesized many of the tools and methods that FDEP and their contractors had developed with the guidance of the TAC. The document described multiple approaches for developing NNC with examples of each and recommendations. IN some cases the method had already yielded a proposed NNC (see clear water streams). However, the draft document which was sent out for review was never finalized, in part due to the initiation of the EPA promulgation process for freshwater systems. The approaches and methods described and discussed in the technical support document included:

1) Setting aquatic life use support thresholds for the stream condition index and lake vegetation index with a discussion of the stream diatom index,

2) Derivation of the numeric criteria for nitrate-nitrite in Florida clear streams,

3) Regionalization of Florida’s numeric nutrient criteria for streams,

4) Development of Stressor-response relationships for freshwater streams

5) Florida’s nutrient benchmark site distributional approach for rivers and streams,

6) Nutrient longitudinal study: downstream effects of nutrients in selected Florida Rivers/Estuaries,

7) Basis for the proposed lake chlorophyll-*a* thresholds in Florida's numeric nutrient criteria development,

8) Investigation of relationships between Cyanobacteria abundance and chlorophyll-*a*, and

9) Stressor response analysis of Florida Lakes.

These methods were previously described above under the discussion of the 2009 *Nutrient Criteria Development Plan* which provided a detailed description of each method. However, several methods and approaches had been updated at the time of the production of the draft TSD. Therefore we have provided additional information on the proposed methodologies described in the document.

Draft TSD: Development of Numeric Nutrient Criteria for Florida Lakes and Streams – 1st Method

In the first method FDEP described their attempt to evaluate the ability of two multimetric biological indices to detect man made disturbance in a waterbody. They accomplished this by using two methods including regressing expert opinion derived biological condition gradient scores (BCG) against several indices of waterbody quality including two multimetric indices, the lake vegetation index and the stream condition index (SCI), and utilizing a statistical characterization of minimally impacted sites. FDEP concluded that the exceptional and impaired thresholds for the SCI and LVI were 40, 61 and 46, 78 respectively. The FDEP also examined the sensitivity of the stream diatom index (SDI) in detecting disturbance. The SDI was not sensitive to anthropogenic disturbance but rather more sensitive to other stream water quality variables.

Draft TSD: Development of Numeric Nutrient Criteria for Florida Lakes and Streams – 2nd Method Nitrate-Nitrate Spring Criteria

The second approach involving the derivation of nitrate-nitrite (NO_x) criteria at clear water springs utilizing multiple lines of evidence. This included 1) laboratory dosing studies, 2) in situ monitoring 3) real world surveys of biological communities and nutrient levels in Florida springs and 4) data regarding nitrate concentrations found in minimally disturbed reference streams. Statistical analysis of NO_x versus benthic algal biomass using change point analysis techniques indicated that change point occurred at approximately 0.44 mg N/L. After considering all lines of evidence the FDEP recommended a 0.35 mg N/L of nitrate-nitrite as protective criterion for clear streams.

Draft TSD: Development of Numeric Nutrient Criteria for Florida Lakes and Streams – 3rd Method Regionalization Method

FDEP had started the regionalization process by using previously established ecoregions. However, after careful examination of underlying geology, especially in regards to natural concentrations of phosphorus minerals, the agency decided to redefine and/or collapse or split these regions to reflect natural patterns in expected background nutrients. As a result they ended up seven regions with distinct natural phosphorus distributions but only two based on nitrogen.

Draft TSD: Development of Numeric Nutrient Criteria for Florida Lakes and Streams – 4th Method Stressor-Response Model Development

The fourth approach discussed was the development and use of *stressor-response* relationships. DEP had conducted multiple analyses using a variety of statistical techniques to investigate the effects of anthropogenic nutrient increases on the biological communities in Florida's streams. These analyses were performed to detect and describe any relationships between nutrients and biological response variables that could be used to develop NNC. These analyses evaluated the influence of nutrients on biological indices such as the SCI and the SDI which is currently under development, and the individual metrics that comprise these indices, and other biological measures such as chlorophyll-*a*, taxonomic composition of macroinvertebrate and algal communities, and frequency of occurrence and abundance of algae using the rapid periphyton survey (RPS).

The results of statistical analyses generally indicate that many of the biological measures evaluated exhibit a statistically significant adverse response to nutrient enrichment, however, the relationships between the biological response variables and nutrient levels were confounded by other factors such as pH, conductivity, color, and canopy cover. This likely confounded the affects of nutrients on biological response variables leading to low r^2 values and/or slope values which are not significantly different from zero.

FDEP believed the effect of nutrients on the biological communities were not large enough in magnitude to be used alone in establishing numeric nutrient criteria. However, the observed relationships between nutrients and the various biological measures did demonstrate the need for nutrient criteria to prevent adverse biological effects in Florida streams. The observed statistical significance for some paired measurement data sets indicated that numeric nutrient criteria should be established and supports the decision to develop and use them. An alternative approach for deriving protective criteria, such as the *Nutrient Benchmark Distribution Approach* that is described below can be used in situations where no strong stressor response relationship is detectable.

FDEP concluded, that based on their studies, specific nutrient thresholds could not be established due to the inherent variability within and between stream systems, and the confounding complexity associated with other cofactors. Since candidate nutrient criteria derived from the benchmark distributional approach is based on data derived <u>only</u> from healthy streams that are fully supportive of the designated use, FDEP planned to apply these criteria to control anthropogenic discharges to streams through source control efforts such as the NPDES and TMDL program.

A reasonable alternative to the stressor-response method to deriving criteria is to obtain data on nutrients and chlorophyll-*a* from minimally impacted sites according to the *Nutrient Benchmark Distribution Approach* protocol. However, FDEP found that based on the method and response variables used (e.g. the Rapid Periphyton Survey and change point analysis of stream periphyton community structure exposed to nutrients), the observed biological response (e.g. chlorophyll-*a* increases etc) to nutrient enrichment generally occurs at levels higher than the criteria values derived from the Nutrient Benchmark Distribution Approach alone. In other words, criteria derived from the Benchmark Distribution Approach was generally more protective and predicted potential impacts at lower concentrations of nutrients.

FDEP also planned to incorporate the *Benchmark Distribution based* stream criteria into their impaired waters 303(d) listing and assessment procedures found in Chapter 62-033 of the F.A.C. entitled "*Identification of Impaired Surface Waters*" or frequently called the "*Impaired Waters Rule"* (IWR). FDEP recommended that the identification of impaired waters should be implemented through a two step process. For example, at sites with nutrient concentrations higher than the 90th percentile, an additional variable that responds to nutrient enrichment would have to be exceeded (e.g. chlorophyll-*a*) to verify that biological impairment is actually occurring and, if so, to definitively establish that nutrients are the primary contributing cause of this impairment. If this confirmatory data is lacking, FDEP will place these waters on the *Planning List*, which captures those water bodies that are potentially impaired but not confirmed as being impaired, and are subsequently targeted for follow-up monitoring and analysis. If confirmatory is available the waterbody is placed on the *Verified List.*

FDEP evaluated the advantages and disadvantages of using the 90th, 95th, and 99th percentiles of the benchmark distribution in setting criteria. Based upon the statistical model on which the distributions were derived, FDEP determined that there was less certainty in the inclusiveness of the 95th and 99th percentiles given the sparseness of data at the extreme end of the distribution. However, FDEP had a higher assurance that the 90th percentile was inclusive of the distribution of minimally disturbed sites due to the sufficiency of the data surrounding this range. However, FDEP noted that they rarely observed biological impairment even at specific nutrient levels greater than the 90th percentile of the benchmark sites. This is the primary disadvantage of using this approach. That is, sites that may not be impaired will be listed as such based solely on their statistical distribution and not because of any empirical evidence. For this reason, for FDEP plans on conducting additional evaluations at sites with nutrient values higher than the 90th percentile to definitively establish whether this level of nutrients will lead to negative impacts on various response variables and result in the impairment of designated uses.

In summary, FDEP recommended in their freshwater technical support document to establish numeric nutrient criteria for TP and TN in streams using the 90th percentile of the benchmark distribution, except for the Bone Valley nutrient region where data is limited, based upon the following reasons:

- It is consistent with EPA guidance;

- FDEP had conducted a rigorous verification to demonstrate that the benchmark sites were minimally disturbed;

- FDEP confirmed that healthy, well balanced biological communities were maintained at nutrient levels above the 90th percentile (greatly minimizing Type II error, the mistake of classifying an impaired site as acceptable);

- The stressor/response analyses, while demonstrating significant relationships between nutrients and biological response, provided no basis for establishing specific nutrient thresholds;

- Use of a 75th percentile would result in a large Type I error (25% of benchmark sites, and a large number of healthy sites would incorrectly be classified as impaired, and subsequent use of resources to "restore" such unimpacted sites on; paper would constitute unwise public policy, and may contradict current state law; and

- Although the 95th and 99th percentiles were evaluated and considered, FDEP determined that there was insufficient knowledge about the inclusiveness of the 95th and 99th percentiles due to the limited availability of data for streams from the extreme end of the distribution. However, FDEP has high assurance that the 90th percentile is inclusive of the distribution of minimally disturbed sites due to the sufficiency of the data surrounding this range in all nutrient regions except for the Bone Valley. In the Bone Valley the <u>75th percentile</u> was used due to the limited amount of data available.

Draft TSD: Development of Numeric Nutrient Criteria for Florida Lakes and Streams – 6th Method Nutrient Longitudinal Study

In the technical support manual FDEP describes the *Nutrient Longitudinal Study* which started during the summer of 2008 to evaluate downstream biological responses to naturally high upstream phosphorus levels (Florida Department of Environmental Protection 2009a). The benefits and drawbacks along with recommendations were previously described under the 2009 Nutrient Criteria Development Plan discussion section above (Florida Department of Environmental Protection 2009c). Consequently we will not discuss these findings further.

The seventh approach and tool that FDEP evaluated and placed into the technical support document was an evaluation of various metrics that could serve as the basis for proposed lake chlorophyll-*a* criteria. FDEP summarized the scientific basis for the chlorophyll-*a* thresholds used by FDEP to establish numeric nutrient criteria for lakes. Based on several lines of evidence, FDEP proposed a chlorophyll-*a* threshold of 20 µg/L for colored lakes and clear lakes with conductivities above 100 µmhos/cm, and 9 µg/L for clear lakes with conductivities below 100 µmhos/cm. FDEP planned to adopt these thresholds as a response variable NNC that would be used to develop numeric criteria for TP and TN (using regression equations that relate nutrient concentrations to annual geometric mean chlorophyll a levels) for Florida lakes. However, before doing this they also needed to adjust one of the indicators used to assess the trophic status of a lake, that is the Carlson type trophic state index (TSI)(Carlson 1977). However, the original TSI, which included secchi disk readings as part of the metric, was originally derived for northern lakes. Therefore FDEP felt it was necessary to modify this for the warmwater Florida lakes which include some waterbodies that are sometimes more turbid due to humic substances.

Salas and Martino (1991) proposed an alternate TSI categorization based on their work in phosphorus limited warm-water tropical lakes, which is more directly applicable to Florida conditions. The TSI and chlorophyll a values in Table 9-1 were determined based upon the TSI relationship with TP. Note that while Carlson would consider a TSI of 50-60 to represent the lower boundary of eutrophy in northern lakes, Salas and Martino considered that same range of TSI values to be mesotrophic in warm-water lakes, while eutrophic conditions would not occur until a warm water lake exhibited a TSI of 70 (Table 21).

Table 21. Warm-water TSI categories after (Salas and Martino 1991) cited in (Florida Department of Environmental Protection 2009a)

TSI	Category	TP (µg/L)	Chlorophyll-*a*
40	Oligotrophic	21.3	5
50	Mesotrophic	39.6	10
70	Eutrophic	118.7	40

As part of Florida’s 305(b) assessment, FDEP revised the TSI by a) replacing Secchi depth with total nitrogen, and b) adding equations that adjust the nutrient component of the TSI to reflect the limiting nutrient. Use of secchi depth in Florida as a measure of trophic state was unsuccessful due to the high frequency of dark-water lakes (< 40 PCU), where tannins originating from the breakdown of vascular plant tissues, rather than algae, diminish transparency. The final proposed TSI for Florida lakes was based on chlorophyll-*a*, TN, and TP concentrations, based on the following set of relationships:

TSI = (CHLATSI + NUTRTSI)/2

NUTRTSI is based on limiting nutrient considerations, as follows:

If TN/TP > 30, then lake is phosphorus limited and NUTRTSI = TP2TSI

$$TP2TSI = 10 \times [2.36 \times LN(TP \times 1000) - 2.38]$$

If TN/TP < 10, then lake is nitrogen limited and NUTRTSI = TN2TSI

$$TN2TSI = 10 \times [5.96 + 2.15 \times LN(TN + 0.0001)]$$

If 10 < TN/TP < 30, then co-limited and NUTRTSI = (TPTSI + TNTSI)/2

$$TNTSI = 56 + [19.8 \times LN(TN)]$$

$$TPTSI = [18.6 \times LN(TP \times 1000)] - 18.4$$

These equations were calculated by FDEP based on the analysis of data from 313 Florida lakes, and were adjusted so that a chlorophyll-*a* concentration of 20 µg/L were equivalent to a TSI value of 60. For the 1998 Florida 305(b) report, a TSI threshold of 60 was used to represent “fair” lakes, while lakes above 70 were assessed as “poor.” FDEP stated that the TSI equation described a theoretical relationship between chlorophyll-*a*, total phosphorus, and total nitrogen. The chlorophyll-*a* roughly doubles with every 10 point increase in the TSI (**Error! Reference source not found.**).

Table 22. Relationship between chlorophyll-*a*, total phosphorus, and total nitrogen, as described by Florida’s TSI.

Trophic State Index	Chlorophyll *a* (µg/L)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
0	0.3	0.003	0.06
10	0.6	0.005	0.10
20	1.3	0.009	0.16
30	2.5	0.01	0.27
40	5.0	0.02	0.45
50	10.0	0.04	0.70
60	20	0.07	1.2
70	40	0.12	2.0
80	80	0.20	3.4
90	160	0.34	5.6
100	320	0.58	9.3

Other methods that were evaluated for determination of appropriate NNC in lakes and are described in the technical support document included:

- Paleolimnologic studies, where pre-human disturbance chlorophyll-*a* values are inferred from an analysis of diatom communities in deep sediment cores;

- Expert elicitation, or best professional judgment, for the determination of protective TSI or chlorophyll-*a* values;
- Fisheries responses to chlorophyll-*a* or TSI levels, dependent upon type of fisheries which are in turn adapted to associated dissolved oxygen conditions (i.e., cold water vs. warm water fisheries);
- Associating lake user visual perceptions (for swimming and aesthetics) with simultaneously measured chlorophyll-*a;*
- Setting the criterion to maintain the existing condition (protection strategy); and
- Using an upper percentile of the distribution of reference lakes.

Multiple lines of evidence were used to evaluate the rigor of protection inherent in the Florida Impaired Waters Rule (IWR) Technical Advisory Committee's TSI- based chlorophyll-*a* recommendations, which were adopted into the IWR in 2002 (Chapter 62-303, FAC). The most current version of the IWR was adopted into rule during the 2006 update. This update did not include any changes to the chlorophyll-*a* levels. Table 23 contains a summary of the various approaches.

Table 23. Lines of evidence used in determining support of the 2002 Florida Impaired Waters Rule Technical Advisory Committee's chlorophyll *a* target recommendations (Florida Department of Environmental Protection 2009a)

Line of Evidence	Chlorophyll-*a* target	State
Paleolimnological studies	14 to 20 µg/L (higher for some lakes)	Florida
Expert opinion	20-33 µg/L	Virginia, Iowa, West Virginia, Maryland
Fisheries responses (warmwater) Fisheries responses (coldwater trout and coolwater)	35-60 µg/L 3-5 µg/L and 25 µg/L, respectively	Virginia Minnesota, Colorado
Lake user perceptions	20-25, up to 30 µg/L in colored lakes; as low as 3 µg/L in Florida Trail Ridge clear lakes	Texas and Florida
Existing levels approach	5-27 µg/L	Alabama
Reference lake approach	2-8 µg/L in clear lakes, 9-18 µg/L in colored lakes	Florida, using 75th percentile

Draft TSD: Development of Numeric Nutrient Criteria for Florida Lakes and Streams – 8th Method Investigation of relationships between Cyanobacteria abundance and Chlorophyll-a

Multiple lines of evidence, including paleolimnology, fisheries success, and user perception, converge to support the Florida IWR TAC's original recommendation that 20 µg/L of chlorophyll *a* in colored lakes is protective of designated uses. It has been hypothesized that phytoplankton populations may switch to communities dominated by cyanobacteria at chlorophyll-*a* levels above 20 µg/L, however, this pattern was not observed in an analysis of 1,364 Florida lakes. Cyanobacteria are usually an unfavorable food source to zooplankton and many other aquatic animals, and some may even produce toxins, which could be harmful to fish and other animals. For this reason, the World Health Organization considers it to be a high risk for swimming when waters are dominated by cyanobacteria and accompanied by an instantaneous chlorophyll *a* of 50 µg/L (symptoms such as skin irritation and conjunctivitis may be more prevalent). Based upon the above multiple lines of evidence, DEP proposed that an annual average chlorophyll *a* of 20 µg/L in colored lakes is protective of designated uses.

Draft TSD: Development of Numeric Nutrient Criteria for Florida Lakes and Streams – 9th Method Stressor Response Analysis of Florida Lakes

There is less support for the IWR TAC's recommendation of 5 µg/L chlorophyll-*a* in clear lakes, which was based on a "maintain existing condition approach" and which was primarily targeted at a specific geographic region of Florida (the panhandle). Although some Alabama lakes do have a target that is as low as the recommended 5 µg/L (based on the goal of maintaining the existing condition), the range of acceptable chlorophyll-*a* in Alabama ranged from 5-27 µg/L. Coldwater trout fisheries (which do not exist in Florida) require chlorophyll-*a* in the 3-5 µg/L range. A reference lake approach proposed by Tetra Tech suggests that chlorophyll-*a* values of up to 8 µg/L in clear lakes represent the 75th percentile of reference lakes. Moreover, the TSI categorization of (Salas and Martino 1991), based on warm water lakes, would consider a chlorophyll-*a* of 10 µg/L (TSI of 50) to be mesotrophic. Thus, a multiple lines of evidence approach suggests that a chlorophyll-*a* concentration <10 µg/L would be a protective threshold for Florida's clear lakes. FDEP solicited input from the Nutrient TAC in June, 2009, and the Nutrient TAC also suggested that maintaining chlorophyll-*a* below 10 µg/L in low conductivity (<100 µmhos/cm) clear lakes would be protective of the designated use, since a value of <10 µg/L would still be categorized as oligotrophic. Therefore, FDEP has established the low conductivity clear lake chlorophyll-*a* threshold at 9 µg/L. The TAC suggested that different nutrient and chlorophyll-*a* expectations should be established for high conductivity (>100 µmhos/cm) clear lakes because of the naturally higher, aquifer-derived phosphorus levels this subset of clear lakes. The TAC suggested that nutrient thresholds in clear, high conductivity lakes be based on preventing the annual average chlorophyll-*a* from exceeding 20 µg/L.

The literature assembled by FDEP also supported the concept of allowing *site specific alternative criteria* (SSACs) for lakes to vary where either higher or lower levels could be justified, based upon scientific information. Therefore FDEP planned to allow development of SSACs for nutrients. This was consistent with provisions of Chapter 62.303 *Identification of Impaired Surface Waters* (IWR) rule that allows development of site-specific thresholds that better represent the levels at which nutrient impairment occurs, and the use of a higher TSI if paleolimnological data indicate a lake was naturally above the applicable TSI.

State Approved Water Quality Standards and Nutrient Criteria 2010

The most current water quality standards were adopted by the State of Florida in 2010 (Florida Department of Environmental Protection 2010a). The state water quality criteria are located in rules 62-302.500 and 62-302.530 F.A.C (Florida Administrative Code)(Florida Department of Environmental Protection 2010a). We have summarized the existing nutrient criteria along with related parameters (nitrates and transparency) that may be used to control nutrient levels that influence aquatic resources (Table 24).

Table 24. Summary of selected current 2010 State of Florida adopted criteria for surface water classifications (62.302.530)(Florida Department of Environmental Protection 2010a). Class V – navigation not listed. Parameters include nutrients and related variables.

Parameter (code) and description.	Units	Class I: Potable Water Supply	Class II: Shellfish Propagation or Harvesting	Class III: Recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife[1]		Class IV: Agricultural Water Supplies
				Predominantly Fresh Waters	Predominantly Marine Waters	
(45) Nitrate	mg/L	≤ 10 or that concentration that exceeds the nutrient criteria				
(47 a) Nutrients		The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter. Man-induced nutrient enrichment (total nitrogen or total phosphorus) shall be considered degradation in relation to the provisions of Rules 62-302.300, 62-302.700, and 62-4.242, F.A.C.				
(47 b) Nutrients		In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.				

[1] Includes special Class III-Limited waters that have at least one site specific alternative criterion

Currently there are no statewide NNC that have been created through the “normal” process of state adoption and federal approval in Florida. There is only one site specific NNC that has been adopted by the State of Florida that targets phosphorus enrichment. This NNC replaces the statewide narrative criteria. A site specific NNC for phosphorus was adopted by the State of Florida for the Everglades on 7-15-04 (Rule 62-302.540, F.A.C) (Florida Department of Environmental Protection 2010a). A summary of the primary features of the NNC for the Everglades Phosphorus Criterion is provided below.

Everglades Phosphorus Criterion

"*The numeric phosphorus criterion for Class III waters in the Everglades Protection Area (EP area), shall be a long-term geometric mean of 10 ppb, but shall not be lower than the natural conditions of the EP area, and shall take into account spatial and temporal variability. Achievement of the criterion shall be determined by the methods in this subsection. Exceedances of the provisions of the subsection shall not be considered deviations from the criterion if they are attributable to the full range of natural spatial and temporal variability, statistical variability inherent in sampling and testing procedures or higher natural background conditions."*

Although we could not find the original technical support document for the Everglades NNC, reference to the approach is included the document entitled "*Florida Numeric Nutrient Criteria: History and Status"* (Florida Department of Environmental Protection 2009b). In that document FDEP summarizes the technical approach used to develop the phosphorus criteria. The following information is extracted from that report. The FDEP established a numeric interpretation of the state narrative criterion for total phosphorus (TP) in the Everglades through the use of the "dose-response" study approach. The criterion was based on maintaining TP concentrations at levels demonstrated to support healthy, well balanced populations of aquatic flora and fauna in minimally disturbed portions of the Everglades.

The FDEP stated that there were major challenges associated with determining specific cause effect relationships in the Everglades and deriving an appropriately protective criterion. They cite for example the fact that biological responses were not uniform across all microhabitats, and there were areas (e.g., bird rookeries) where naturally higher TP values have led to small scale, non-anthropogenic increases in TP and algal community structure. Other potential stressors such as hydrologic modification and natural low DO regimes also needed to be accounted for and understood in order to develop nutrient criterion. Extensive dosing studies were conducted to better establish the type and magnitude of adverse biological changes associated with specific levels of TP. FDEP's stated that their experience in the Everglades highlighted the complexity of assessing biological responses across the natural systems and the difficulty in establishing an appropriate criterion that provides the appropriate level of protection (Florida Department of Environmental Protection 2009b).

State Water Quality Screening Values for Identification of Impaired Surface Waters for 303d listing - 2006

Although not considered a formal NNC, "threshold or screening values" are used by the FDEP under the "*Identification of Impaired Surface Waters"* rule (F.A.C Chapter 62-303) to determine whether a waterbody is not meeting it's designated use (e.g. fish and wildlife propagation) due to elevated nutrients (or other pollutants)(Florida Department of Environmental Protection 2006). Under Florida law if it is believed based on preliminary data that a waterbody is not meeting its designated use due to a excessive pollutants (e.g. nutrients) the waterbody may be placed on "*planning list*' for further evaluation. If the evaluation of data, including new focused studies, supports and confirms the preliminary planning listing of this waterbody, the status will be changed to a "*verified listing"*. These waterbodies are then placed on the 303(d) list for eventual development of a TMDL to control the pollutant causing a reduction or loss of uses. This "*Impaired Waters Rule*" (IWR) relies on "threshold" chlorophyll-*a* and Trophic State Index (TSI) values as the primary means of assessing whether a waterbody should be assessed further for nutrient impairment. These values are developed similarly to draft NNC and are usually discussed separately within Nutrient Criteria Development Planning documents (Florida Department of Environmental Protection 2009c). Portions of the current IWR regulations including screening values are listed verbatim.

Planning List Procedures

62-303.350 Interpretation of Narrative Nutrient Criteria.

(1) Trophic state indices (TSIs) and annual mean chlorophyll a values shall be the primary means for assessing whether a waterbody should be assessed further for nutrient impairment. Other information indicating an imbalance in flora or fauna due to nutrient enrichment, including, but not limited to, algal blooms, excessive macrophyte growth, decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation, changes in algal species richness, and excessive diel oxygen swings, shall also be considered.
(2) To be used to determine whether a waterbody should be assessed further for nutrient enrichment,
(a) Data must meet the requirements of paragraphs (2)-(4), (7), and (8) in rule 62-303.320, F.A.C.
(b) At least one sample from each season shall be required in any given year to calculate a Trophic State Index (TSI) or an annual mean chlorophyll a value for that year (for purposes of this chapter, the four seasons shall be January 1 through March 31, April 1 through June 30, July 1 through September 30, October 1 through December 31),
(c) If there are multiple chlorophyll a or TSI values within a season, the average value for that season shall be calculated from the individual values and the four quarterly values shall be averaged to calculate the annual mean for that calendar year,
(d) For data collected after the effective date of this rule, individual TSI values shall only be calculated when the nitrogen, phosphorus, and chlorophyll data were collected at the same time and location,
(e) If there are insufficient data used to calculate a TSI or an annual mean chlorophyll a value in the planning period, but there are data from at least four consecutive seasons, the mean TSI or mean chlorophyll a value for the consecutive seasons shall be used to assess the waterbody,
(f) There must be annual means from at least four years when evaluating the change in TSI over time pursuant to paragraph 62-303.352(3), F.A.C., and
(g) To be assessed under this rule, chlorophyll a data collected after the effective date of this rule shall be corrected chlorophyll a, except for data used to establish historical chlorophyll-*a* levels. Corrected chlorophyll a is the calculated concentration of chlorophyll-*a* remaining after the chlorophyll degradation product, phaeophytin-*a*, has been subtracted from the uncorrected chlorophyll a measurement.

(3) When comparing changes in chlorophyll a or TSI values to historical levels, historical levels shall be based on the lowest five-year average for the period of record. To calculate a five year average, there must be annual means from at least three years of the five-year period.

62-303.351 Nutrients in Streams.

A stream or stream segment shall be included on the planning list for nutrients if the following biological imbalances are observed:

(1) Algal mats are present in sufficient quantities to pose a nuisance or hinder reproduction of a threatened or endangered species, or

(2) **Annual mean chlorophyll-*a* concentrations are greater than 20 µg/L or if data indicate annual mean chlorophyll-*a* values have increased by more than 50% over historical values for at least two consecutive years**.

62-303.352 Nutrients in Lakes.

For the purposes of evaluating nutrient enrichment in lakes, TSIs shall be calculated based on the procedures outlined on pages 86 and 87 of the State's 1996 305(b) report, which are incorporated by reference. Lakes or lake segments shall be included on the planning list for nutrients if:

(1**) For lakes with a mean color greater than 40 platinum cobalt units, the annual mean TSI for the lake exceeds 60, unless paleolimnological information indicates the lake was naturally greater than 60,** or

(2) **For lakes with a mean color less than or equal to 40 platinum cobalt units, the annual mean TSI for the lake exceeds 40, unless paleolimnological information indicates the lake was naturally greater than 40**, or

(3) For any lake, data indicate that **annual mean TSIs have increased over the assessment period, as indicated by a positive slope in the means plotted versus time, or the annual mean TSI has increased by more than 10 units over historical values**. When evaluating the slope of mean TSIs over time, the FDEP shall require at least a 5 unit increase in TSI over the assessment period and use a Mann's one-sided, upper-tail test for trend, as described in Nonparametric Statistical Methods by M. Hollander and D. Wolfe (1999 ed.), pages 376 and 724 (which are incorporated by reference), with a 95% confidence level.

62-303.353 Nutrients in Estuaries and Open Coastal Waters.

Estuaries, estuary segments, or open coastal waters shall be included on the planning list for nutrients if their **annual mean chlorophyll-*a* for any year is greater than 11 µg/L**

or if data indicate annual mean chlorophyll a values have increased by more than 50% over historical values for at least two consecutive years.

Verified List

62-303.450 Interpretation of Narrative Nutrient Criteria.

(1) A waterbody shall be placed on the verified list for impairment due to nutrients if there are sufficient data from the last five years preceding the planning list assessment, combined with historical data (if needed to establish historical chlorophyll a levels or historical TSIs), to meet the data sufficiency requirements of rule 62-303.350(2), F.A.C. If there are insufficient data, additional data shall be collected as needed to meet the requirements. Once these additional data are collected, the Department shall determine if there is sufficient information to develop a site-specific threshold that better reflects conditions beyond which an imbalance in flora or fauna occurs in the water segment. If there is sufficient information, the Department shall re-evaluate the data using the site-specific thresholds. If there is insufficient information, the Department shall re-evaluate the data using the thresholds provided in rule 62-303.351-.353, F.A.C., for streams, lakes, and estuaries, respectively. In any case, the Department shall limit its analysis to the use of data collected during the five years preceding the planning list assessment and the additional data collected in the second phase. If alternative thresholds are used for the analysis, the Department shall provide the thresholds for the record and document how the alternative threshold better represents conditions beyond which an imbalance in flora or fauna is expected to occur.

(2) If the water was listed on the planning list for nutrient enrichment based on other information indicating an imbalance in flora or fauna, as provided in Rule 62-303.350(1), F.A.C., the Department shall verify the imbalance before placing the water on the verified list for impairment due to nutrients and shall provide documentation supporting the imbalance in flora or fauna.

(3) The thresholds for impairment due to nutrients used under this section are not required to be used during development of wasteload allocations or TMDLs.

Existing Federal Promulgated Standards and Technical Basis

As previously mentioned in 2010 the EPA promulgated freshwater NNC standards for the state of Florida (United States Environmental Protection Agency 2010f). The final standards established specific numeric criteria, on the nutrient concentrations and associated chlorophyll-*a* levels in Florida's lakes, rivers, streams and springs (United States Environmental Protection Agency 2010a; United States Environmental Protection Agency 2010k). A complete description of the analytical procedures and methods used to develop numeric nutrient criteria for Florida's Inland surface fresh waters is described in the EPA technical support document (Crawford et al. 2010). The majority of these standards will become effective 15 months from the date of promulgation (January 2012).

Table 25. Summary of EPA's numeric criteria for Florida streams promulgated in 2010 (United States Environmental Protection Agency 2010a).

Nutrient Watershed Region	Instream Protection Value Criteria	
	TN (mg/L)*	TP (mg/L)*
Panhandle West	0.67	0.06
Panhandle East	1.03	0.18
North Central	1.87	0.30
North Central	1.65	0.49
Peninsula	1.54	0.12

* For a given waterbody, the annual geometric means of TN or TP concentrations shall not exceed the applicable criterion concentration more than once in a three-year period.

Table 26. Summary of EPA's numeric criteria for Florida Lakes promulgated in 2010 (United States Environmental Protection Agency 2010a).

Lake Color[a] and Alkalinity	Chl-a (mg/L)[b] *	TN (mg/L)	TP (mg/L)
Colored Lakes[c]	0.20	1.27 [1.27-2.23]	0.05 [0.05-0.16]
Clear Lakes, High Alkalinity[d]	0.02	1.05 [1.05-1.91]	[1.05-1.91]
Clear Lakes, Low Alkalinity[e]	0.006	0.51 [0.51-0.93]	0.01 [0.01-0.03]

[a] Platinum Cobalt Units (PCU) assessed as true color free from turbidity.
[b]Chlorophyll-*a* is defined as corrected chlorophyll, or the concentration of chlorophyll- *a* remaining after the chlorophyll degradation product, phaeophytin a, has been subtracted from the uncorrected chlorophyll-*a* measurement.
[c] Long-term Color > 40 Platinum Cobalt Units (PCU)
[d]Long-term Color ≤ 40 PCU and Alkalinity > 20 mg/L CaCO3
[e] Long-term Color ≤ 40 PCU and Alkalinity ≤ 20 mg/L CaCO3
* For a given waterbody, the annual geometric mean of chlorophyll-*a*, TN or TP concentrations shall not exceed the applicable criterion concentration more than once in a three-year period.

This phased in schedule was done to allow cities, towns, businesses and other stakeholders as well as the State of Florida a full opportunity to review the standards and develop flexible strategies for implementation.

The EPA utilized two primary approaches to develop and promulgate the freshwater numeric nutrient criteria in Florida. This included the 1) biological response or stressor-response relationship and 2) reference condition or ecoregion approach (Gibson et al. 2000; United States Environmental Protection Agency 2000h; United States Environmental Protection Agency 2010j) (United States Environmental Protection Agency 2010j).

In order to utilize the stressor-response approach, research studies and monitoring of water bodies within a particular waterbody type must be conducted to determine the nutrient concentration and environmental conditions at which impacts on the designated use are no longer acceptable. This method is the favored approach by EPA because it directly links the nutrient "stressor" or causative variable (e.g. nutrients) with the undesirable biological "response" e.g. elevated chlorophyll-a, fish kills, algal blooms.

If there is not sufficient information to determine stressor-response relationship, then a frequently used alternative method is the reference waterbody or ecoregion approach (Gibson et al. 2000; United States Environmental Protection Agency 2000h). The first step involves identifying relatively healthy or minimally impacted water bodies of a particular class (e.g. pond size) within a particular geographic region (e.g. watershed, ecoregion). Water quality data from these water bodies are then characterized and candidate numeric nutrient criteria are generated based on the distribution of nutrient concentrations found at these sites. Subsequently a water body is considered healthy if it has conditions that are below the "threshold" for impairment (e.g. nutrient level). With the reference approach, it is assumed that biological integrity is protected as judged by the minimally impacted reference conditions, and that increasing nutrient concentrations above reference would unacceptably impact the designated use.

The reference-based and algal or nitrogen/phosphorus threshold approaches have been peer reviewed and have been available for many years. In addition to these empirical approaches, consideration of established (e.g. published) nutrient response thresholds is also an acceptable approach for deriving criteria (United States Environmental Protection Agency 2010a).

Criteria for Florida Streams and Rivers

The NNC that were promulgated by EPA for Florida streams and rivers were based on classifying waterbodies based on similar biogeography and hydrology (i.e. reference stream approach). To accomplish this EPA utilized five different watershed based regions within Florida, which resulted in different total nitrogen and phosphorus (TN and TP) criteria, for streams in each region (Table 25). For this phase EPA used a reference waterbody approach, which involved the evaluation of extensive biological information and data on the levels of nutrients in relevant Florida streams. Much of this data had been collected by the State of Florida. The derived standards were based on nutrient concentrations in least-disturbed streams that were unimpaired for nutrients.

The promulgated Florida NNC for streams and rivers also contained provisions for the downstream protection of lakes receiving water from upstream tributaries (United States Environmental Protection Agency 2010a). This was needed in cases where the instream criteria for the tributary streams may not be stringent enough to meet downstream lake criteria. Downstream protection of lakes will be accomplished through establishment of *Lake Downstream Protection Values* (DPVs). EPA provided three options that can be used to estimate DPV values. The first option was to use water quality models such as BATHTUB, WASP or others to estimate appropriate instream concentrations of TN and TP that generate downstream loading estimates that will meet lake NNC. Alternatively if the downstream lake is meeting its appropriate lake criteria, then the DPV is assumed to be the current ambient stream condition. A third option if the concentration is not modeled and the lake criteria is not being met can be to set the instream concentration at the level of the lake criteria.

Criteria for Florida Lakes

For lakes, EPA used a stressor response approach to link nitrogen/phosphorus concentrations to predictions of corresponding chlorophyll-*a* concentrations (United States Environmental Protection Agency 2010j). The criteria that EPA used for classifying Florida's lakes included color and alkalinity (Table 26). The agency identified three groups (colored, clear & alkaline, clear & acidic) and assigned different values for TN, TP, and chlorophyll-*a* to each lake group. The resulting NNC were based on the observed biological response (chlorophyll-*a* production) to TN and TP levels in Florida's lakes. EPA used the ambient chlorophyll-*a* concentration as an indicator of a healthy biological condition, supportive of natural balanced populations of aquatic flora and fauna in each of the classes of Florida's lakes. Excess algal growth (high chlorophyll-*a*) is associated with degradation in aquatic life. The levels of TN and TP which are associated with levels of chlorophyll-*a* that are associated with algal blooms were then used to define NNC (Table 26). Therefore the method used for defining NNC in lakes used a combination of the reference water body and the stressor-response approach).

Criteria for Florida Springs

EPA also established a nitrate-nitrite criterion for springs based on experimental laboratory data and field evaluations that document the response of nuisance algae to nitrate-nitrite concentrations. EPA used the stressor-response approach to promulgate the numeric criterion for nitrate+nitrite for Florida's springs classified as Class I or III waters under Florida law. Based on their analysis the applicable nitrate (NO_3^-)+Nitrite (NO_2^-) criterion was set at 0.35 mg/L as an annual geometric mean, not to be exceeded more than once in a three-year period.

Additional Provisions

In addition to establishing final numeric nutrient water quality standards for Florida, EPA announced a flexible approach for deriving federal site-specific alternative criteria (SSAC) based upon stakeholder submission of scientifically defensible recalculations of protective levels that meet the requirements of CWA section 303(c). This will allow for case-by-case adjustments depending on local environmental factors while protecting water quality. Governments or other stakeholder groups can seek site-specific consideration in cases where water bodies have been extensively assessed by the State and local communities and effective measures are in place to reduce nutrient pollution. Existing or new Total Maximum Daily Load (TMDL) targets that differ from EPA's final criteria can be submitted to EPA by Florida for consideration as new or revised water quality standards and will be reviewed under this SSAC process. EPA also promulgated new WQS regulatory tool for Florida, referred to as restoration standards. This tool will enable Florida to set enforceable incremental water quality targets (designated uses and criteria) for nutrients, while at the same time retaining protective criteria for all other parameters, to meet the full aquatic life use. All of the data used by EPA to develop the freshwater criteria rule can be found at http://publicfiles.dep.state.fl.us/DEAR/Weaver/.

Ongoing Federal Nutrient Criteria Development Efforts

As a result of the lawsuit EPA will also establish rules to protect estuaries and south Florida canals. These standards for coastal waters must be promulgated by August 2012. In order to accomplish this EPA produced a draft technical support document (TSD) entitled "*Methods and approaches for deriving numeric criteria for nitrogen/phosphorus pollution in Florida's Estuaries, Coastal Waters, and Southern Inland Flowing Waters"* on November 17, 2010 (Carleton et al. 2010). In addition, a public peer review was conducted by EPA's Scientific Advisory Board (SAB). The public was also invited to submit comments to the SAB based on their individual agency review of the TSD. The FDEP did review the TSD and submitted comments (Florida Department of Environmental Protection 2011d). The SAB review report was issued on July 19, 2011. A summary of the TSD, FDEP and SAB review comments are provided below. Much of what follows is taken verbatim from portions of these documents, in addition to our own clarifying comments where appropriate (Carleton et al. 2010; Science Advisory Board 2011).

Although the eventual method that will be used to develop nutrient criteria is subject to change, after input and review of the SAB it is useful to review the major recommendations made by (Carleton et al. 2010) in the TSD. The authors felt that the recommended approach must fully consider characteristics of estuarine ecosystems (e.g., water quality and biological communities in estuaries are affected by a combination of basin shape, tides, and the magnitude, location, and quality of freshwater inflows. In order to accomplish the task of developing NNC for individual estuaries the authors of the report provided a conceptual model, to help guide their overall strategy on how nutrient criteria will be derived (Figure 13). In some of Florida's estuaries, the semi-enclosed basins that define their spatial extent may also create sub-regions with different and distinct water quality and aquatic life uses, which could also result in water quality criteria specific to a particular sub-region.

Due to the unique nature and extensive human management of South Florida waters, the approach the TSD authors are considering for deriving numeric nutrient criteria for estuarine waters in South Florida differed from that outlined for other estuarine and near coastal areas. Therefore the authors recommend conducting these two analyses separately (estuarine and South Texas) and divided the methodology for each system into two separate chapters. Under the proposed EPA methodology the agency would first delineate the estuaries into discrete areas around Florida's coastline for the purpose of organizing the criteria development process. Each of these discrete areas would then be evaluated to determine the appropriate "assessment endpoints" and "measurement endpoints."

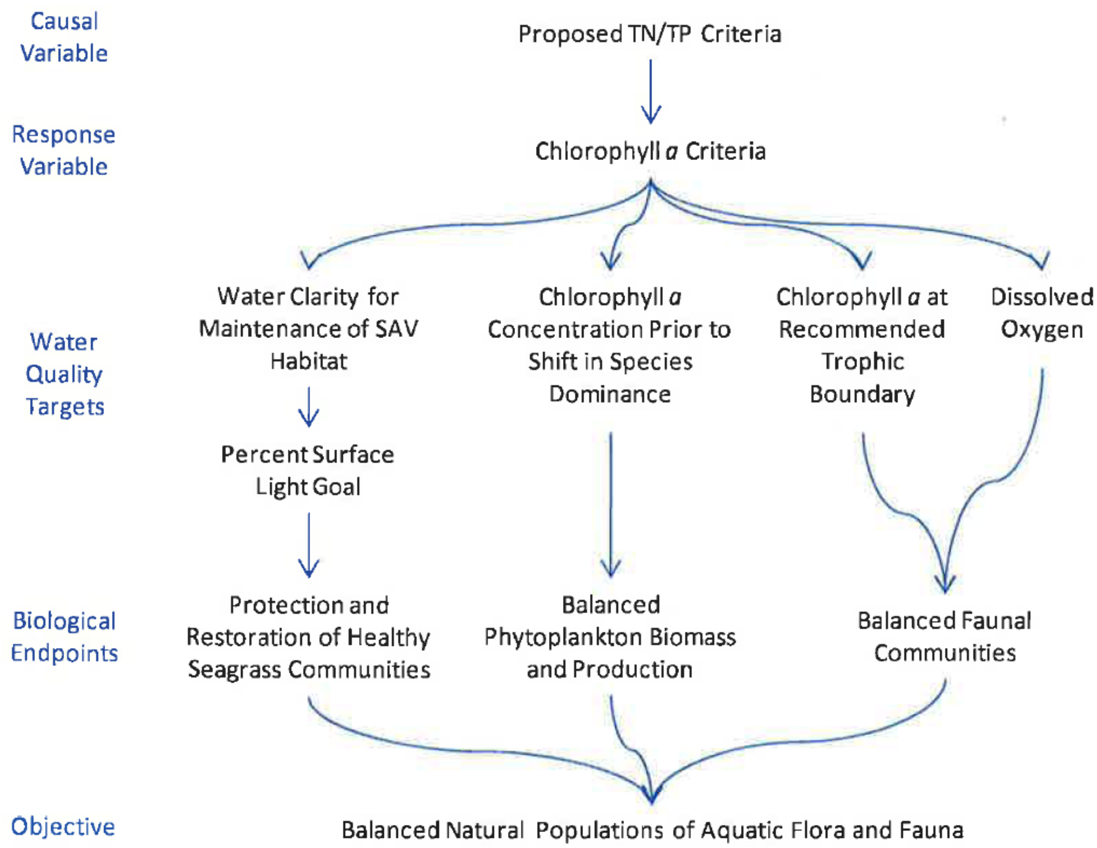


Figure 13. Pathways for nutrient effects on estuarine and coastal aquatic life uses. From: (Carleton et al. 2010).

The EPA considered several assessment endpoints and indicator variables for evaluating and developing NNC (Table 27 and Table 28). The specific endpoints and indicators that EPA eventually recommended for use in the development of numeric criteria in Florida's estuaries include: 1) protection and restoration of healthy seagrass communities, 2) balanced communities of benthos, plankton, and nekton, and 3) balanced algal biomass and production. The authors discussed the rationale for selecting specific variables. The EPA report has an extensive bibliography of seagrass endpoint literature as it pertains to light and nutrients.

Table 27. Assessment endpoints for evaluating the magnitude and effects of nutrients, including advantages and disadvantages. From: (Carleton et al. 2010).

	Importance	Linkages to, or Effects of, Nutrients	Advantages	Disadvantages
Seagrass	• Valuable marine habitat • Primary food source for many organisms	• Spatial extent, density, growth rates decline with decreased light transmittance • Light transmittance decreases with decreased clarity/increased nutrients • Light requirement usually 20–25% surface irradiance	• Mechanism of nutrient impact mostly well-understood • Colonization depth (Z_c) useful indicator • Once Z_c goal established, can use light requirements to infer water clarity requirement and chlorophyll a criteria • Historical depth of colonization could be used to infer reference water clarity	• Co-factors exist – salinity stress, food web change, dredging, propeller scarring, sediment loading, disease • Response to nutrients can be slow (especially recovery)
Phytoplankton	• Primary producers and important component of marine food web • Excess growth affects clarity, DO, habitat, aesthetics	• Nutrients are key limiting factors for algal growth rate.	• Responsive to nutrients, Well-established basis for use as indicator • Biomass data in estuarine waters are routinely monitored and data are generally abundant • Satellite-derived chlorophyll data readily available in many coastal waters	• Other factors can interfere with evaluating stressor-response relationships • Species composition data limited; differences in field sample and taxonomic methods may increase uncertainty • Field-collected biomass data in coastal (offshore) waters are limited • Most estuaries lack species composition models developed for nutrient response • Lack of phytoplankton data in healthy canals

Table 29. Continued.

	Importance	Linkages to, or Effects of, Nutrients	Advantages	Disadvantages
Harmful Algal Blooms	• Certain HABs impact human health/other marine organisms, and aquatic ecosystems • Often associated with toxins leading to faunal kills, shellfish contamination, economic impacts, decline in aesthetic value, environmental and ecological damage	• HAB species other than K. *brevis* occur in Florida marine waters, but are less studied	• Foul odor and reduced aesthetics can lead to public awareness • Once driven toward landfall, there is some evidence that *K. brevis* bloom duration may be extended by land-based sources of nutrients	• *K. brevis* initiation occurs in coastal waters beyond 3 miles • It is unclear that reduction in land-based nutrients would reduce *K. brevis* blooms. Current Gulf of Mexico *K. brevis* models (see Appendix C) are focused on research applications
Corals	• Highly productive and valued ecosystem • High species richness and diversity	• Nutrient-poor habitat • Nutrients may contribute to bleaching, disease, and excess macroalgal growth	• Highly valued resource	• Role of nutrients on coral health is mixed • Method limitations • Interacting factors are important (dissolved organic carbon, fish, etc.) • May depend on duration of enrichment
Epiphytes	• Excess growth hinders seagrass growth	• Epiphyte biomass increases with nutrient enrichment	• Responsive to nutrients • May be more sensitive than seagrass loss, especially epiphyte composition • Clear linkage to important aquatic life (seagrass)	• Biomass responses sometimes equivocal • Confounding factors (light, grazing, etc.) • Composition difficult to measure • Limited data
Invertebrates	• Reliable indicator of biological conditions	• Invertebrate community changes from increased phytoplankton food base and reduced benthic food base • Severe community changes with hypoxia	• Established indicator of biological conditions • Existing monitoring programs • Stream Classification Index in canals decreases with increasing nutrient concentration	• Many confounding factors (e.g., seagrass and other habitat loss, sediment toxicity, overfishing, indirect effects of nutrients)
Fish	• Indicator of biological condition	• Nutrient loading may impact habitat quality for fish (e.g., due to hypoxia or seagrass loss) HABs can cause fish mortality or reduced fish growth. • Excess nutrients can also stimulate fisheries production by increasing prey abundance. •	• Highly visible • Substantial public concern	• Many confounding factors (e.g., overfishing, stocking, seagrass and other habitat loss, indirect effects of nutrients)

Table 28. Indicator variables for evaluating the magnitude and effects of nutrients, including advantages and disadvantages. From:(Carleton et al. 2010)

	Importance	Linkages to, or Effects of, Nutrients	Advantages	Disadvantages
Clarity	• Affects growth of plants and phytoplankton	• Nutrient enrichment enhances phytoplankton growth, reducing clarity	• Easy to measure (photosynthetically active radiation [PAR], Secchi) • Clear linkage to important aquatic life (e.g., seagrass) • Sensitive to nutrient enrichment • Responsive to water quality management	• Confounding factors (e.g., inorganic particles, dissolved organic carbon [DOC])
Dissolved Oxygen	• Hypoxia kills fish and invertebrates • Hypoxic or low DO areas nullified as suitable habitat	• Nutrients affect organic loading through algal growth, depleting oxygen • Nutrients accelerate decomposition rates by microbial stimulation, consuming oxygen	• Existing criteria • Well established basis for protection of aquatic life • Clear linkages to nutrient enrichment • Extensive database	• Need to model relationship between nutrients and DO
Chlorophyll a	• Chlorophyll is an indicator of phytoplankton production and biomass	• Nutrients are key limiting factors for algal growth	• Responsive to nutrients • Biomass is a well-established as indicator of phytoplankton production • Biomass data in estuarine waters are routinely monitored and data are generally abundant • Satellite-derived chlorophyll data readily available in many coastal waters	• Establishing protective concentrations for non-seagrass uses is less well studied • Other factors can interfere with evaluating stressor-response relationships • Field-collected biomass data in coastal (offshore) waters are limited • Lack of phytoplankton data in healthy canals
Total Nitrogen	• N is typically more limiting of algal growth than P in estuarine systems	• N directly related to phytoplankton production in N-limited systems	• Estuarine water quality best predicted in the short term by antecedent TN loading rates or freshwater discharge • TN concentration is associated with TN loading over the long term	• Nutrient transport and transformation processes complex
Total Phosphorus	• Algal production can be P-limited in areas with less soil P such as in South Florida	• P directly related to phytoplankton production in P-limited systems • P-limitation more common in spring when N loading is highest	• TP loading best predicts water quality response in P-limited systems • TP concentration is associated with influent TP loading over the long term	• Water quality response relationship less strong in N-limited systems

After the regionalization of estuarine zones and selection of specific endpoints and indicators it is likely that three approaches and three indicators would be used for developing numeric nutrient criteria in estuaries. These include: (1) reference conditions, (2) stressor-response relationships, and (3) water quality simulation modeling that could be used independently or in combination with the other two methods to develop numeric criteria for chlorophyll-*a*, TN and TP (Carleton et al. 2010). For the majority of Florida's coastal waters, EPA is considering a reference-based approach with satellite-derived chlorophyll-*a* (Chl_{RS}-a) observations. Satellite ocean color remote sensing technology has advanced over the past decade and historical Chl_{RS}-a data are available for the past ten years. In contrast there is relatively little field monitoring data of chemical and biological constituents along the Northwest Gulf Coast and Atlantic Coast of Florida.

Coastal physical drivers such as wind, currents, and tides are known to influence coastal chlorophyll dynamics together with nutrient loadings from the land. All of these processes can be characterized better when using remote sensing as a reference condition approach. Therefore based on available data EPA is considering the use of remote sensing data to develop numeric criteria for the Northwest and West Gulf Coasts, and Atlantic Coastal Areas of Florida.

Due to interference from colored dissolved organic matter and bottom reflectance on satellite measurements, EPA has ruled out the derivation of numeric criteria using remote sensing data in coastal waters from Apalachicola Bay to Suwannee River (Big Bend) and South Florida (Carleton et al. 2010). Instead EPA is recommending a different approach for deriving numeric criteria for nitrogen/phosphorus pollution in South Florida marine and inland flowing waters. EPA has defined South Florida inland flowing waters as free-flowing, predominantly fresh surface water in a defined channel, and includes, streams, rivers, creeks, branches, canals, freshwater sloughs, and other similar water bodies located in the South Florida nutrient watershed region. South Florida marine waters include estuarine and coastal waters extending three nautical miles offshore. For these waters, EPA has recommended a reference-based approach to derive numeric TN and TP criteria for South Florida inland flowing waters and numeric chlorophyll-*a*, TN, and TP criteria in South Florida marine waters using least-disturbed sites that support balanced natural populations of aquatic flora and fauna.

Alternative methods of criteria derivation for inland flowing waters that EPA may consider include 1) stressor-response relationships between chlorophyll *a* and TN and TP, and 2) a distributional approach using all sites. However, EPA did not recommend a new TP criteria for canals in the Everglades Protection Area (EvPA) in deference to the Everglades Forever Act (EFA) and existing standards (Florida Department of Environmental Protection 2010a).

As previously noted, the federally promulgated NNC recognized the need to protect downstream uses and incorporated the concept of downstream protection values (DPVs) for lakes (United States Environmental Protection Agency 2010a). That is water quality standards in streams must ensure the attainment and maintenance of downstream water quality standards. Similarly, EPA proposed deriving numeric nutrient criteria for streams in Florida in order to protect the estuarine waterbodies that ultimately receive nitrogen/phosphorus pollution from the watershed. These criteria, which EPA will refer to as Downstream Protection Values, or DPVs, will apply in place of the stream's TN and TP criteria if the applicable DPV is more stringent. The conceptual approach that EPA is considering for developing stream DPV criteria will begin with estimates of limits on TN and TP loading rates that are needed to support balanced natural populations of aquatic organisms in estuarine waters. EPA envisioned setting loading limits as part of the criteria development effort for estuarine waters. The protective load limits would be scaled by average streamflow entering the estuary to determine criteria for TN and TP concentrations in streams as they discharge into estuaries. Finally, DPVs could be determined for upstream reaches within watersheds by evaluating expected losses and/or permanent retention of TN and TP within the stream network. Because of the complexities associated with the managed flows in South Florida inland flowing waters the fraction of TN or TP from the upstream tributary reach that eventually flows into marine waters cannot be estimated or predicted. Therefore, EPA suggested expressing DPVs at the terminal reach of the tributary into an estuary as protective concentrations or, alternatively, protective loads.

As previously described the SAB completed their review of the TSD and has issued their final comments (Science Advisory Board 2011). The draft review comments issued by the SAB were available for public review. The public and FDEP were given opportunities to submit review comments of the TSD to the SAB. The FDEP did provide review comments (Florida Department of Environmental Protection 2011d). A summary of their key comments are listed in Table 29.

The SAB review of the Florida Estuarine TSD was released on July 19, 2011 (Science Advisory Board 2011). Numerous review comments were provided that described the strong points and weaknesses of the approaches recommended. None of these are unique to the proposed approach recommended in the TSD. Instead they mostly reflect ongoing issues surrounding the ability of current technology and science to predict causal relationships between nutrients and indicators of eutrophication. Examples of some of the more important comments provided by SAB included taking into account other variables that influence chlorophyll-*a*, the appropriateness of TN and TP versus reactive N and P, defining end-points for both causal and response variables that equate with community "balance", using TN and TP loadings versus concentrations as drivers, the inability of chlorophyll-*a* to measure species composition and productivity, the inability of water column chlorophyll-*a* to predict impacts to seagrass from epiphyte or macroalgae fouling, the need to calibrate satellite imagery with real time chlorophyll-*a* measurements, and the inclusion of other endpoints including dissolved oxygen, algal community structure, primary productivity and benthic community structure. There were also recommendations on how to establish reference conditions by statistical models. We describe in more detail the major review comments provided by SAB.

The SAB acknowledged the substantial effort that already had been made by EPA to develop the TSD. However, the SAB concluded that much work remains to be done to develop nutrient criteria for Florida waters (for example, to develop and validate models for numerous estuarine systems). To guide its development of nutrient criteria, the EPA proposed a conceptual model that links nitrogen and phosphorus levels in Florida waters to biological endpoints to be protected using one or more analytical approaches.

Table 29. Key review comments provided by FDEP to the SAB on the proposed EPA method to derive NNC for estuaries, coastal waters, and southern inland flowing waters (Florida Department of Environmental Protection 2011d).

1. EPA document is an excellent review of background information on the development of NNC.

2. EPA guidance is similar to draft methods being developed by FDEP for estuarine waters entitled "*Draft: Overview of approaches for numeric criteria development in marine waters"*, which was released in December 2010 (Florida Department of Environmental Protection 2010c). However, different terminologies were used in both documents for similar processes and concepts.

3. Major difference in state versus federal guidance documents was the level of detail provided.

4. Agreed estuarine NNC should be derived individually for each estuary. However, NNC derived for open bay portions of the estuary should not apply to enclosed tidal creeks, salt marshes, mangrove swamps, embayments or marine lakes. NNC for these systems should be developed separately.

5. Felt that the TSD implied all estuaries are impaired for nutrients when many are not

6. Agreed that there is a need to defined or identify "healthy, well balanced aquatic communities" used in reference condition approach.

7. Agreed that statistical methods used to define current data needs to account for natural variability. Need to manage type 1 errors, i.e. identifying a healthy estuary as impaired.

8. NNC should reflect the spatial variability in nutrient and chlorophyll-*a* levels either by establishing different criteria for other parts of estuary or addressing relationships between nutrients and salinity.

9. EPA TSD authors noted preference for using stressor response relationships and water quality simulation models, but need to acknowledge limitation of each approach including defining the range of uncertainty for dose response relationship and need to acknowledge the time constraints on our ability to create and calibrate water quality models, including data availability.

10. EPA recognized that current and future TMDLs adopted and approved by EPA could be used to develop NNC. However FDEP said that there are a variety of issues that must be addressed when translating nutrient TMDLs into NNC, including loading versus concentration issues.

11. FDEP noted that the TSD included the use of dissolved oxygen (DO) as an endpoint to be protective of faunal communities. However, EPA should recognize that many estuarine systems violated DO criteria due to natural reasons, unrelated to nutrients. FDEP suggested that DO needs and criteria should be based on estuary specific development.

12. FDEP noted that EPA TSD noted the absence of downstream protection values (DPVs) for estuaries. This is due to the fact that FDEP does not believe they are legally or technically required.

13. FDEP agreed with conclusion of EPA TSD, that is development of NNC for estuaries is hard due to the complex and sites specific response estuarine systems to excess nutrients. FDEP believes that agencies including EPA needs to resist urge to simplify things given limited time for NNC. Simplified NNC could results in over-protective NNC.

SAB stated that EPA believed that nitrogen and phosphorus may be limiting in different portions of the fresh-to-marine continuum, and in some cases may be co-limiting. Thus, a dual nutrient (N and P) strategy was warranted, and they agreed with EPA's decision to take this approach.

Although the general conceptual model presented by EPA in the TSD provided a starting point for choosing numeric criteria, the SAB had numerous concerns about how the stressor variables including TN and TP would be linked to measurable biological endpoints. The SAB recommended that the EPA provide a more detailed conceptual model that includes additional endpoints and flows, and suggested that system-specific diagrams be included for each of the four waterbody types (estuaries, coastal waters, inland flowing waters (including canals) in South Florida, and South Florida Marine waters).

The EPA had proposed three general approaches to relate nutrient levels to balanced natural populations in the various waterbodies considered. These included the (1) reference condition approach; (2) predictive stressor-response relationships; and/or (3) numerical water quality models. However, SAB noted that the EPA provided an uneven treatment of the three approaches (i.e., the emphasis on water quality modeling), and encouraged the EPA to continue to develop all three. The SAB also agreed that these approaches all have utility and recommended that a combination be used where data and models are available. However, they recommended that EPA should also provide more detail on the adequacy of the data for applying each approach; how decisions would be made on which approaches to use; and how discrepancies in targets derived from different approaches would be resolved.

Although a complete uncertainty analysis may not be feasible, the SAB felt the document should clearly indicate what is included in any uncertainty analysis undertaken or considered. In particular, the EPA may need to specify some probabilistic goals for meeting the specified nutrient criteria and then set thresholds for TN and TP loading to ensure that the NNC are met with a desired level of confidence. SAB stated that the proposed biological endpoints (healthy seagrasses, balanced phytoplankton biomass, and balanced faunal communities) are appropriate. However, the reviewers felt that it was critical that the EPA define "balanced" for each of these endpoints, preferably in quantitative terms.

The SAB agreed with the Agency's broad delineation of Florida coastal waters into four categories (estuaries, coastal waters, South Florida inland waters, and South Florida estuarine and coastal waters) for purposes of criteria development, but suggested some refinements to segmentation within these categories to address the unique nature and complexity of estuaries. The SAB also commented on plans by EPA to propose and use "*downstream protection values*" (DPV) criteria to ensure that upstream nutrient criteria will be set at levels that will also protect downstream estuaries. The SAB agreed with the goal of downstream protection from nutrient impact. However, the SAB was concerned with the overlap between the DPV and the Total Maximum Daily Load (TMDL) processes.

The SAB provided numerous recommendations to strengthen the application of the three approaches to develop numeric nutrient criteria for Florida waters. However, given EPA's short time frame, the SAB offered the following priority recommendations:

• In order to provide greater confidence in the criteria, SAB recommended a combination of approaches should be used to develop numeric nutrient criteria for each category of waters where data and models are available.

• For estuaries, the SAB recommended that the EPA adopt additional measures of seagrass health beyond the proposed use of chlorophyll-*a*, and encouraged the use of direct measures of the faunal communities to be protected, rather than relying on a dissolved oxygen criterion.

• For coastal waters, the SAB agreed that a criterion based on satellite-derived estimates of chlorophyll may be the only feasible approach for this large, poorly sampled region. However, the SAB recommended that the EPA expand the dataset to include waters farther than three miles offshore and verify and validate the strength of the relationship between pollutant loads from land and observed chlorophyll-*a* concentrations using direct measurements of nutrients, where possible.

• For South Florida inland waters, the SAB was not convinced by the available data that nutrient criteria based on instream protection values were meaningful for man-made and managed canals. They stated that these canals do provide ecosystem services, but habitat quality and flows, instead of nutrients, probably has the greatest influence on biological condition in these managed waterways. The SAB did agree that nutrients in canal waters should be managed to ensure downstream, estuarine designated uses.

• For South Florida coastal and estuarine waters, the SAB recommended that seagrass endpoints be considered in addition to chlorophyll-*a*.

• If the DPV approach is pursued, the SAB recommended that apportionment strategies not preclude flexible nutrient allocation across tributaries to achieve the necessary estuarine load reductions.

In closing, the SAB encouraged the EPA to continue efforts to develop NNC for Florida estuarine and coastal waters, using the best available scientific data and methods. Ongoing changes in regional hydrology and climate, which will alter freshwater flows (and therefore, nutrient concentrations) and associated ecological responses, make it necessary that adopted nutrient criteria be revisited periodically in an adaptive management approach.

Ongoing State of Florida Nutrient Criteria Development Efforts

The most recent actions pertaining to NNC development in Florida can be found at the FDEP web page http://www.dep.state.fl.us/water/wqssp/nutrients/ . Due to the rapidly changing situation in this state as it pertains to NNC, it is advised that the reader consult this web site for new developments. There is likely that new developments in NNC will occur in Florida over the next few years for multiple reasons. First, the EPA is still under a court ordered schedule for the development of federally promulgated standards. Also, most recently the State of Florida formally requested the EPA to rescind the federally promulgated freshwater NNC, and allow the state adopt both freshwater and marine NNC. As a result, based on recent information the FDEP continues to discuss possible options and alternatives to federal promulgation of NNC. The outcome of this is unknown, however additional technical information and guidance will likely be produced that will likely be beneficial to any state considering development of NNC.

As stated earlier the State of Florida has been working on the development of NNC formally since 2002 with the release of three Nutrient Criteria Development Plans in 2002, 2007 and 2009 (Florida Department of Environmental Protection 2002a; Florida Department of Environmental Protection 2007; Florida Department of Environmental Protection 2009b). During the latest standards revision in 2010 no major changes occurred, although draft criteria where in the process of being developed for consideration. During and through the EPA promulgation of Florida inland water quality standards the FDEP continued to work on development of NNC including drafting of estuarine NNC and/or approaches for deriving NNC in estuarine systems. However, extensive work on inland freshwater criteria by FDEP was halted. Three notable activities and publications were produced concurrently to or after the release of 2010 Florida State Standards and EPA promulgated freshwater NNC. These include 1) publication of the draft state technical guidance for derivation of marine NNC, 2) publication of proposed estuary specific NNC based in part of the state technical guidance document and 3) drafting of proposed revisions to the NNC in the state water quality standards. We provide a short review of each below.

Estuarine Technical Support Document

The FDEP published several drafts of the estuarine technical support document (ETSD) entitled "*Overview of approaches for numeric nutrient criteria development in marine waters*" (Florida Department of Environmental Protection 2010b). A final version of the document has not been approved. The most recent draft was published in December 2010. The guidance provided methodology for derivation of NNC in estuaries. The methods were developed with the guidance of the marine technical guidance committee (MTAC).

The ETSD summarized the approaches that FDEP and local Florida scientists are utilizing to develop numeric nutrient criteria (NNC) for Florida's estuarine and coastal waters. FDEP stated that the primary purpose of the NNC is to protect healthy, well-balanced natural populations of flora and fauna from the effects of excess anthropogenic nutrient enrichment. Estuarine and marine aquatic life use support was generally considered to be more sensitive to anthropogenic nutrient enrichment than other designated uses, such as human health/recreation.

Florida estuaries and coastal systems exhibit significant variation in natural geomorphology, hydrology, and water quality. Multiple factors, such as daily tidal fluxes, seasonal freshwater inflows, temperature regime, habitat, and biogeochemistry vary considerably between and within individual estuaries. Florida's estuaries and coastal systems are subject to an assortment of freshwater sources. Florida has a variety of estuarine ecosystem types including river-dominated alluvial systems, those possessing extensive seagrass communities, salt marsh dominated systems, mangrove dominated systems, systems dominated by inputs from blackwater rivers, and those systems where coral reefs are the dominant feature. These differing influences result in a range of characteristic biological communities, each of which must be understood in the context of potential nutrient responses. Due to the diversity of Florida's estuaries and associated marine systems, FDEP has fundamentally recommended development of an "estuary-specific" approach. This required that all existing information for each individual estuary would be synthesized, and criteria bee based on the ecological endpoints most relevant for each particular system. Concurrent to the development of the ETSD the FDEP also produced technical support documents and recommended NNC for each of the major estuarine systems in the state. These are presented in the next section.

In the ETSD the FDEP used the term "estuaries and coastal waters" because it was used by EPA in its determination letter that NNC were required to implement the federal Clean Water Act (CWA) in Florida. EPA's Nutrient Criteria Technical Guidance Manual for Estuaries broadly defines estuaries to include all shallow coastal ecosystems, including "tidal rivers, embayments, lagoons, coastal river plumes, and river dominated coastal indentations," and defines coastal waters as those that "lie between the mean highwater mark of the coastal baseline and the shelf break, or approximately 20 nautical miles offshore when the continental shelf is extensive" (United States Environmental Protection Agency 2001j). The FDEP pointed out that Florida water quality standards do not define "estuaries." Instead, they define "coastal waters" as "all waters in the state that are not classified as fresh waters or as open waters" and define "open waters" as "all waters in the state extending seaward from the most seaward 18-foot depth contour line (3-fathom bottom depth contour) which is offshore from any island; exposed or submerged bar or reef; or mouth of any embayment or estuary which is narrowed by headlands. Thus, "coastal waters" as defined in Florida's water quality standards are equivalent to EPA's definition of estuary, and "open waters" are equivalent to EPA's term "coastal waters." FDEP planned on using its definitions for "predominantly marine waters" (defined as "surface waters in which the chloride concentration at the surface is greater than or equal to 1,500 milligrams per liter" and "predominantly fresh waters" (defined as "surface waters in which the chloride concentration at the surface is less than 1,500 milligrams per liter" to distinguish where estuarine and freshwater criteria apply. FDEP stated that there has been some discussion on whether the estuarine criteria would also apply to tidal creeks in addition to open bays. The ETSD had not clearly clarified this issue in the December 2010 draft.

Under the “estuary-specific” approach the FDEP first identified the major estuarine/coastal systems in Florida and then synthesized all available, relevant information for each distinct area. FDEP worked with local experts and scientists, then identified the most sensitive, valued ecological attributes for each system and subsequently determined the nutrient regime that would result in the protection of that resource, which means maintaining full support of aquatic life use. FDEP compiled the following information was compiled for each individual estuary or marine system throughout the state:

• A physical/chemical description of each system, including causal parameters (nutrients) and supporting variables (hydrodynamics, water residence time, transparency, salinity, dissolved oxygen [DO], etc);

• A biological description of each system, including key biological response variables. The type, quality, community structure, and areal extent of valued ecological attributes were documented, emphasizing those expected to respond to anthropogenic nutrient enrichment, including seagrass, coral, hardbottom benthic communities, phytoplankton, epiphytes, benthic invertebrates, and fish;

• The main sources of nutrients, including any point sources and dominant land uses in the watershed;

• The available scientific evidence quantifying the relationship between anthropogenic nutrient inputs and adverse effects on biological communities, including both primary responses (e.g., excess phytoplankton or macroalgal growth) and secondary responses (e.g., reduction in depth to seagrass, etc.);

• Existing regional nutrient loading and hydrodynamic models, especially those able to predict the fate and transport of nutrients to estimate assimilative capacity; and

• Proposed numeric targets needed for protecting or restoring the system, including a demonstration of the bases for the nutrient targets (Florida Department of Environmental Protection 2010b).

The FDEP’s initial effort consisted of soliciting input from local area experts by conducting a series of nine public workshops in February and March 2010. Scientists most familiar with each estuary were invited to attend and assist in the process which focused on the goal of describing relationships between nutrient loading/concentrations and valued ecological attributes Figure 14. These experts provided information and in some cases, assisted in writing the documents for each system. The FDEP then synthesized the information in reports, focusing on the requirements for developing water quality standards and NNC.

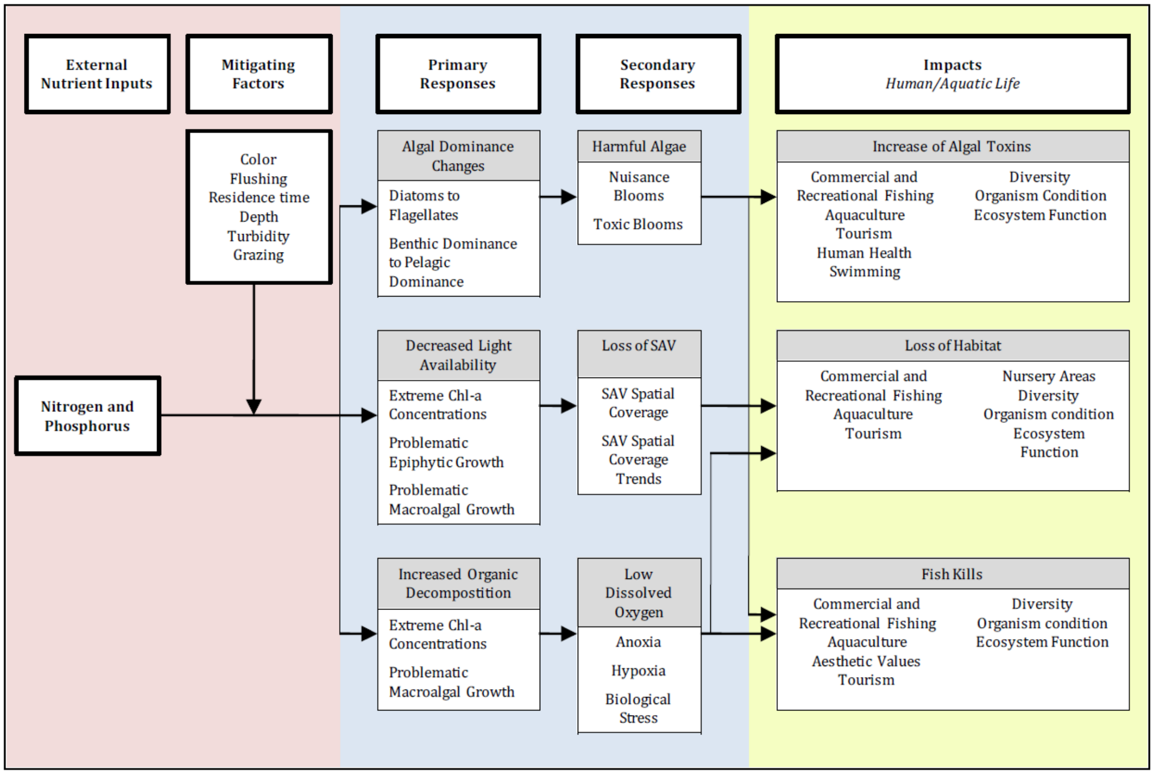


Figure 14. Simplified eutrophication conceptual model used by FDEP to assess impacts of nutrients on aquatic life and human uses. From: (Florida Department of Environmental Protection 2010b). Model adapted from (Bricker et al. 1999). Relationships between nutrients and biological responses are highly influenced by system type and mitigating factors.

The FDEP pointed out that NNC must protect existing designated uses for an estuary. In the case of aquatic life use, this meant preventing biological impairment. The FDEP has historically defined biological impairment caused by anthropogenic nutrient enrichment as levels that cause imbalances of native flora or fauna. For over 30 years, Florida has relied on narrative nutrient criteria: "*In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna*" (Florida Department of Environmental Protection 2010a). FDEP also pointed out that federal and state regulations require not only that the criteria protect the designated use, but they must also be based on a sound, scientific rationale, include sufficient parameters to protect the designated use, and support the most sensitive use. In Florida, the vast majority of waters are designated to support healthy, well-balanced aquatic communities and to provide for recreation in and on the water. The ETSD provided various approaches to translate this narrative statement into NNC. Unlike many toxic pollutants, the ETSD pointed out that nutrients exist naturally in the environment and are absolutely necessary for life. Nutrients are usually not directly toxic (with the exception of ammonia, which is controlled by existing water quality criteria in all states); therefore, the use of a "toxics-based" risk model was inappropriate for nutrients.

A key consideration for NNC development is how a state defines a healthy, well-balanced community. The FDEP and EPA have historically considered a healthy community as one that maintains a characteristic community structure and function (specific to the resource), while allowing for small fluctuations in aquatic biological community structure compared to background condition. Therefore FDEP concluded that a healthy, well-balanced community is not restricted to one described as “pristine” or “undisturbed.” As part of the development of the EPA Biological Condition Gradient, national experts from academia, EPA, and state environmental protection agencies agreed that ecosystem change is acceptable if the following conditions are present:

• There continue to be reproducing populations of sensitive taxa;

• An overall balanced distribution of all expected major groups is maintained; and

• Ecosystem functions are largely intact due to redundant system attributes (Davies and Jackson 2006; United States Environmental Protection Agency 2005).

The FDEP has historically used a *weight-of-evidence approach*. to determine when a system is healthy versus “imbalanced”. FDEP summarize that this is accomplished by using the best scientific information available information to estimate the normal structure and function of the system while accounting for inherent variability. Then a particular system is evaluated to determine if significant departures from the expected conditions have occurred, that is beyond natural variation. FDEP pointed out that although standardized multimetric biological indices have been established for freshwater streams and lakes, the complexity of marine systems has thus far precluded the development of a marine standardized index, making a *weight-of-evidence* approach the best option for assessing marine system biological health. This involves gathering site-specific information for each distinct estuary, carefully evaluating the many factors that influence the biological integrity of the ecosystem, and using scientific reasoning to reach a conclusion about the system’s relative health with respect to all potential stressors including human and natural influences. FDEP pointed out that some systems may have factors other than nutrients (e.g., decreased or altered freshwater inflows) causing stress, which complicates the assessment. However, these other factors need to be identified and evaluated because reduction of nutrient loads and concentration may not result in any beneficial improvements in systems affected by these other stressors.

In order to develop NNC that are protective of a well-balanced community, FDEP pointed out that it is necessary to account for natural variability in both the nutrient regime and in the biological communities, and account for other influences on the ecosystem (Figure 15). FDEP pointed out that even healthy, well-balanced communities will at times exhibit moderate changes in community structure compared with natural background conditions, yet may remain fully functional.

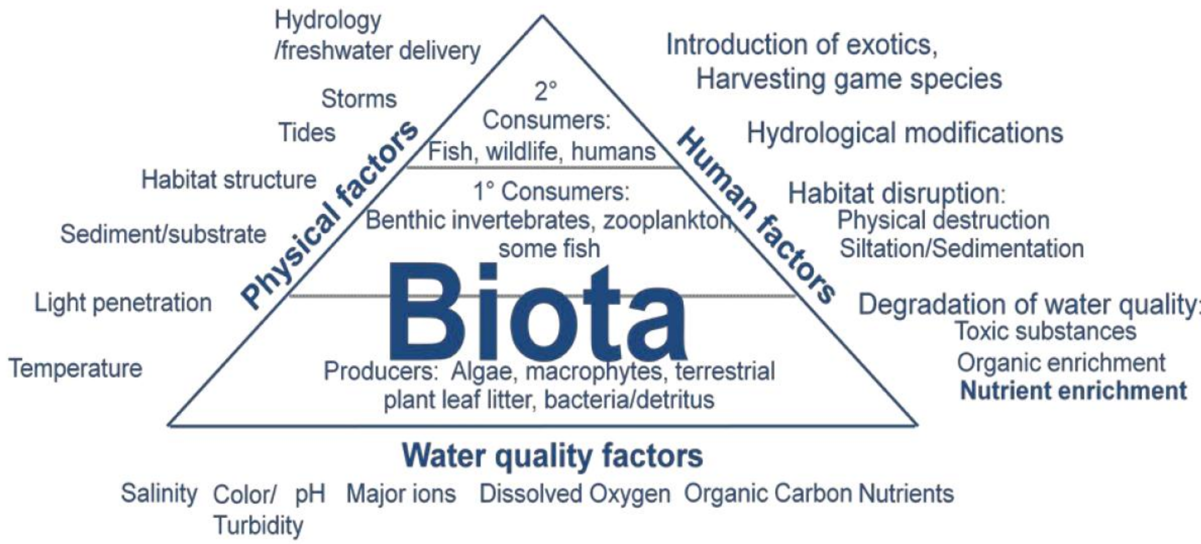


Figure 15. Natural and human factors affecting marine ecosystems. Nutrient effects must be understood in the context of how these factors interact and their ultimate influence on ecosystem structure and function. From:(Florida Department of Environmental Protection 2010b).

FDEP stated that nutrient criteria must be based on a sound scientific rationale, which includes employing legally defensible data (e.g. following FDEP's Quality Assurance Rule) and providing a reasonable ecological process linking nutrients to designated use. The criteria derivation and validity should also be reproducible by other scientists, account for and manage confounding factors during derivation, and control for Type I and Type II errors. FDEP defined a Type I error rate as incorrectly concluding that a system is impaired, when it is actually healthy (a "false positive"). In contrast a Type II error consists of incorrectly concluding that a system is healthy, when it is actually impaired (a "false negative").

During FDEP's extensive data-gathering exercise, each estuary report included a checklist that summarized all available information related to the symptoms of nutrient enrichment, including hypoxia, algal blooms, loss of seagrass, and fish kills. An example from their ETGD is presented (Table 30). The checklist of symptoms of eutrophication for each estuary provided very important information relevant to the development of NNC, particularly in those cases where FDEP determined that the estuarine system was healthy. The ultimate determination of whether an estuary was healthy was conducted using a site-specific, weight of evidence approach. That is individual symptoms of eutrophication would not automatically exclude estuaries from being considered as having a healthy aquatic community. Issues that should be taken into account include the timing, duration, frequency, and spatial extent of any observed symptoms. Furthermore FDEP recognized that the presence of some of the factors related to eutrophication, such as low DO, high indicator bacteria and/or red tide algae, while potentially related to human effects, do not necessarily equate with the effects of anthropogenic nutrient enrichment. Non-nutrient related effects, such as high-volumes of freshwater releases (resulting in adverse salinity fluctuations) can also be a factor.

Table 30. Example of checklist of nutrient enrichment symptoms for St. Joseph Bay, Florida - = Empty cell/no data. From: (Florida Department of Environmental Protection 2010b).

Response Variable	Observed Historically?	Observed Currently?	Explanation	Source
Low DO (hypoxia/anoxia)	No	No	The St. Joseph Bay system is shallow, well-mixed, and open to the Gulf of Mexico.	Department (Office of Coastal and Aquatic Managed Areas [CAMA]) 2009
Reduced clarity	No	No	Secchi depths long-term average 7 to 8 feet.	Department (CAMA) 2009
Increased chlorophyll *a* concentrations	No	No	Chlorophyll *a* concentrations are low throughout the bay.	Department/coast data (2000–09)
Phytoplankton blooms (nuisance or toxic)	Yes	Sporadic	Episodic *K. brevis* blooms, which begin in offshore waters and are transported into the bay by currents. Conditions within the bay are not responsible for the blooms.	Fish and Wildlife Research Institute (FWRI) http://research.myfwc.com/features/category_main.asp?id=2309; Livingston 2010
Problematic epiphyte growth	No	No	No problematic epiphyte growth reported.	-
Problematic macroalgal growth	No	No	No problematic macroalgal growth has been reported for the system.	-
Submersed aquatic vegetation (SAV) community changes or loss	No	No	Estimates of SAV coverage vary, but areas with SAV are stable. Communities dependent on seagrasses are characterized as healthy.	Sargent 1995; Florida Environmental Research Institute (FERI) 2007; Department (CAMA) 2009
Emergent vegetation community changes or loss	No	Yes	Some small amount of marsh loss due to physical disturbance.	-
Coral/hardbottom community changes or loss	Not applicable	Not applicable	-	-
Impacts to benthic community	No	No	A 3-year study by CAMA shows a diverse, abundant juvenile fish and invertebrate community associated with seagrass. Scallop population healthy.	Department (CAMA) 2009
Fish kills	Yes	Sporadic	Related to *K. brevis* blooms or brevetoxins present in the water column when bloom observed. The source of the blooms is offshore water.	FWRI http://research.myfwc.com/fishkill/

The generally preferred approach by FDEP for deriving a numeric water quality criterion is via a demonstrated cause-effect (also called dose-response or stressor-response) relationships that clearly links a meaningful threshold (a sensitive biological indicator endpoint) to a level of the given pollutant. In addition, the meaningful threshold must be linked to designated use support, (e.g. healthy, well-balanced aquatic community). The resulting NNC must be established at a level that will support the designated use and will protect against negative responses in the aquatic biological community that are inconsistent with the designated use.

After synthesizing extensive nutrient and biological information, the Department identified dose-response relationships in only a few of Florida's marine systems (although a relationship between nutrients and chlorophyll-a was observed using a statewide data set, which FDEP indicated will be discussed and evaluated with the MTAC at future meetings). A major finding reported in the ETGD was that during the data-gathering phase of this project, many Florida expert marine scientists provided information that most Florida estuaries were currently healthy, or did not suffer from nutrient-related issues. Because of this, alternate approaches for criteria development were necessary for most systems. Through this process of gathering site-specific information, the FDEP identified three main approaches appropriate for establishing numeric criteria in Florida estuaries (Florida Department of Environmental Protection 2010b). These include:

1. Maintain healthy existing conditions approach: This approach provides for maintaining the current nutrient regime in a system determined to be biologically healthy (from the standpoint of nutrient enrichment). Variations of this approach are used in systems that historically exhibited adverse responses, but due to restoration actions or other reasons, their current status is healthy; or in systems that may not currently be biologically healthy, but nutrients are not the cause of the impairment.

2. Historical conditions approach: This method identifies a protective nutrient regime based on a historical period associated with biologically healthy conditions. The healthy conditions typically occurred prior to subsequent nutrient enrichment and biological imbalances.

3. Total Maximum Daily Load (TMDL) modeling or response-based approach: Determination of the maximum allowed nutrient loadings based on demonstrated cause-effect relationships between biological (or response-based) indictors and nutrients. A variation of this approach includes the use of an estuarine model that predicts nutrient response variables (chlorophyll-*a*, DO, etc.) and sets nutrient limits that ensure protection of the designated use.

Under the "*maintain healthy existing approach*" the EPA NNC development guidance recommends a "reference condition" approach for criteria development in the absence of cause-effect relationships (United States Environmental Protection Agency 2001j). "Reference-based" approaches are based on the theory that the continued maintenance of nutrient levels (the data distribution) associated with healthy biological conditions will fully support the designated use and protect and support those uses into the future. However, FDEP points out and the technical guidance emphasizes that that exceeding a criterion derived from a "reference-based approach" does not automatically mean that deleterious biological responses, or use impairment, will occur. FDEP further stated that a criteria derived using a "reference-based approach" is inherently protective of the resource, provided the following are true:

• Information indicates that the waterbody fully supports a healthy, well-balanced community;

• The reference waterbody must be similar and comparable to the target population of estuaries to which it will be compared; and

• The nutrient regime (data distribution) is sufficiently characterized, including the full range of temporal and spatial variability.

The FDEP believed that the probability of being overprotective (Type 1 error rate) or under-protective (Type II error rate) should be both minimized wherever possible.

FDEP in cooperation with marine experts, identified a number of estuaries that can be characterized as healthy and attaining designated use. These systems either exhibit the minimal eutrophication responses illustrated in Figure 14 or, if biological stress was observed, evidence was presented that nutrients were most likely not the cause for the response. For the "healthy existing conditions" approach, it was concluded that the observed nutrient regime was inherently protective of the system under the conditions unique to that system. Although some signs of biological stress may have been observed in some of these estuaries, the preponderance of the information indicates that eutrophication did not cause or contribute to the degradation. The technical arguments and data supporting these healthy existing condition determinations are presented in a series of technical support documents for each estuary that were assembled by the FDEP and local experts, and are available on the FDEP website (http://www.dep.state.fl.us/water/wqssp/nutrients/estuarine.htm). In the following section we also summarize this data in tabular format in the following section.

Potential deleterious responses to elevated nutrient levels were summarized into checklists of nutrient enrichment symptoms for each system, and the weight of evidence approach described above was used to determine if designated use was being supported. These checklists provided a summary of the detailed information presented within each individual estuary report. The "healthy existing conditions" approach can be used to ultimately derive protective NNC for an estuary where the supporting data and information provides sufficient evidence that the estuary is currently meeting its designated uses.

Within the ETGD, the FDEP described their process to derive NNC that include the necessary components of a criteria that meets the requirements of state and federal Clean Water Act (CWA) including magnitude, frequency, and duration components (Florida Department of Environmental Protection 2010b). Magnitude was defined as a measure of how much of a pollutant may be present in the water without an unacceptable adverse effect. Duration was defined as a measure of how long a pollutant may be above the magnitude, and frequency is defined as how often the magnitude may be exceeded without adverse effects. As noted previously, it is preferable to derive the magnitude component of a criterion through a cause-effect relationship (such as that measured through a laboratory or mesocosm toxicity test). The magnitude would then be set at a level that would protect a majority of the sensitive aquatic organisms inhabiting the system. However, without such a demonstrated cause-effect relationship, the magnitude may be set at a level designed to maintain the current data distribution (i.e. historical condition), accounting for natural temporal variability.

If response-based data are available, frequency and duration components for criteria are established at levels that result in minimal long-term effects on aquatic life uses. However, when a criterion is derived using a reference distribution there is no direct link to any observed cause-and-effect relationship. Consequently we can only conclude that maintaining the reference distribution will preserve the uses associated with that distribution. Therefore, the frequency and duration components are also established as additional descriptors of the reference condition data distribution. Specifically, to determine compliance with criteria these components should be part of a statistical test designed to determine whether the long-term distribution has shifted upward (or potentially downward) from the reference distribution. This test could then be used to establish whether future monitoring data are consistent with the magnitude (e.g., long-term average) defined by the baseline period. In addition, this shift would determine whether compliance with NNC is still occurring.

FDEP argued that estuarine NNC based on the reference approach as outlined here should be less likely to have Type II errors (concluding systems healthy when in fact it is impaired) because the criteria are derived from a long-term dataset representing an ecological condition that is not harmed by excess nutrients. Therefore, it is very unlikely that a strategy designed to maintain the existing distribution of nutrient values would result in Type II errors. From a biological standpoint, the "healthy" biota should be entirely adapted to the existing nutrient regime (including its range of variability, which includes some naturally higher levels). Therefore, harmful ecological changes would not be expected to occur unless the overall nutrient regime was increased (shifted) in a statistically significant manner over the baseline nutrient regime. Furthermore, due to mitigating factors such as additional assimilation, limited transparency, and short water residence time, statistically significant increases in nutrients (when compared with a baseline period) may still be able support a healthy, well-balanced estuarine community.

Based on the very low probability of committing a type II error the FDEP believed that it was more important to control Type I errors (incorrectly concluding that a system is impaired, when it is actually healthy a "false positive"), and proposes to establish a reasonable Type I error rate target of 10%. A common method of reducing type 1 error rates is to increase the amount of replication. So, the type I error rate could potentially be reduced by increasing the assessment period (number of years) and the allowable number of exceedances. FDEP attempted to this by analyzing the data set using cumulative binomial frequency distributions for assessment periods, ranging from 3 to 7 years, where the annual probability of is 0.5. FDEP concluded that although increasing the assessment period and number of exceedances would reduce the Type I error, the number of exceedances required to achieve an acceptable Type I error (e.g., 10%) would also increase and would result in an impractical assessment tool due to the delayed response time. A more viable alternative is to adjust the probability of annual exceedance (p).

The magnitude component represents a level of nutrients demonstrated to be protective of the designated use. For the "healthy existing conditions" approach, the magnitude may be interpreted as the central tendency of the baseline data distribution and may be set at a level that represents a long-term average condition of that distribution. St. Joseph Bay was provided as an example of this approach. This estuary has been monitored for 9 years (2001-2009) at 8 water quality monitoring stations, and based on the assessment by experts has been biologically healthy for the entire period. For this example, natural log-transformed total phosphorus (TP) data were averaged by station and year, for years with at least 4 samples. The resulting station annual averages were then averaged by year and then across years to calculate a long-term network geometric mean of 13.14 micrograms per liter (μg/L). This magnitude component therefore represented the maximum allowable central tendency of a frequency distribution and would be protective of the designated uses. FDEP pointed out that due to the lack of cause-effect relationships between nutrients and biological response, that this value may still be somewhat overly protective.

FDEP used the geometric mean in the St. Joseph Bay example because nutrient data are typically positively skewed. A distribution is said to be positively skewed if the values in the distribution tend to cluster toward the lower end of the scale (that is, the smaller numbers) with increasingly fewer values at the upper end of the scale (that is, the larger numbers). In this situation the geometric mean is generally considered to be the most robust estimate of the central tendency for positively skewed data. It is the mean of the logarithms, transformed back to the original data. For positively skewed data, the geometric mean is typically very close to the median. When the logarithms of the data are symmetric, the geometric mean is also an unbiased estimate of the true median (Helsel and Hirsh 1992). For distributions that are positively skewed and vary over orders of magnitude (such as microorganisms or nutrients), the geometric mean is a more accurate indicator of the central tendency than the arithmetic mean (Sanders et al. 2003). FDEP stated that the use of a geometric mean, coupled with a defined period, has precedent both within Florida and nationally. For example, the Everglades phosphorus criterion is expressed as both annual and long-term geometric means (Florida Department of Environmental Protection 2010a). Geometric means are also used in EPA-approved NNC in Hawaii and Oklahoma (Hawaii Department of Health 2009; Oklahoma Department of Environmental Quality 2010; Oklahoma Water Resources Board 2010; State of Hawaii 2009).

FDEP stated that Dr. Xufeng Niu, Florida State University (FSU) Professor of Statistics, evaluated the nutrient data used for their analysis and supported their Department's assumption of a log-normal distribution(Florida Department of Environmental Protection 2010b). Dr. Niu noted that nutrient data typically follow or approximate a log-normal distribution, but acknowledged that this assumption can only be verified with large datasets (such as those with over 200 data points). FDEP stated that he concluded that it is acceptable to assume a log-normal distribution even if deviations from a true log-normal distribution occur at the tails of the sampled distribution, as long as the fit is very good at the 75th percentile.

For the "*maintain healthy existing conditions*" approach, the FDEP proposed establishing the magnitude at the following:

1. An annual geometric mean, not to be exceeded more than once over a five- year period; and

2. A long-term geometric mean of the distribution, expressed as a five-year geometric mean, never to be exceeded.

The objective of these two magnitude components is to maintain the long-term average concentration at the level observed in the baseline data set (e.g., 13.1 µg/L TP in St. Joseph Bay). Exceedance of one or both of these components would provide strong evidence that waterbody nutrient levels had increased above the baseline distribution. The five-year geometric mean is intended to preserve the baseline central tendency, while the annual limit accounts for natural variability above the central tendency.

To be protective, the duration of the criteria (e.g., annual geometric mean, long-term mean) must be linked to the response time frame of the sensitive endpoint. If a sufficiently robust cause-effect relationship documented in the literature or through monitoring data demonstrates that an adverse response occurs over a short time frame, then short-term averaging periods (e.g., 1 to 30 days) would be appropriate for nutrient criteria, provided the response can be linked to nonattainment of the designated use. If, however, such a short-term response cannot be demonstrated, or there is no indication of designated use impairment, then longer averaging periods that are scientifically defensible are needed. FDEP stated that during development of freshwater criteria EPA and FDEP found poor statistical relationships between nutrients and daily chlorophyll-*a* values, but much better fits at annual time steps. EPA used these relationships to propose nutrient criteria for Florida lakes expressed as annual geometric means. Coincidentally, the use of an annual geometric mean was consistent with the derivation of the magnitude and observed response time frame.

Because criteria derived using the "healthy existing conditions" approach are not linked to any particular response time frame, this approach does not suggest any inherently protective duration. However, an analysis of the relationships between chlorophyll-*a* and phosphorus and nitrogen concentration in Florida's healthy estuaries demonstrates the linkage between long-term nutrient levels and response. FDEP stated that they had preliminary evidence suggesting that a long-term duration is in fact appropriate for the purposes of establishing NNC. Therefore, FDEP is proposing that the duration of NNC be expressed over periods ranging from one to five years.

Given the goal of maintaining an existing frequency distribution, a scientifically defensible approach would be to use the frequency and duration components, in conjunction with magnitude, to assess whether the distribution has shifted in estuaries (Florida Department of Environmental Protection 2010b). Previous proposals by EPA have utilized three-year assessment periods to express the magnitude and duration nutrient criteria components. Although it is possible to construct a test that achieves the

10% Type I error rate target over a 3-year period, a slightly longer period (5 years) will provide better control for Type II error and will more fully capture climatic cycles (e.g., El Niño, La Niña, and the Atlantic Multi-decadal Oscillation), which tend to be longer than 3 years in Florida. Furthermore, a 5-year period is consistent with both the state's 5-year 303(d) assessment and National Pollutant Discharge Elimination System (NPDES) permit renewal cycles.

An acceptable excursion frequency can be set using a five-year period as the basis of assessment. The excursion frequency should account for interannual nutrient patterns and be established at a frequency that allows for effective and timely nutrient control—i.e., it should account for and allow natural interannual variability associated with climatic cycles, and recognize that multiple high nutrient years can occur in succession. A consideration of this interannual correlation would suggest that the excursion frequency should allow for multiple excursions in a five-year period, such as two out of five or three out of five years. However, regulatory agencies often target a more rapid assessment period to allow for the implementation of corrective action in a timely manner, making less frequent excursions more desirable for expressing the criteria (e.g., only once in a five-year period).

Once an acceptable excursion frequency has been selected, a nutrient target can be set at a level that is expected to result in no more than a 10% Type I error rate, given the observed variability in the baseline dataset. The target is set at a percentile or upper prediction interval that corresponds with a 5-year cumulative exceedance probability of no more than 0.9. FDEP stated that they were currently evaluating the relative merits of the 2-in-5 year and 1-in-5 year excursion frequencies(Florida Department of Environmental Protection 2010b).

The ETSD provides guidance for development of NNC in systems where excessive anthropogenic nutrient loading has historically resulted in biological impairment in a marine/estuarine system, and if nutrient and biological data are available both before and after this disturbance. The recommended approach for this scenario is called the *Historical Conditions Approach.* This approach is similar to the *Maintain Healthy Conditions Approach* previously described. The *Historical Conditions Approach* requires the following:

• A positive demonstration that the system was biologically healthy during the reference period;

• Adequate nutrient and biological data associated with pre- and post-disturbance; and

• A response variable that links the nutrients to impairment.

For example, FDEP provides an example where extensive pre- and post-disturbance data are available from Perdido Bay. These data document a period when a healthy, well-balanced biological community was characteristic of the system, before anthropogenic nutrient loading resulted in adverse responses. The Department proposed to derive criteria based on the distribution of nutrient data during the healthy "baseline period," when the waterbody was biologically healthy and achieved its designated use. The derivation of the criteria would then follow the procedure described in the "maintaining healthy existing conditions" section.

The "*response-based approach*" is the preferred method for developing NNC, but the approach to date has generally been limited to cases where there have been demonstrated adverse biological responses to anthropogenic nutrient enrichment. A description of this approach is provided verbatim from the ETSD (Florida Department of Environmental Protection 2010b). For this approach to be scientifically defensible, the dose-repose relationship must be explicitly quantified, within a range of uncertainty, and criteria must be established at a concentration (or loading) where the adverse response is not expected to occur, given a specified confidence level. This type of information is available for estuaries that have been identified as impaired by nutrients and for which nutrient TMDLs were developed.

FDEP pointed out that nutrient TMDLs have been developed for several major estuarine systems in Florida. These TMDLs have generally been based on one of two main approaches: (1) combined hydrodynamic and water quality models that use literature-based relationships between nutrient levels and algal growth; or (2) empirical relationships between nutrient levels (concentration or load) and some biological response, typically chlorophyll-*a* or seagrass distribution.

Since nutrient TMDLs have the same basic goal as NNC (i.e. to establish the amount of nutrients the waterbody can assimilate and still maintain applicable water quality standards), the FDEP plans to submit the adopted nutrient TMDLs to EPA as the estuary-specific NNC for each of these systems. However, a variety of issues and questions must be addressed when translating nutrient TMDLs into NNC, including whether it is necessary to convert TMDL loads into concentration, how to convert loads into concentrations (if necessary), clarification of the frequency and spatial component of the TMDL, and how to develop NNC for causal variable not addressed by the TMDL. It should be noted that nutrients are being controlled indirectly through a basin wide TMDL for Chesapeake Bay which has resulted in chlorophyll-*a* NNC (United States Environmental Protection Agency 2010b). This will be discussed briefly later in this report.

Estuarine Specific Criteria - Overview

As previously noted NNC were proposed and published during 2010 for multiple individual estuarine systems in 2010. The general methodology was based on guidance outlined in (Florida Department of Environmental Protection 2010b) which was in some cases being concurrently developed. Based on their analyses preliminary NNC were either drafted by FDEP or proposed by other organizations for consideration by FDEP. The proposed criteria citations are listed in Table 31 and linked to excerpts from original documents summarizing the criteria. The approach used to develop NNC varied depending on the availability of monitoring data and the estimated status of attainment of designated uses, with a focus on two uses "*shellfish propagation or harvesting and recreation propagation*" and "*maintenance of a healthy well-balanced population of fish and wildlife*" in respect to nutrients. In particular FDEP focused on several key attributes or services provided in each estuary including support of fisheries, shellfish harvesting (e.g. frequency of harmful algal blooms), seagrasses, and fish and wildlife. The proposed criteria were based on whether estuaries fell into several classes including 1) currently meeting all designated uses (*Maintain Healthy Conditions Approach*), 2) had met designated uses at some time but may not being do so at the present (*Historical Condition Approach*) and 3) is currently not meeting designated uses but is being managed under a TMDL or modeling approach that depends on a cause-effect relationship to define the relationship between nutrients and response variables that ultimately influenced designated uses (*response-based approach*).

Estuarine Specific Criteria - Alligator Harbor

FDEP proposed three sets of potential criteria for Alligator Harbor: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010q). The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in Alligator Harbor, as well the annual limits for each segment, are provided in Table 32. Because of the small size and relative homogeneity of the system, segmentation was not needed, and a single set of criteria is proposed.

Estuarine Specific Criteria – Apalachee Bay

FDEP intends to proposed three sets of potential criteria for greater Apalachee Bay when sufficient data are available: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010t). FDEP is in the process of collecting nutrients and chlorophyll a at 12 stations throughout Apalachee Bay. Until sufficient data are available to calculate concentration-based criteria as described above, interim criteria would consist of preventing increases in the loads from the St. Marks, Aucilla, Econfina, and Steinhatchee Rivers, as shown in Table 33. The Fenholloway River loads are addressed via an EPA approved TMDL.

Table 31. Proposed numeric nutrient criteria for individual Florida estuaries.

Estuary System	Criteria Development Method[1]	Date of Draft Plan	Proposed Criteria Listing	Citation
Alligator Harbor	M	8/24/10	Table 32	(Florida Department of Environmental Protection 2010q)
Apalachee Bay	R	8/24/10	Table 33	(Florida Department of Environmental Protection 2010t)
Apalachicola Bay	M	8/24/10	Table 34	(Florida Department of Environmental Protection 2010r)
Choctawhatchee Bay	M	8/24/10	Table 35	(Florida Department of Environmental Protection 2010d)
Ochlockonee Bay	M	8/24/10	Insufficient data	(Florida Department of Environmental Protection 2010u)
Pensacola Bay	M	8/24/10	Table 36	(Florida Department of Environmental Protection 2010g)
Perdido Bay	H	8/24/10	Incomplete - draft	(Florida Department of Environmental Protection 2010h)
St. Andrew Bay	M	8/24/10	Table 37	(Florida Department of Environmental Protection 2010i)
St. Joseph Bay	M	8/24/10	Table 38	(Florida Department of Environmental Protection 2010j)
Biscayne Bay	M	8/26/10	Table 39	(Florida Department of Environmental Protection 2010s)
Florida Bay	M	8/26/10	Table 40	(Florida Department of Environmental Protection 2010e)
Florida Keys	M	8/26/10	Table 41	(Florida Department of Environmental Protection 2010k)
Lake Worth Lagoon	H	8/26/10	Further analysis required	(Florida Department of Environmental Protection 2010f)
Loxahatchee Estuary	M	8/26/10	Table 42	(Florida Department of Environmental Protection 2010m)
Southeast Coastal Reef Tract	M	8/26/10	Table 43	(Florida Department of Environmental Protection 2010n)
St. Lucie Estuary	R	8/26/10	0.72 mg/L TN and 0.081 mg/L TP as a long-term average	(Florida Department of Environmental Protection 2010{)
Halifax Estuary	H/R	8/31/10	Varies with segment: TP; 0.39-0.61 mg/L TN and 0.12 mg/L TP as annual medians; and 0.51-0.90 mg/L TN and 0.18-0.19 mg/L TP as July–September medians	(Florida Department of Environmental Protection 2010x)
Indian River Lagoon	R	8/31/10	chlorophyll-*a* 5-2.5 μg/L in BRL and North IRL, and 4-2 μg/L in the central IRL	(Florida Department of Environmental Protection 2010l)
Nassau-St. Mary's Estuary	M/R	8/31/10	Incomplete – no recommendation	(Florida Department of Environmental Protection 2010z)

Estuary System	Criteria Development Method[1]	Date of Draft Plan	Proposed Criteria Listing	Citation
St. Johns River Estuary	R	8/31/10	chlorophyll-*a* target of 40 μg/L not to be exceeded more than 10% of the time. Table 46	(Florida Department of Environmental Protection 2010y)
Tolomato-Matanzas Estuary	M	8/31/10	Table 47	(Florida Department of Environmental Protection 2010|)
Sarasota Bay	R/M	9/2/10	0.25-1.34 μg/L TN 5.1-11.8 μg/L chlorophyll-*a*	(Janicki Environmental Inc. 2010b)
Southwest Florida Estuaries	M	9/2/10	Table 48-Table 50	(Florida Department of Environmental Protection 2010o)
Springs Coast	M	9/2/10	Table 51	(Florida Department of Environmental Protection 2010p)
St. Joseph Sound & Clearwater Harbor	incomplete	9/2/10	incomplete	(Florida Department of Environmental Protection 2010v)
Suwannee/Waccasassa/Withlacoochee Estuaries	M	9/2/10	Table 52 - Table 53Table 54	(Florida Department of Environmental Protection 2010w)
Tampa Bay	R	9/2/10	Annual geometric mean •Old Tampa Bay TN=0.93 mg/L TP=0.31 mg/L •Hillsborough Bay TN=1.01 mg/L TP=0.45 mg/L •Middle Tampa Bay TN=0.87 mg/L TP=0.29 mg/L •Lower Tampa Bay TN=0.74 mg/L TP=0.10 mg/L. Derived from: Table 56	(Janicki Environmental Inc. 2011)

[1] M = Maintain Healthy Conditions Approach; H = Historical Condition Approach; R = response-based approach e.g. stressor-response regression, TMDL or modeling done or in process.

Table 32. Proposed numeric nutrient criteria for Alligator Harbor, including TP, TN, and chlorophyll-*a*.[1] For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations throughout the system exceed the network average more than twice in a 5 year period. The last row shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. Note: FDEP is evaluating if there are currently sufficient data to promulgate numeric nutrient criteria for this system. From:(Florida Department of Environmental Protection 2010q)

Proposed Criteria	TP (ug/L)	TN (ug/L)	Chlorophyll *a (ug/L)*
Existing Long Term Geometric Mean	27.325	364.892	4.863501
Maximum Allowed Long Term Geometric Mean	30.058	401.382	5.350
Annual Geometric Mean for the Network of Stations (2 of 5 year exceedance rate)	41.242	495.999	8.802
Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)	45.707	534.890	9.991

[1]Because of the small size and relative homogeneity of the system, segmentation was not needed, and a single set of criteria is proposed.

Table 33. TN and TP loads and concentrations for the St. Marks, Aucilla, Econfina, and Steinhatchee Rivers (Apalachee Bay System). From:(Florida Department of Environmental Protection 2010t).

System	TN Loads (ranges) (lbs/day)	TN Loads (long-term geometric means) (lbs/day)	TP Loads (ranges) (lbs/day)	TP Loads (long-term geometric means) (lbs/day)	TN Concentration (long-term geometric means) (mg/L)	TP Concentration (long-term geometric means) (mg/L)
St. Marks[1]	400-4,000	1,337	70-340	155	0.36	0.04
Aucilla[2]	100-6,000	2,040	10-370	120	1.1	0.06
Econfina[3]	100-1,700	478	1-95	40	0.89	0.09
Steinhatchee[4]	<100-3,500	760	1-280	62	0.92	0.08

[1] St. Marks loads (1950–2009) were calculated by HydroQual from USGS Station: 02326900 near Newport, and thus do not include Wakulla River nutrients. Concentration data are from LakeWatch 2001 estuarine stations; the sites used were WAK1-3, sampled on January 10, March 23, and May 17, 2001.
[2] Aucilla loads (1950–2009) were calculated by HydroQual from USGS Station: 02326512 near Scanlon. Concentration data are from LakeWatch 2001 estuarine stations; the sites used were TAY1-3, sampled on January 10, March 23, and May 17, 2001.
[3] Econfina loads (1950–2009) were calculated by HydroQual from USGS Station: 02326000 near Perry. Concentrations are annual geometric means for the Econfina River area, Stations E06, E08, E09, E10, and E11 (annual calculations include May–October data only). Data are from BVA, and calculations performed by HydroQual.
[4] Steinhatchee loads were calculated by HydroQual from USGS Station: 02324000 near Cross City. Concentration data are from Project COAST (1997–2008). Monthly average TN and TP were collected for 10 estuarine stations in the Steinhatchee Estuary.

Estuarine Specific Criteria – Apalachicola Bay

FDEP proposed three sets of potential criteria for Apalachicola Bay: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010r).

The proposed long-term criteria for the protection of a healthy, well-balanced aquatic community in Apalachicola Bay, as well the annual limits for each segment, are provided in Table 34. Due to the importance of providing a minimum nutrient load (and flow) to maintain the health of the bay, FDEP was also evaluating the need to establish a minimum nutrient load for Apalachicola Bay, and is seeking input on this concept.

Estuarine Specific Criteria – Choctawhatchee Bay

FDEP proposed three sets of potential criteria for Choctawhatchee Bay: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010d). The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in Choctawhatchee Bay, as well the annual limits for each segment, are provided in Table 35.

Estuarine Specific Criteria – Ochlockonee Bay

Although there is evidence to indicate that maintaining the existing nutrient regime would fully support the designated use of Ochlockonee Bay, FDEP concluded that there currently are insufficient data to propose numeric criteria (Florida Department of Environmental Protection 2010u). FDEP recommended that a monitoring program be established to secure the needed nutrient and chlorophyll a data. When adequate data are available, the criteria would be established using the “healthy existing conditions” approach.

Estuarine Specific Criteria – Pensacola Bay

FDEP proposed three sets of potential criteria for Pensacola Bay: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010g). The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in Pensacola Bay, as well the annual limits for each segment, are provided in Table 36.

Table 34. Proposed numeric nutrient criteria for all segments of Apalachicola Bay, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. From:(Florida Department of Environmental Protection 2010r)

TP (ug/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Apalachicola Bay	0.042	0.046	0.073	0.077
East Bay	0.041	0.045	0.064	0.071
St George Sound	0.023	0.025	0.051	0.054
St. Vincent Sound	0.043	0.047	0.074	0.074
Bay Wide	0.041	0.046	0.070	0.077
TN (ug/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Apalachicola Bay	0.69	0.76	1.00	1.03
East Bay	0.68	0.74	0.85	0.89
St George Sound	0.45	0.50	0.57	0.59
St. Vincent Sound	0.64	0.70	0.75	0.75
Bay Wide	0.68	0.75	0.95	1.00
Chlorophyll a (ug/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Apalachicola Bay	5.14	5.65	11.08	12.75
East Bay	4.14	4.55	7.36	8.80
St George Sound	1.78	1.96	3.70	4.10
St. Vincent Sound	8.20	9.02	25.33	25.33
Bay Wide	5.42	5.97	10.45	12.91

Table 35. Proposed numeric nutrient criteria for all segments of Choctawhatchee Bay, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. N/A=Not applicable, because data were not sufficient for this analysis; criteria not yet proposed for segment. From:(Florida Department of Environmental Protection 2010d).

Total Phosphorus (µg/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
West	17	19	28	30
Central	16	18	25	26
East	23	25	26	27
Baywide	18	19	26	29
Total Nitrogen (µg/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Central	373	410	516	523
Middle	342	376	452	460
East	399	439	447	453
Baywide	370	407	502	514
Chlorophyll a (ug/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
West	3.59	3.95	5.18	5.31
Central	2.84	3.12	3.64	3.71
East	N/A	N/A	N/A	N/A
Baywide	2.93	3.22	4.26	4.79

Table 36. Proposed numeric nutrient criteria for all segments of Pensacola Bay, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. From: (Florida Department of Environmental Protection 2010g)

Total Phosphorus (mg/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
East Bay	0.022	0.024	0.033	0.038
Escambia Bay	0.032	0.035	0.050	0.055
Pensacola Bay	0.016	0.018	0.024	0.028
Santa Rosa Sound	0.019	0.021	0.035	0.043
Total Nitrogen (mg/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
East Bay	0.340	0.374	0.471	0.534
Escambia Bay	0.549	0.603	0.749	0.842
Pensacola Bay	0.373	0.410	0.512	0.552
Santa Rosa Sound	0.349	0.384	0.599	0.615
Chlorophyll *a* (ug/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
East Bay	3.21	3.54	5.32	5.35
Escambia Bay	5.28	5.81	10.0	11.4
Pensacola Bay	2.97	3.27	4.17	4.62
Santa Rosa Sound	3.50	3.85	5.00	5.08

Estuarine Specific Criteria – Perdido Bay

FDEP has yet to propose criteria for Pensacola Bay although data collected for this effort illustrated that protective nutrient loading to Perdido Bay, occurred during 1988 to 1991, associated with a healthy, well balanced community(Florida Department of Environmental Protection 2010h). FDEP is in the process of having additional meetings and analysis to accomplish this. We have not seen any new information on this bay system.

Estuarine Specific Criteria – St. Andrew Bay

FDEP proposed three sets of potential criteria: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010i). The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in St. Andrew Bay as well the annual limits for each segment, are provided in Table 37.

Estuarine Specific Criteria – St. Joseph Bay

FDEP proposed three sets of potential criteria: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010j). The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in St. Joseph Bay, as well the annual limits for single stations, are provided in Table 38.

Estuarine Specific Criteria – Biscayne Bay

FDEP proposed that the magnitude component of protective nutrient criteria for Biscayne Bay be expressed as a long-term geometric mean concentration target, derived as the geometric mean of the annual geometric mean concentrations from the long-term baseline dataset plus a 10% increase (Florida Department of Environmental Protection 2010s). The duration component of the criteria would be a 1-year assessment period, with the annual target being expressed as the 75th percentile for the geometric mean target based on a log-normal distribution. Finally, the frequency component of the criteria would be expressed as the annual target cannot be exceeded in more than 2 out of 5 years. The frequency and duration components were designed to assess whether the interannual variability is consistent with the maintenance of the long- term mean, considering natural variability around that mean. FDEP concluded that if the frequency and duration components of the criteria are satisfied, it can be concluded, with a known level of statistical certainty, that the long-term target is also being achieved.

Table 37. Proposed numeric nutrient criteria for all segments of St. Andrew Bay, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which a single station shall not exceed, by segment, more than twice in a 5 year period. From:(Florida Department of Environmental Protection 2010i).

Total Phosphorus (µg/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Central Bay	16.5	18.2	25.6	29.9
East Bay	13.8	15.2	20.1	25.9
Grand Lagoon	14.2	15.6	26.5	36.6
Mouth	9.0	9.9	12.5	13.7
North Bay	11.5	12.7	14.8	16.4
West Bay	16.1	17.7	22.3	26.1
Baywide*	16.1	17.8	22.7	26.4
Total Nitrogen (µg/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Central Bay	419	461	626	651
East Bay	N/A	N/A	N/A	N/A
Grand Lagoon	407	448	552	569
Mouth	322	354	508	526
North Bay	N/A	N/A	N/A	N/A
West Bay	415	456	555	582
Baywide*	415	456	575	626
Chlorophyll a (ug/L)				
Segment	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Central Bay	4.6	5.0	5.8	5.8
East Bay	N/A	N/A	N/A	N/A
Grand Lagoon	2.5	2.7	3.2	3.4
Mouth	2.1	2.3	3.0	3.0
North Bay	N/A	N/A	N/A	N/A
West Bay	3.3	3.6	5.5	6.4
Baywide*	3.5	3.9	5.8	6.1

N/A=not available. Data did not meet sufficiency requirements for analysis, so criteria not yet proposed for segment
*Baywide analysis did not include Grand Lagoon or Mouth segments

Table 38. Proposed numeric nutrient criteria for St. Joseph Bay, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations exceed the network average more than twice in a 5 year period, nor shall an individual station exceed the single station average more than twice in a 5 year period. From: (Florida Department of Environmental Protection 2010j).

Parameter (µg/L)	Existing Long Term Geometric Mean	Maximum allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 out of 5 year exceedance rate)	Annual Geometric Mean for a Single Station (2 out of 5 year exceedance rate)
Total Phosphorus (TP)	13.1	14.5	16.6	17.2
Total Nitrogen (TN)	225	248	279	308
Chlorophyll *a*	2.0	2.2	2.8	3.1

Table 39 provides the proposed long-term targets as well the annual limits for each sub-basin in Biscayne Bay. FDEP is now evaluating the similarities among the different sub-basins to determine if any of the sub-basins could be combined in respect to criteria development. Upon completion of this process FDEP may issue revised proposed NNC.

Estuarine Specific Criteria – Florida Bay

FDEP proposes three sets of potential criteria for Florida Bay: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period. The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in Florida Bay, as well the annual limits for each segment, are provided in Table 40. FDEP stated that establishing numeric nutrient criteria for Florida Bay was especially challenging because of the significant system-wide changes that have occurred in recent history making it difficult to establish the "natural" condition of the system. However, FDEP stated that since the mid-1990s, seagrasses and other components of the biological community, such as sponges, have been increasing and turbidity and chlorophyll a concentrations have been decreasing. FDEP believed that this recent period of record represents conditions that are supportive of healthy biology and indicate the system is currently meeting its designated use. Therefore the proposed numeric nutrient criteria would maintain nutrient concentrations at present levels.

Table 39. Proposed numeric nutrient criteria for all segments of the Biscayne Bay, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. From: (Florida Department of Environmental Protection 2010s).

Total Phosphorus ($\mu g\ l^{-1}$)				
	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedence rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Manatee Bay-Barnes Sound	6.90	7.59	10.13	10.28
South Central Outer-Bay	5.20	5.72	6.69	6.88
South Central Inshore	5.88	6.47	7.70	7.90
South Central Mid-Bay	5.31	5.84	7.06	7.31
Card Sound	5.90	6.49	7.87	8.04
Southern North Bay	7.86	8.65	9.98	10.19
North Central Inshore	5.59	6.15	7.49	7.62
North Central Outer-Bay	6.35	6.98	8.13	8.30
Northern North Bay	9.86	10.84	12.22	12.45
Total Nitrogen ($\mu g\ l^{-1}$)				
	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedence rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Manatee Bay-Barnes Sound	459	505	588	602
South Central Outer-Bay	190	209	250	259
South Central Inshore	391	430	504	518
South Central Mid-Bay	282	310	365	371
Card Sound	257	283	350	370
Southern North Bay	231	254	299	304
North Central Inshore	247	272	325	329
North Central Outer-Bay	221	243	286	289
Northern North Bay	235	259	310	315
Chlorophyll a ($\mu g\ l^{-1}$)				
	Existing Long Term Geometric Mean	Maximum Allowed Long Term Geometric Mean	Annual Geometric Mean for a Network of Stations (2 of 5 year exceedence rate)	Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)
Manatee Bay-Barnes Sound	0.50	0.55	0.89	0.91
South Central Outer-Bay	0.21	0.23	0.27	0.31
South Central Inshore	0.28	0.31	0.38	0.39
South Central Mid-Bay	0.25	0.28	0.34	0.36
Card Sound	0.34	0.37	0.52	0.55
Southern North Bay	0.85	0.93	1.10	1.15
North Central Inshore	0.32	0.36	0.46	0.50
North Central Outer-Bay	0.49	0.54	0.72	0.79
Northern North Bay	1.41	1.55	1.81	1.86

Table 40. Proposed numeric nutrient criteria for all segments of Florida Bay, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. From:(Florida Department of Environmental Protection 2010e).

Total Phosphorus ($\mu g\ l^{-1}$)				
Sub-basin	***Existing Long Term Geometric Mean***	***Maximum Allowed Long Term Geometric Mean***	***Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)***	***Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)***
Central Florida Bay	13.93	15.32	19.36	20.90
Southern Florida Bay	6.95	7.65	9.37	9.83
Western Florida Bay	12.02	13.22	15.67	17.63
East Central Florida Bay	5.89	6.48	7.60	7.89
Northern Florida Bay	8.18	9.00	10.91	11.38
Coastal Lakes	33.93	37.33	46.49	46.49
Total Nitrogen ($\mu g\ l^{-1}$)				
Sub-basin	***Existing Long Term Geometric Mean***	***Maximum Allowed Long Term Geometric Mean***	***Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)***	***Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)***
Central Florida Bay	723.18	795.50	1016.65	1052.98
Southern Florida Bay	486.38	535.02	660.53	693.87
Western Florida Bay	300.95	331.04	388.67	420.69
East Central Florida Bay	516.59	568.25	678.55	695.96
Northern Florida Bay	545.26	599.78	708.92	724.72
Coastal Lakes	938.85	1032.74	1305.93	1305.93
Chlorophyll a ($\mu g\ l^{-1}$)				
Sub-basin	***Existing Long Term Geometric Mean***	***Maximum Allowed Long Term Geometric Mean***	***Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)***	***Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)***
Central Florida Bay	1.33	1.47	2.07	2.24
Southern Florida Bay	0.52	0.58	0.76	0.83
Western Florida Bay	0.92	1.01	1.32	1.64
East Central Florida Bay	0.29	0.32	0.39	0.42
Northern Florida Bay	0.60	0.66	0.84	0.90
Coastal Lakes	6.53	7.18	9.55	9.55

Estuarine Specific Criteria – Florida Keys

FDEP proposes three sets of potential criteria for the Florida Keys: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period. The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in the Florida Keys, as well the annual limits for each segment, are provided in Table 41.

Estuarine Specific Criteria – Lake Worth Lagoon

The Lake Worth Lagoon has been adversely affected by anthropogenic activities, with habitat destruction, extreme salinity fluctuations, and turbidity/sedimentation being the chief issues of concern (Florida Department of Environmental Protection 2010f). The most sensitive biological endpoint in the lagoon is seagrass. Seagrass coverage decreased dramatically during the 1970s due to dredge-and-fill activities, and then increased significantly by 2001, but decreased moderately after the 2004 to 2005 hurricane damage. It is currently unclear if anthropogenic nutrients contribute to the seagrass losses, but chlorophyll-*a* values (4.4 μg/L from 2001 to 2006) have not been excessive.

FDEP proposed that a method analogous to the one employed at the adjacent Indian River Lagoon be used to establish numeric nutrient criteria for the Lake Worth Lagoon. That is depth to seagrass targets should be established, and the parameter most limiting transparency should be controlled to fully restore seagrass populations. This analysis may determine that the most effective management action to be a combination of turbidity reduction and hydrologic restoration, although some nutrient/chlorophyll reductions may also be needed to ensure that the Lake Worth Lagoon is meeting its designated uses and is maintaining a healthy, well-balanced community.

Estuarine Specific Criteria – Loxahatchee Estuary

FDEP proposed three sets of potential criteria: (a) a long-term geometric mean concentration; (b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and (c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period (Florida Department of Environmental Protection 2010m).

Table 42 lists the proposed long-term targets for TP, TN, and chlorophyll-*a* for the protection of a healthy, well-balanced aquatic community in the Loxahatchee Estuary, as well the annual limits for each segment. Because of the small size and relative homogeneity of the system, segmentation was not needed, and a single set of criteria is proposed.

Table 41. Proposed numeric nutrient criteria for all segments of the Florida Keys, including TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. From: (Florida Department of Environmental Protection 2010k).

Total Phosphorus ($\mu g\ l^{-1}$)				
Segment	**Existing Long Term Geometric Mean**	**Maximum Allowed Long Term Geometric Mean**	**Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)**	**Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)**
Marquesas	6.42	7.06	8.12	8.77
Back Country	8.72	9.59	10.88	11.61
Bayside	7.49	8.24	9.75	10.42
Dry Tortugas	5.86	6.45	7.79	8.26
Oceanside	5.66	6.23	7.33	7.89
Total Nitrogen ($\mu g\ l^{-1}$)				
Segment	**Existing Long Term Geometric Mean**	**Maximum Allowed Long Term Geometric Mean**	**Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)**	**Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)**
Marquesas	143	157	196	209
Back Country	196	216	247	269
Bayside	196	216	260	279
Dry Tortugas	129	142	184	194
Oceanside	147	162	186	204
Chlorophyll a ($\mu g\ l^{-1}$)				
Segment	**Existing Long Term Geometric Mean**	**Maximum Allowed Long Term Geometric Mean**	**Annual Geometric Mean for a Network of Stations (2 of 5 year exceedance rate)**	**Annual Geometric Mean for a Single Site (2 of 5 year exceedance rate)**
Marquesas	0.35	0.39	0.50	0.63
Back Country	0.36	0.39	0.50	0.65
Bayside	0.26	0.29	0.37	0.47
Dry Tortugas	0.21	0.23	0.31	0.37
Oceanside	0.19	0.21	0.28	0.33

Table 42. Proposed numeric nutrient criteria for TN in the Loxahatchee Estuary. Note: For compliance purposes, the long-term geometric mean shall not exceed the long-term limit, nor shall the average of all stations throughout the system exceed the network average more than twice in a five-year period. The last row shows the value which single station shall not exceed, by segment, more than twice in a five-year period. From: (Florida Department of Environmental Protection 2010m).

Proposed Criteria TN	Marine (mg/L)	Polyhaline (mg/L)	Meso/Oligohaline (mg/L)
Existing long-term geometric mean	0.62	0.97	1.16
Maximum allowed long-term geometric mean	0.68	1.07	1.28
Annual geometric mean for the network of stations (2 of 5 year exceedance rate)	1.11	1.48	1.54
Annual geometric mean for single site (2 of 5 year exceedance rate)	1.19	1.56	1.59
Proposed Criteria TP	**Marine (mg/L)**	**Polyhaline (mg/L)**	**Meso/Oligohaline (mg/L)**
Existing long-term geometric mean	0.019	0.039	0.067
Maximum allowed long-term geometric mean	0.021	0.043	0.074
Annual geometric mean for the network of stations (2 of 5 year exceedance rate)	0.027	0.052	0.09
Annual geometric mean for single site (2 of 5 year exceedance rate)	0.03	0.059	0.107
Proposed Criteria Chl-A	**Marine (ug/L)**	**Polyhaline (ug/L)**	**Meso/Oligohaline (ug/L)**
Existing long-term geometric mean	2.9	7.9	5.1
Maximum allowed long-term geometric mean	3.2	8.7	5.6
Annual geometric mean for the network of stations (2 of 5 year exceedance rate)	4.2	11.4	7.0
Annual geometric mean for single site (2 of 5 year exceedance rate)	5.1	13.0	7.5

Estuarine Specific Criteria – Southeast Florida Coastal Reef Tract

FDEP proposed three sets of potential criteria for the Southeast Florida Coastal Reef Tract: (1) a long-term geometric mean concentration; (2) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and (3) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period. The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in the southeast Florida coast are provided in Table 43. The proposed criteria are based on a data from sampling locations selected as representative of minimally affected by anthropogenic sources. Data from each of these sites were used to develop chlorophyll-*a* and DIN values.

Table 43. Proposed numeric nutrient criteria for TP, TN, chlorophyll-*a* and DIN (*μg/L*) for the Southeast Florida Coastal Reef Tract. From: (Florida Department of Environmental Protection 2010n).

Total Phosphorus

Depth	Long-Term Geometric Mean	Long-Term Limit	Network Average 2 Out of 5 Year Annual Limit	Assessed as a Single Site Geometric Mean 2 Out of 5 Year Annual Limit
Surface	7.13	7.85	9.7	9.9
Bottom	6.92	7.61	9.4	9.6
Surface to Bottom	7.04	7.74	9.6	9.7

Total Nitrogen

Depth	Long-Term Geometric Mean	Long-Term Limit	Network Average 2 Out of 5 Year Annual Limit	Assessed as a Single Site Geometric Mean 2 Out of 5 Year Annual Limit
Surface	118	130	164	168
Bottom	112	124	157	161
Surface to Bottom	116	127	161	165

Chlorophyll-*a*

Depth	Long-Term Geometric Mean	Long-Term Limit	Network Average 2 Out of 5 Year Annual Limit	Assessed as a Single Site Geometric Mean 2 Out of 5 Year Annual Limit
Surface	0.46	0.51	0.69	0.78
Bottom	0.38	0.41	0.54	0.60
Surface to Bottom	0.43	0.47	0.63	0.69

DIN

Depth	Long-Term Geometric Mean	Long-Term Limit	Network Average 2 Out of 5 Year Annual Limit	Assessed as a Single Site Geometric Mean 2 Out of 5 Year Annual Limit
Surface	9.1	10.0	12.6	13.3
Bottom	10.6	11.7	14.0	14.9
Surface to Bottom	10.1	11.1	13.5	14.2

Estuarine Specific Criteria – St. Lucie Estuary (SLE)

Following the adoption of a nutrient TMDL by rule in March 2009, FDEP initiated development of a Basin Management Action Plan (BMAP) pursuant to the 1999 Florida Watershed Restoration Act (FWRA) (Chapter 99-223, Laws of Florida) (Florida Department of Environmental Protection 2010{). The St. Lucie River Watershed Protection Plan published in 2009 included a chapter on TMDLs (Chapter 5) and inventories existing and planned programs and projects to determine the cumulative benefit provided by those initiatives. As described in the Plan, there are a number of structural and non-structural activities that are focused on reducing nutrient loads to the estuary and the frequency and duration of undesirable salinity ranges.

The nutrient TMDL considered TN and TP targets of 0.72 mg/L TN and 0.081 mg/L TP, respectively to determine reductions necessary to restore designated uses in the SLE. According to the 2004 Indian River Lagoon (IRL-S) Plan, these targets would be protective of both the SLE itself and SAV in the IRL. The FDEP proposed to adopt the TMDL targets as concentration based numeric nutrient criteria of 0.72 mg/L TN and 0.081 mg/L TP, respectively, that would apply throughout the SLE (North Fork, South Fork, Middle Estuary, and Outer Estuary) as a long-term average (Florida Department of Environmental Protection 2010{). The FDEP was in the process of soliciting additional public comment regarding adopting numeric nutrient criteria with both concentration and loading components.

Estuarine Specific Criteria – Halifax River Estuary (HRE)

FDEP conducted this study to support the development of NNC for the Halifax River Estuary (HRE)(Florida Department of Environmental Protection 2010x). The Halifax River is a 40-kilometer-long tidal estuary located on the Atlantic coast near Daytona Beach, with its major ocean connection situated at Ponce de Leon Inlet. Based on the results of the study three lines of evidence were tabulated and compared for the Halifax River Estuary (
Table 44 and Table 45). The results from the HRE-specific regression models and the general models compared well with the reference period (2000-08) results. For the south HRE, the results of a TN regression model did not compare well with predictions from the reference period method. This inconsistency was the only exception in an otherwise solid, weight-of-evidence case for the HRE.

For the north HRE, the potential for current (circa 2004) nutrient loadings to induce eutrophy has possibly been mitigated by the estuary's turbidity (more specifically non-algal turbidity), suggesting that current nutrient loadings can serve as the loading limits protective of the system's current trophic state (mesotrophy to oligo-mesotrophy). In addition, the three lines of evidence for the north HRE produced a tight range of annual and wet-season median concentrations. Therefore, the north HRE current loading estimates (ca 2004) and reference period results are proposed as that segment's nutrient criteria: 257,832 kg/yr TN and 43,494 kg/yr TP; 0.61 mg/L TN and 0.12 mg/L TP as annual medians; and 0.90 mg/L TN and 0.18 mg/L TP as July–September medians (
Table 44).

Table 44. Summary of lines-of-evidence results: loading and concentration limits for the north HRE.

Target condition is mesotrophy (chlorophyll-*a* targets are an annual median of 4.5 µg/L and a seasonal median of 7.9 µg/L for July through September). Source: (Florida Department of Environmental Protection 2010x).

-	TN (kg/yr)	TN (kg/yr)	TP (kg/yr)	TP (kg/yr)
Loading Limit (current loading)	257,832	257,832	43,494	43,494
-	Median (mg/L) Annual	Median (mg/L) July–September	Median (mg/L) Annual	Median (mg/L) July–September
Reference Period (2000–08)	0.61	0.90	0.12	0.18
Regressions (1992–2008 data)	0.58	0.90	Not significant	0.17
General Models	0.62, [a]	N/A	0.2, [a]	N/A

(-) = Empty cell/no data; kg/yr = Kilograms per year; mg/L = Milligrams per liter; N/A = Not applicable; [a]0.62 mg/L TN and 0.2 mg/L TP are predicted concentrations based on current loadings (ca. 2004).

Table 45. Summary of lines-of-evidence results: loading and concentration limits for the south HRE. Target condition is oligo-mesotrophy (chlorophyll-*a* targets are an annual median of 3.5 µg/L and a seasonal median of 5.8 µg/L for July through September). Source: (Florida Department of Environmental Protection 2010x).

-	TN (kg/yr)	TN (kg/yr)	TP (kg/yr)	TP (kg/yr)
Loading Limit (current loading)	222,000	222,000	38,000	38,000
-	Median (mg/L) Annual	Median (mg/L) July–September	Median (mg/L) Annual	Median (mg/L) July–September
Reference Period (2000–08)	0.39	0.51	0.12	0.19
Regressions (1992–08 data)	0.30	0.41	Not significant	0.15
General Models	0.42	N/A	0.135 (0.09, 0.18)[a]	N/A

For the south HRE, the current (circa 2004) loadings of TN and TP are proposed as loading limits. Current TN and TP loadings should maintain the oligo-mesotrophic condition in the south HRE. The predicted trophic state and concentration limits from the regression analysis and the general models support that conclusion and are generally consistent with the 2000–08 reference period results. Consequently, the south HRE current loadings (ca 2004) and reference period results are proposed as that segment's nutrient criteria: 222,000 kg/yr TN and 38,000 kg/yr TP; 0.39 mg/L TN and 0.12 mg/L TP as annual medians; and 0.51 mg/L TN and 0.19 mg/L TP as the July through September medians (Table 45).

Estuarine Specific Criteria – Indian River (IRL) and Banana River Lagoon (BRL)

The Indian River Lagoon (IRL) Basin is located along the east central coast of Florida and extends for 155 miles between Ponce de Leon Inlet near New Smyrna Beach (Volusia County) to Jupiter Inlet (Palm Beach County). The basin has been divided into six major subbasins: Mosquito Lagoon, North IRL, Banana River Lagoon, Central IRL, South IRL, and the St. Lucie River and Estuary. There have been extensive hydrologic modifications to the IRL watershed. As a result, the drainage area for the IRL has been expanded to well over 1.4 million acres.

The FDEP conducted a study to support the development of numeric nutrient criteria for the Indian River Lagoon system (IRL)(Florida Department of Environmental Protection

2010l). The primary purpose of the proposed numeric nutrient criteria is to protect healthy well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment. The investigators utilized several approaches to derive NNC.

The weight-of-evidence approach for IRBR consists of four separate analyses plus a consideration of addressing harmful algal blooms (HABs), with a focus on *Pyrodinium bahamense var. bahamense*, in the development of nutrient criteria. The different data analyses or lines of evidence used for the IRBR consist of an (1) application of sublagoon nutrient loading – seagrass depth-limit regression models (or the IRBR nutrient TMDL method), (2) a reference segment-year method, (3) sublagoon seagrass light attenuation models or optical models (OM), (4) two nutrient models that pertain to estuaries in general, and (5) a preliminary *P. bahamense* – TP relationship analysis.

FDEP described the seagrass light attenuation or optical model (OM). This model is composed of a series of multivariate regressions or optical models that were developed for the IRL system, including one specific to southern Mosquito Lagoon, which can be used to set levels for the major light attenuators (e.g., turbidity, chlorophyll-*a*) required to meet a seagrass light attenuation (K_d) target. The models are geometric mean function regressions (GMFR) that can deal with more than two explanatory variables. A GMFR is a Model II multiple regression that minimizes errors in the direction of all variables (x, y, and z), not just in the direction of the dependent variable (y), establishing a functional relationship among all variables. Thus, a GMFR equation can provide a unique solution no matter which one is used as the response variable (Florida Department of Environmental Protection 2010l).

Another major approach used by was a reference condition approach where the unit used was reference segment-year (RSY). This specific method is called the "*Reference segment-year*" method. Certain segments in each of the sublagoons have attained the "-10% DL" threshold (i.e., attained ≥90% of the seagrass depth-limit target) for particular seagrass mapping years, especially the very recent mapping years (Figure 36). Turbidity, chlorophyll-*a*, color, TN, and TP data were aggregated for those segment-years per sublagoon to calculate 6-month (March – August, seagrass growing season), 12-month or annual, and 18-month medians. Those selected periods immediately precede and overlap the growing season up through August of the seagrass mapping year. We report only the annual medians and the 90th percentile values (as representing maximum monthly values for the wet season) from the reference segment-year (RSY) method. It is assumed that results of the RSY method would generally indicate the water quality conditions required to attain the "-10% DL" threshold.

FDEP concluded that due to its ability to reduce light and therefore negatively affect seagrass depth limits and because it is a significant indicator of trophic status, phytoplankton or chlorophyll-*a* should be maintained at very low levels in the IRBR. Taken together, the seagrass light attenuation or optimal model (OM) and the reference segment-year (RSY) methods both predicted that the chlorophyll-*a* should be maintained well below 5 μg/L in BRL and North IRL, and below 4 μg/L in the Central IRL; maybe at even at 50% of those levels (2.0 to 2.5 μg/L) to achieve mesotrophy and depth limit targets. The nutrient concentrations estimated by the RSY method and general models should help not only achieve the chlorophyll-*a* limits but also help limit excessive growth of drift algae and epiphytes that can potentially restrict seagrass coverage.

Estuarine Specific Criteria – Nassau-St. Mary's Estuary

FDEP applied a general nutrient model to the St. Marys to predict limits or acceptable ranges of nutrient loadings and concentrations related to a desirable trophic state (mesotrophy or oligotrophy). It is an empirically defined relationship between water residence times and nutrient loading limits for mesotrophic Florida systems. Initial results showed that the line of best fit lies along the upper mesotrophic boundary. If, based on healthy biological communities, the waterbodies are meeting their designated uses, the trophic positions of the points in the graphs could be used as a basis for nutrient criteria, and the current TN and TP loadings can be considered the loading limits.

FDEP intends to propose three sets of potential criteria: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period. These calculations for the Nassau-St. Mary's Estuaries have not yet been completed.

Estuarine Specific Criteria – St. Johns River Estuary

The lower St. Johns River (LSJR) is a sixth-order, darkwater river estuary, and, along its length, it exhibits characteristics associated with riverine, lake, and estuarine aquatic environments (Florida Department of Environmental Protection 2010y). Eutrophication impacts associated with nutrient enrichment, such as elevated algal biomass, periodic blooms of nuisance and/or toxic algae, and fish kills, have been documented in the LSJR.

Portions of the LSJR were placed on the 1998 303(d) for development of nutrient Total Maximum Daily Loads (TMDLs). Through a collaborative approach with the St. Johns River Water Management District (SJRWMD) and FDEP, a nutrient TMDL for the main stem of the LSJR was adopted by the state and subsequently approved by EPA. A Basin Management Action Plan (BMAP) that identified a series of programs and projects that would be implemented by stakeholders in the basin to achieve the TMDL was adopted in October 2008.

In the freshwater segment of the LSJR, the TMDL was based upon a numeric chlorophyll-*a* target of 40 μg/L exceeded no more than 10% of the time based on a long-term average. The target was based upon several factors. First, chlrorophyll-*a* concentrations greater than 40 μg/L are generally recognized as causing nuisance conditions. Second, when above 40 μg/L, phytoplankton community composition typically consists of greater than 80 percent cyanobacteria. Third, site-specific analyses of zooplankton diversity and abundance indicated negative ecological effects are associated with concentrations of chlorophyll-*a* greater than 40 μg/L for prolonged periods. Fourth, in nutrient enrichment assays, the incidence of high microcystin concentration increased when chlorophyll-*a* exceeded 40 μg/L.

In the marine segment, nitrogen reductions were based on improving DO conditions during the July – September period. A State of Florida site specific alternative criteria (SSAC) in the marine segment was established based on the approach described in the EPA Ambient Aquatic Saltwater Criteria (Virginian Province; EPA-822-D-99-002)(Environmental Protection Agency 2000). This method uses information and data on the biological response of sensitive aquatic organisms to hypoxic stressors to derive DO criterion that provide adequate protection from acute and chronic effects of exposure to low DO levels in marine waters. In the Lower St. Johns, the calculated SSAC is a minimum DO concentration of 4 mg/L and a total fractional exposure to DO levels in the range of 4.0 to 5.0 mg/L of 1.0 or less over the year.

When the nutrient levels specified in the TMDL are achieved, the above described negative effects will not occur, and the designated use (healthy, well balanced aquatic communities) will be fully supported. The nutrient TMDL established the following allowable annual loads that would restore the Lower St. Johns and meet designated uses (Table 46). The Department proposed to adopt the annual TMDL nutrient loads for the marine portion of the LSJR as load based numeric nutrient criteria that would apply to the marine portion of the LSJR, and adopt the annual TMDL TN and TP loads for the freshwater portion of the river as downstream protection values that will protect the LSJR estuary. The chlorophyll-*a* target of 40 μg/L not to be exceeded more than 10% of the time is proposed as a numeric nutrient target applicable to the tidal freshwater portion of the LSJR as a long-term average. At the time of the proposed NNC FDEP was still soliciting input from the public regarding the potential adoption of numeric nutrient criteria based on concentration, as an alternative or in addition to the loading-based criteria developed under the TMDL. The FDEP was also soliciting input on the need for TP criteria for the marine portion of the river.

Table 46. Nutrient TMDL annual nutrient loads for the Lower St. Johns. (-) = Empty cell/no data.(Florida Department of Environmental Protection 2010y).

WBID Type	Parameter	TMDL (kg/yr)	WLA[1] (kg/yr)	LA (kg/yr)
Freshwater	-	-	-	-
2213I to 2213N	Total Nitrogen	8,571,563	236,695	8,334,868
2213I to 2213N	Total Phosphorus	500,325	46,357	453,968
Marine	-	-	-	-
2213A to 2213H	Total Nitrogen	1,376,855	1,027,590	349,265

Estuarine Specific Criteria – Tolomato-Matanzas Estuary (TME)

The Tolomato-Montanzas (TME) estuary is an 80-kilometer-long tidal estuary located on the Atlantic coast near the city of St Augustine, its major ocean connections are the St. Augustine and Matanzas Inlets (Florida Department of Environmental Protection 2010|). Based on available information the FDEP concluded that the Tolomato- Matanzas Estuary (TME) appears to have healthy well balanced biological. There are extensive salt marshes and mollusk reefs and a high diversity of plants and animals, including many protected species. The evidence presented in their technical document showed that aquatic life designated use in the TME is fully supported. FDEP therefore proposed that the numeric nutrient criteria be crafted to maintain the existing nutrient regime.

The three lines of evidence that were used in developing numeric nutrient criteria for the TME include:

- a reference period method;
- results from chlorophyll a – nutrient regression analyses; and
- two estuary empirical models

The chlorophyll-*a* and trophic responses of the TME segments appear to be affected by water residence time and nutrient loading. Nutrient loading is the one factor that can be controlled to manage the estuary's trophic response; the other two factors are largely natural factors that cannot be controlled. FDEP felt that the addition of numeric nutrient criteria can help ensure protection of the current trophic state. The recommended nutrient criteria are based on the reference-period concentration results and the current external loading rates, which can be rounded up to the nearest 10,000 kg/yr for TN and to the nearest 1,000 for TP (e.g., Tolomato TN loading limit of 76,727 kg/yr rounded up to 80,000 kg/yr)(Florida Department of Environmental Protection 2010|).

Table 47. Summary of lines-of-evidence results: loading and concentration limits for the Tolomato and north and south portions of the Tolomato Estuary. Source: (Florida Department of Environmental Protection 2010|).

Tolomato: mesotrophy (Chla targets: 4.5 µg/L annual median; 6.4 µg/L Jun – Sep median)

- = Empty cell/no data

Loading Limit (current loading)	TN (kg/yr) 76,727–80,000	TN (kg/yr) 76,727–80,000	TP (kg/yr) 11,264–12,000	TP (kg/yr) 11,264–12,000
-	*[TN] median (mean) (mg/L) Annual*	*[TN] median (mean) (mg/L) June-September*	*[TP] median (mean) (mg/L) Annual*	*[TP] median (mean) (mg/L) June-September*
Reference Period ('00-09 period)	0.52 (0.56)	0.61 (0.65)	0.085 (0.096)	0.095 (0.105)
Regressions ('86-09 data)	Not significant	0.62	Not significant	0.110
General Models	0.48	Not applicable	0.060	Not applicable

N. Matanzas: oligo-mesotrophy (Chla targets: 3.1 µg/L annual median; 4.0 µg/L Jun – Sep median)

- = Empty cell/no data

Loading Limit (current loading)	TN (kg/yr) 237,074–240,000	TN (kg/yr) 237,074–240,000	TP (kg/yr) 43,792–44,000	TP (kg/yr) 43,792–44,000
-	*[TN] median (mean) (mg/L) Annual*	*[TN] median (mean) (mg/L) June-September*	*[TP] median (mean) (mg/L) Annual*	*[TP] median (mean) (mg/L) June-September*
Reference Period ('00-09 period)	0.37 (0.41)	0.42 (0.46)	0.073 (0.083)	0.074 (0.085)
Regressions ('86-09 data)	Not significant	0.46	Not significant	0.095
General Models	0.38	Not applicable	0.073	Not applicable

S. Matanzas: mesotrophy (Chla targets: 4.3 µg/L annual median; 6.3 µg/L Jun – Sep median)

- = Empty cell/no data

Loading Limit (current loading)	TN (kg/yr) 208,025–210,000	TN (kg/yr) 208,025–210,000	TP (kg/yr) 37,142–40,000	TP (kg/yr) 37,142–40,000
-	*[TN] median (mean) (mg/L) Annual*	*[TN] median (mean) (mg/L) June-September*	*[TP] median (mean) (mg/L) Annual*	*[TP] median (mean) (mg/L) June-September*
Reference Period ('00-09 period)	0.45 (0.49)	0.54 (0.62)	0.089 (0.103)	0.112 (0.127)
Regressions ('86-09 data)	Not significant	0.61	Not significant	0.120
General Models	0.45	Not applicable	0.109	Not applicable.

Estuarine Specific Criteria – Sarasota Bay Estuary (TME)

In October 2009, the Sarasota Bay Estuary Program (SBEP) Policy and Management boards directed the Technical Advisory Committee (TAC) to develop numeric nutrient criteria for the estuarine waters of the Sarasota Bay system (Janicki Environmental Inc. 2010b). Information regarding the process and data used to derive NNC for Sarasota Bay is provided verbatim with limited editorial comments (Janicki Environmental Inc. 2010b). This effort would fulfill the need for establishing NNC based on the best available data for the following SBEP estuarine segments:

- Palma Sola Bay
- Sarasota Bay
- Roberts Bay
- Little Sarasota Bay
- Blackburn Bay

A water quality subcommittee of the TAC began the NNC development process by reviewing existing seagrass and chlorophyll-*a* data and proposing a set of chlorophyll-*a* targets to support the development of the NNC. This review confirmed that the recent extents of seagrasses are meeting the established targets. Therefore the subcommittee determined that the recent chlorophyll-*a* concentrations and resultant water clarity must be protective of the seagrasses in each of the segments. Upon review of the chlorophyll-*a* concentration data, it was deemed appropriate to include mean chlorophyll-*a* concentrations from this overall period (2001-2005). These data were used to establish the targets for each segment. These targets are:

- Palma Sola Bay – 8.5 μg/L
- Sarasota Bay – 5.2 μg/L
- Roberts Bay – 8.2 μg/L
- Little Sarasota Bay – 8.2 μg/L
- Blackburn Bay – 6.0 μg/L

The subcommittee further recognized that there may be years in which these targets may be exceeded without causing significant reductions in seagrass cover. This means that there is some allowable, or acceptable, amount of variation that should not elicit a significant degradation in water quality and therefore seagrass coverage. The subcommittee defined this level of variation as “the standard deviation around the mean annual chlorophyll-*a* concentration in each segment for the entire period of record”. Therefore, a distinction is made between a target, i.e., a desired chlorophyll-*a* concentration and a threshold, i.e., a chlorophyll-*a* concentration above which undesirable chlorophyll-*a* concentrations exist and should not be exceeded. The chlorophyll-*a* threshold for each segment is “the sum of the target and the standard deviation around the mean annual chlorophyll a concentrations for that segment”. Therefore, the sum of the mean chlorophyll-*a* concentrations for 2001-2005 and the standard deviation around the mean annual chlorophyll-*a* concentrations for that segment are the thresholds that were used in the development of the numeric nutrient criteria in the SBEP estuarine waters. The proposed chlorophyll-*a* NNC are:

• Palma Sola Bay – 11.8 μg/L
• Sarasota Bay – 6.1 μg/L
• Roberts Bay – 11.0 μg/L
• Little Sarasota Bay – 10.4 μg/L
• Blackburn Bay – 8.2 μg/L

The water quality data used in these analyses were provided by Sarasota and Manatee counties. These data included monthly chlorophyll-*a*, TN, TP, salinity, color, turbidity, and other variables. The nutrient and hydrologic loading estimates were developed by applying the Spatially Integrated Model for Pollutant Loading Estimates (SIMPLE) which was designed and calibrated by Jones Edmunds & Associates, Inc. for Sarasota County. In addition to the water quality and nutrient loading data, estimates of residence times for each segment were derived based on the physical features and hydrologic loads for each segment.

A linear regression model approach was used to develop statistically defensible relationships between potential stressors and water quality responses. The independent variables used in the model building process included nutrient loadings, nutrient concentrations, and estimates of residence time. The loadings data included monthly hydrologic, TN, and TP loads as well as cumulative total loads extending from two to six months (e.g., 2-month cumulative TN load = TN load current month + TN load one-month prior). The water quality constituents included TN and TP concentrations along with numerous other constituents.

The stressor-response relationships for Roberts Bay, Little Sarasota Bay, and Blackburn Bay indicated very similar responses in chlorophyll-*a* concentration to changes in nutrient concentrations (Janicki Environmental Inc. 2010a). Specifically, two terms, TN concentration and season, explained more than 60% of the variation in the chlorophyll-*a* data. These results indicate that there are significant relationships between chlorophyll-*a* and TN concentrations in each of these segments and that these relationships vary between the wet and dry seasons. The relationship between chlorophyll-*a* and TN concentrations in Sarasota Bay is more complex. This relationship depends upon location within the segment (north vs. south) and the ambient water color. Based on the quantitative relationships between chlorophyll-*a* and TN concentrations in each of these segments and the chlorophyll a thresholds, the NNC expressed as mean annual TN concentrations were determined for each segment (Janicki Environmental Inc. 2010b). These criteria are:

• Roberts Bay – 0.54 mg/L,
• Little Sarasota Bay – 0.60 mg/L,
• Blackburn Bay – 0.43 mg/L, and
• Sarasota Bay – 0.28-1.34 mg/L (based on ambient water color for the period 1998-2009).

No significant relationship was found between chlorophyll a concentrations and either nutrient (TN or TP) concentrations or loadings in Palma Sola Bay. Given this result, an alternative method for proposing NNC for Palma Sola Bay was necessary. The SBEP water quality subcommittee of the TAC considered three potential candidate methods for estimating the TN criterion for Palma Sola Bay. These methods included a logistic regression approach, a change point analysis approach, and an approach similar to that used to define the chlorophyll-*a* thresholds. All three potential candidate methods give relatively similar results. The subcommittee recommended the third option – i.e., that based on the 2001-2005 ambient TN data. The proposed NNC for Palma Sola Bay was a mean annual TN concentration of 0.93 mg/L. The full TAC concurred with the subcommittee's recommendation on 23 July 2010.

Estuarine Specific Criteria – Southwest Florida Estuaries

The Florida in cooperation with local scientists, produced a technical support document to support development of numeric nutrient criteria for the Southwest Coastal Estuaries, including Naples Bay, Rookery Bay, the Ten Thousand Islands, Whitewater Bay, and the surrounding areas (Florida Department of Environmental Protection 2010o). The primary purpose of the proposed NNC was to protect healthy, well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment.

Many of the waters within the Southwest Coastal Estuaries region are also Class II, with a designated use of shellfish propagation or harvesting. Additionally, many of these waters are designated as Outstanding Florida Waters (OFWs) (Chapter 62-302, Florida Administrative Code [F.A.C.]). Urban development in the region has led to intermittent adverse effects in some parts of the system, especially in the northern portions. Most of these impacts have resulted from channelization and drainage activities, which have dramatically changed the hydrologic and salinity regimes in the estuaries and bays.

FDEP proposes three sets of potential criteria for Southwest Florida estuaries. These include: (1) a long-term geometric mean concentration; (2) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and (3) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period.

Table 48-53 provide the proposed long-term targets for the protection of a healthy, well-balanced aquatic community, as well the annual limits for each sub-basin, in the Southwest Coastal Estuaries region (Florida Department of Environmental Protection 2010o). FDEP is in the process of finalizing the proposed criteria and is evaluating the similarities among the different sub-basins to determine if any of them could be combined for criteria development. They stated that the results will be provided once the analysis has been completed.

Table 48. Proposed numeric TP (µg/L) criteria for sub-basins within the Southwest Coastal Estuaries region. (-) = Empty cell/no data. Source: (Florida Department of Environmental Protection 2010o).

Sub-Basin Map Code	Sub-Basin Name	Existing Long-Term Geometric Mean Concentration	Maximum Allowed Long-Term Geometric Mean	Annual Geometric Mean for Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for Single Site (2 of 5 year exceedance rate)
Whitewater Bay to Ten Thousand Islands Area	-	-	-	-	-
WWB	Whitewater Bay	19.4	21.3	26.6	27.2
PD	Ponce De Leon	19.2	21.1	25.0	25.3
SRM	Shark River mouth	16.9	18.6	22.8	24.1
MR	Mangrove River	17.4	19.2	22.4	23.5
CTZ	Coastal Transition Zone	29.2	32.1	36.1	37.6
IWW	Inner Waterway	27.9	30.7	34.9	36.3
GI	Gulf Islands	33.0	36.2	40.7	42.4
BLK	Blackwater River	44.9	49.4	55.7	58.3
Naples Bay to Rookery Bay Area	-	-	-	-	-
MARC	Marco Island	37.0	40.7	46.0	48.0
NPL	Naples Bay	39.5	43.5	50.2	51.4
CI	Collier Inshore	26.7	29.4	33.5	34.0

Table 49. Proposed numeric TN (µg/L) criteria for sub-basins within the Southwest Coastal Estuaries region. (-) = Empty cell/no data. Source: (Florida Department of Environmental Protection 2010o).

Sub-Basin Map Code	Sub-Basin Name	Existing Long-Term Geometric Mean Concentration	Maximum Allowed Long-Term Geometric Mean	Annual Geometric Mean for Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for Single Site (2 of 5 year exceedance rate)
Whitewater Bay to Ten Thousand Islands Area	-	-	-	-	-
WWB	Whitewater Bay	0.63	0.69	0.84	0.87
PD	Ponce De Leon	0.40	0.44	0.54	0.55
SRM	Shark River mouth	0.56	0.61	0.77	0.79
MR	Mangrove River	0.55	0.61	0.74	0.75
CTZ	Coastal Transition Zone	0.48	0.52	0.63	0.64
IWW	Inner Waterway	0.53	0.58	0.71	0.73
GI	Gulf Islands	0.36	0.40	0.46	0.48
BLK	Blackwater River	0.34	0.37	0.43	0.44
Naples Bay to Rookery Bay Area	-	-	-	-	-
MARC	Marco Island	0.26	0.29	0.32	0.33
NPL	Naples Bay	0.27	0.29	0.32	0.33
CI	Collier Inshore	0.22	0.24	0.27	0.27

Table 50. Proposed numeric Chl-A (µg/L) criteria for sub-basins within the Southwest Coastal Estuaries region. (-) = Empty cell/no data. Source: (Florida Department of Environmental Protection 2010o).

Sub-Basin Map Code	Sub-Basin Name	Existing Long-Term Geometric Mean Concentration	Maximum Allowed Long-Term Geometric Mean	Annual Geometric Mean for Network of Stations (2 of 5 year exceedance rate)	Annual Geometric Mean for Single Site (2 of 5 year exceedance rate)
Whitewater Bay to Ten Thousand Islands Area	-	-	-	-	-
WWB	Whitewater Bay	2.7	3.0	4.0	4.3
PD	Ponce De Leon	2.3	2.6	3.0	3.1
SRM	Shark River mouth	1.8	2.0	2.4	2.5
MR	Mangrove River	3.1	3.4	4.0	4.3
CTZ	Coastal Transition Zone	3.2	3.5	4.0	4.4
IWW	Inner Waterway	4.1	4.5	5.3	5.5
GI	Gulf Islands	2.9	3.2	3.6	3.9
BLK	Blackwater River	3.4	3.7	4.2	4.5
Naples Bay to Rookery Bay Area	-	-	-	-	-
MARC	Marco Island	4.3	4.7	5.4	5.9
NPL	Naples Bay	3.9	4.2	4.8	5.2
CI	Collier Inshore	2.3	2.5	3.1	3.2

Estuarine Specific Criteria – Springs Coast Estuaries

This report was prepared by the Florida Department of Environmental Protection (FDEP), in cooperation with local scientists, to support the development of numeric nutrient criteria for the Springs Coast. The primary purpose of the proposed numeric nutrient criteria is to protect healthy, well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment. The Springs Coast of Florida, encompassing the coastal areas of Citrus, Hernando, and Pasco Counties, is a low-energy coastline that functions like an estuary, despite the lack of physical barriers and enclosures. The region is characterized by extensive tidal marshes and swamps, with much of the coastline in conservation land, and a wide continuous seagrass bed that extends 15-30 miles offshore in some areas due to the very shallow and clear water of this coastline. Marine habitats in the area include extensive seagrass beds, patches of limestone hardbottom habitat that support macroalgal and coral communities, oyster reefs, and some mangrove areas. Submerged aquatic vegetation (SAV), which includes seagrass and macroalgae, is the most nutrient-sensitive biological endpoint. SAV mapping conducted in between 1985 and 2007 suggested that SAV acreage and the location of the deep edge has not been degraded during that interval (Florida Department of Environmental Protection 2010p).

Nitrogen concentrations in the estuary have been stable in recent years. Total phosphorus concentrations have been stable or declining during that period. Nutrient limitation studies have shown that algal growth is either limited by phosphorus or co-limited with nitrogen in this region. Therefore, limits for TN and TP are warranted. Biological data from the region suggested that the designated aquatic life use was currently being fully supported, and so the nutrient regime of the recent record (the past 15 years) is protective of that use (Florida Department of Environmental Protection 2010p).

FDEP proposed three sets of potential criteria: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period. Data from Crystal and Anclote river estuaries were not included in the calculations for proposed criteria. The proposed long-term targets for the protection of a healthy, well-balanced aquatic community in Springs Coast, as well the annual limits for each segment, are provided in Table 51. The appropriate salinity zone was determined for a station based on the annual mean salinity.

Table 51. Proposed numeric nutrient criteria for all segments of Springs Coast, including TP, TN, and chlorophyll a. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. Source: (Florida Department of Environmental Protection 2010p).

TP (µg/L)				
			Network Average	Assessed as a Single Site GM
Salinity Zone	LT_GM	LT_Limit	2:5 Annual Limit	2:5 Annual Limit
<20	15.8	17.3	20.1	24.3
20-25	9.7	10.6	13.0	14.1
>25	8.6	9.4	12.0	12.6
TN (µg/L)				
			Network Average	Assessed as a Single Site GM
Salinity Zone	LT_GM	LT_Limit	2:5 Annual Limit	2:5 Annual Limit
<20	381	419	468	500
20-25	432	476	550	586
>25	368	404	456	466
Chlorophyll *a* (µg/L)				
			Network Average	Assessed as a Single Site GM
Salinity Zone	LT_GM	LT_Limit	2:5 Annual Limit	2:5 Annual Limit
<20	2.4	2.6	3.5	4.2
20-25	1.1	1.2	2.0	2.1
>25	0.8	0.9	1.4	1.5

Estuarine Specific Criteria – St. Joseph Sound and Clear Water Harbor

A technical support document was prepared by the Florida Department of Environmental Protection (FDEP), in cooperation with the Pinellas County Department of Environmental Management (Florida Department of Environmental Protection 2010v). Submersed aquatic vegetation (SAV), including seagrass and macroalgae, is the most nutrient sensitive biological endpoint in St. Joseph Sound, Clearwater Harbor, and Boca Ciega Bay, and extensive water quality and seagrass data exist for the system since 1992 (since 1950 for seagrass in Boca Ciega Bay). Historically, the portion of Pinellas County that borders these estuaries is heavily urbanized, and there have past impacts on water quality and SAV. Impacts from urbanization have been mitigated in recent decades, and water clarity has generally increased while SAV coverage is extensive in these areas. St. Joseph Sound has lower chlorophyll-*a* and a greater percentage of SAV coverage than Clearwater Harbor or Boca Ciega Bay, portions of which are on the 303(d) list for chlorophyll a. The impaired portions of Clearwater Harbor and Boca Ciega Bay have longer residence times and less contact with the Gulf of Mexico than the other portions of this region, which would contribute to higher chlorophyll a in those areas, even in the absence of urban influence. Chlorophyll-*a* concentration have declined in the past two decades in the entire region, and SAV coverage has increased during that time, likely due to nutrient control measures employed by county and city government in this region.

Based on the information provided in the report, aquatic life use is being fully supported in St. Joseph Sound, northern Clearwater Harbor, and southern Boca Ciega Bay, and efforts are underway to attain fully supported aquatic life use in southern Clearwater Harbor and northern Boca Ciega Bay, to support the development of site specific numeric nutrient criteria for St. Joseph Sound, Clearwater Harbor, and Boca Ciega Bay. The primary purpose of the proposed numeric nutrient criteria is to protect healthy well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment.

Pinellas County had hired Janicki Environmental consulting firm to develop nutrient and transparency targets for St. Joseph Sound and Clearwater Harbor. That work is being overseen by the Clearwater Harbor/St. Joseph Sound Comprehensive Conservation Management Plan (CCMP) Working Group. The anticipated completion date for the nutrient and transparency targets is late 2010. FDEP does not plan to propose numeric nutrient criteria for these regions until their work is complete.

Nutrient loading targets have been set for southern Boca Ciega Bay as part of the *Tampa Bay Nitrogen Management Consortium*, and FDEP supports those recommendations. FDEP proposed that the chlorophyll-*a* target for Lower Tampa Bay (5.1 μg/L) be adopted for lower Boca Ciega Bay. However, FDEP is waiting for Janicki Environmental, Inc., to complete work on southern Clearwater Harbor. FDEP will then consider if the proposed criteria for that segment would also be appropriate for northern Boca Ciega Bay.

Estuarine Specific Criteria – Suwannee Estuary Complex

FDEP prepared a technical support document to support the development of NNC for the Suwannee, Waccasassa, and Withlacoochee Estuaries. The primary purpose of the proposed NNC was to protect healthy, well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment. The Suwannee, Waccasassa, and Withlacoochee Estuaries are open, shallow estuaries in Florida’s Big Bend. These estuaries are fed by rivers with a high percentage of wetlands in their watersheds, so color and organic matter concentrations are high, which suppresses algal productivity in the rivers but naturally fuels it in the estuary. During high river flow, swamp water (originating from the Okeefenokee Swamp) dominates, and color and organic nutrient concentrations are relatively high, but inorganic nutrient concentrations are very low. Color and non-chlorophyll particulates are the major contributors to light limitation, except at times of very low river flow. During low flow periods, the river is dominated by Floridan Aquifer spring flow, and water clarity and anthropogenic nitrate concentrations are high.

Submersed aquatic vegetation (SAV) beds are abundant along this part of the coast, but not quite as dense when compared with adjacent regions such as Apalachee Bay. Reductions in SAV have been observed north of the Suwannee River mouth and have been linked to high river flows during years of abnormally high rainfall. The reduction in light is strongly influenced by water color, turbidity, and chlorophyll a, and it is unclear which of these factors may be linked to SAV loss and if that loss is to be expected after extreme high-flow periods. The Suwannee River is impaired for excess nitrate concentrations, but data indicate that the nitrate is diminished to background levels at the estuary interface. Some increased benthic algal growth was observed during very low river flow periods, possibly related to the excess nitrate. Phytoplankton, zooplankton, and fish communities are healthy, as determined by qualitative interpretation of research studies. Concentrations of total nitrogen and total phosphorus are strongly linked to salinity in this system.

Waccasassa Bay has the highest nutrient and chlorophyll a concentrations of the region, despite the extremely minimal anthropogenic activity in the basin. However, evidence gathered shows that conditions have not changed in this estuary since the 1960s, when there was nearly no development and no point source discharges into the basin, so it follows that the existing condition protects the aquatic life use in the estuary.

The Withlacoochee Estuary has been hydrologically modified by the Inglis Dam, the Cross Florida Barge Canal, and the Crystal River Power Plant. TN and chlorophyll a concentrations have not changed in this estuary since the 1980s, and there is no evidence of other impairment in the estuary. There is a strong relationship between nutrient concentrations and salinity due to the dominance of the Withlacoochee River in the estuary.

The evidence gathered by FDEP and presented in this document shows that aquatic life use in the Waccasassa and Withlacoochee estuaries is fully supported, and will be fully supported in the Suwannee estuary pursuant to the Suwannee River TMDL implementation. FDEP therefore proposed that the numeric nutrient criteria be crafted to maintain the existing nutrient regime, except for reduction in total nitrate loading into the Suwannee Estuary, commensurate with the established TMDL for nitrate in the Suwannee River.

FDEP proposed three sets of potential criteria: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period. The proposed long-term concentrations for the protection of a healthy, well-balanced aquatic community in Suwannee, Waccasassa, and Withlacoochee Estuaries, as well the annual limits for each segment, are provided in Table 52 -Table 54. Offshore values represent sites with annual average salinity greater than 25 ppt. Nearshore values represent sites with annual average salinity less than 25 ppt and greater than 3 ppt. FDEP noted that values proposed for nearshore Suwannee TN and chlorophyll-*a* will be revised to take into account reductions in nitrate required for the Suwannee River TMDL.

Table 52. Proposed numeric nutrient criteria for all segments of the Suwannee Estuary for TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. (-) = Empty cell/no data.(Florida Department of Environmental Protection 2010w)

Segment	LT_GM	LT_Limit	Network Average 2:5 Annual Limit	Assessed as a Single Site GM 2:5 Annual Limit	Comments
TP	-	-	-	-	-
Nearshore	69.7	76.7	92.8	101.6	-
Offshore	32.3	35.5	43.9	46.8	-
TN	-	-	-	-	-
Nearshore	722	794	969	1075	To be determined
Offshore	422	464	560	600	-
Chla	-	-	-	-	-
Nearshore	4.60	5.06	7.25	9.84	To be determined
Offshore	5.27	5.79	7.40	7.83	

Table 53. Proposed numeric nutrient criteria for all segments of the Withlacoochee Estuary for TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. (-) = Empty cell/no data. (Florida Department of Environmental Protection 2010w)

Segment	LT_GM	LT_Limit	Network Average 2:5 Annual Limit	Assessed as a Single Site GM 2:5 Annual Limit
TP	-	-	-	-
Nearshore	39.4	43.3	50.0	51.8
Offshore	25.6	28.2	33.5	34.0
TN	-	-	-	-
Nearshore	427	470	536	546
Offshore	326	358	408	413
Chla	-	-	-	-
Nearshore	5.31	5.84	7.46	7.68
Offshore	3.80	4.18	5.66	5.78

Table 54. Proposed numeric nutrient criteria for all segments of the Waccasassa Estuary for TP, TN, and chlorophyll-*a*. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period. (-) = Empty cell/no data. (Florida Department of Environmental Protection 2010w)

Segment	LT_GM	LT_Limit	Network Average 2:5 Annual Limit	Assessed as a Single Site GM 2:5 Annual Limit
TP	-	-	-	-
Nearshore	56	62	69	76
Offshore	35	38	47	55
TN	-	-	-	-
Nearshore	627	690	772	835
Offshore	480	528	610	664
Chla	-	-	-	-
Nearshore	6.3	7.0	8.8	10.8
Offshore	5.0	5.5	8.0	9.4

Estuarine Specific Criteria – Tampa Bay

The Tampa Bay estuary is located on the eastern shore of the Gulf of Mexico in Florida. At 882 km2, it is Florida's largest open water estuary(Tampa Bay Nitrogen Management Consortium 2010). More than 2 million people live in the 5700 km^2 watershed, with the population projected to double by 2050. Land use in the watershed is mixed, with about 40% of the watershed undeveloped, 35% agricultural, 16% residential, and the remaining commercial and mining. Major habitats in the Tampa Bay estuary include mangroves, salt marshes, and submerged aquatic vegetation.

Between 1950 and 1990, an estimated 40-50% of the seagrass acreage in Tampa Bay was lost due to excess nitrogen loading and related increases in algae concentration which caused light limitation detrimental to seagrass survival and growth (Tampa Bay Nitrogen Management Consortium 2010). In 1980, all municipal wastewater treatment plants were required to provide Advanced Wastewater Treatment (AWT) for discharges directly to the bay and its tributaries. In addition to the significant reductions in nitrogen loadings from municipal wastewater treatment plants, stormwater regulations enacted in the 1980s also resulted in reduced nitrogen loads to the bay. Estimates for average annual total nitrogen loadings to Tampa Bay for 1976 are more than 2 times as high as current (2003-2007) estimates (Tampa Bay Nitrogen Management Consortium 2010).

A key focus of Tampa Bay resource and water quality agencies has been to reduce and manage nitrogen loading in Tampa Bay to encourage seagrass recovery (Tampa Bay Nitrogen Management Consortium 2010). A number of studies in the 1990s clearly established that nitrogen was the limiting nutrient in the Tampa Bay estuary and that phosphorus loadings to the bay from the enriched Bone Valley region were not controlling estuarine production (Tampa Bay Nitrogen Management Consortium 2010).

In August 1996, the Tampa Bay Estuary Program's governmental partners joined with key industries in the Tampa Bay region to create an ad-hoc public/private partnership known as the Tampa Bay Nitrogen Management Consortium (Tampa Bay Nitrogen Management Consortium 2010). The Consortium's intent and mission was to implement an Action Plan to meet the protective nutrient load targets developed for Tampa Bay. During development of the targets, bioassay experiments, empirically-derived nutrient-response relationships, and water quality modeling simulations indicated that controlling nitrogen loads to the bay should be the primary watershed management focus to limit phytoplankton production and allow for improvements in bay water clarity. These early studies clearly established that nitrogen loads were the limiting nutrient in the Tampa Bay estuary and that phosphorus loadings to the bay from the enriched Bone Valley region were not controlling estuarine production. In 1996, local government and agency partners of the Tampa Bay Estuary Program (TBEP) approved a long-term goal to restore 95% of the seagrass coverage observed in 1950.

In November 2002, FDEP concluded that the Tampa Bay Nitrogen Management Consortium's nitrogen management strategy provided "*reasonable assurance"* that the state water quality criteria for nutrients would be met in Tampa Bay (Tampa Bay

Nitrogen Management Consortium 2010). To monitor compliance with the reasonable assurance requirement, the TBEP developed a chlorophyll-*a* threshold value that would be evaluated bay wide. The TBEP and its partners adopted chlorophyll-*a* targets for Tampa Bay based on the light requirements of the seagrass species *Thalassia testudinum* (turtlegrass). The average annual chlorophyll-*a* targets for each major bay segment based on an unimpaired base period were:

Old Tampa Bay 8.5 μg/L
Hillsborough Bay 13.2 μg/L
Middle Tampa Bay 7.4 μg/L
Lower Tampa Bay 4.6 μg/L

The Impaired Waters Rule (IWR) threshold for potential nutrient impairment, based on the historical "unimpaired" chlorophyll-*a* level in these bays, was set at 11 μg/L(Florida Department of Environmental Protection 2002b).

Prior to this state determination, the EPA recognized a 1998 action by FDEP that proposed a total maximum load ("federally-recognized TMDL") of nitrogen that could be discharged to the bay annually and still meet state water quality standards related to nutrients (Tampa Bay Nitrogen Management Consortium 2010). Both FDEP's "*Reasonable assurance"* determination and the total maximum nitrogen loading recognized by EPA are based on statistical modeling and data analyses peer-reviewed by the TBEP, its partners, and state and federal regulators (Tampa Bay Nitrogen Management Consortium 2010). Thus, the TBNMC believed that nutrient loading targets developed for the major bay segments of Tampa Bay had been previously acknowledged by both FDEP and EPA as protective nutrient loads for this estuary.

With implementation of the adaptive nutrient management plan adopted by the TBNMC and FDEP through its *Reasonable Assurance* (RA) process, the maintenance of full aquatic life support within the Tampa Bay estuary has been achieved through establishment of stable water quality conditions (chlorophyll-*a* thresholds achieved >85% of the time since 1996), the expansion of seagrass resources (>3,200 ha since 1982), and stable, well-balanced populations of benthic and nekton species. As such, the TBNMC believed that the nutrient regime of the recent record is protective of full aquatic life support, and the that the goals of the TBNMC to maintain N loads at levels consistent with the 2003-2007 period will ensure that the recovery of Tampa Bay is sustained (Tampa Bay Nitrogen Management Consortium 2010).

In March 2010 the TBNMC provided comments to the EPA in regards to development of protective loads for the Tampa Bay estuary as it relates to establishing numeric criteria for inland waters and estuaries in Florida. As part of that effort TBNMC provided protective nutrient loads for the Tampa Bay estuary. The TBNMC stated in that document that these recommendations be implemented in order to maintain consistency in the adaptive resource-based nutrient management approach utilized in Tampa Bay that ensures:

1) the protection of the estuary from degradation associated with excessive nutrient loadings;

2) a balance of full aquatic life support being sustained and enhanced; and,

3) the attainment of all designated uses, the TBNMC requested that EPA establish the nitrogen and phosphorus loading (Table 55), recognized by both FDEP and EPA as being protective of the Tampa Bay estuary through separate administrative actions, as the protective nutrient loads for the Tampa Bay estuary.

The TBNMC requested that EPA finalize the existing TN and TP loads (specified for each major bay segment in Table 55, as the protective loads used in determining downstream protective values for flowing waters and as the protective Estuarine Nutrient Criteria for the Tampa Bay estuary. Furthermore, the TBNMC requested that EPA finalize the protective estuarine loads established in for nutrients in flowing waters as part of the second phase of this rulemaking process in coordination with the proposal and finalization of numeric criteria for estuarine and coastal waters that is anticipated to occur in 2011.

Table 55. Protective nutrient loads for the Tampa Bay estuary established by the Tampa Bay Nitrogen Management Consortium, and accepted through separate administrative action by FDEP (acceptance of the 2002 Reasonable Assurance (RA), 2007 RA Update & 2009 RA Addendum) and EPA (establishment of the 1998 federally-recognized TMDL for Tampa Bay). Source: (Tampa Bay Nitrogen Management Consortium 2010).

Bay Segment	EPA's Protective Load to the Tampa Bay Estuary Defined in the Jan. 14th, 2010 Draft Rule for Total Nitrogen Load expressed as tons/year (kilograms/year)	Tampa Bay NMC Proposed Alternative Total Nitrogen Load expressed as tons/year (kilograms/year)	Tampa Bay NMC Proposed Total Phosphorus Load (Attachment V) expressed as tons/year (kilograms/year)
Old Tampa Bay	None specified	486 (440,892)	104 (94,127)
Hillsborough Bay	None specified	1,451 (1,316,325)	1,093 (993,755)
Middle Tampa Bay	None specified	799 (724,841)	140 (127,673)
Lower Tampa Bay	None specified	349 (316,607)	52 (47,564)
Remainder of Lower Tampa Bay	None specified	629 (570,619)	112 (101,464)

In order to further support development of estuarine NNC the TBEP in cooperation with the Sarasota Bay Estuary Program and Charlotte Harbor National Estuary Program, supported the development of a document that indentified potential methods for the estimation of NNC for southwest Florida estuaries (Janicki Environmental Inc. 2010a). This report identified and reviewed various methods being considered by both EPA and FDEP in their most recent technical support documents (Carleton et al. 2010; Florida Department of Environmental Protection 2010b).

The TBEP, in cooperation with the Sarasota Bay Estuary Program and Charlotte Harbor National Estuary Program, supported the development of a document that identified the potential methods for the estimation of numeric nutrient criteria for southwest Florida estuaries (Janicki Environmental Inc. 2010a). This document produced in 2010 identified several methods currently being considered by both EPA and FDEP to establish numeric nutrient criteria for Florida estuarine waters.

On February 2011 the Tampa Bay Estuary Program released a NNC recommendation document for Tampa Bay, that had been sponsored by their program (Janicki Environmental Inc. 2011). Recommendations for numeric criteria expressed both in terms of original loading estimates and as alternative concentration based values were both presented. The TBEP formally endorsed the TBNMC recommended loading "criteria" listed in Table 55. The TBNMC proposed TN and TP loading criteria for the four mainstem segments of Tampa Bay are illustrate again as it was displayed in their technical guidance document (Janicki Environmental Inc. 2010a; Janicki Environmental Inc. 2011).

Table 56. Recommended TN and TP loadings recommended by TBNMC and endorsed by TBEP. Source: (Janicki Environmental Inc. 2011).

Proposed TN and TP loading criteria for the segments of Tampa Bay.		
Segment	**TN Load (tons/year)**	**TP Load (tons/year)**
Old Tampa Bay	486	104
Hillsborough Bay	1451	1093
Middle Tampa Bay	799	140
Lower Tampa Bay	349	52

The TBEP stated that the TBNMC had effectively argued that their approach, which was an established state and federally-approved nitrogen loading target for the estuary, follows all of EPA's technical guidance policies including the preferred quantitative stressor-response relationship approach for establishing numeric nutrient criteria. TBEP stated that multiple lines of empirical evidence justified maintaining existing TN and TP loads to the Tampa Bay Estuary. For example, water quality and clarity in the Bay had improved tremendously since significant management actions were initiated starting in the 1980s, seagrass acreage had increased to the highest levels observed since the 1950s and continues to increase, and economically important fish and wildlife populations had been maintained at elevated sustainable levels since routine monitoring programs began in the 1990s.

In addition to the methodology reviewed in their previously sponsored technical report, the TBEP also addressed several other NNC issues associated with the establishment of numeric nutrient criteria in Tampa Bay Estuary (Janicki Environmental Inc. 2011). These included:

- Expression of recommended TN and TP criteria as concentrations.
- The need for establishment of downstream protective values (DPVs) for terminal reaches that drain directly into Tampa Bay.

TN and TP Concentration Criteria

The following summarizes the TBEP recommendations regarding the expression of TN and TP criteria concentrations. Previous efforts by the TBEP have developed strong relationships between nutrient supply to Tampa Bay and resultant chlorophyll a concentrations in the bay, and between chlorophyll-*a* concentrations and light availability for seagrasses. Thus, management actions have focused on controlling nitrogen loads to Tampa Bay, with measureable success as expressed by increases in a biological endpoint, seagrass acreage. The relationships are between nitrogen loads and chlorophyll-*a*, however, not nitrogen concentrations in the bay and chlorophyll-*a*. However, TBEP recognized that EPA intends to establish criteria for TN and TP and that these criteria may be expressed as ambient concentrations. Although the TBEP recommendations for TN and TP criteria remain the TN and TP loads reported above, recommendations for concentration-based numeric nutrient criteria consistent with the TN and TP loading recommendations were developed and provided by the TBEP in the event that EPA determined that loadings cannot be used as numeric nutrient criteria (Janicki Environmental Inc. 2011).

The "*Reference Period*" approach was selected to establish the proposed concentration-based numeric criteria for TN and TP. Based on a 1992-1994 reference period, segment-specific chlorophyll-*a* targets have been identified and implemented as part of the Tampa Bay Nitrogen Management Strategy since 2000. Using this similar and consistent approach, segment-specific annual geometric mean TN and TP concentrations from the 1992-1994 period were derived for this current effort. TN and TP concentration thresholds, as were developed for established, regulatory-recognized chlorophyll-*a* thresholds, account for the inter-annual variability in the TN and TP concentrations observed from 1992-2009. Application of the Reference Period approach resulted in the following recommendations for concentration-based TN and TP criteria for Tampa Bay. These criteria are:

- Old Tampa Bay TN=0.93 mg/L TP=0.31 mg/L
- Hillsborough Bay TN=1.01 mg/L TP=0.45 mg/L
- Middle Tampa Bay TN=0.87 mg/L TP=0.29 mg/L
- Lower Tampa Bay TN=0.74 mg/L TP=0.10 mg/L.

TBEP stated that the criteria referenced above should be assessed as an annual geometric mean from long-term monthly water quality monitoring stations currently used in the state's chlorophyll-*a* threshold assessments under the Tampa Bay RA determination. The assessment of TN and TP concentrations attainment should only occur when chlorophyll-*a* thresholds are exceeded within a bay segment, and should coordinate with current regulatory assessments under the FDEP RA determination and EPA TMDL for TN loads in Tampa Bay. Further, compliance assessments should be conducted over five-year time frames, with no more than two consecutive years being greater than these established criteria if chlorophyll-*a* threshold (11 μg/L) is also exceeded during the same time period. This approach is analogous to the chlorophyll-*a* threshold assessments currently being conducted under the regulatory requirements for the FDEP RA determination and EPA TMDL for Tampa Bay.

Downstream Protection Values

The TBEP reiterated past arguments made by the TBNMC that existing TMDL derived TN and TP loading restrictions are sufficient and that EPA should not derive new downstream protection values (DPVs) for Tampa Bay. Continued attainment of chlorophyll-*a* thresholds in the major bay segments of Tampa Bay should provide sufficient evidence that the TN and TP contributions of tributaries draining to Tampa Bay are protective of the estuary. Therefore, the protective TN and TP loads recommended by the TBNMC in March 2010 to the EPA are sufficiently protective to attain in-bay chlorophyll-*a* thresholds for Tampa Bay.

Tidal Creeks

Due to their unique hydrology, ecology, water quality, biota, and geomorphology the TBEP provided recommended that tidal creeks NNC be considered separately from efforts associated with open bay criteria. Based on the recognized need to define distinct biological endpoints for tidal tributaries and water quality criteria to support them, TBEP staff recommended that tidal tributaries be treated as a separate waterbody class; and that EPA and/or FDEP should consider setting a schedule (i.e., within 3 years) by which time endpoints and criteria will be proposed, but do not attempt to set interim or final criteria with insufficient data for tidal creeks.

State of Florida Proposed Rules - 2011

The State of Florida has initiated rulemaking to adopt quantitative nutrient water quality standards to facilitate the assessment of designated use attainment for its waters (Florida Department of Environmental Protection 2011a). The most recent information on the proposed rules can be found at http://www.dep.state.fl.us/water/wqssp/nutrients/. The most significant change in the proposed state standards is the formal incorporation of the recent EPA promulgated freshwater water quality standards. However, FDEP has also proposed methodology that would supplement the EPA NNC by providing biologically based community indices (e.g. SCI) that would also be used to determine if a waterbody may be experiencing problems due to excess nutrients in addition to the use of NNC. Also, FDEP has added a section on standardization of chlorophyll-a measurements.

Georgia

Information on the State of Georgia's activities associated with development of NNC were obtained from the EPA and State of Georgia and through information obtained from, Ms. Elizabeth Booth who is a staff member of the Environmental Protection Division (GEPD) of the Georgia Department of Natural Resources (GDNR). (http://www.georgiaepd.org/Documents/about.html). The Environmental Protection Division (EPD) of the Georgia Department of Natural Resources is the state agency responsible for protection and management of Georgia's water resources through the authority of state and federal environmental statutes. Georgia's water quality standards are found in Chapter 391-3-6-.03 of the Georgia Rules and Regulations for Water Quality Control.

Georgia has six designated uses for waterbodies in their state. These include:

1) Drinking water supply;
2) recreation;
3) fishing;
4) wild river;
5) scenic river and
6) coastal fishing.

Each designated use has numeric and narrative water quality criteria that have been developed to protect the use. We limit our discussion to activities associated with the development of nutrient criteria associated with protection of aquatic life uses including fishing, wild river, scenic river and coastal fishing. Currently, Georgia only has nutrient standards on a limited number of lakes, however the state is considering nutrient standards for all waters (Risse and Tanner 2009). The current state adopted and federally approved NNC are limited to TN, TP and chlorophyll-*a* NNC for selected lakes/reservoirs and TP in selected rivers and streams (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ga.cfm).

The state of Georgia's most recent Nutrient Criteria Development plan was published in 2006 (Georgia Department of Natural Resources 2006). Historically, Georgia has generally addressed nutrient issues on a site-specific basis in response to documented water quality impairment or to address major public lakes. The recent implementation of the supplemental lake water quality standards for the six major publicly owned lakes has led to nutrient control strategies in their respective watersheds.

Table 57. Current numeric nutrient criteria for selected lakes and major lake tributaries in Georgia. From: 2002 Georgia Rules and Regulations for Water Quality Control Chapter 391-3-6.03(17). Specific Criteria for Lakes and Major Lake Tributaries (Georgia Department of Natural Resources 2005). Only nutrient criteria sections shown.

Lake and Tributary Nutrient Criteria

(a) West Point Lake: Those waters impounded by West Point Dam and downstream of U.S. 27 at Franklin.

(i) Chlorophyll-*a*: For the months of April through October, the average of monthly photic zone composite samples shall not exceed 27 μg/L at the LaGrange Water Intake more than once in a five-year period.

(iii) Total Nitrogen: Not to exceed 4.0 mg/L as Nitrogen in the photic zone.

(iv) Phosphorus: Total lake loading shall not exceed 2.4 pounds per acre foot of lake volume per year.

(viii) Major Lake Tributaries: For the following tributaries, the annual total phosphorus loading to West Point Lake shall not exceed the following:

1. Yellow Jacket Creek at Hammet Road: 11,000 pounds

2.New River at Hwy 100: 14,000 pounds.

3.Chattahoochee River at U.S. 27: 1,400,000 pounds.

(**b) Lake Walter F. George:** Those waters impounded by Walter F. George Dam and upstream to Georgia Highway 39 near Omaha.

(i) Chlorophyll-*a*: For the months of April through October, the average of monthly photic zone composite samples shall not exceed 18 μg/L at mid-river at U.S. Highway 82 or 15 μg/L at mid-river in the dam forebay more than once in a five-year period.

(ii) Total Nitrogen: Not to exceed 3.0 mg/L as nitrogen in the photic zone.

(iii) Phosphorous: Total lake loading shall not exceed 2.4 pounds per acre-foot of lake volume per year.

(viii) Major Lake Tributary: The annual total phosphorous loading to Lake Walter F. George, monitored at the Chattahoochee River at Georgia Highway 39, shall not exceed 2,000,000 pounds.

(c) Lake Jackson: Those waters impounded by Lloyd Shoals Dam and upstream to Georgia Highway 36 on the South and Yellow Rivers, upstream to Newton Factory Bridge Road on the Alcovy River and upstream to Georgia Highway 36 on Tussahaw Creek.

(i) Chlorophyll-*a*: For the months of April through October, the average of monthly mid-channel photic zone composite samples shall not exceed 20 μg/L at a location approximately 2 miles downstream of the confluence of the South and Yellow Rivers at the junction of Butts, Newton and Jasper Counties more than once in a five-year period.

(iii) Total Nitrogen: Not to exceed 4.0 mg/L as nitrogen in the photic zone.

(iv) Phosphorous: Total lake loading shall not exceed 5.5 pounds per acre-foot of lake volume per year.

(viii) Major Lake Tributaries: For the following major tributaries, the annual total phosphorous loading to Lake Jackson shall not exceed the following:

1. South River at Island Shoals: 179,000 pounds

2. Yellow River at Georgia Highway 212: 116,000 pounds

3. Alcovy River at Newton Factory Bridge Road: 55,000 pounds

4. Tussahaw Creek at Fincherville Road.: 7,000 pounds

(d) Lake Allatoona: Those waters impounded by Allatoona Dam and upstream to State Highway 5 on the Etowah River, State Highway 5 on Little River, the Lake Acworth Dam, and the confluence of Little Allatoona Creek and Allatoona Creek. Other impounded tributaries to an elevation of 840 feet mean sea level corresponding to the normal pool elevation of Lake Allatoona.

(i) Chlorophyll-*a*: For the months of April through October, the average of monthly mid-channel photic zone composite samples shall not exceed the chlorophyll a concentrations at the locations listed below more than once in a five-year period:

1. Upstream from the Dam 10 μg/L

2. Allatoona Creek upstream from I-75 12 μg/L

3. Mid-Lake downstream from Kellogg Creek 10 μg/L

4. Little River upstream from Highway 205 15 μg/L

5. Etowah River upstream from Sweetwater Creek 14 μg/L

(iii) Total Nitrogen: Not to exceed a growing season average of 4 mg/L as nitrogen in the photic zone.

(iv) Phosphorous: Total lake loading shall not exceed 1.3 pounds per acre-foot of lake volume per year.

Lake and Tributary Nutrient Criteria

(viii) Major Lake Tributaries: For the following major tributaries, the annual total phosphorous loading to Lake Allatoona shall not exceed the following:

1. Etowah River at State Highway 5 spur and 140, at the USGS gage - 340,000 lbs/yr
2. Little River at State Highway 5 (Highway 754) - 42,000 lbs/yr
3. Noonday Creek at North Rope Mill Road - 38,000 lbs/yr
4. Shoal Creek at State Highway 108 (Fincher Road) - 12,500 lbs/yr

(e) Lake Sidney Lanier: Those waters impounded by Buford Dam and upstream to Belton Bridge Road on the Chattahoochee River, 0.6 miles downstream from State Road 400 on the Chestatee River, as well as other impounded tributaries to an elevation of 1070 feet mean sea level corresponding to the normal pool elevation of Lake Sidney Lanier.

(i) Chlorophyll-*a*: For the months of April through October, the average of monthly mid-channel photic zone composite samples shall not exceed the chlorophyll a concentrations at the locations listed below more than once in a five-year period:

1. Upstream from the Buford Dam forebay 5 μg/L
2. Upstream from the Flowery Branch confluence 5 μg/L
3. At Browns Bridge Road (State Road 369) 5 μg/L
4. At Bolling Bridge (State Road 53) on Chestatee River 10 μg/L
5. At Lanier Bridge (State Road 53) on Chattahoochee River 10 μg/L

(iii) Total Nitrogen: Not to exceed 4 mg/L as nitrogen in the photic zone.

(iv) Phosphorous: Total lake loading shall not exceed 0.25 pounds per acre-foot of lake volume per year.

1. Chattahoochee River at Belton Bridge Road - 178,000 pounds
2. Chestatee River at Georgia Highway 400 - 118,000 pounds
3. Flat Creek at McEver Road - 14,400 pounds

(f) Carters Lake: Those waters impounded by Carters Dam and upstream on the Coosawattee River as well as other impounded tributaries to an elevation of 1072 feet mean sea level corresponding to the normal pool elevation of Carters Lake.

(i) Chlorophyll a: For the months of April through October, the average of monthly mid-channel photic zone composite samples shall not exceed the chlorophyll a concentrations at the locations listed below more than once in a five-year period:

1. Carters Lake upstream from Woodring Branch - 5 μg/L
2. Carters Lake at Coosawattee River embayment mouth 76 - 10 μg/L

(ii) Total Nitrogen: Not to exceed 4.0 mg/L as nitrogen in the photic zone.

(iii) Phosphorous: Total lake loading shall not exceed 172,500 pounds or 0.46 pounds per acre-foot of lake volume per year.

iv) Major Lake Tributaries: For the following major tributaries, the annual total phosphorous loading at the compliance monitoring location shall not exceed the following:

1. Coosawattee River at Old Highway 5 - 151,500 pounds
2. Mountaintown Creek at U.S. Highway 76 - 8,000 pounds

According to their Nutrient Criteria Development Plan, Georgia plans to research and develop nutrient criteria for the waters of the State, and to adopt these criteria according to USEPA guidance and requirements. One of the first things Georgia conducted was developing an inventory of all state waters (Georgia Department of Natural Resources 2005). This information will help characterize waters and assist in prioritizing them. To maximize manpower and resources, the GEPD plan to implement their nutrient criteria development plan.

The nutrient criteria development process began with large public lakes because they have the greatest human exposure as they are used for public drinking water supplies and for recreation. GAEPD planned to use this phased approach to move forward in a timely manner and learn as the process proceeds. GAEPD planned to follow a sequence in which nutrient criteria will be developed for other waterbody types is large public lakes, small public lakes, wadeable streams, non-wadeable streams, estuaries, and wetlands. To accommodate the various waterbody types, the waters of the GAEPD divided waterbodies into four groups: lakes and reservoirs, streams and rivers, estuaries and coastal marine waters, and wetlands. GAEPD intends to develop nutrient criteria for lakes and reservoirs, streams and rivers, and estuaries and coastal marine waters. GAEPD will address wetlands last since at time of the preparation of Georgia's Plan for the Adoption of Water Quality Standards for Nutrients in April 2006 USEPA has not developed the guidance for developing nutrient criteria for wetlands. To distinguish between waterbodies in the variety of chemical and biological environments throughout the State, nutrient criteria will be developed according to Georgia's Level IV Ecoregions or some aggregation thereof. The Level IV Ecoregions will provide a spatial and geographic framework for criteria development and may be accompanied by secondary frameworks such as river basin or designated use classifications.

The GAEPD anticipated using water quality parameters related to both the causes of and responses to nutrient overenrichment for use as nutrient criteria. They anticipated that the causal parameters, total nitrogen and total phosphorus, will be investigated for all waterbody types, while response parameters such as algae, periphyton, macroinvertebrates, turbidity, and dissolved oxygen will be investigated according to the appropriate waterbody type.

The State of Georgia planned to use water quality data from neighboring states with similar ecoregions, particularly data for minimally impaired reference sites, will be used where appropriate (Georgia Department of Natural Resources 2005). The criteria development process will begin with an evaluation of the adequacy of existing data for the development of nutrient criteria for each waterbody type and ecoregion. Much of Georgia's water quality data is maintained in the Water Resource Database (WRDS), GAEPD planned to use this database to mine for both nutrient and response parameters., Starting in the early 1990’s the GAEPD started monitoring point source discharges for nutrients. A group of parameters collectively termed "Nutrient Series" was defined, All point sources sampled since that time have included analyses of the Nutrient Series parameter suite. The parameters that constitute a Nutrient Series include ammonia-nitrogen. Total Kjeldahl Nitrogen (TKN), nitrates/nitrites, and total phosphorous. In addition, communities in Georgia with new or expanding wastewater treatment facilities, greater than 1 million gallons per day (MGD) were required to conduct a Watershed Assessment. Watershed Assessments require chemical and biological water quality monitoring. These efforts will provide data on in-stream nutrients, habitat, and macroinvertebrate and fish communities. Results from these studies will be used by GAEPD assist in evaluating the effects of nutrients on aquatic life and will be used In developing nutrient criteria that are protective of all of Georgia's designated uses. Where data are insufficient, additional data collection programs will be developed and implemented according to available staff and financial resources.

The GAEPD planned on using two analytical methods to screen preliminary criteria. One method will apply a statistical analysis to the entire water quality data set for all waters of a given waterbody type, ecoregion, and applicable category. The second method will apply a similar statistical analysis method to a subset of these waters considered to be minimally impacted or reference waters. Results from these analyses will be compared for the purposes of assessing preliminary numeric criteria. Potential numeric nutrient criteria for further consideration will be derived from the results of these two analyses. However, these approaches do not describe the underlying cause and response relationship and other influencing factors that are associated with nutrient overenrichment. In addition, it does not address the potential nutrient assimilative capacity of a specific waterbody, nor the allowable nutrient conditions for the designated use. Therefore, the data analysis approach will be supplemented by a waterbody-specific effects-based approach for selected waterbodies where the water quality issues justify and investigative resources can support such an evaluation.

Various statistical analysis alternatives will be performed. When one parameter is analyzed, such as phosphorus in various ecoregions and/or waterbody types, the mean, standard deviation, and various percent confidence intervals (25th percentile, 75th percentile, 95th percentile) will be determined. When multiple parameters are analyzed, such as nutrient levels and biological responses, parametric and/or non-parametric statistical analyses will be performed.

The GAEPD intends to collaborate with these professionals by developing an internal Technical Planning Group consisting of representatives from GAONR's Environmental Protection Division, Wildlife Resources Division, and Coastal Resources Division. In addition, technical advisors representing local academia will be invited to participate in the Technical Planning Group. The Technical Planning Group participants will be charged with coordinating all planning, data collection, assessment, and determination activities. In addition, GA EPD personnel will continue to attend and participate in nutrient criteria workshops and conferences.

Georgia's goal for beginning to adopt nutrient standards into its Rules and Regulations for Water Quality Control is January 2012. By this time GAEPD believed it would have sufficient data to perform the necessary analyses for some waterbody types to propose scientifically defensible standards for selected nutrient parameters. Scientifically defensible nutrient standards for other waterbodies will be proposed after additional data collection and analyses.

Georgia has developed and implemented water quality standards for selected publicly owned reservoirs for several years, Therefore, the nutrient criteria development strategy for lakes and reservoirs will incorporate Georgia's existing supplemental water quality standards for lakes. The Georgia General Assembly passed a Senate Bill (D.C,G.A 12-5-23.1) in 1990, known as the Lake Law, which required GAEPD to develop supplemental water quality standards for publicly owned lakes. The Lake Law required site-specific minimum water quality standard parameters that included:

- Chlorophyll a concentration
- Total phosphorus concentration
- Total nitrogen concentration
- Dissolved oxygen concentration
- Water temperature
- pH
- Fecal coliform bacteria
- Total phosphorus loading from major lake tributaries

According to the Lake Law, the site-specific standards could only be developed after a comprehensive study of the lake had been performed. Previous lake studies funded by the Clean Lakes Program have been completed, and there are currently no financial resources to fund similar studies to develop criteria, according to the Lake Law, for other lakes in Georgia.

As a direct result of the Lake Law, the Georgia Rules and Regulations for Water Quality Control Chapter 391-3-6 includes numerical water quality standards for lakes and major lake tributaries in section 391-3-6-.03(16) for six lakes. Publicly owned lakes having supplemental water quality standards and the year in which standards were adopted are listed below;

- West Point (1995)
- Jackson (1996)
- Walter F. George (1996)
- Sidney Lanier (2000)
- Auatoona (2000)
- Carters (2002)

In addition to adopting the supplemental water quality standards for these selected lakes, GAEPD has implemented an annual monitoring and assessment program to evaluate compliance with the water quality standards for each lake. The program consisted of monthly lake monitoring for the selected parameters during the April through October growing season, and monthly major lake tributary sampling for estimating annual total phosphorus loadings.

Recently (Sheldon and Alber 2011) conducted a literature review on potential estuarine water quality parameters for evaluation of estuarine water quality. Several variables were used to evaluate the trophic status of estuaries. Based on their review they generated proposed water quality screening variables for Georgia estuaries. They are listed below.

Table 58. Proposed indicators, criteria, metrics and ancillary data for assessing the generally quality of Georgia coastal and estuarine waters (Sheldon and Alber 2011). Other variables not shown include pH, salinity, specific conductance, dissolved oxygen, BOD, and temperature.

Indicator	Units	Good	Fair	Poor	Metric
TDN	mg/L	<0.1	0.1-1.0	>1.0	Annual median
TDP	mg/L	<0.01	0.01-0.1	>0.1	Annual median
Chl-A	μg/L	<5	5-20	>20	Annual maximum and median
Transparency	Secchi disk	TBD	TBD	TBD	Annual median

Guam

The territory of Guam has NNC for orthophosphates, nitrate nitrogen and turbidity in both their marine and freshwater bodies Table 12 (Guam Environmental Protection Agency 2001). The following information reflects Guam's 2001 water quality standards posted to the Water Quality Standards Repository as of November 2010 (Guam Environmental Protection Agency 2001) http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_gu.cfm. The designated uses and descriptions are provided below. Current criteria are listed in

Guam Section 5102. Categories of Waters.

B. Marine Waters.

This category includes all coastal waters off-shore from the mean high water mark, including estuarine waters, lagoons and bays, brackish areas, wetlands and other special aquatic sites, and other inland waters that are subject to ebb and flow of the tides.

1. Category M-1 Excellent.

Water in this category must be of high enough quality to protect for whole body contact recreation, and to ensure the preservation and protection of marine life, including corals and reef-dwelling organisms, fish and related fisheries resources, and enable the pursuit of marine scientific research as well as aesthetic enjoyment. This category of water shall remain substantially free from pollution attributed to domestic, commercial and industrial discharges, shipping and boating, or mariculture, construction and other activities which can reduce the waters' quality.

2. Category M-2 Good.

Water in this category must be of sufficient quality to allow for the propagation and survival of marine organisms, particularly shellfish and other similarly harvested aquatic organisms, corals and other reef-related resources, and whole body contact recreation.. Other important and intended uses include mariculture activities, aesthetic enjoyment and related activities.

3. Category M-3 Fair.

Water in this category is intended for general, commercial and industrial use, while allowing for protection of aquatic life; aesthetic enjoyment and compatible recreation with limited body contact. Specific intended uses include the following: shipping, boating and berthing, industrial cooling water, and marinas.

C. Surface Waters.

This category includes all of surface freshwater and includes: (1) waters that flow continuously over land surfaces in a defined channel or bed, such as streams and rivers; (2) standing water in basins, such as lakes, wetlands, marshes, swamps, ponds, sinkholes, ponding basins, impoundments, and reservoirs, either natural or man-made; and (3) all waters flowing over the land as runoff, or as runoff confined to channels with intermittent flow.

1. Category S-1 High.

Surface water in this category is used for drinking water, wilderness areas, propagation and preservation of aquatic life, whole body contact recreation and aesthetic enjoyment. It is the objective of these standards that these waters shall be kept free of substances or pollutants from domestic, commercial and industrial discharges, or agricultural activities, construction or other land-use practices that may impact water quality.

2. Category S-2 Medium.

Surface water in this category is used for recreational purposes, including whole body contact recreation, for use as potable water supply after adequate treatment is provided, and propagation and preservation of aquatic wildlife and aesthetic enjoyment.

3. Category S-3 Low.

Surface water in this category is primarily used for commercial, agricultural and industrial activities. Aesthetic enjoyment and limited body contact recreation are acceptable in this zone, as well as maintenance of aquatic life. Discharges within this zone may be required to have construction and/or discharge permits under existing Guam Sediment and Soil Erosion regulations or under National Pollution Discharge Elimination System ("NPDES").

Table 59. Guam water quality NNC criteria. Citation: Section 5103. Water Quality Criteria. From:(Guam Environmental Protection Agency 2001).

A. General Criteria Applicable to All Waters of Guam.

1. All waters shall meet generally accepted aesthetic qualifications, shall be capable of supporting desirable aquatic life, and shall be free from substances, conditions or combinations thereof attributable to domestic, commercial and industrial discharges or agriculture, construction and land-use practices or other human activities that:

c. Produce objectionable color, odor or taste, directly or by chemical or biological action.

e. Induce the growth of undesirable aquatic life.

C. Numeric Water Quality Criteria for Marine and Surface Waters.

	Applicable to*	
3. Nutrients		
<u>a. Phosphorus</u>		
Orthophosphate (PO_4-P) shall not exceed 0.025 mg/L	M-1	S-1
Orthophosphate (PO_4-P) shall not exceed 0.05 mg/L	M-2	S-2
Orthophosphate (PO_4-P) shall not exceed 0.10 mg/L	M-3	S-3
<u>b. Nitrogen</u>		
Nitrate-nitrogen (NO_3-N) shall not exceed 0.10 mg/L	M-1	S-1
Nitrate-nitrogen (NO_3-N) shall not exceed 0.20 mg/L	M-2	S-2
Nitrate-nitrogen (NO_3-N) shall not exceed 0.50 mg/L	M-3	S-3
	Applicable to*	
7. Turbidity		
a. Turbidity at any point, as measured by nephelometric turbidity units ("NTU"), shall not exceed 0.5 NTU over ambient conditions, except when due to natural conditions.	M-1	S-1
b. Turbidity values (NTU) at any point shall not exceed 1.0 NTU over ambient conditions, except when due to natural conditions.	M-2 S-2	M-3 S-3
c. When debris, rapidly settling particles and true color give low readings when using nephelometric methods in making turbidity determinations, and one (1) or more of these conditions exist in marine and surface water, Secchi disc determinations will be used. Secchi-disc visibility shall not decrease by more than five (5) meters from ambient conditions, except when due to natural conditions.		

Hawaii

The State of Hawaii has statewide and waterbody specific NNC (Hawaii Department of Health 2004; Hawaii Department of Health 2009). These standards were adopted in 1998 and revised in 2004 (United States Environmental Protection Agency 2008b)(http://water.epa.gov/scitech/swguidance/standards/wqslibrary/hi_index.cfm). The methods that were used to derive them is however unclear, since we could not find the technical approach used to derive these NNC. A summary of all NNC is depicted in the following series of tables. There was no Nutrient Criteria Development Plan available for this state.

The information on NNC adopted by Hawaii and EPA is depicted in Table 60 -Table 66. The language presented below comes directly from state water quality standards and applies to various designated use classes of waterbodies within the state (unless a waterbody type or designated use is noted)(Hawaii Department of Health 2004; Hawaii Department of Health 2009).

Table 60. Specific NNC criteria for streams in Hawaii.

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to Exceed the given value more than two percent of the time
Total Nitrogen (µg N/L)	250.0* 180.0**	520.0* 380.0**	800.0* 600.0**
Nitrate + Nitrite Nitrogen (µg [NO3+NO2] -N/L)	70.0* 30.0**	180.0* 90.0**	300.0* 170.0**
Total Phosphorus (µg TP/L)	50.0* 30.0**	100.0* 60.0**	150.0* 80.0**
Total Suspended Solids (mg/L)	20.0* 10.0**	50.0* 30.0**	80.0* 55.0**
Turbidity (NTU)	5.0* 2.0**	15.0* 5.5**	25.0* 10.0**

* Wet season - November 1 through April 30.
** Dry season - May 1 through October 31.

Table 61. Specific NNC for Hawaiian estuaries except Pearl Harbor. Source:(Hawaii Department of Health 2004; Hawaii Department of Health 2009)

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to Exceed the given value more than two percent of the time
Total Nitrogen (µg N/L)	200.00	350.00	500.00
Nitrate + Nitrite Nitrogen (µg [NO3+NO2] -N/L)	8.00	25.00	35.00
Total Phosphorus (µg P/L)	25.00	50.00	75.00
Chlorophyll-*a* (µg/L)	2.00	5.00	10.00
Turbidity (NTU)	1.5	3.00	5.00

Table 62. NNC criteria for all Hawaiian marine embayments excluding those described in site specific standards (Note that criteria for embayments differ based on fresh water inflow) Source:(Hawaii Department of Health 2004; Hawaii Department of Health 2009)

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to Exceed the given value more than two percent of the time
Total Nitrogen (µg N/L)	200.00* 150.00**	350.00* 250.00**	500.00* 350.00**
Nitrate + Nitrite Nitrogen (µg NO3+NO2] -N/L)	8.00* 5.00**	20.00* 14.00**	35.00* 25.00**
Total Phosphorus (µg P/L)	25.00* 20.00**	50.00* 40.00*	75.00* 60.00**
Chlorophyll-*a* (µg/L)	1.50* 0.50**	4.50** 1.50**	8.50* 3.00**
Turbidity (NTU)	1.5* 0.40**	3.00* 1.00**	5.00* 1.50**

* "Wet" criteria apply when the average fresh water inflow from the land equals or exceeds one percent of the embayment volume per day.
** "Dry" criteria apply when the average fresh water inflow from the land is less than one percent of the embayment volume per day.

Table 63. NNC criteria specific for all open coastal waters in Hawaii, excluding those described in site specific standards for coastal waters 11-54-6(d). (Note: criteria for open coastal waters differ, based on fresh water discharge). Source:(Hawaii Department of Health 2004; Hawaii Department of Health 2009)

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to Exceed the given value more than two percent of the time
Total Nitrogen (µg N/L)	150.00* 110.00**	250.00* 180.00**	350.00* 250.00**
Nitrate + Nitrite Nitrogen (µg [NO3+NO2] -N/L)	5.00* 3.50**	14.00* 10.00**	25.00* 20.00**
Total Phosphorus (µg P/L)	20.00* 16.00**	40.00* 30.00**	60.00* 45.00**
Chlorophyll-*a* (µg/L)	0.30* 0.15**	0.90* 0.50**	1.75* 1.00**
Turbidity (NTU)	0.50* 0.20**	1.25* 0.50**	2.00* 1.00**

* "Wet" criteria apply when the open coastal waters receive more than three million gallons per day of fresh water discharge per shoreline mile.
** "Dry" criteria apply when the open coastal waters receive less than three million gallons per day of fresh water discharge per shoreline mile.

Table 64. State of Hawaii nutrient criteria specific for oceanic waters. Source:(Hawaii Department of Health 2004; Hawaii Department of Health 2009).

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to Exceed the given value more than two percent of the time
Total Nitrogen (µg N/L)	50.00	80.00	100.00
Nitrate + Nitrite Nitrogen (µg [NO3+NO2] -N/L)	1.50	2.50	3.50
Total Phosphorus (ug P/L)	10.00	18.00	25.00
Chlorophyll-*a* (µg/L)	0.06	0.12	0.20
Turbidity (NTU)	0.03	0.10	0.20

Table 65. Site specific NNC for the Pearl Harbor Estuary in Hawaii. Source: (Hawaii Department of Health 2004; Hawaii Department of Health 2009)

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to Exceed the given value more than two percent of the time
Total Nitrogen (µg N/L)	300.00	550.00	750.00
Nitrate + Nitrite Nitrogen (µg [NO3+NO2] -N/L)	15.00	40.00	70.00
Total Phosphorus (µg P/L)	60.00	130.00	200.00
Chlorophyll-*a* (µg/L)	3.50	10.00	20.00
Turbidity (NTU)	4.00	8.00	15.00

Table 66. Area-specific NNC for oceanic waters of the Kona (west) coast of the island of Hawaii in areas where nearshore marine water salinity is greater than 32.00 parts per thousand[1]. Source: (Hawaii Department of Health 2004; Hawaii Department of Health 2009)

Parameter	Geometric mean not to exceed the given single value
Total Dissolved Nitrogen (µg N/L)	100.00
Nitrate + Nitrite Nitrogen (µg [NO3+NO2] -N/L)	4.50
Total Dissolved Phosphorus (µg P/L)	12.50
Phosphate (µg PO4 -P/L)	5.00
Chlorophyll-*a* (µg/L)	0.30
Turbidity (NTU)	0.10

Parameter	**M**
Nitrate and Nitrite Nitrogen (µg [NO3+NO2] -N/L)	-31.92
Total Dissolved Nitrogen (µg N/L)	-40.35
Phosphate (µg PO4 -P/L)	-3.22
Total Dissolved Phosphorus (µg P/L)	-2.86

Idaho

The Idaho Department of Environmental Quality (IDDEQ), Water Quality Division is responsible for development of water quality standards in the State of Idaho (http://www.deq.idaho.gov/water-quality.aspx). The beneficial uses identified in Idaho's Water Quality Standards are very dependent on temperature regime. The following are the beneficial uses identified in Section 100 of Idaho's Water Quality Standards (IDAPA

58.01.02.100)(http://www.deq.idaho.gov/water-quality/surface-water/beneficial-uses.aspx).

Aquatic Life

The standards associated with this use are designed to protect animal and plant species that live in the water.

The following are subclassifications for the aquatic life designation:

Bull trout: unique in that this is a species-specific use.

Cold water: water quality appropriate for the protection and maintenance of a viable aquatic life community for coldwater species.

Salmonid spawning: waters that provide or could provide a habitat for active self-propagating populations of salmonid fishes.

Seasonal cold water: water quality appropriate for the protection and maintenance of a viable aquatic life community of cool and coldwater species, where coldwater aquatic life may be absent during, or tolerant of, seasonally warm temperatures.

Warm water: water quality appropriate for the protection and maintenance of a viable aquatic life community for warm water species.

Modified: water quality appropriate for an aquatic life community that is limited due to one or more conditions that preclude attainment of reference streams or conditions.

Except for the modified use, the main distinction between the subclassifications of aquatic life is different temperature criteria.

The State of Idaho currently lacks NNC (Idaho Department of Environmental Quality 2008). Currently their narrative nutrient criteria states "Surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses". However, the State of Idaho does have a "Numeric Nutrient Criteria Development Plan" which was released in November 2007 (Idaho Department of Environmental Quality 2007). At the time of the publication of "Plan" in 2007, the IDDEQ stated that little if any non-project monitoring had been conducted historically. As a result the IDDEQ recommended in the Plan that the state needed to 1) analyze existing data on nutrients and algal communities in the state, 2) review literature from other state programs and published technical articles regarding nutrient criteria development and 3) classify and prioritize waters for criteria development and 4) devise a sampling plan for collect additional data to assess the relationships among nutrient levels, algal growth and designated uses. As a result IDDEQ initiated a program called the Beneficial Use Reconnaissance Program (BURP) framework. Questions that this program were supposed to answer was characterization of current levels of nutrients and chlorophyll-*a* in state waterbodies along with other related variables and whether there was any correlation between nutrient levels and periphyton assemblages in the waterbody at the time of sampling?

In the Plan the IDEQQ summarizes previous worked sponsored by their agency including a compilation of the 25^{th} percentile nutrient values for Idaho lakes and reservoirs, and rivers and streams at the level IV ecoregion classification. One of the main issues they found that although the agency had good spatial coverage there was often a lack of paired causal and response (e.g. chlorophyll-*a*) data making it very difficult to utilize any type of stressor-response model. Another important finding was when IDEQQ compared new monitoring data with EPA Ecoregion target values, i.e. candidate NNC, many of the waterbodies exceeded the nutrient levels that had been recommended by EPA but few exceeded the chlorophyll-a values suggesting a very weak relationship between the two(Idaho Department of Environmental Quality 2007). The IDEQQ went on to discuss the benefits and negative aspects of several EPA recommended approaches for developing NNC including percentile distribution of all sites, ecoregion reference condition based criteria, stressor response modeling, principal components analysis (PCA), classification and regression tree analysis and other approaches. They also discuss various implementation procedures once a NNC had been established. In the end the authors recommended pursuing CART modeling of the nutrient dataset available and combine that approach with the tiered approach they developed for implementation. This implementation procedure involves the use of combined biological and nutrient data to evaluate whether a site was actually exceeding NNC AND negatively affecting aquatic life use as well. The causal variables they were considering was TP and TN and the response variables were benthic algal and phytoplankton chlorophyll levels.

Illinois

The Illinois EPA (IEPA) is responsible for water quality management programs and development of water quality standards in the State of Illinois (http://www.ipcb.state.il.us/SLR/IPCBandIEPAEnvironmentalRegulations-Title35.asp) and (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_il.cfm). The State of Illinois currently lacks statewide river, stream, lake or reservoir NNC. However, site specific criteria for certain classes of lakes exist. These were extracted from the current State Water Quality Standards and are listed below. These were approved by the EPA back in 1998 ((United States Environmental Protection Agency 2008b).

Subpart B:General Use Water Quality Standards (Illinois Environmental Protection Agency 2009).

Section 302.205 Phosphorus
Phosphorus (STORET number 00665): After December 31, 1983, phosphorus as P shall not exceed 0.05 mg/L in any reservoir or lake with a surface area of 8.1 hectares (20 acres) or more, or in any stream at the point where it enters any such reservoir or lake. For the purposes of this Section, the term "reservoir or lake" shall not include low level pools constructed in free flowing streams or any body of water which is an integral part of an operation which includes the application of sludge on land.

Subpart E: Lake Michigan Basin Water Quality Standards. (Source: Amended at 23 Ill. Reg. 11249, effective August 26, 1999)
Section 302.504 Chemical Constituents
The following concentrations of chemical constituents must not be exceeded, except as provided in Sections 302.102 and 302.530:

c) In addition to the standards specified in subsections (a) and (b) of this Section, the following standards must not be exceeded at any time in the Open Waters of Lake Michigan as defined in Section 302.501.

Constituent	STORET Number	Unit	Water Quality Standard
Nitrate-Nitrogen	00620	mg/L	10.0
Phosphorus	00665	µg/L	7.0

The IEPA does have a Nutrient Standard Development Plan that was released in 2006 (Illinois Environmental Protection Agency 2006). Like many other states at that time IEPA described the process by which they would attempt to develop NNC. This included analysis and classification of nutrient data by ecoregions. They also briefly described several projects that had been funded by an agricultural research organization (CFAR) looking at the influence of phosphorus on stream periphyton. They also laid out a plan to work with the Region 5 RTAG and groups interested in NNC.

In 2005, EPA Regional 5 sponsored studies to begin to evaluate procedures for development of NNC in Illinois and Midwestern streams. (Markus et al. 2005) conducted a study to develop a stream classification system for nutrient criteria in Illinois. (Mosher and Terrio 2010) reported on recent efforts by the State of Illinois to develop NNC in Illinois. In their presentation they describe the statistically based EPA ecoregion criteria recommendations for Illinois that ranged from 0.010 to 0.128 mg/L TP (designated the 25th percentile from EPA ecoregion guidance documents for ecoregion VI, VII, VIII, IX, X, and XI. They quoted that Illinois like many other states felt that the ecoregion statistical based approach is flawed because the levels suggested don't necessarily reflect a critical level where effects on the response variable would be visualized. They reviewed cause/effect studies conducted by 4 teams of researchers during the previous year who had received funding from the CFAR grant program. The focus of these studies, were to evaluate the relationship between TN, TP and algae/chlorophyll. They summarized that based on these studies many of their streams are phosphorus limited and that a strong relationship between nutrients and the chlorophyll-*a* were lacking. The IEPA stated that it would now reanalyze the data using change-point analysis and different end-points (Mosher and Terrio 2010).

Indiana

Indiana currently lacks NNC for most of its waters (Thomas 2011; United States Environmental Protection Agency 2008b) (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_in.cfm). There is however, one site specific standard for Lake Michigan (Indiana State 2007). The rule is quoted below.

Rule 1.5. Water Quality Standards Applicable to All State Waters Within the Great Lakes System. (Excerpt Below pertaining to nutrients).

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327 IAC 2-1.5-8 Minimum surface water quality criteria
(j) Additional requirements for the open waters of Lake Michigan are as follows:
(1) In addition to complying with all other applicable subsections, open waters in Lake Michigan shall meet the following criteria:
Additional Criteria for Lake Michigan

Parameters	Criteria
Total Phosphorus	See 327 IAC 5-10-2

(2) During each triennial review of the water quality standards, prior to preliminary adoption of revised rules, the department shall prepare a report for the board on the monitoring data for the constituents in the following table (see Table 8-10), as measured at the drinking water intakes in Lake Michigan. If these data indicate that the levels of the constituents are either increasing or exceed the levels in the table, the report shall provide available information on the known and potential causes of the increased levels of these parameters, the known and potential impacts on aquatic life, wildlife, and human health, and any recommended revisions of the criteria.

Table 8-10 (not this report – reference made to Indiana regulation above.
Parameters Levels
Total phosphorus
Monthly average 0.03 mg/L
Daily maximum 0.04 mg/L

Recently however the state has conducted analyses of water quality data using multiple lines of evidence (Selvaratnam 2010a)(**Error! Reference source not found.**). They tilized multiple approaches including distributional/reference approach, stressor-response (effects Based), scientific literature, models and experiments. They utilized regional water quality data collected from their monitoring network and compared this to the ecoregion data provided by EPA which demonstrated that EPA data was no longer valid. Indiana is composed of aggregate nutrient ecoregions VI, VII, IX. Based on 7 years of data and multiple water quality data metrics they classified each lake and reservoir into various geomorphic classes and groups that were subject to various levels of stress. They also used change point analysis to detect and identify threshold inflection points. The distribution method yield different (lower) criteria values than those derived using stressor-response methods. The State of Indiana is now working with EPA to develop a final recommendation.

Table 67. Results of analyses conducted by the State of Indiana to develop preliminary estimates of numeric nutrient criteria. From: (Selvaratnam 2010a).

	TP (µg/L)	Chl *a* (µg/L)	SD (m)
Distribution Based			
Natural	23	2.4	2.7
Reservoir	28	1.7	2.5
Mine Pit	12	0.6	4.5
Other	31	4.2	2.0
Stressor-Response			
Natural	47		
Reservoir	56		
Mine Pit	35		

http://www.indianawea.org/resources/Other%20Presentations/YP-GA%20Nutrient%20Seminar/IDEM_Shivi.PDF

Iowa

The State of Iowa currently lacks statewide and site specific numeric nutrient criteria (Iowa State 2007; State of Iowa 2011; United States Environmental Protection Agency 2009b)(http://www.iowadnr.gov/Environment/WaterQuality.aspx). However, the State does have a approved Numeric Nutrient Criteria Plan (Iowa Department of Natural Resources 2006). According to the plan Iowa Department of Natural Resources (IDNR) will be focusing on lake responses to nutrient levels depend on both nutrient loading rates and lake morphology. In Iowa, lake morphology may play a stronger role than most national/worldwide eutrophication models predict. Further sub-classifications of lentic systems will likely be needed to distinguish these differing morphological factors. Natural vs. manmade lakes, mean depth, residence time and drainage area to lake surface ratio are some of the factors that will be investigated to further refine lake use classifications in concert with the adoption of nutrient standards.

Iowa officials also believed that further refinement of the nutrient ecoregions or alternative regionalization schemes will also be important in any future Use Attainability Analyses (UAAs). UAAs will be needed to define the uses attainable associated with the level of nutrient reduction that can be achieved with cost effective and reasonable nonpoint source best management practices. Ecoregional characteristics such as geology and land use may be related to nutrient levels and any UAAs must recognize these differences. At this time, Iowa plans to establish nutrient criteria in two phases. Criteria for lakes will be established first, followed by streams and rivers.

Another major issue for Iowa is coordination with other adjacent states. Iowa shares border waters with Illinois and Wisconsin (Mississippi River) and Nebraska and South Dakota (Missouri and Big Sioux rivers) and upstream-downstream waters with Minnesota and Missouri. Iowa will coordinate any proposed nutrient criteria for these interstate waters with adjacent states. This will be accomplished largely through existing efforts such as the Region VII RTAG and the UMRBA Water Quality Task Force.

The IDNR is utilizing a technical advisory committee (TAC) to assist with development of nutrient criteria for the protection of stream aquatic life. The TAC is assisting IDNR examine important technical issues concerning nutrients and their effects in streams, and will develop criteria recommendations that represent the best-available scientific information. Based on their recent schedule of meetings the group has been extremely busy.

The Iowa Nutrient Technical Advisory Committee has also been assisting IDNR develop nutrient budgets for various waterbodies. According to Iowa Code 459.312(10)2b:

The department shall develop a state comprehensive nutrient management strategy. Prior to developing the state comprehensive nutrient management strategy, the department shall complete all of the following:

(i) The development of a comprehensive state nutrient budget for the maximum volume, frequency, and concentration of nutrients for each watershed that addresses all significant sources of nutrients in a water of this state on a watershed basis.
(ii) The assessment of the available nutrient control technologies required to identify and assess their effectiveness.

(iii) The development and adoption of administrative rules pursuant to chapter 17A required to establish a numeric water quality standard for phosphorus (http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/Nutrients.aspx).

Kansas

The management of the State of Kansas water quality regulatory programs including surface water quality standards is under the jurisdiction of the Kansas Department of Health and Environment (KDHE), Bureau of Water (http://www.kdheks.gov/water/#regs). The current designated used classes include:

A. Agricultural Water Supply Use

B. Aquatic Life Support Use,

1. Special Aquatic Life Use. Surface waters that contain unique habitats or biota that are not commonly found in the state,

2. Expected Aquatic Life Use. Surface waters that contain habitats or biota found commonly in the state,

3. Restricted Aquatic Life Use. Surface waters that contain biota in limited abundance or diversity due to the physical quality or availability of habitat compared to more productive habitats in adjacent waters,

C. Domestic Water Supply Use. Surface waters that are used, after appropriate treatment, for a potable water resource,

D. Food Procurement Use. Surface waters that are used for obtaining edible aquatic or semi-aquatic life for human consumption,

E. Groundwater Recharge Use. Surface waters used for replenishing useable groundwater resources,

F. Industrial Water Supply Use. Surface water used for non-potable purposes including cooling or process water and,

G. Recreational Use. Surface water used for primary or secondary contact recreation (Kansas Department of Health and Environment 2004a).

Currently the State of Kansas lacks NNC. The state relies instead on the use of narrative criteria. In response to ongoing efforts by EPA to encourage States to implement NNC, the KDHE

The current approach Kansas has taken toward developing NNC is outlined in their *Surface Water Nutrient Reduction Plan* (Kansas Department of Health and Environment 2004b). However, since publication of that document there is no doubt that additional unforeseen sources of information have been gathered and new approaches toward development of NNC based on recent publications and activity. Based on its 1998 Nutrient Strategy, EPA developed an ambitious plan to initiate the adoption of nutrient criteria within a very short timeframe. The urgency of the plan revolved around the fact that nutrients were, and still are, one of the major contributing factors leading to degraded water quality.

Initial attempts were made to develop numeric nutrient criteria based on the ecoregion based method which is previously described under other state sections. Basically the approach tried in Kansas used all available existing water quality from 14 “ecoregions” in Kansas. Ecoregions were defined as areas of relative homogeneity in ecological systems and their components. Possible concerns with the approach were raised at past meetings on NNC by the U.S. Geological Survey (USGS) and several States. A recently publication of the USGS predicted that the estimated background concentrations for total phosphorus exceed EPA criteria in 52% of stream reaches nationwide (Smith et al. 2003). In other words, over half the streams nationwide would not be able to meet the EPA-derived criteria for phosphorus due to natural background conditions. This was due to the high variability in nutrient concentration between sites over a short distance. Due to uncertainties in deriving and implementing NNC, Kansas did not make much progress using this approach. According to the KDNR most streams and lakes in Kansas currently fail to meet the published EPA nutrient criteria (Kansas Department of Health and Environment 2004b). For Kansas streams, EPA’s ecoregional criteria range from 0.56 to 2.18 mg/L for TN and from 0.020 to 0.067 mg/L for TP.

Kansas is currently in the process of considering development of NNC for chlorophyll-*a* to protect and support human use (drinking water supply primarily) of public water supply lakes or reservoirs. A white paper on this subject was published prior to consideration of future amendments to the current state water quality standards (Kansas Department of Health and Environment 2011). The recommendations ranged between 8-10 μg/L chlorophyll-*a* in reservoirs as based on single instantaneous measurements with safety margins or long term averages. This number was arrived at by examining several lines of evidence including published reports and analysis of monitoring data (Dodd et al. 2006).

Kentucky

Water quality regulatory programs are administered by the Kentucky Department of Environmental Protection (KDEP) which housed in the Energy and Environment Cabinet of the Commonwealth of Kentucky (http://water.ky.gov/waterquality/ Pages/WaterQualityStandards.aspx). The Clean Water Act requires states to establish water quality standards and then perform reviews every three years.
Kentucky completed its triennial review of water quality standards regulations in September 2004 with approval of the regulations by the Agriculture and Natural Resources Committee. It is currently completing the current triennial review. According to the KDEP on their web site they state *"The next triennial review will be devoted primarily to a single significant water quality issue -- nutrient criteria for wadeable streams and reservoirs"(http://water.ky.gov/waterquality/Pages/ WaterQualityStandards.aspx.).*

The designated use classifications are described in the Kentucky Water Quality Standards 401 KAR 10:026. (http://lrc.ky.gov/kar/401/010/026.htm).

The designated uses are:

(a) Warm water aquatic habitat;

(b) Cold water aquatic habitat;

(c) Primary contact recreation;

(d) Secondary contact recreation;

(e) Domestic water supply; and

(f) Outstanding state resource water.

As with the other state descriptions we focused on activities associated with development of NNC for protection of aquatic life and associated functions. Based on our review there currently there are no NNC listed either statewide or for specific waterbodies in the most recent version of the Kentucky water quality standards listed in *401 KAR 10:031. Surface water standards*(http://lrc.ky.gov/kar/401/010/031.htm)(Natural Resources and Environmental Protection Cabinet 2004).

The KDEP however did publish a Nutrient Criteria Development Plan on August 2007 which provides guidance on future planning and research activities in support of NNC development ((Kentucky Department for Environmental Protection 2007). After reviewing this document we have highlighted some of the more important recommendations. Much of the information below was extracted verbatim.

Kentucky has relatively few natural lakes compared to northern and western states. Most natural lakes in the state are floodplain lakes located near the Ohio and Mississippi rivers. These lakes are naturally highly eutrophic. There are at least 45 of these lakes Summary statistics for the data set are:

	Median	Range
TP (mg/l)	0.114	0.043 – 0.397
TN (mg/l)	0.792	0.525 – 2.217
Chl *a* (ug/l)	36.2	20.1 – 300.4
Secchi (m)	0.3	0.2 – 1.2
Carlson TSI (Chl *a*)	65.8	60 – 86.6
Max. Depth (m)	2	1 – 6

The Carlson TSI values for chlorophyll-*a* indicate that the lakes range from highly eutrophic to hypereutrophic. The authors also illustrate some very important issues and mechanisms that have applicability when others are attempting to develop NNC in their state. That is local knowledge of "natural" processes is often extremely important in deciphering possible mechanisms for high levels of nutrients and response variable levels, i.e. chlorophyll-*a* The causes for this are related to natural processes, such as the phosphorus inputs from the 1) Ohio River during flooding (median bimonthly TP of 0.08 mg/L, range <0.05 - 0.31, 1999 - 2001), 2) their shallow nature which allows mixing of sediment phosphorus back into the water column where it can be utilized by algae, and 3) most importantly their location in the Mississippi Flyway. The Flyway is a major duck and geese migratory route. In the winter, thousands of ducks and geese frequent these lakes on a daily basis and fertilize them as a consequence. As a result FDEP plans on grouping this group of waterbodies separately and assessments will be made as to whether criteria development is necessary. Many of them are in waterfowl refuges, on private property, or inaccessible by road.

According to KDEP, reservoirs are more common in Kentucky, but not particularly numerous. There are about 105 publicly-owned reservoirs that are routinely monitored by the Kentucky Division of Water (KDOW) or other agencies such as the U.S. Army Corps of Engineers (COE). Most large reservoirs are managed by the COE. An important observation that was made was that the variety of reservoirs both in size and shape but also in function may have a tremendous influence on "normal" nutrient levels. The variety of reservoirs mentioned ranged from small to large (>1000 acres), and operated for flood control, water supply, recreation and for fish production in smaller pond reservoirs. KDEP mentioned that nutrient criteria development will focus on publicly-owned lakes and reservoirs. Large (generally greater than 1000 acres in size) reservoirs will be addressed as a group. These in turn can be grouped by type, such as mainstem run-of-the-river, mainstem storage, and tributary storage. Smaller reservoirs less than 1000 acres will be a second group and will be further grouped by management agency.

KDEP made an interesting observation that may be applicable in other states. They noted that some smaller lakes are fertilized by the Kentucky Department of Fish and Wildlife Resources (KDFWR), apparently to enhance fisheries production. KDEP therefore they felt that for these waterbodies it may not be appropriate to develop nutrient criteria. This provides an excellent example of illustrating the dual nature of nutrients in terms of providing beneficial products (e.g. fish production) when managed properly. It also illustrates a potential are of disagreement with the non-fisheries management public and users who may not see fishing opportunities as an acceptable and appropriate goal for subjecting a lake to artificial enrichment.

Currently Kentucky has narrative criteria in its water quality standards to protect waters from unwanted effects of eutrophication. New criteria development will be focused on "effect-based relationships" that quantifiably link nutrients to use impairments. KDEP will concentrate on the following parameters for this analysis in classes of waters and uses as shown below:

Water Class	Use	Parameters
Wadeable Streams	Aquatic Life	TN, TP
Boatable Waters	Aquatic Life	TN, TP, Chl *a*,
	Domestic Water Supply	TN, TP, Chl *a*, Taste and Odor
Lakes and reservoirs	Aquatic Life	TN, TP, Chl *a*
	Domestic Water Supply	Secchi depth

Like many other states KDEP planned to prioritize their efforts on protection of the aquatic life uses of waterbodies. The KDEP left out a measure of turbidity and chlorophyll-*a* from the parameter list for wadeable streams because they are periphyton dominated and KDEP planned on using biotic index relationships to determine aquatic life impacts in streams. A measure of turbidity is not included for "boatable" waters because of the dominant role of inorganic turbidity in Kentucky waters. In these rivers KDEP argued that turbidity measurements mostly reflect suspended solids, not algal concentrations.

As mentioned previously, the KDEP (KDOW) focused on developing an effects-based approach for nutrient criteria development in Kentucky waters. We have provided a brief discussion on the development for each type of broad class of waters.

Wadeable Streams

Due to the expertise in diatom taxonomy and ecology, the amount of data collected over the past 27 years, and the sensitive bioassessment tool that had been developed, KDOW chose to examine the diatom community structure instead of algal biomass as a method for assessing aquatic life use support in wadeable streams. KDEP stated that the association between biomass and aquatic life use was not well developed. KDEP claimed that they had observed past associations between benthic biomass and a recreation or aesthetics use impairment. An example is nuisance mats of blue green algae impeding or preventing swimming.

The metric KDEP was interested in utilizing to assess impacts to aquatic life from nutrients was the *Diatom Bioassessment Index* (DBI). This multimetric index of six parameters, was derived in 1992 and updated in 2000. The DBI had been intrinsically designed to be sensitive to nutrient enrichment and other impacts such as sedimentation, salinity, acidity, and metals. According to KDEP, the DBI provides water resource managers with a precise community-structure based tool for assessing aquatic life use support.

Diatom community structure does not change within a reach unless a stressor influences a shift in the community. Diatoms respond quickly to acute pollution contamination. They also are good indicators of chronic problems. There may be species level changes in the community throughout the growing season; however, in most cases, the overall community structure and associated bioassessment results normally remains the same, so collections can be made throughout most of the growing season.

FDEP preferred using the DBI over biomass as an indicator of nutrient impacts. They argued that for example, algal biomass can be highly variable within the same reach of stream. Nutrient enrichment is not the sole factor influencing biomass accrual. For example the availability of light is the dominant factor affecting algal biomass. Other major variables include grazing pressure, flow, substrate types, and mat density. It would be difficult to isolate the effects of nutrients on the biomass from these other factors. Seasonality can also influence algal biomass at a stream reach.

KDEP points out that as seasons change, succession of algal divisions occurs. Therefore multiple collections throughout the growing season would be required in order to account for this natural variability. Surface area calculations are often difficult to obtain from natural substrates. In reaches where large, flat boulders or cobbles or bedrock are present, surface area can be easily determined. However, in streams dominated by fines (sand or sediment) or small round pebbles, surface area calculations are problematic.

At the time of the publication of the Nutrient Criteria Development Plan the Division of Water within KDEP, i.e. KDOW had just completed a study entitled "*Determining Nutrient Impairment Using Biological and Other Non-Chemical indicators in Kentucky Streams"* (Brumley et al. 2004). The authors had been charged with evaluating the sensitivity of diatom and macroinvertebrate metrics to exposure to elevated nutrient levels. They suggested that depending on the ecoregion levels of TP or TN at concentrations at 0.045 mg/L or 0.860 mg/L respectively could degrade algal and macroinvertebrate integrity. In other streams TP levels greater 0.163 mg/L was associated with degraded and impaired community structure. The authors stated more information was needed and that this was considered preliminary results.

"Boatable" Waters

KDEP provided a copy of the draft implementation plan for the Ohio River developed by the Ohio River Valley Water Sanitation Commission (ORSANCO). Kentucky is a member of the nutrient workgroup that is working on this approach with other members (Ohio River Valley Water Sanitation Commission 2002). KDEP expected to apply the framework of this plan to other large boatable (nonwadeable) rivers in Kentucky as well. However, they pointed out that the relationship of biota in other Kentucky boatable waters to use impairment is poorly understood and not well developed. FDEP stated that they will continue to work with ORSANCO and the EPA Cincinnati office to refine biological collection methods for large rivers. They planned that after methods have been finalized, metrics will be developed to use in assessing aquatic life use impairment. At that time, an assessment could be made to determine if any of these metrics can be related to nutrient impairments. Since there are no boatable waters in the state that can serve as a reference condition for other similar waters, least impacted segments of individual rivers will need to be defined.

A major problem that KDEP acknowledge was the lack of a good historical record for water quality and biota on specific rivers or if present is not very robust to use as a surrogate condition. Therefore, as noted in the referenced ORSANCO report, it may be necessary to use domestic water supply use impairment and chlorophyll-*a*/nutrient and taste and odor relationships as the basis for developing nutrient criteria for these waters.

Lakes and Reservoirs

KDEP did not believe that EPA's recommended ecoregion based criteria are based on a realistic assessment of their attainability in Kentucky waters . Preliminary comparisons of recent reservoir data from waters that meet aquatic life uses show that EPA's recommended criteria are frequently exceeded, but with little pattern by parameter over time. The values in Table 1 represent growing season whole lake averages from three samples taken from May to October, the normal sampling frequency to assess use support.

The EPA criteria are drawn from parameters that have known relationships. However, since the criteria were taken from separate databases for each parameter (the 25th percentile of the medians of individual lake data sets), the relationships are not reflected in the criteria. This resulted in a random pattern of observations exceeding recommended criteria. One would expect that if the chlorophyll-*a* or Secchi depth criterion is exceeded, then a causal parameter (TP or TN) also would be exceeded. However, that was not always the case. For example, several lakes data indicated that Chl-A, TP, and TN exceed criteria with no apparent pattern. Therefore the State of Kentucky felt it would be a dilemma to list lakes as impaired where response parameters (Chl-A, Secchi disk depth) are exceeded but causal parameters (nutrients) are not. For example, developing a Chl-A TMDL would be problematic if nutrients are not the cause of impairment. The considerations above have led us to focus on an effect-based approach. One approach that Kentucky will investigate is to set chlorophyll-*a* criteria (based on a TSI value) for individual reservoirs that reflect the unimpaired condition and back-calculate the TP and Secchi disk depth from TSIs that correspond to that value. This preserves the relational integrity of the associated parameters. The relationship between TN and trophic state in lakes is not well developed and will be investigated. If it is not strongly limiting, criteria may not be necessary.

Domestic water supply use impairment and chlorophyll a/nutrient and taste and odor relationships will also be investigated as a basis for developing nutrient criteria for reservoirs used as a source of drinking water.

Priority for Nutrient Criteria Development

The priority for KDEP in nutrient criteria development is listed below and is based on those waters that have the most abundant currently available data.

1. Wadeable streams and intrastate reservoirs
2. Ohio River
3. Other boatable waters
4. Interstate and border waters

Wadeable Streams and Reservoirs

KDEP stated that priority will be give to developing nutrient criteria on wadeable streams. Intrastate reservoirs that are not on the current 303(d) list or that do not have approved TMDLs or a TMDL under development for aquatic life impairment because of nutrients will be prioritized next for nutrient criteria development. If new waters are added to the 303(d) list because of nutrient impairment before criteria are established, the TMDL process may be used to set nutrient concentrations. If we are confident in our criteria development at that time, we may set targets for the TMDL utilizing the draft criteria to see how effective they will be in restoring the aquatic life use.

Ohio River

The interstate waters of the Ohio River are managed by the Ohio River Valley Water Sanitation Commission (ORSANCO). ORSANCO has a published nutrient criteria strategy which calls for this to be a priority for compact states. KDEP and KDOW is actively participating in this effort. However, the effort has been delayed because a suitable endpoint cannot be determined. ORSANCO is proposing to bring in a team of consulting experts to assist in the effort.

Other Boatable Waters

FDEP stated that these waters will by necessity be addressed later because methods and indices need to be developed by ORSANCO, EPA and others before cause and effect relationships can be investigated.

Interstate and Border Waters

FDEP stated that development of nutrient criteria for interstate waters and for waters flowing into or out of Kentucky to other border states will be addressed by forming workgroups with West Virginia and Virginia for the Big Sandy and Tug Fork rivers, with Virginia for the Russell Fork, and with Tennessee for the Cumberland and Red rivers. Similar workgroups will be formed on shared reservoirs with Tennessee (Dale Hollow, Kentucky, and Barkley). Management agencies, including the USCOE, state fish, and wildlife agencies and universities with active limnological research programs, will be asked to participate. Priority for nutrient criteria development on these waters will be dictated by coordinating the priorities and schedules of each state.

Other Planned Activities

Other high priority issues that were identified included, locating and characterizing environmental and water quality data from various sources including quality of those data. In addition, FDEP planned to establish a regular series of public meetings and meetings of the Nutrient Technical Advisory Team.

Related Studies

The EPA and FDEP provided support to the U.S. Geological Survey to conduct a study to investigate methods to develop NNC in regional streams (Crain and Caskey 2010). Specifically the U.S. Geological Survey and the Kentucky Division of Water collected and analyzed water chemistry, turbidity, and biological-community data from 22 streams throughout the Crawford-Mammoth Cave Upland ecoregion. This data was needed to assist Kentucky in development of NNC in the Pennyroyal Bioregion, (U.S. Environmental Protection Agency Level IV Ecoregion, 71a) within the Pennyroyal Bioregion from September 2007 to May 2008. Statistically significant and ecologically relevant relations among the stressor (total phosphorus, total nitrogen, and turbidity) variables and response (macroinvertebrate-community attributes) variables and the breakpoint values of biological-community attributes and metrics in response to changes in stressor variables were determined. They found that thirteen of 18 macroinvertebrate attributes were significantly and ecologically correlated (p-value < 0.10) with at least one nutrient measure. The biological breakpoint relations with median concentrations of TP in this study were similar to the U.S. Environmental Protection Agency proposed numeric TP criteria (0.037 mg/L), but were 1.5 times higher than the proposed numeric criteria for concentrations of TN (0.69 mg/L). The breakpoints determined in this study, in addition to Dodds' trophic classifications, were used as multiple lines of evidence to show changes in macroinvertebrate community and attributes based on exposure to nutrients.

Louisiana

Information on the status of Louisiana's progress toward development of NNC including studies and regulations were obtained from the state web page, EPA's web page on state actions, N-STEPS web site and EPA's summary documents (Laidlaw 2010b; Thomas 2011; United States Environmental Protection Agency 2008b). In addition, Ms. Kristine Pintado, who works in the section of the Louisiana Department of Environmental Quality which deals with Water Quality Standards provided both verbal information and directed us to appropriate documents. Currently the State of Louisiana does not have any numeric nutrient criteria (Laidlaw 2010b; Louisiana Department of Environmental Quality 2006a; Louisiana State 2011; Thomas 2011; United States Environmental Protection Agency 2008b). However, Louisiana has produced a recent Nutrient Criteria Plan (Louisiana Department of Environmental Quality 2006b). The following information and description of their objectives and procedures is largely extracted from that document.

The Louisiana Department of Environmental Quality (LDEQ) submitted its first Nutrient Criteria Development Plan in December 2001 and continued working towards development of ecoregionally-based numeric nutrient criteria for Louisiana water bodies. LDEQ submitted an updated and expanded version of its plan in December 2004 for EPA review and comment. The most recent version of the plan, dated May 2006, incorporates the comments received from EPA Region 6 staff during July 2005. The Nutrient Criteria Development Plan will be updated as necessary. According to LDEQ EPA will be informed of progress towards the nutrient criteria adoption process and any changes to the plan at least on an annual basis, or as necessary.

LDEQ plans to develop numeric nutrient criteria for water body types within its 12 ecoregion boundaries as delineated by (Louisiana Department of Environmental Quality 2006b). The water body types scheduled for nutrient criteria development in Louisiana (by order of priority) are 1) inland rivers and streams; 2) freshwater wetlands; 3) freshwater lakes and reservoirs; 4) big rivers and floodplains/boundary rivers and associated water bodies; and 5) estuarine and coastal waters (including up to Louisiana's three mile boundary in the Gulf of Mexico). LDEQ has compiled nutrient data from LDEQ's Ambient Water Quality Monitoring Network database, EPA's STORET, USGS NAWQA and NWIS, and from studies conducted by LDEQ for nutrient criteria development. The nutrient database contains the following parameters that could be used for nutrient criteria development: TP, TKN, NO_2-NO_3, Secchi depth, DO, turbidity (NTU), and TDS for over a ten year period beginning in January 1990 through December 2003. The data has been arranged into the Louisiana/LDEQ ecoregion format and preliminary statistical analysis has been conducted for each water body type within the ecoregions.

LDEQ has identified data gaps and further data will be collected to fill these gaps as part of the nutrient criteria development process. Studies have been initiated by LDEQ for the first priority water bodies, which include rivers and streams, to assess relationships between nutrients, DO, stream habitat, and the abundance and species composition of resident fishes in least-impacted reference streams. Preliminary work towards nutrient criteria for freshwater forested and marsh wetlands demonstrates that nutrient effects in these systems are reflected in above-ground productivity and therefore nutrient criteria for these water bodies may be best described in terms of loading rates.

LDEQ will consider all feasible and scientifically defensible methods for deriving nutrient criteria. LDEQ stated that it will rely on the three general approaches for nutrient criteria development developed and described in EPA's guidance including: 1) identification of reference reaches for each stream class (or water body type) based on best professional judgment or percentile selections of data plotted as frequency distributions; 2) use of predictive relationships (i.e., trophic state, models, etc.); and, 3) application and/or modification of established nutrient/algal thresholds (i.e., periphytometer studies). LDEQ will also possibly use a weight of evidence approach that will combine any or all of these approaches to produce appropriate and defensible nutrient criteria for Louisiana's waters.

Maine

Maine does not currently have numeric nutrient criteria (Laidlaw 2010b; Thomas 2011; United States Environmental Protection Agency 2008b). The Maine Department of Environmental Protection (MEDEP) adopted a nutrient criteria plan in February 2002 and revised in 2005 (Richardson 2002), Maine Department of Environmental Protection 2005). Excerpts of the original Plan are provided below with some discussion where needed to provide a historical context and approach used by this state. However, Maine recently proposed new NNC but has retracted these due to unfavorable reviews from EPA. This is discussed later in this section. Maine's specific approaches to nutrient criteria development vary by waterbody type, and are described in the separate sections below devoted to lakes, rivers and streams, wetlands, and estuaries.

Lakes - Historical Approach to Nutrient Criteria Development & Implementation

"Existing Allowable Numerical Incremental Change-Based Methodology"

MEDEP's current and past approach to lakes nutrient criteria development and implementation is geared toward lake protection and conservation on a state-wide basis, through the control of nonpoint sources of pollution from human development within lake watersheds. MEDEP considers this a "designated use" approach, designed to implement existing narrative water quality standards for lakes with a translator procedure (Gibson et al. 2000) involving acceptable (non-polluting) increases in phosphorus loading to lakes. Maine has evaluated site-specific lake data, and has determined that designated uses will be protected for all categories of lakes, provided that increases in total phosphorus levels do not exceed certain threshold levels. MEDEP felt that this "nondegradation" approach fully reflected localized conditions and protected specific designated uses. FDEP stated that in their deliberations with EPA it appeared that this was also the federal preferred approach to nutrient criteria development when feasible.

Relationship of Nutrient Criteria to Water Use Classification

The current water use classification system in Maine has a single GPA classification for all "Great Ponds", as well as natural lakes and ponds less than 10 acres in size. This GPA water use classification also includes some impoundments of rivers that are defined as great ponds. The GPA narrative water quality standard requires "a stable or decreasing trophic state (based on measures of chlorophyll-*a* content, Secchi disk transparency, TP, and other appropriate criteria), subject only to natural fluctuations and freedom from culturally induced (nuisance) algal blooms which impair their use and enjoyment." [MRSA Title 38 §465-A]. Within the lakes context of numerical (incremental) nutrient criteria development in Maine, it is important to note that new direct pollutant discharges are not allowed into Class GPA waters, so nonpoint sources are the primary sources of nutrient enrichment. Any point source discharges licensed prior to January 1, 1986 are allowed to continue only until practical alternatives exist (there are only a few of these remaining in Maine). Also, no change of land use in the watershed may, by itself or in combination with other activities, cause water quality degradation that would impair the characteristics and designated uses or cause an increase in the trophic state of GPA waters. According to MEDEP, the basis for Maine's lake nutrient criteria methodology was the recognition of stable or decreasing trophic state for any given lake statewide, that is recognizing that minor increases in phosphorus levels may occur without any violation in water quality standards (i.e., increased trophic state). The incremental total phosphorus concentration criteria is not used to determine if a lake is attaining the narrative stable or decreasing trophic state water quality standard. Trend analysis using a variety of in-lake trophic parameters (e.g., transparency, chlorophyll-a, dissolved oxygen profiles), which are more sensitive and robust than phosphorus measures alone, are used to determine violations in lake water quality standards. The incremental phosphorus criteria methodology was rather used to manage new non-point (watershed) total phosphorus loadings to lakes in order to avoid any perceivable increase in lake trophic state.

Although Maine DEP's water quality standards and classification system recognizes only one lake class (GPA), MEDEP has examined state-wide data for transparency, phosphorus, Chl-A, color, summertime dissolved oxygen levels, and seasonal fluctuations in algal and nutrient levels to determine lake sensitivity to additional loadings of total phosphorus. MEDEP subsequently established five categories of water quality for Maine lakes based on this analysis (See **Error! Reference ource not found.** below taken from Appendix C on page 105 of *Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development*, Dennis et al., Maine DEP, revised 1992). Note this original document has been revised extensively and is not longer available and does not contain this table. The most current version of this guidance document is dated 2008 and is not written by the same author. The revised document can be found at the web link below. (http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps/index.htm.) Subsequently, total phosphorus allocations are calculated for any new developments within the lake watershed, through site plan reviews under local town land use or subdivision ordinances and Maine DEP's Stormwater Management Law. The top three ("outstanding, good, moderate/stable") categories of lakes definitely meet the MEDEP narrative water quality standard of freedom from nuisance algal blooms Table 68. The fourth category (moderate/sensitive) of lakes are generally, but not always algal bloom free, while the fifth category ("poor/restorable") includes lakes which usually do not meet the freedom from algal bloom criteria. For lakes not attaining water quality standards, Maine DEP calculates a lake-specific target total phosphorus concentration as part of a TMDL. The numeric phosphorus target concentration for an impaired lake is selected using best professional judgment based on a review of statewide water quality data for lakes taking into consideration available lake-specific water quality data and the water quality goals of MEDEP. Lakes water quality data reviewed include average epilimnion grab/core samples corresponding to non-bloom conditions, as reflected in measures of Secchi disk transparency (> 2.0 m) and chlorophyll-*a* (< 8.0 ppb).

The incremental numeric lake nutrient criteria approach applies to all Maine lakes and effectively supports current water use classification and existing narrative lake water quality standards. Currently, however, the lake watershed phosphorus control process is applied by towns on a voluntary basis in lake watersheds, except for site development covered by Maine's Stormwater Management Law (Richardson 2002)

Table 68. Categories of water quality for Maine lakes. From: Dennis et al. 1992.

Water Quality Category	Secchi Disk (feet)	Chlorophyll a (ppb)	Phosphorus (ppb)	Algal Bloom Risk and Comments
Outstanding	>30	$\leq$ 2	2 - 5	Exceptional water quality. Very clear lakes with low algae levels and very low phosphorus concentrations. Rare and unique aquatic resources which are particularly sensitive to small increases in phosphorus.
Good	20 - 30	2 - 4	5 - 10	Generally clear lakes with relatively low algae and phosphorus levels. Fairly common type for larger lakes.
Moderate/ Stable	10 - 20	4 - 6	10 - 15	Less clear lakes which do not have summer algae blooms. Moderate algal and phosphorus levels. Not at high risk; stable algal and nutrient levels with little seasonal variation.
Moderate/ Sensitive	6 - 10	6 - 8	15 - 20	Lakes with similar water quality as above, but have high potential for developing algae blooms due to: significant declines in dissolved oxygen levels and/or large seasonal algal & nutrient level fluctuation.
Poor/ Restorable	<6	>8	>20	Lakes usually supporting nuisance summer algal blooms which receive conservative treatment to increase the feasiblity for restoration.

Accordingly, MEDEP had established a range of acceptable increases in lake phosphorus concentration (ppb) for each water quality category, in order to define the level of increased phosphorus concentration that would not risk a perceivable increase in lake trophic state and hence, a violation of narrative water quality standards. Table 3-2 (page 11) from the Maine DEP 1992 lake watershed phosphorus control technical guide (see below Table 69) represented the "translator" process between the narrative water quality standards and the acceptable increase in phosphorus concentration which was viewed as a surrogate numeric nutrient criteria or control parameter. Phosphorus control was more stringent (lower acceptable increase) for sensitive waters ("outstanding" and "moderate/sensitive") which would tend to respond much more dramatically to any given increase in total phosphorus than a "good" or "moderate/stable" lake.

Table 69. Relationship between water quality and lake phosphorus levels. From: (Table 3-2 in Dennis et al. 1992)

Acceptable Increase in Lake Phosphorus Concentration (ppb)		
Water Quality Category	**Lake Protection Level**	
	High	**Medium**
Outstanding	0.5	1.0
Good	1.0	1.5
Moderate/Stable	1.0	1.25
Moderate/Sensitive	0.75	1.0
Poor/Restorable	0.2-0.5	

NOTE: A high level of protection is assigned to public water supplies and coldwater fisheries. All other lakes are assigned a medium level of protection.

MEDEP Current "Phosphorus Control Methodology in Lake Watersheds"

The lake watershed phosphorus control evaluation process now in place enables local town planning boards to use specific information provided by MEDEP to select an acceptable water quality goal or lake protection level (high to low) for any given lake (Maine Department of Environmental Protection 2008). In addition to proposed new NNC (see next section), Maine still retains modified phosphorus standards, designed to limit phosphorus runoff from new development which are a continuation of the original standards implemented in 1992. These standards were established because state law requires that 1) all lakes shall have "stable or decreasing trophic state" and that 2) no change in land use in a watershed of a lake may result in water quality impairment or increase of trophic state of the lake (Title 38, Article 4-A, § 465-A.1).

These two provisions were addressed in part by the Maine Department of Environmental Protection (DEP) under the Chapter 500 Stormwater Management Rules and by many local ordinances, both of which require certain new developments to incorporate stormwater phosphorus mitigation measures based on lake specific watershed phosphorus budgets and other provisions in Volume II of the Maine Stormwater Best Practices Manual - Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development (Maine Department of Environmental Protection 2008). The newer guidance also defined the acceptable increase in phosphorus concentration for different types of lakes (**Error! Reference source not found.**).

Table 70. Acceptable increase in lake phosphorus concentrations (ppb). From: (Maine Department of Environmental Protection 2008)

Water Quality Category	Public Water Supplies & Coldwater Fisheries	All Other Lakes
Outstanding *Exceptional clarity; very low phosphorus and chlorophyll concentrations; low risk of internal recycling from sediments*	0.5	1.0
Good *Average to better than average clarity, phosphorus, and chlorophyll; low risk of recycling from bottom sediments*	1.0	1.5
Sensitive *Average clarity, phosphorus, and chlorophyll; high potential for phosphorus recycling from bottom sediments*	0.75	1.0
Poor (restorable) *Poor clarity; high phosphorus, and chlorophyll concentrations; supports blue green algal blooms; good prospects for restoration*	(0.2 – 0.5)	(0.2 – 0.5)
Poor (natural) *Poor clarity; high phosphorus, and chlorophyll concentrations; supports blue green algal blooms; poor prospects for restoration because lake is naturally very productive*	2.0	2.0

Data Sources Supporting Lakes Nutrient Criteria Development

MEDEP had an extensive and comprehensive statewide lake water quality data base, dating back to the 1970's, with over 1,000 lakes sampled. MEDEP also conducted routine lakes baseline monitoring of 120 lakes on an annual basis. A large number of these lakes are specifically chosen (non-probabilistically) to refine Maine water quality categories on a statewide basis. Currently, there are no plans, or perceived needs, for the collection of any additional field data to support the existing lakes nutrient criteria implementation process.

Data Analysis

According to MEDEP, data have already been and will continue to be analyzed to evaluate lake potential for internal phosphorus recycling, dissolved oxygen depletion rates, coldwater fishery impacts, and assigning waterbody sensitivity ratings. Data are also analyzed from the perspective of specific high value water resources, such as public water supplies and coldwater fisheries. Water quality categories inclusion for individual lakes in Maine may be modified as a result.

Historical Rivers and Streams Nutrient Criteria Development

Past Approach

Maine planned to develop nutrient criteria for rivers and streams that will detect cultural eutrophication as a result of increases in nutrient loading (Richardson 2002). MEDEP planned to use scientifically defensible methods to develop nutrient criteria suitable to protect designated uses. MEDEP will also investigate the use of chemical nutrient concentration thresholds identified in the EPA's Nutrient Criteria Guidance Documents for Rivers & Streams in Ecoregions VII and XIV (United States Environmental Protection Agency 2000h). MEDEP felt that the wide range of spatial and temporal nutrient conditions inherent to flowing waters means that a single indicator or measurement does not always represent ambient conditions. The approaches being considered by MEDEP initially included a combination of the following: vegetative productivity indicators, biochemical indicators, chemical nutrient concentrations, and human aesthetic standards. Vegetative productivity is an integrated response to nutrient inputs in conjunction with geography, flow and light conditions. This means that flow conditions (slow versus fast) and other logical variables that result in distinct community responses will be used to stratify the proposed sampling method.

Relationship to Water Use Classification

Maine has a well defined stream and river classification system as defined in Maine's Water Classification Program, Maine Revised Statutes, Title 38, Article 4-A. This statute states, '…that it is the State's objective to restore and maintain the chemical, physical and biological integrity of the State's waters…". Flowing freshwaters are protected by a system of four classes (AA, A, B, C) that are characterized by naturally occurring conditions and a set of regressive standards for dissolved oxygen, bacteria, and aquatic life. This system was developed to preserve the natural conditions of relatively undisturbed waters and maintain the biological integrity of waters in culturally developed watersheds. Maine will consider fitting nutrient criteria for rivers and streams into this existing classification system. In accordance with this system, nutrient criteria would be developed for unimpacted waters and waters that have anthropogenic influences that range from permitted discharges to nonpoint sources of pollution.

Coordination with Regional Technical Assistance Group/ Integrate with Adjacent States

MEDEP staff has participated in Regional Technical Assistance Group (RTAG) meetings, conference calls and workshops related to nutrient criteria development to stay informed of current technical issues. MEDEP felt that participation in the RTAG should provide Maine the opportunity to share information and exchange administrative concerns with neighboring states (Richardson 2002). MEDEP staff also actively participated in regional environmental professional organizations dealing with water quality and aquatic/marine biology.

Data Sources and Needs- Streams

At the time of the release of the first Nutrient Criteria Development Plan, nutrient data in Maine's rivers and streams was limited since numerical criteria for water quality classification were determined by dissolved oxygen, bacteria and macroinvertebrate community structure. These parameters represented the majority of past data collection efforts, since they legally defined the classification system. Phosphorus data had been collected incidentally during sampling programs designed to determine the impact of point source discharges and develop TMDL's. MEDEP felt that these sampling efforts should have been expanded to better define the relationship between phosphorus concentrations and other measures of degradation, such as dissolved oxygen or aquatic life. High phosphorus concentrations in the water column had been connected to low dissolved oxygen, but studies had also observed low phosphorus concentrations in flowing waters with obvious signs of enrichment, such as heavy densities of macrophytes and attached plankton. In these systems it is hypothesized that phosphorus is rapidly taken up by vegetation, leaving low concentrations in the water column. Vegetative growth during the summer may mask nutrient inputs and contribute towards the variability found in phosphorus concentrations in rivers. High phosphorus concentrations usually indicate a nutrient related problem, conversely low phosphorus concentrations do not necessarily exclude nutrient problems. Additionally, the majority of phosphorus data in Maine had historically been collected on culturally influenced systems and little data exists that characterizes unimpaired systems or reference conditions. A surge in phosphorus concentrations during storm water runoff events is observed in both undisturbed and disturbed watersheds. The variability in phosphorus concentrations in flowing systems may result not only from cultural enrichment, but also from instream vegetative growth, storm water runoff and geographic factors like soils and slopes. There is a lack of widespread sampling data to adequately characterize the range of phosphorus concentrations found in Maine, from relatively undisturbed systems and those dominated by non point source pollution.

At that time MEDEP was initiating the first steps to develop specific approaches to gauge the impact of nutrient enrichment on established designated uses. To accomplish this objective, Maine DEP seeks to establish the connection between nutrient enrichment, dissolved oxygen and a symptom of enrichment (excessive growth in algal communities). This would eventually require continuing and expanding MEDEP's recently initiated periphyton sampling program. Ideally, the issue of how nutrients and vegetative growth interfere with designated uses will be explored by gauging human perception of stream quality (odor and vegetation density).

Data Analysis

As part of the nutrient criteria development process, MEDEP continued to review various available data analysis methods that cover sampling instream algal communities. Sources may include the scientific literature, EPA and other agency technical guidance documents and DEP staff expertise. MEDEP felt that it was also necessary to try and quantify the effects of eutrophication on human perception of aesthetics and desire to use the waterbody. The study of human perception would require finding collaborators with expertise in studying the human dimensions in natural resources and developing protocols and methods.

Outside Expertise and Peer Review

MEDEP had used outside expertise for taxonomic identification of biological samples and laboratory analyses of water samples. MEDEP was also working with Dr. Jan Stevenson of Michigan State University to develop algal methods and indicators to stream quality based on periphyton sampling.

Staffing and Resource Needs

In order to develop and implement nutrient criteria for freshwater streams and rivers by 2004, MEDEP estimated that it would need additional resources including staff and other professionals (social sciences) to complete the studies on algal communities, characterize reference conditions and initiate the study on human perception.

Administrative Procedures for Implementation

After the Maine DEP determines the best technical approach to nutrient criteria, then DEP would probably incorporate the approach into the existing stream and river classification system. Alternatively, nutrient criteria may also be used to add an anti-degradation standard to the current classification system. Once the nutrient criteria becomes part of Maine's Water Classification Program, then it will be another set of standards used to evaluate the whether a stream or river meets classification. Water bodies that violate classification are then subject to additional Department scrutiny and eligible for restoration efforts.

Public Participation and Stakeholder Involvement

Maine DEP planned on soliciting public participation for rulemaking and statutory changes through public meetings of the Board of Environmental Protection and public hearings as needed. Maine DEP may also convene a technical stakeholders group to involve interested parties in addressing major issues, which arise. At the time of the original Plan, the MEDEP was hoping to adopt nutrient criteria by the target date of 2004. Although at the time the agency already had major concerns of being to meet that deadline.

Wetlands

Approach

Due to the range of natural conditions inherent to wetlands, including wide spatial and temporal variability in nutrient concentrations, Maine plans to develop nutrient criteria based on biological response indicators. Approaches being considered include the use of algal and vegetative indicators of wetland nutrient enrichment (community composition, productivity, etc). These approaches were presented in EPA's "Methods for Evaluating Wetland Condition" Modules (DRAFT EPA 843-B-00- 002, May 2001). Note this has been finalized and is correctly referenced as (United States Environmental Protection Agency 2008a). Maine DEP was also participating in a cooperative project with Michigan State University to develop algal assessment methods for wetlands. MEDEP will also investigate the use of chemical nutrient concentration thresholds as appropriate for specific wetland classes.

Relationship to Water Use Classification

The current use classification system in Maine needs legal clarification with respect to wetlands. Although Maine does not have wetland-specific water quality standards, existing uses and criteria for fresh surface waters and estuarine and marine waters may be applicable to wetlands as an interim measure. This approach has been used by other states and by some Department programs, but has not been consistently applied in Maine. Biological impairment thresholds developed for nutrients will be tied to existing use classes, if it is determined that these classes are applicable to wetlands. Otherwise, new classes will need to be defined and adopted into law. The long-term goal for Maine is to develop wetland-specific uses and criteria.

Wetland Classification

MEDEP planned on evaluating various a priori classification systems, including Cowardin, US Fish and Wildlife Service (hydrogeomorphic-type), and the Maine Natural Areas Program classifications. Maine DEP may modify or combine classification approaches based on analysis of monitoring data, and will also examine differences among wetlands on a regional basis to determine the applicability of ecoregional classes.
Data Sources and Needs

Existing data for Maine wetlands is limited. MEDEP is currently developing a wetland biological assessment program, and has collected physical, chemical and biological data (including nutrients, macroinvertebrates, and algae) for freshwater wetlands in portions of southern Maine. Maine DEP plans to monitor the remainder of the state using a five-year rotating basin approach, provided adequate funding levels can be maintained. Although vegetative indicators will likely be important for assessing
wetland trophic status, DEP does not currently have staff resources to monitor vascular plant assemblages or measures of productivity. Maine DEP will coordinate with other agencies and organizations, including the Wells National Estuarine Reserve and Maine Natural Areas Program to assemble appropriate existing data, but will also need to collect additional statewide data for both freshwater and coastal wetlands.

Data Analysis

As part of the nutrient criteria development process, Maine DEP will review various available data analysis methods. Sources may include EPA and other agency technical guidance documents and the scientific literature.

Outside Expertise and Peer Review

MEDEP currently uses outside expertise for taxonomic identification of biological samples and laboratory analyses of water samples. MEDEP was also working with Dr. Jan Stevenson of Michigan State University to develop algal methods and indicators to assess wetland condition. DEP staff actively participate in EPA's national and regional Biological Assessment of Wetlands Workgroups (BAWWG and NEBAWWG), as well as relevant professional organizations. Work related to the Department's emerging wetland biological assessment program had been peer reviewed through presentations to BAWWG, NEBAWWG, the Society of Wetland Scientists, and the New England Association of Environmental Biologists. MEDEP also expected to collaborate with other groups and agencies as appropriate.

Administrative Procedures for Implementation

Since the Maine use classification system would need to be clarified with respect to wetlands, it is uncertain at this time what administrative procedures MEDEP felt it would be necessary to implement wetland nutrient criteria. The first step will be to determine through the Office of the Maine Attorney General if existing uses may be applied to wetlands on an interim basis. Doing so would require Departmental policy changes to ensure consistent interpretation of Maine's water classification law among all wetland-related programs. Maine would also need to revise its regulations to document wetland monitoring and assessment methods and thresholds for impairment, which will be linked to nutrient criteria. Related statutes will also be reviewed to determine if any changes are necessary.

Marine Estuaries

Approach

Coastal marine nutrient criteria are less developed in Maine, than criteria for lakes and rivers and streams, but solid progress is being made within the data-gathering stage through the projects described below. Current data at that time in Maine indicated that some small embayments with circulation issues may be experiencing depressed dissolved oxygen levels due to nitrogen inputs. Maine DEP would need to examine the sources of nitrogen, since some come from offshore, i.e. the Labrador current and the Gulf Stream. Maine may also have to group marine waters based on physical characteristics because of these offshore sources. For example, nitrogen is probably not the limiting nutrient in areas of upwelling, such as the Maine coastal current.

Relationship to Water Use Classification

The current water use classification system in Maine has three tiers for marine and estuarine waters: SA, SB, and SC, with all three meeting the fishable/swimmable goals of the Clean Water Act. All three classes contain narrative biological standards as well as criteria for dissolved oxygen and bacteria. Maine's coastal monitoring is attempting to gather data on nutrients in the water column and sediments, as well as benthic community structure to further the goal of using biocriteria to manage Maine's coastal waters.

National Coastal Assessment Project

The State of Maine participates with US EPA in the National Coastal Assessment Project, formerly known as "Coastal 2000". Maine State Partners include the MEDEP, the Coastal Program of the Maine State Planning Office, the Department of Marine Resources (DMR), and the Casco Bay Estuary Project (CBEP). The shared goals include uniform assessment and condition of coastal resources, implementation of state-wide coastal monitoring strategies, definition of ambient conditions for coastal waters, and support for the development of biocriteria. Estuarine monitoring under this program has a probability-based sampling design along the coast of Maine. Sampling occurred between early July and mid-September for 2000 - 2001, and 2002. Note this program recently conducted another round of coastal monitoring during 2010. Many different indicators of water quality (DO, salinity, temperature, depth, nutrients, chlorophyll-a), sediment quality, and biota (benthic and fish community structures, fish external pathology and tissue analysis) are measured using methods developed by EMAP during the past 10 years. It was recognized that a small number of stations will be used to represent a 5,296-mile coastline, and that annual differences in temperature, pulse storm events, etc. are important factors affecting the marine ecosystem.

Reference Conditions Project

MEDEP coordinated with the EPA National Nutrient Criteria Program on the 2001-2002 reference condition development projects. MEDEP, in cooperation with EPA, selected a set of candidate reference sites within Maine's coastal waters, including sites reflecting both minimal human use and developmental impacts. Sampling of up to fifty stations was which most likely occurred. Collected samples will be analyzed for TN, TP, chlorophyll-*a*, and Secchi depth in addition to standard CTD (conductance, temperature, depth) probe readings.

Recent Freshwater Criteria Development

Streams

In preparation for development of new NNC, MEDEP evaluated and developed a new indicator that integrated the effects of phosphorus loading into a stream (Danielson 2009a). The State of Maine used diatoms that are indicative of high phosphorus levels in streams. The steps for calculating the diatom total phosphorus index (DTPI) is illustrated below (Danielson 2009c)

Diatom Total Phosphorus Index (DTPI)

1) Exclude Taxa without TP Coefficients. Only include those species with TP coefficients in Table 1 (Danielson 2009) when calculating the DTPI as shown in (Table 2 of Danielson 2009.

2) Model Formula. $TP^* = 1.322585 + \sum_i x_i \beta_i^{TP}$

i. TP^* is the $\log_{10}$ TP (μg/L)

ii. Σ is the symbol for summation.

iii. x_i is the square root percent abundance of species *i*

iv. is the TP coefficient of species *i* in Table 1

The concept is that the TP* value shows a strong correlation with actual TP values for a stream and can be therefore TP can be measured indirectly by evaluating diatom communities. Ultimately a modified system was developed that uses both criteria (

Table 71. Total phosphorus limits either computed by the Diatom Total Phosphorus Index (DTPI) or measured as an average of water samples. From: (Maine Department of Environmental Protection 2010). Referred to as Table 1 in that document.

Statutory Class	Total Phosphorus Limit (ppb)
AA and A	≤ 18.0
B	≤ 30.0
C	≤ 33.0
GPA	≤ 15.0

Table 72).

In 2009 MEDEP proposed new NNC for phosphorus and other response variables (Danielson 2009a; Maine Department of Environmental Protection 2010). However, the most current Stormwater regulations designed to reduced phosphorus lake loadings and meet concentration based nutrient thresholds are unaffected by the new proposed NNC (Maine Department of Environmental Protection 2008). The proposed nutrient criteria would enhance and add to the existing narrative criteria and "translator" values that will not be discontinued.

Although the 2009 version of the draft NNC appeared to receive positive review from EPA the 2010 draft version did not (http://www.maine.gov/dep/blwq/ rules/Other/nutrients_freshwater/). EPA expressed concern about the wording on contradictory situations (Box 2 Figure 16) where biological indicators show no problem while nutrient levels indicated more eutrophic conditions are likely. EPA and Maine now disagree on how to handle waters meeting the biological response variable (TP diatoms index) but exceeding the TP criterion. Box 2 represented waterbodies that have mean total phosphorus concentrations greater than the criterion of the assigned class, but environmental responses that indicate attainment of designated uses. EPA's current position is that waterbodies in Box 2 would not attain the numeric nutrient criteria in Table 71 (aka Table 1 in the proposed rule) regardless of the response criteria. Most stakeholders support the decision framework in its current form. Table 72 (Table 1 in the NNC Rule) represents target variables criteria or screening levels to determine impacts on designated uses.

	Total phosphorus concentration is less than or equal to the limit in Table 1	Total phosphorus concentration is greater than the limit in Table 1
All measured environmental response criteria meet limits in Table 2	Box 1. **Not Impaired.** Phosphorus **did not** cause an impairment of a use.	Box 2. **Not Impaired.** Phosphorus **did not** cause an impairment of a use.
One or more measured environmental response criteria do not meet limits in Table 2	Box 3. **Impaired.** Indeterminate cause requiring additional analysis to determine cause.	Box 4. **Impaired.** Phosphorus **did** cause or contribute to an impairment of a use.

Figure 16. Decision framework used in recent proposed numeric nutrient criteria freshwater systems in Maine (Danielson 2009a; Maine Department of Environmental Protection 2010). From:(Maine Department of Environmental Protection 2010)

Table 71. Total phosphorus limits either computed by the Diatom Total Phosphorus Index (DTPI) or measured as an average of water samples. From: (Maine Department of Environmental Protection 2010). Referred to as Table 1 in that document.

Statutory Class	Total Phosphorus Limit (ppb)
AA and A	≤ 18.0
B	≤ 30.0
C	≤ 33.0
GPA	≤ 15.0

Table 72. Environmental response criteria. (Danielson 2009a; Maine Department of Environmental Protection 2010). From: (Maine Department of Environmental Protection 2010). Referred to as Table 2 in that document.

Statutory Class	AA/A	B	C	Impounded A	Impounded B	Impounded C	GPA Not colored	GPA colored
Secchi Disk Depth (meters)[a, b]	≥ 2.0	≥ 2.0	≥ 2.0	≥ 2.0	≥ 2.0	≥ 2.0	≥ 2.0	≥ 2.0 AND
Water Column Chl *a* (µg/L, parts per billion)	≤ 3.5[a] (≤ 5.0[a,c])	≤ 8.0[a]	≤ 8.0[a]	≤ 5.0[a,d]	spatial mean ≤ 8.0[d] and no value > 10.0[d]	spatial mean ≤ 8.0[d] and no value > 10.0[d]	≤ 8.0[a,e]	≤ 8.0[a,e]
Percent of Substrate Covered by Algal Growth[a]	≤ 20.0	≤ 25.0	≤ 35.0	--	--	--	--	--
Patches of Bacteria and Fungi[a]	None observed	None observed	None observed	None observed	None observed	None observed	--	--
Dissolved Oxygen (mg/L, parts per million)[a]	See 38 M.R.S.A. § 465						--	--
pH[a]	6.0 – 8.5							
Aquatic Life[a]	See 38 M.R.S.A. § 465 and where applicable *Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams,* 06-096 CMR 579 (Effective May 27, 2003)						See 38 M.R.S.A. § 465-A	

a - Can be based on single sample following standard protocols and quality control.
b - This variable is attained if the Secchi disk depth is 1) greater than or equal to 2.0 meters for waterbodies greater than or equal to 2.0 meters deep or 2) equal to the depth of the waterbody for waterbodies less than 2.0 meters deep. If the water is colored or turbid because of non-algal particles, Secchi disk depth shall be accompanied by chlorophyll a samples to confirm nonattainment condition.
c - Applicable to low gradient, slow flowing Class A and AA waters.
d - Chlorophyll a samples from impoundments are collected using depth-integrated, photic-zone cores or depth-integrated, epilimnetic cores.
e - GPA chlorophyll a samples are collected using depth-integrated, epilimnetic cores.

The Department recommended the use of the following decision framework Figure 16 to determine whether phosphorus or another nutrient has caused or contributed to the impairment of a designated use (Maine Department of Environmental Protection 2010). The decision framework uses a variety of nutrient indicators, including total phosphorus concentrations and environmental responses of nutrient enrichment. MEDEP will use the decision framework to determine; (1), if there is an impaired use; and (2), if phosphorus or another nutrient caused or contributed to the impairment. The total phosphorus criteria for each class are described in Section 4 of Chapter 583(Maine Department of Environmental Protection 2010). Environmental response criteria for each class are described in Section 5 of the same Chapter. The criteria and decision framework are also used in evaluations of existing uses for antidegradation purposes pursuant 38 M.R.S.A. § 464(4)(F).

A. Not impaired - all nutrient criteria are attained. If the mean total phosphorus concentration is less than or equal to the limit of the assigned class from (Table 1 of the Rule) and all environmental response criteria that are measured in a waterbody attain the limits of the assigned class of (Table 2 of Rule), then the Department will conclude that phosphorus has not caused an impairment of a use (Box 1 in Figure 1 of the Rule).

B. Not impaired - total phosphorus exceeds the limit but environmental response criteria are attained. If the mean total phosphorus concentration is greater than the limit of the assigned class from Table 1, but all environmental response criteria that are measured in a waterbody attain the limits of the assigned class of Table 2, then the Department will conclude that phosphorus has not caused an impairment of a use (Box 2 in Figure 1). Given the potential for total phosphorous concentrations in excess of the limits assigned in (Table 1 of the rule) to cause or contribute to downstream water quality impacts even if they do not do so in the monitored segment, the Department subsequently may monitor downstream waterbodies for adverse effects.

C. Impaired - total phosphorus is less than or equal to the limit but one or more environmental response criteria are not attained. If the mean total phosphorus concentration is less than or equal to the limit of the assigned class from Table 1, but one or more environmental response criteria that are measured in a waterbody do not attain the limits of the assigned class of Table 2, then the attainment result is impaired with indeterminate cause (Box 3 in Figure 1). Indeterminate results require additional evaluation and best professional judgment to make the final determination. The MEDEP will use a weight-of-evidence approach to determine if total phosphorus or another nutrient caused or contributed to an impairment of a use.

(1) The Department will conclude that total phosphorus caused or contributed to an impairment of a use if it is shown through weight-of-evidence that phosphorus is a plausible cause.

(2) The Department will conclude that another nutrient, such as nitrogen or carbon, has caused or contributed to an impairment of a use if it is shown through weight-of-evidence that the nutrient is a plausible stressor responsible for the impairment.
(3) The Department will conclude that the impairment was caused by a non-nutrient stressor if it is shown through weight-of-evidence to be the primary cause responsible for the impairment.

(4) The Department will conclude that the cause of impairment is indeterminate if there is insufficient information and more data collection is necessary to determine the cause of impairment.

D. Impaired - total phosphorus exceeds the limit and one or more environmental response criteria are not attained. If the mean total phosphorus concentration is greater than the limit of the assigned class from Table 1 of the Proposed Rule, and one or more environmental response criteria that are measured in a waterbody do not attain the limits of the assigned class of Table 2 of the Proposed Rule, then the Department will conclude that phosphorus has caused or contributed to an impairment of a use (Box 4 in Figure 1 of the Proposed Rule).

E. Atypical situations. The Department will use best professional judgment to interpret decision framework outcomes and make a final determination when natural conditions have contributed to elevated nutrient levels or atypical environmental responses, such as unusual periods of drought or flood, or proximity to unimpaired wetlands, lake outlets, tidal areas, or naturally occurring concentrations of fish or wildlife.

4. Total phosphorus criteria (ppb). The total phosphorus criteria for each statutory class are set forth in Table 1 of the proposed rule. Total phosphorus can either be measured as the mean of an established set of samples or determined using the Diatom Total Phosphorus Index (DTPI), which is computed using the protocols described in "Protocols for Calculating the Diatom Total Phosphorus Index (DTPI) and Diatom Total Nitrogen Index (DTNI) for Wadeable Streams and Rivers" (DEPLW-0970A) dated December 1, 2009. If total phosphorus measurements are inconclusive because of lab error, lost samples, etc., then potential attainment results would be limited to either Box 1 or Box 3 in Figure 1 in the Rule.

5. Environmental response criteria. The following environmental responses of nutrient enrichment indicate an impairment of a use described in 38 M.R.S.A. §§ 464(4), 465, and 465-A. A variety of environmental responses are necessary because of the variety of surface waters in Maine. The Department samples and evaluates one or more of the most appropriate environmental responses from this section and Table 2 (of the Rule) depending on the type of surface water being sampled.

A. Secchi disk depth (meters). This variable is an indicator of phytoplankton blooms and relates to designated uses and criteria in 38 M.R.S.A. § 465-A(1)

(B) and the recreation and aquatic life components of § 465-A. Summer (June 1 – September 30) algal blooms usually are dominated by cyanobacteria; however they may also be dominated by other types of algae. This variable is attained if the Secchi disk depth is (1) greater than or equal to 2.0 meters for waterbodies greater than or equal to 2.0 meters deep or (2) equal to the depth of the waterbody for waterbodies less than 2.0 meters deep (Table 2). Secchi disk depth measurements are restricted to still or slow moving waters in which water velocity does not substantially interfere with the measurements. If the water is colored or turbid because of non-algal particles, Secchi disk depth must be accompanied by chlorophyll a samples to confirm that algae caused non-attainment conditions.

B. Water column chlorophyll-*a* (ppb). This variable is an indicator of phytoplankton blooms and relates to designated uses and criteria in 38 M.R.S.A. § 465-A(1)(B) and the habitat, recreation, and aquatic life components of 38 M.R.S.A. §§ 464(4) and 465. This variable is attained if the water column chlorophyll a concentration is less than or equal to the limit set forth in Table 2 for the statutory class of the waterbody. In addition, concentrations of cyanotoxins above appropriate health guidelines for recreational exposure are evidence of exceedance of nutrient criteria.

C. Percent cover of algae. This variable indicates the amount of algae growing on substrates on the bottom of a stream or river and relates to the designated uses and narrative criteria associated with habitat, recreation, and aquatic life in 38 M.R.S.A. §§ 464(4) and 465. This variable is attained if the percent of substrate covered by filamentous algae and periphyton mats greater than 1 millimeter thick is less than or equal to the limit set forth in Table 2 for the statutory class of the waterbody.

D. Patches of fungi and filamentous bacteria. This variable indicates major shifts in trophic state and relates to the designated uses and narrative criteria associated with habitat, recreation, and aquatic life in 38 M.R.S.A. §§ 464(4) and 465. This variable is attained if there are no macroscopically observable patches of fungi and filamentous bacteria on the substrate, excluding iron and manganese bacteria.

E. Dissolved oxygen concentrations (ppm). This variable protects fish and other aquatic life. This variable is attained if the waterbody attains the dissolved oxygen criteria as described in 38 M.R.S.A. §§ 465 and 465-A.

F. pH. This variable protects fish and other aquatic life and relates to designated uses and criteria associated with aquatic life as described in 38 M.R.S.A. §§ 465 and 465-A. Very acidic or alkaline water can be harmful to aquatic life and can be caused by nutrient enrichment. This variable is attained if the waterbody is within the range of pH, 6.0 – 8.5, or as naturally occurs.

G. Aquatic life use attainment. This variable is an indicator of the condition of aquatic biological communities. This variable is attained if the waterbody attains the narrative and numeric aquatic life use criteria as described in 38 M.R.S.A. §§ 465 and 465-A, and where applicable Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams, 06-096 CMR 579 (Effective May 27, 2003).

MEDEP is working on a solution that will retain the current intent of Box 2, but will satisfy the EPA's concerns. The current rulemaking schedule, however, did not provide sufficient time to make the necessary changes to Chapter 583. As a result, the Department terminated the current rulemaking process to allow the Department time to make the necessary changes and start a new rulemaking with a revised rule.

Recent Marine Criteria Development

The EPA recently contracted with Batelle to assist EPA Region 1 and Maine in the development of nutrient criteria for coastal waters (Batelle 2008). A summary of their findings was extracted from that report. Maine, like many states, had focused on the development of nutrient criteria in freshwater systems (lakes/reservoirs and rivers/streams). These systems represent clearly defined water bodies that have been monitored by MEDEP over the past few decades. The development of nutrient criteria for Maine's estuaries and coastal waters has been a lower priority back seat until recently. This has also been the case on the national level as only a few states have developed estuarine nutrient criteria for N, P or response parameters (e.g. HI, MD, DE, VA, CT, and NY). The Maryland, Delaware and Virginia NNC were actually developed as part of the Chesapeake Bay criteria effort (United States Environmental Protection Agency 2003a) and the Connecticut and New York criteria are only for dissolved oxygen in Long Island Sound. The difficulty in developing estuarine and coastal criteria was understood by EPA and evident in the order in which EPA published the technical guidance manuals for nutrient criteria development. The lakes/reservoirs and rivers/streams manuals were published first while the estuarine and coastal manual was published a year and half later (United States Environmental Protection Agency 2001j). In Maine, the process of developing estuarine and coastal water nutrient criteria was pushed forward in 2007 with passage of LD 12971 by the 123rd Maine State Legislature. EPA Region 1 assisted MEDEP in their efforts to comply with LD 1297 by providing logistical support to begin development of a conceptual plan for establishing estuarine and coastal nutrient criteria in Maine.

The timeframe for marine nutrient criteria development has been seen as a multi-year process (Figure 17). The planning report skips over the initial planning phase and the efforts covered in the report fall in the data assessment phase (Batelle 2008) . However, clearly understood goals underlying the effort to establish the criteria (e.g. maintain water quality to sustain fisheries, human activities, ecological health, etc.) and the variables to examine (at least initially) are limited to the data in hand or the data that will be collected by ongoing programs. Thus, the major step that was been passed over is classification of waterbodies. There are a wide range of waterbody types along the Maine coast – from highly river influenced systems such as Penobscot Bay and Merrymeeting Bay to semi-enclosed, long residence time embayments like Quahog Bay and the New Meadows River. At the time, the authors of the report acknowledged the lack of readily available physical and hydrographic data to classify these systems, as well as the limited amount of nutrient data available, making both classification of water bodies and development of waterbody type specific criteria essentially impossible. Thus, they needed to use readily available data on total nitrogen (TN), dissolved inorganic nitrogen forms, chlorophyll, and DO to attempt to examine potential approaches to developing criteria for these waters.

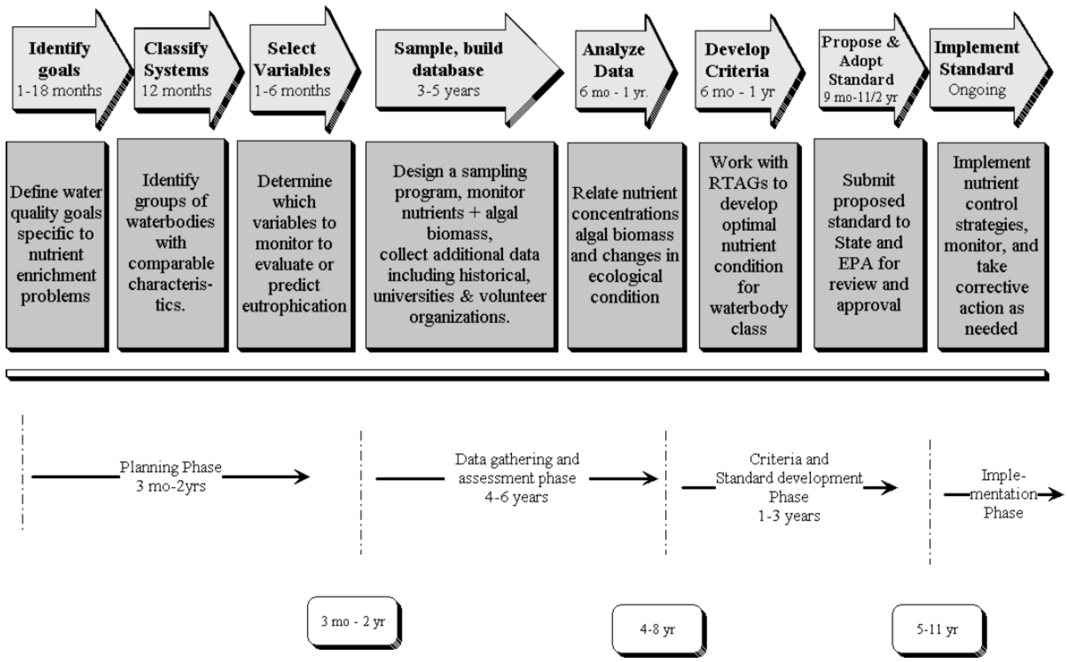


Figure 17. Planning and development process for marine nutrient criteria in Maine starting in 2008. Source: (Batelle 2008).

In their report, Battelle proposed and provided an example of an approach similar to that taken in the Yaquina Estuary and Pensacola Bay pilot studies (Batelle 2008). They examined the data currently available, compared TN levels across the region, state, and Casco Bay. The data were presented in a manner by which median or percentile levels could be chosen as a potential criteria level. A similar approach could be used to examine the other parameters of interest (DIN, chlorophyll, and DO). The authors acknowledged that this approach by necessity was provided with a limited dataset and limited funds. Consequently a weight of evidence approach was taken using data from these two pilot studies. As in Yaquina and Pensacola, Maine had relatively good water quality along the coast with some localized problems. The authors felt that the practical approach taken in this report should provide reasonable initial values that could be proposed and discussed by the various stakeholders prior to institution of the criteria. The study not only provided an example of how Maine might approach criteria development, but it also highlighted a number of problems or issues that will have to be addressed during the process of nutrient criteria development. Data acquisition and database development was a major issue. In their study, they used three clearly defined datasets. The first from a long term monitoring program in Casco Bay and the other two from short term EPA studies in the region. They had serious problems integrating datasets due to differences in format, units, methods, and years. This led to database problems or caveats in their interpretation of the results. As Maine proceeds with criteria development, clear database structure and management procedures need to be developed. This will be important no matter what approach ME DEP decides to pursue; whether it is data mining, additional monitoring, effects based or predictive modeling, or some combination of these. There will be more data acquired and it needs to be managed/stored in a clearly defined manner.

There are inherent issues involved with integrating relatively disparate datasets, but data identification and acquisition is a more cost effective approach than instituting new, large scale monitoring efforts. The findings in this report suggest that water quality in the coastal waters of Maine is relatively good, which is consistent with the findings of recent national water quality assessments. The analysis has also identified a few areas of concern as have also been suggested in the national assessments and numerous state and locally based reports. The TN values were elevated in Portland Harbor.

Maryland

We have summarized NNC information for the State of Maryland. This data is taken from both EPA and State of Maryland web sites dedicated to nutrient criteria development.

Table 73. Existing Maryland Numeric Nutrient Criteria (Maryland Department of the Environment 2005; State of Maryland ; State of Maryland ; State of Maryland 2008).[1]

Waterbody Type	N	P	Chl-a	Clarity[2]
Lakes & Reservoirs			S	
Rivers & Streams				
Estuaries				S[3]
Wetlands				

S = Statewide W = For selected waterbody N / A=Not Applicable
[3]Part of the Chesapeake Bay TMDL criteria

The following information reflects Maryland's water quality standards as of August 2011(Maryland Department of the Environment 2005; State of Maryland ; State of Maryland ; State of Maryland 2008)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_md.cfm)(http://www.mde.maryland.gov/programs/Water/TMDL/Water%20Quality%20Standards/Pages/Programs/WaterPrograms/TMDL/wqstandards/index.aspx.).

26.08.02.03-3 Water Quality Criteria Specific to Designated Uses. C. Criteria for Use II Waters—Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting.

(9) Water Clarity Criteria for Seasonal Shallow-Water Submerged Aquatic Vegetation (SAV) Subcategory.

(a) Water Clarity Criteria Measurement. A Bay segment has attained the shallow water designated use if:

(ii) The shallow-water acreage that meets or exceeds the water clarity criterion expressed in Secchi depth equivalence from Table 74 (= Table 1 of Maryland Regulation) of this regulation at the segment specific application depth specified in Regulation .08 of this chapter (excluding SAV no grow zones) is 2.5 times greater than the SAV Acreage Restoration Goal from Table 2 of this regulation; or

(iii) A combination of the actual SAV acreage attained and meeting the applicable water clarity criteria in an additional, unvegetated shallow water surface area equals 2.5 times the remaining SAV acreage necessary to meet the segment's restoration goal.

Table 74. Numerical water clarity criteria (in secchi depth equivalents for general application to shallow water aquatic vegetation bay grass designated use (application depths given in 0.5 Meter attainment intervals[1]).

Water Clarity Criteria as Secchi Depth (meters)						
Salinity Regime	Water Quality Criteria as Percent Light through Water	Water Clarity Criteria Application Depths (meters)				Seasonal Application
		0.5	1.0	1.5	2.0	
Secchi Depth Equivalents for Criteria Application Depth						
Tidal Fresh	13%	0.4	0.7	1.1	1.4	Apri1 1 to October 1
Oligohaline	13%	0.4	0.7	1.1	1.4	Apri1 1 to October 1
Mesohaline	22%	0.5	1.0	1.4	1.9	Apri1 1 to October 1

[1] Based on application f the formula PLW = 100exp$^{(-KdZ)}$, the appropriate PLW criterion value and the selected application depth (Z) are inserted and the equation is solved for K_d. The generated K_d value is then converted to Secchi depth (in meters) using the conversion factor K_d = 1.45/Secchi depth.

Criteria for Public Water Supply Reservoirs.

Until recently the State of Maryland did not have any nutrient criteria except for turbidity standards in estuaries to meet the Chesapeake Bay TMDL derived standards. However, a reservoir criteria was adopted by Maryland and approved by EPA in July 2010. A numeric criteria for chlorophyll-*a* of 0.01 mg/l was adopted to protect public water supply lakes (Laidlaw 2010b). The following criteria apply in freshwater reservoirs designated Use I-P, III-P or IV-P:

(I) The arithmetic mean of a representative number of samples of chlorophyll-*a* concentrations, measured during the growing season (May 1 to September 30) as a 30-day moving average may not exceed 10 µg/L; and

(2) The 90th-percentile of measurements taken during the growing season may not exceed 30 µg/L.

Maryland Site-specific Criteria

The following information reflects Maryland's water quality standards posted to the Water Quality Standards Repository as of August 2011. The following criteria were EPA-approved on December 2010. We only report the water clarity criteria associated with meeting nutrient related TMDL goals for the Chesapeake Bay(United States Environmental Protection Agency 2004; United States Environmental Protection Agency 2010b; United States Environmental Protection Agency 2010c).

Maryland State Regulations: 26.08.02.03-3 Water Quality Criteria Specific to Designated Uses.

C. Criteria for Use II Waters—Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting.
(Dissolved oxygen and water quality criteria are only applicable only to the waters of the Chesapeake Bay and its tidally influenced tributary waters).

(9) Water Clarity Criteria for Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory.

(a) Water Clarity Criteria Measurement. A Bay segment has attained the shallow water designated use if:

(i) Submerged aquatic vegetation (SAV) acreage meets or exceeds the SAV acreage restoration goal in Table 2 of this regulation;

(c) Table 2. SAV Acreage Restoration Goals. (Table 75 this document)

Table 75. Maryland SAV acreage restoration goals associated with Chesapeake Bay Nutrient TMDL (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_md.cfm) and (State of Maryland 2008; United States Environmental Protection Agency 2010b).

Segment Description[1]	Segment Designator	SAV Acreage Restoration Goal	Secchi Application Depth
Northern Chesapeake Bay	CB1TF2	12,149	2 meters
Northern Chesapeake Bay	CB1TF1	754	1.0 meters
Lower Pocomoke River Mesohaline	POCMH	877[2]	1.0 meters
Manokin River Mesohaline	MANMH1	4,294	2.0 meters
Manokin River Mesohaline	MANMH2	59	0.5 meters
Big Annemessex River Mesohaline	BIGMH1	2,021	2.0 meters
Big Annemessex River Mesohaline	BIGMH2	22	0.5 meters
Tangier Sound Mesohaline	TANMH1	24,683[2]	2.0 meters
Tangier Sound Mesohaline	TANMH2	74	0.5 meters
Middle Nanticoke River Oligohaline	NANOH	12	0.5 meters
Lower Nanticoke River Mesohaline	NANMH	3	0.5 meters
Wicomico River Mesohaline	WICMH	3	0.5 meters
Fishing Bay Mesohaline	FSBMH	197	0.5 meters
Middle Choptank River Oligohaline	CHOOH	72	0.5 meters
Lower Choptank River Mesohaline	CHOMH2	1,621	1.0 meters
Mouth of Choptank River Mesohaline	CHOMH1	8,184	2.0 meters
Little Choptank River Mesohaline	LCHMH	4,076	2.0 meters
Honga River Mesohaline	HNGMH	7,761	2.0 meters
Eastern Bay	EASMH	6209	2.0 meters
Upper Chester River Tidal Fresh	CSHTF	1	0.5 meters
Middle Chester River Oligohaline	CHSOH	77	0.5 meters
Lower Chester River Mesohaline	CHSMH	2,928	1.0 meters
Chesapeake & Delaware (C&D) Canal	C&DOH	7	0.5 meters
Northeast River Tidal Fresh	NORTF	89	0.5 meters

Segment Description[1]	Segment Designator	SAV Acreage Restoration Goal	Secchi Application Depth
Bohemia River Oligohaline	BOHOH	354	0.5 meters
Elk River Oligohaline	ELKOH1	1,844	2.0 meters
Elk River Oligohaline	ELKOH2	190	0.5 meters
Sassafras River Oligohaline	SASOH1	1,073	2.0 meters
Sassafras River Oligohaline	SASOH2	95	0.5 meters
Bush River Oligohaline	BSHOH	350	0.5 meters
Gunpowder River Oligohaline	GUNOH2	572	2.0 meters
Mouth of Gunpowder River	GUNOH1	1,860	0.5 meters
Middle River Oligohaline	MIDOH	879	2.0 meters
Back River Oligohaline	BACOH	30	0.5 meters
Patapsco River Mesohaline	PATMH	389	1.0 meters
Magothy River Mesohaline	MAGMH	579	1.0 meters
Severn River Mesohaline	SEVMH	455	1.0 meters
South River Mesohaline	SOUMH	479	1.0 meters
Rhode River Mesohaline	RHDMH	60	0.5 meters
West River Mesohaline	WSTMH	238	0.5 meters
Upper Patuxent River Tidal Fresh	PAXTF	205	0.5 meters
Middle Patuxent River Oligohaline	PAXOH	115	0.5 meters
Lower Patuxent River Mesohaline	PAXMH1	1,459	2.0 meters
Lower Patuxent River Mesohaline	PAXMH2	172	0.5 meters
Lower Patuxent River Mesohaline	PAXMH4	1	0.5 meters
Lower Patuxent River Mesohaline	PAXMH5	2	0.5 meters
Lower Potomac River Tidal Fresh	POTTF	2,142[2]	2.0 meters
Piscataway Creek Tidal Fresh	PISTF	789	2.0 meters
Mattawoman Creek Tidal Fresh	MATTF	792	1.0 meters
Lower Potomac River Oligohaline	POTOH1	1,387[2]	2.0 meters
Lower Potomac River Oligohaline	POTOH2	262	1.0 meters
Lower Potomac River Oligohaline	POTOH3	1,153	1.0 meters
Lower Potomac River Mesohaline	POTMH	7,088[2]	1.0 meters
Upper Chesapeake Bay	CB2OH	705	0.5 meters
Upper Central Chesapeake Bay	CB3MH	1,370	0.5 meters
Middle Central Chesapeake Bay	CB4MH	2,533	2.0 meters
Lower Central Chesapeake Bay	CB5MH	8,270[2]	2.0 meters

[1] The segments West Branch Patuxent River (WBRTF-application depth = 0.5 meters), and Lower Patuxent River Mesohaline Subsegments 3 and 6 (PAXMH3 & PAXMH6-application depths = 0.5 meters), and the Anacostia River Tidal Fresh (ANATF-application depth = 0.5 meters) are not listed above because the SAV Restoration goal for each segment is 0 acres, based on no historical mapped SAV and because the available bathymetry data is too limited to allow for a calculation of an SAV restoration acreage goal using the method described in the U.S. Environmental Protection Agency publication "Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and its tidal Tributaries—2007 Addendum (EPA 903-R-07-003)". These segments have been assigned a water clarity criteria and application depth. Attainment of the shallow-water designated use will be determined using the method outlined in §C(9)(a)(iii) and (e) of this regulation.

[2] Maryland portion of the segment.

The attainment of the water clarity criteria that apply to the seasonal shallow-water submerged aquatic vegetation use subcategory in the Chesapeake Bay and tidally influenced tributary waters are documented and described within the U.S. Environmental Protection Agency publications "Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll-*a* for the Chesapeake Bay and its Tidal Tributaries (EPA 903-R-03-002)", and subsequent revisions (United States Environmental Protection Agency 2004; United States Environmental Protection Agency 2007; United States

Environmental Protection Agency 2010b; United States Environmental Protection Agency 2010c).

Massachusetts

The information below summarizes NNC development activities listed for the State of Massachusetts on the EPA and State of Masschusetts web pages (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ma.cfm)((Massachusetts Department of Environmental Protection 2006; Zimmerman and Campo 2007).

Table 76. Existing Numeric Criteria for the State of Massachusetts (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ma.cfm)(http://www.mass.gov/dep/water/laws/regulati.htm.). [1]

Waterbody Type	N	P	Chl-A	Clarity[2]
Lakes & Reservoirs				
Rivers & Streams				
Estuaries	W			
Wetlands				

S = Statewide W = For selected waterbody N ⁄ A=Not Applicable
[1] From Massachusetts' water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved September 2007). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for aquatic life uses. After a review of state WQS we concluded that all stated adopted NNC have been approved by EPA. There are no current proposed NNC.
[2] Source: (United States Environmental Protection Agency 2008b).

The following information reflects Massachusetts' water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved September 2007) and the (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ma.cfm).

4.06: Basin Classification and Maps

Table 77. Site Specific Criteria for Massachusetts waterbodies based on Section 4.06 basin classification and maps of the Massachusetts state regulations .

Basin/Drainage Area & Waterbody	Boundary or Town	Site Specific Criteria
Cape Cod Drainage Area		
Stage Harbor System		
Little Mill Pond	Chatham	Nitrogen 0.38 mg/L
Mill Pond	Chatham	Nitrogen 0.38 mg/L
Mitchell River	Chatham	Nitrogen 0.38 mg/L
Oyster Pond	Chatham	Nitrogen 0.38 mg/L
Oyster River	Chatham	Nitrogen 0.38 mg/L
Stage Harbor	Chatham	Nitrogen 0.38 mg/L
Sulphur Springs System		
Bucks Creek	Chatham	Nitrogen 0.38 mg/L
Cockle Cove Creek	Chatham	Nitrogen 0.38 mg/L
Sulphur Springs	Chatham	Nitrogen 0.38 mg/L
Taylors Pond System		
Mill Creek	Chatham	Nitrogen 0.38 mg/L
Taylors Pond	Chatham	Nitrogen 0.38 mg/L

Basin/Drainage Area & Waterbody	Boundary or Town	Site Specific Criteria
	Bassing Harbor System	
Bassing Harbor	Chatham	Nitrogen 0.527-0.552 mg/L*
Crows Pond	Chatham	Nitrogen 0.527-0.552 mg/L*
Frost Fish Creek	Chatham	Nitrogen 0.527-0.552 mg/L*
Ryder Cove	Chatham	Nitrogen 0.527-0.552 mg/L*
	Muddy Creek System	
Lower Muddy Creek	Chatham	Nitrogen 0.552 mg/L
Upper Muddy Creek	Chatham	Nitrogen 0.552 mg/L

*The nitrogen criteria for the Bassing Harbor System are interim criteria unless, based on its assessment of Pleasant Bay, the Department determines that the nitrogen criteria for the Bassing Harbor system should remain in effect.

The state of Massachusetts does have a state adopted EPA approved Nutrient Criteria Development Plan (Massachusetts Department of Environmental Protection 2004). The Massachusetts Department of Environmental Protection (MADEP) indicated that they would consider all the various methods that were being developed by EPA. They pointed out that EPA had proposed that for all waterbodies, numeric criteria should be be developed for two causal indicators: total phosphorus (TP) and total nitrogen (TN), and two response indicators: chlorophyll-*a* and a measure of water clarity, to prevent and control the effects of nutrient enrichment. They pointed out that EPA had highlighted several basic approaches at the time of the drafting of their NNC Development Plan. This included 1) the statistical distribution of (one or more) of the indicators, 2) the relationship of one or more of the indicators to the impairment of designated uses, and 3) and the development of quantifiable "translators" for narrative statements in water quality standards.

At the time, Massachusetts believed that the most meaningful approach to setting nutrient criteria was to base NNC on attainment of designated uses. To this end, water quality data would be compared to observations and data on the attainment of "aesthetic" and "aquatic life" uses. Analyses of the relationships between nutrient concentrations and impairments (non use attainment) would hopefully result in the identification of "threshold" nutrient concentrations, below which, no impairments occur (e.g. designated uses will be attained). Massachusetts also planned on exploring the utility of criteria developed, according to EPA guidance, by assessing the statistical distribution of data and using various percentiles to set the criteria. The recommended ecoregion reference site method was to select either the 25th percentile of nutrient concentrations from all waters, or the 75th percentile of the nutrient concentrations of reference sites only.

A third approach, that will be explored, is the development of quantifiable "translators" for the Massachusetts narrative standard that simply states that nutrients can't occur in concentrations that cause impairments (without quantifying the impairments). This approach will entail the selection of quantitatively measurable indicators of nutrient impairments, and setting an acceptable or allowable limit for the indicators, such as dissolved oxygen concentrations that meet the water quality standards, a percentage of the bottom of wadeable streams that is allowed to be covered by nuisance algae without impairing aquatic life or aesthetic values, or a minimum acceptable water transparency that would be used to indicate unimpaired waters.

Each of the three approaches described above will be conducted on data grouped according to the location of waterbodies within various "regions" in Massachusetts. Two "regional schemes" are currently being considered - the EPA "ecoregions", and the "Phosphorus Regions" proposed (Rohm et al. 1995) cited (Massachusetts Department of Environmental Protection 2004). To explore the possible refinement of the ecoregion–specific criteria suggested by the EPA, data will be analyzed according to Aggregate Ecoregions VIII and XIV. (Rohm et al. 1995) had been modified, for this evaluation, to include three regions characterized by low, medium, and high phosphorus levels.
In addition to "regional" groupings, river reaches would be analyzed according to various size classifications (watershed drainage area), and free flowing versus impounded status. Similarly, MADEP planned to group lakes according to depth and stratification characteristics. In the case of marine waters (specifically estuaries) MADEP planned to evaluate each waterbody on a site-specific, or embayment-specific basis to develop nutrient criteria. They concluded that this was necessary because of their unique characteristics (depth, width, flushing rate, watershed area and land uses, sediment type and amount, biological communities, nutrient load, and quality of incoming tidal waters) result in differences in the severity of the response to nutrient inputs. Massachusetts also recognized the need to develop wetlands criteria that can serve as a "yardstick" for evaluating monitoring data to assess attainment of designated uses or for determining safe contaminant load allocations. They however placed a lower priority on this waterbody type due to current lack of EPA guidance at the time of production of the Nutrient Criteria Development Plan (Massachusetts Department of Environmental Protection 2004). Coastal wetlands, specifically salt marsh systems, were currently being studied as part of the Massachusetts Estuaries Program, in an effort to determine criteria for acceptable nitrogen loading.

The protection of downstream uses is an important consideration in any environmental protection program, including considerations related to allowable nutrient concentrations in surface waters. The MADEP noted that the setting of nutrient criteria in a water body, based on assumptions of possible downstream impacts is problematic. The approach preferred by the State of Massachusetts was to protect all uses through a combination of the MADEP Assessment Program, the development of the Integrated List of Waters (sections 303d and 305b of the Clean Water Act), and the Total Maximum Daily Load Programs. Thus, if uses of a water body are not attained, all sources of the responsible contaminant(s), including upstream water bodies, would be assessed, quantified, and prioritized for remediation.

The following is an overview of the approach Massachusetts planned on taking for rivers, streams, lakes and coastal waters in 2004 when their Nutrient Criteria Development Plan was developed. Much of the information provided below was taken verbatim from that document.

Approach for Nutrient Criteria Development

1. Water quality "goals"
Water quality goals, with regard to managing nutrient enrichment problems in Massachusetts' surface waters are reflected in the "water quality classifications" and the "designated uses" established in the State's Water Quality Standards (SWQS). These goals are in the form of numeric standards and narrative statements. Focusing on these "classifications" and "uses" will help identify attainable water quality goals and will help in assessing the success of the criteria development process.

Massachusetts inland waters are classified as follows:

• Class A: These waters are designated as a source of public water supply. To the extent compatible with this use they shall be an excellent habitat for fish, other aquatic life and wildlife, and suitable for primary and secondary contact recreation. These waters shall have excellent aesthetic value. These waters are designated for protection as Outstanding Resource Waters under 314 Code of Mass Regulations (CMR) 4.04.3.

• Class B: These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

• Class C: These waters are designated as a habitat for fish, other aquatic life and wildlife, and for secondary contact recreation. These waters shall be suitable for the irrigation of crops used for consumption after cooking and for compatible industrial cooling and process uses. These waters shall have good aesthetic value.

Coastal and Marine waters are classified as follow:

• Class SA: These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, and for primary and secondary contact recreation. These waters shall have excellent aesthetic value.

• Class SB: These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. These waters shall have consistently good aesthetic value.

• Class SC: These waters are designated as a habitat for fish, other aquatic life and wildlife, and for secondary contact recreation. They shall also be suitable for certain industrial cooling and process uses. These waters shall have good aesthetic value.

For the purposes of the Massachusetts Water Quality Standards, Aquatic Life is defined as a native, naturally diverse, community of aquatic flora and fauna. Primary contact recreation is defined as any recreation or other water use in which there is a

prolonged and intimate contact with the water with a significant risk of ingestion of water. (i.e. wading, swimming, diving, surfing and
water skiing). Secondary contact recreation is defined as any recreation or other water use in which contact with the water is either incidental or accidental. These include but are not limited to fishing, boating and limited contact incident to shoreline activities.

For most waterbodies the Massachusetts narrative water quality standard for nutrients states, “nutrients shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication”.

Proposed Classification of water bodies

Classes (i.e., “groupings”) of water bodies, with comparable characteristics (i.e., biological, ecological, physical, and chemical features), will be identified and selected. Grouping lakes, rivers and streams into classes reduces the variability of water body - related measures (e.g. physical, biological, or water quality attributes) within classes and maximizes variability among classes in order to “identify” criteria on a broad scale rather than a site-specific scale. In an effort to establish regionally based nutrient criteria that reflect the natural variability in water quality, the EPA has divided the country into nutrient ecoregions (Gibson et al. 2000; Rohm et al. 1995; United States Environmental Protection Agency 2000h). (Rohm et al. 1995; Rohm et al. 2002) have also developed phosphorus regions within New England. The utility of both of these regional classification schemes will be explored as part of the criteria development for rivers and lakes. Marine waters are divided into open coastal areas and estuaries.

Proposed Classification of rivers and streams

For purposes of various comparisons, there is a need for a quantitative measure of stream size. Stream order is commonly used, however, it does not always provide a meaningful characterization of the key physical properties and biological capacities of streams. For these reasons, many researchers prefer a flow-based classification system that would provide a meaningful characterization. MADEP cited (Hughes and Omernick 1981) who suggested using mean annual discharge per unit area, mean annual discharge, watershed area, or mean annual discharge range (in that order of preference) instead of stream order. Therefore, for exploratory analytical purposes, the following size-related “groupings” of rivers and streams will be considered within each of the “regional” schemes:

- Watershed area
    - o < 10 mi^2 (headwater streams, roughly 2nd and 3nd order)
    - o 10 - 100 mi^2 (major tributaries to main stem rivers, roughly 4th order)
    - o 100 - 1000 mi^2 (main stem rivers, roughly 5th order and above)
    - o >1000 mi^2 (Connecticut and Merrimack Rivers)

Within each of the size groupings, the effects of flow (in the broad sense, as related to impounding) will be taken into account, therefore the classification of river and stream reaches will also include:

- Impounded (less than 14 day residence time for the impounded stream reach)
- Free-flowing

Proposed Classification of lakes

Lake eutrophication is a natural process by which lakes progress, over geologic time, to wetlands and ultimately dry land. MADEP felt that at a minimum, the expected goals for shallow lakes will be different in some aspects from those for deeper lakes that stratify. The MADEP proposed classification scheme for lakes is to divide them into these categories:

• Stratified
• Shallow, non-stratified, open water
• Shallow (less than 6 ft)
• Color
• EPA Phosphorus regions
• Seepage lakes

Proposed Classification of marine waters

For the purpose of nutrient criteria development, marine waters will be classified as:

• Open coastal waters • Estuaries

Proposed Water quality variables, response indicators, and habitat characteristics

Measurable attributes, that can be used to evaluate or predict the condition or degree of eutrophication in a water body, will be selected for analyses. Existing data, as well as any additional data to be collected to fill gaps, will be included in the effort.

For rivers and streams, the "primary" variables that will be examined are:

• Total nitrogen
• Total and dissolved phosphorus
• Periphyton chlorophyll-*a* from rocky substrates of wadeable streams, reported as µg chlorophyll/m^2 • Filamentous algae coverage (related to aquatic life and aesthetics use support). This semi-quantitative observation will be coupled with the quantitative collection and measurement of periphyton on the substrates of wadeable streams listed above.
• Phytoplankton chlorophyll *a* from the water column of deeper, non wadeable streams and impounded reaches, reported as ug chlorophyll/L
• Floating (non-rooted) plants (biomass), methodology will be explored for assessing impounded reaches of rivers
• Turbidity
• Secchi disc in impounded reaches.

These variables provide a means of evaluating nutrient enrichment and can form the basis for establishing regional and water body-specific nutrient criteria. Data will also be gathered on stream depth and instantaneous flow. All data will be assessed relative to observations on attainment of designated uses, primarily related to excessive algal growth such as filamentous algae and/or algal mats. Rooted aquatic plants will not be assessed as part of this effort, because even though there is an observable relationship between nutrients and plant abundance and biomass, quantifying the mechanisms is confounded by many factors, key of which is that bottom sediments act as the primary nutrient source and water column nutrients must be incorporated into the sediments before they become available for uptake. Additional “secondary variables” (and response indicators) may be considered including Benthic invertebrate community metrics, Fish community data (where available, will be explored) in the free-flowing wadeable streams, dissolved oxygen, temperature, and turbidity.

For lakes, the “primary” variables that will be examined are:

• Total phosphorus
• Chlorophyll-*a*
• Secchi disk depth (related to aquatic life and primary contact recreation uses)
• Color

For marine waters, the following variables will be examined:

Water column:
• Dissolved inorganic nitrogen
• Particulate organic nitrogen
• Dissolved organic nitrogen
• Nitrate + Nitrite
• Ammonia
• Temperature
• Total phosphorus
• Chlorophyll-*a*
• Turbidity
• Dissolved oxygen

Habitat assessment:
• Eelgrass
• Macro algae
• Benthic invertebrate community
• Benthic sediment nitrogen flux

Databases

A dedicated database for use in developing the nutrient criteria includes existing MADEP data, “new” data (collected to fill in gaps), and other available data as can be identified and incorporated.

Data analyses and numeric criteria selection

Criteria selection for rivers and streams

MADEP intends to explore several possible criteria development methodologies: 1) percentile distributions, statistical analyses of nutrient concentrations associated with quantifiable measures of use impairment (designated use support analyses) 2) and quantitative translators of the existing nutrient narrative standard.

The data sets that will be subjected to these methodologies, include: analysis by ecoregion, phosphorus region, drainage area size (stream order), impounded stream reaches, free flowing stream reaches, stratified lakes, shallow non-stratified open water lakes, and lakes less than two meters in depth. The intent is to select criteria that will assure optimal nutrient-related conditions in each stream class, protect adjacent downstream impoundments and estuaries, and, when achieved, will result in streams attaining their designated uses.

1) EPA percentile method

The first approach is a statistical method (recommended by the EPA) by which the 25th percentiles of the frequency distribution of concentrations of the selected variables (total phosphorus, total nitrogen, chlorophyll a, and a measure of clarity), for all streams studied, are used to set the criteria. A variation on this approach is using reference stream data only, and setting the criteria as the 75th percentile of the frequency distribution of concentrations of the selected variables. The criteria could also be developed using the range of values between the 75th percentile of the reference reaches and the 25th percentile of all streams. Massachusetts intends to explore the use of published “regional” classifications to determine if the environmental responses to nutrients vary between “regions” within the State. Two classifications will be used: the EPA aggregate ecoregions VIII and XIV, and the phosphorus regions proposed by Rohm, C., J. M. Omernik and C. W. Kiilsgaard (1995).

The percentile approach discussed above will be applied to all the data, combined statewide, and applied for each of the geographic regions (“phosphorus regions” and the EPA ecoregions) to determine if “regional” differences need to be considered in determining criteria. The use of statistics such as analysis of variance may be used to test the various regional classification schemes.

2) Designated use support analysis

MADEP will explore the “support of designated uses” approach for each river/stream classification (watershed size, free flowing and impounded - described above in the “Classification of Rivers and Streams” section) in combination with each ecoregion and phosphorus region in Massachusetts. It is anticipated that aquatic life support may be the critical “use” for defining nutrient criteria. As such, biological “trigger” conditions (impairment thresholds), which indicate a biological impairment (aquatic use) will be determined. For example, in small wadeable streams the critical factor may be based on the percent cover of filamentous algae on the stream bottom. Streams with high benthic algal densities will be related to high nutrient concentrations. In larger unwadeable rivers, either water-column chlorophyll-*a* or percent cover of non-rooted macrophytes (percent cover of duckweed) or some other measure, such as dissolved oxygen, will be used to define conditions which support aquatic life and these conditions will again be related to high nutrient concentrations. MADEP planned on using statistical analyses such as discriminant analysis or logistic regression to relate the nutrient concentrations to the attainment of acceptable conditions in each water type. These statistics will not necessarily be used to set the final criteria. The final criteria will be set using <u>*weight of evidence*</u> based on scientific literature, data collected on Massachusetts waters, and the results of the statistical analysis.

Quantitative translator method

Another approach that relates to "designated uses" is the narrative statement in the Water Quality Standards (e.g. "free from excess nutrients that cause or contribute to undesirable or nuisance aquatic life"). However, the EPA expects States that rely on narrative statements in their water quality standards to establish procedures to quantitatively translate these statements for both assessment and source control. Therefore, MADEP planned on exploring the possible use of quantitative "translators" such as existing water quality standards (e.g. DO) as well as establish quantitative threshold values of measurable translators, such as percent of stream bottom covered by filamentous algae or macroalgae, concentration of chlorophyll *a* (water column in impounded reaches of rivers or periphyton in shallow streams), secchi disc transparency, turbidity, etc. The exceedance of selected threshold values of these translators would trigger the necessity to reduce nutrient concentrations or loadings to the system. A major benefit of this approach is that nutrient controls will be triggered by measurement of impact (i.e., excess nuisance algae) that "integrate" long-term, or seasonal, fluctuating nutrient concentrations (thereby precluding the need for extensive nutrient sampling that would be necessary if there were numeric standards, which would be complicated by seasonal numeric limits. Sampling to measure nutrient concentrations in-stream for modeling purposes, TMDL development, setting targets, etc., can be conducted for specific objectives after impairments are documented.

Criteria selection for lakes

The completed dataset (previously existing data, and any new data collected to fill gaps as part of this effort) will be used to explore various approaches to developing nutrient criteria, including the EPA statistical approach (use of the 25th percentile for all lakes and the 75th percentile for reference lakes) as well as the "attainment of designated uses" approach (aquatic life, primary recreation, and aesthetics). The data will be subdivided to explore the influence of such factors as lake type (stratified, non-stratified, shallow) as well as other factors such as flushing rate, water color and distributions within ecoregions and/or nutrient zones. The attainment of designated uses will focus on the most appropriate groupings of lake types and assignment of uses to those groups. The lakes will be assessed to determine if the uses are being met or not. This determination will then be compared to determine the relationship of nutrients, secchi disk, chlorophyll *a* (and possibly color) to attainment of uses in each group. Appropriate statistics such as discriminant analysis and/or logistic regression will be used to determine the final nutrient criteria and establish the statistical confidence of the criteria within the sample dataset.

Site-Specific Criteria Selection for Marine Waters

Criteria for nitrogen in coastal waters will be developed by a phased approach: first, criteria will be developed for nitrogen-sensitive embayments in southeastern Massachusetts (Cape Cod, Buzzards Bay, Nantucket, Martha's Vineyard, and Mt. Hope Bay) by combined efforts of municipalities, the Massachusetts DEP and SMAST (partnering with the USGS, Cape Cod Commission, Applied Coastal, inc., and others) as part of the Massachusetts Estuaries Project (MEP). The criteria that will be developed by way of the MEP will be embayment-specific because each estuary, or embayment, reacts differently to nitrogen inputs (or loadings) because of differences in chemical, physical, and biological characteristics of each embayment. The second phase of the criteria development, for open coastal waters, will follow a process similar that used for the nitrogen-sensitive embayments, depending on available resources.

Indicators for Embayment-Specific Threshold Determination

MADEP felt that the assessment of embayment health and subsequent determination of critical nutrient thresholds capable of maintaining or restoring the ecological health for a specific embayment must be conducted relative to scientifically justifiable and agreed upon habitat measures. There are a wide variety of measures that give indications of the ecological health of an embayment. Some of the indicators are biological (eelgrass, macro algae, benthic animals) while others are chemical (Dissolved Oxygen, organic and inorganic nitrogen, phytoplankton pigments, etc.), physical (water clarity, temperature) or geochemical (sediment characteristics).

Habitat indicators that are of primary concern in gaging embayment health and nitrogen assimilative capacity are:
• plant presence and diversity (eelgrass, macro algae, etc.)
• animal species presence and diversity (finfish, shellfish, infauna) • nutrient concentrations (nitrogen species)
• chlorophyll concentration
• dissolved oxygen levels in the embayment water column

These indicators form the basis of an assessment of an estuary's present health. When coupled with a full water quality synthesis and projections of future conditions based upon water quality modeling, site-specific thresholds can be developed for these systems.

Michigan

This section provides information about Michigan NNC development efforts. Michigan does not have any NNC currently.

Table 78. Existing Michigan Numeric Criteria.[1,2]

Waterbody Type	N	P	Chl-a	Clarity[2]
Lakes & Reservoirs				
Rivers & Streams				
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = For selected waterbody N/A=Not Applicable

[1] From Michigan's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved January 2006). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes. If a state/territory has criteria for the protection of drinking water or human health, those criteria may be found on the tabs for either statewide or site-specific criteria.

[2] Source: EPA's (LeSage and Smith 2010; Michigan Department of Environmental Quality 2006b; Michigan Department of Environmental Quality 2006c; United States Environmental Protection Agency 2008b)

The Michigan Department of Environmental Quality (MIDEQ) does have a Nutrient Criteria Development Plan (Michigan Department of Environmental Quality 2006a). Basically the plan outlined the primary steps that will be taken to develop NNC including assembling of data, classification of waterbodies, prioritization of waterbodies NNC development, evaluation of primary methods including ecoregion based methods and stressor response techniques provided by EPA guidance. Recent research funded by the MIDEQ included paleolimnological studies to evaluate baseline conditions in regional lakes, development of translator values to describe stressor response relationships in area lakes and development of watershed models that would predict natural levels of phosphorus in watersheds. Michigan is close to quantifying thresholds in TP levels that result in shifts in biological indicators.

Minnesota

Numeric Criteria Development

The information presented below gives a summary of state progress towards the development of numeric criteria. The information comes from various sources including the State of Minnesota and EPA (Minnesota Pollution Control Agency 2008a; Minnesota Pollution Control Agency 2008b; United States Environmental Protection Agency 2008b)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_mn.cfm)(http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/water-quality-standards.html).

Links to the Minnesota's Nutrient Criteria Plan and state water quality standards are also provided (Heiskary et al. 2010; Heiskary and Markus 2001; Heiskary and Markus 2003; Heiskary and Parson 2010; Heiskary and Wilson 2008; Laidlaw 2010a)

Table 79. Existing Minnesota Numeric Criteria[1]

Waterbody Type	N	P	Chl-a	Clarity[2]
Lakes & Reservoirs		S	S	S
Rivers & Streams				
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = For selected waterbody N/A=Not Applicable

[1] From Minnesota's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved May 2008). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes. If a state/territory has criteria for the protection of drinking water or human health, those criteria may be found on the tabs for either statewide or site-specific criteria.

[2] Source: (Minnesota Pollution Control Agency 2005; Minnesota Pollution Control Agency 2008a; Minnesota Pollution Control Agency 2008b);(United States Environmental Protection Agency 2008b)

The statewide nutrient criteria for Minnesota are listed in the following sections of the Minnesota regulations.

7050.0220 Specific Water Quality Standards by Associated Use Classes.

Table 80. The tables of standards in subparts 3a to 6a include the following abbreviations and acronyms.

AN means aesthetic enjoyment and navigation, Class 5 waters
CS means chronic standard, defined in part 7050.0218, subpart 3
DC means domestic consumption (drinking water), Class 1 waters
– double dashes means there is no standard
FAV means final acute value, defined in part 7050.0218, subpart 3
IC means industrial consumption, Class 3 waters
IR means agriculture irrigation use, Class 4A waters
LS means agriculture livestock and wildlife use, Class 4B waters
MS means maximum standard, defined in part 7050.0218, subpart 3
NA means not applicable

Table 81. Eutrophication standards for Class 2Bd lakes, shallow lakes, and reservoirs in Minnesota. From: (Minnesota Pollution Control Agency 2008a).

Lakes, Shallow Lakes, and Reservoirs in Northern Lakes and Forest Ecoregion.

Substance, Characteristic, or Pollutant (Class 2Bd)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	30	NA	–	–	NA
Chlorophyll-a	µg/L	9	NA	–	–	NA
Secchi disk transparency	meters	Not less than 2.0	NA	–	–	NA

Lakes and Reservoirs in North Central Hardwood Forest Ecoregion

Substance, Characteristic, or Pollutant (Class 2Bd)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	40	NA	–	–	NA
Chlorophyll-a	µg/L	14	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.4	NA	–	–	NA

Lakes and Reservoirs in Western Corn Belt Plains and Northern Glaciated Plains Ecoregions

Substance, Characteristic, or Pollutant (Class 2Bd)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	65	NA	–	–	NA
Chlorophyll-a	µg/L	22	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.9	NA	–	–	NA

Shallow Lakes in North Central Hardwood Forest Ecoregion

Substance, Characteristic, or Pollutant (Class 2Bd)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	60	NA	–	–	NA
Chlorophyll-a	µg/L	20	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.0	NA	–	–	NA

Shallow Lakes in Western Corn Belt Plains and Northern Glaciated Plains Ecoregions

Substance, Characteristic, or Pollutant (Class 2Bd)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	90	NA	–	–	NA
Chlorophyll-a	µg/L	30	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.7	NA	–	–	NA

Table 82. Eutrophication standards for Class 2B lakes, shallow lakes, and reservoirs in Minnesota. From: (Minnesota Pollution Control Agency 2008a)

Lakes, Shallow Lakes, and Reservoirs in Northern Lakes and Forest Ecoregion

Substance, Characteristic, or Pollutant (Class 2B)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	30	NA	–	–	NA
Chlorophyll-a	µg/L	9	NA	–	–	NA
Secchi disk transparency	meters	Not less than 2.0	NA	–	–	NA

Lakes and Reservoirs in North Central Hardwood Forest Ecoregion

Substance, Characteristic, or Pollutant (Class 2B)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	40	NA	–	–	NA
Chlorophyll-a	µg/L	14	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.4	NA	–	–	NA

Lakes and Reservoirs in Western Corn Belt Plains and Northern Glaciated Plains Ecoregion

Substance, Characteristic, or Pollutant (Class 2B)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	65	NA	–	–	NA
Chlorophyll-a	µg/L	22	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.9	NA	–	–	NA

Shallow Lakes in North Central Hardwood Forest Ecoregion

Substance, Characteristic, or Pollutant (Class 2B)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	60	NA	–	–	NA
Chlorophyll-a	µg/L	20	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.0	NA	–	–	NA

Shallow Lakes in Western Corn Belt Plains and Northern Glaciated Plains Ecoregion

Substance, Characteristic, or Pollutant (Class 2B)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Phosphorus, total	µg/L	90	NA	–	–	NA
Chlorophyll-a	µg/L	30	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.7	NA	–	–	NA

As illustrated above lake and reservoir numeric criteria were adopted in 2008 (Laidlaw 2010b; United States Environmental Protection Agency 2008b). A more concise summary is listed below. Different lake classes were established based on ecoregion and lake morphometry. Criteria were based on reference distributions, user and perception surveys (recreational uses) (Laidlaw 2010) (Table 83).

Table 83. Summary of Minnesota's numeric lake criteria. Source: Laidlaw 2010.

Ecoregion	TP	Chl-a	Secchi
	ppb	ppb	meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
CHF – Stream trout (Class 2A)	< 20	< 6	> 2.5
CHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
CHF – Aquatic Rec. Use (Class 2B) Shallow lakes	< 60	< 20	> 1.0
WCP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCP & NGP – Aquatic Rec. Use (Class 2B) Shallow lakes	< 90	< 30	> 0.7

Minnesota has recently drafted a NNC support document for rivers (http://www.pca.state.mn.us/index.php/view-document.html?gid=14947). The lakes criteria support document for Minnesota is found at: (http://www.pca.state.mn.us/index.php/view-document.html?gid=6503).(Heiskary et al. 2010; Heiskary and Wilson 2008).

Mississippi

Data on Mississippi's NNC development efforts were obtained from interviews with staff participating in the Gulf of Mexico Alliance Nutrient Priority Team, and the EPA and Mississippi water quality standards web site (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ms.cfm.)(http://www.deq.state.ms.us/mdeq.nsf/page/wmb_water_quality_standards?opendocument). As of July 2011, Mississippi lacks NNC but does have a Nutrient Criteria Development Plan that was published by Mississippi in July 2010, and adopted by EPA on October 7, 2010 (Mississippi Department of Environmental Quality 2007; Mississippi Department of Environmental Quality 2010). The strategy used by Mississippi Department of Environmental Quality (MSDEP) is outlined verbatim below.

The focus of Mississippi's strategy will be to develop nutrient criteria based primarily on the linkage between nutrient concentrations and impairment of designated uses. For the purposes of this document, "nutrient criteria" are defined as one of, or potentially a combination of, three forms:

• Causal and/or response variables expressed as numerical concentrations and/or mass quantities or loadings

• Causal and/or response variables expressed as narrative statements with a translator mechanism to derive or calculate numerical concentrations and/or mass quantities or loadings

• Casual and/or response variables expressed as narrative statements only.
MSDEQ will consider all of the above criterion forms when establishing criteria for causative variables (such as phosphorus and nitrogen) and response variables (such as chlorophyll-*a* and turbidity) that are associated with the prevention and assessment of eutrophic conditions. It is possible that a combination of numeric criteria and narrative criteria with translators will be developed for some Mississippi water bodies. Also, it is possible that Mississippi may derive criteria based on a "reference condition approach." Using a reference condition approach, water quality criteria are derived from data collected at least disturbed sites, and an upper percentile of the data is taken to establish the numeric criteria. The flaw in this approach is that it does not provide a definite link between nutrient concentrations and impairment. But rather, it presents statistically-derived values for causal and response variables from sites that are known to be least impacted. It says nothing about the water body's capacity to assimilate nutrient inputs. Additionally, by definition, a portion of the water bodies will not attain the water quality standard, even if their designated uses are being fully attained. However, it has been portrayed by EPA to be an acceptable and scientifically defensible approach, and some states have used it to derive their criteria.

An effects-based approach is undoubtedly the preferred means to arrive at values that are neither over- nor under-protective; however, due to limitations in time, data, and resources the reference condition approach may be used in certain water body types. MSDEQ will look for cause/effect relationships between nutrient concentration and biological impacts. However, if those relationships cannot be found, then our "fallback" positions may be to set reference-based or designated uses-based criteria.

Missouri

Missouri currently lacks federally approved NNC but does have a Nutrient Criteria Development Plan (Laidlaw 2010a; Missouri Department of Natural Resources 2005; Missouri Department of Natural Resources 2009; Missouri Department of Natural Resources 2010; United States Environmental Protection Agency 1988a).

Montana

The following information reflects Montana's water quality standards posted to the Water Quality Standards Repository as of November 2010 and on their web site (EPA-approved September 2008)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/ states_mo.cfm.)(Montana Department of Environmental Quality 2008a).

Table 84. Existing Numeric Criteria for Montana[1]

Waterbody Type	N	P	Chl-a	Clarity[2]
Lakes & Reservoirs				
Rivers & Streams	W	W	W	
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = For selected waterbody N/A=Not Applicable
[1] From Montana's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved September 2008). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for aquatic life uses.
[2] Source: EPA's (Montana Department of Environmental Quality 2008a; United States Environmental Protection Agency 2008b).

The current NNC for Montana is listed below. These standards only apply to selected streams and rivers.
Montana Regulation: 17.30.631 Numeric Algal Biomass and Nutrient Standards

(1) No person may violate the numeric water quality standards identified below.
(2) The numeric nutrient and standing crop of benthic algae water quality standards for the mainstem Clark Fork River from below the Warm Springs Creek confluence (N46º11'17", W112º46'03") to the confluence with the Flathead River (N47º21'45", W114º46'43") are as follows: (a) In the mainstem Clark Fork River from below the Warm Springs Creek confluence (N46º11'17", W112º46'03") to the confluence with the Blackfoot River (N46º52'19", W113º53'35") the numeric water quality standards for Total Nitrogen, Total Phosphorus, and benthic algal chlorophyll a, applicable from June 21 to September 21, are as follows:

Table 85. Nutrient criteria for the mainstem Clark River below Warm Springs Creek confluence, Montana.

(i)	Parameter	Concentration
	Total Phosphorus as P	20 µg/L
	Total Nitrogen as N	300 µg/L
(ii)	Parameter	Density
	(Summer mean) - Benthic algal chlorophyll-*a*	100 mg/square meter
	(Maximum) - Benthic algal chlorophyll a	150 mg/square meter

(b) In the Clark Fork River from the confluence with the Blackfoot River (N46º52'19", W113º53'35") to the confluence with the Flathead River (N47º21'45", W114º46'43") the numeric water quality standards for Total Nitrogen, Total Phosphorus, and benthic algal chlorophyll-*a*, applicable from June 21 to September 21, are as follows:

Table 86. Nutrient criteria for the Clark Fork River from confluence of Blackfoot River to confluence of the Flathead River in Montana.

(i)	Parameter	Concentration
	Total Phosphorus as P	39 µg/L
	Total Nitrogen as N	300 µg/L
(ii)	Parameter	Density
	(Summer mean) - Benthic algal chlorophyll a	100 mg/square meter
	(Maximum) - Benthic algal chlorophyll a	150 mg/square meter

Montana does have a Nutrient Criteria Development Plan (Suplee 2002). However, since publication of the plan numerous studies have been published to support development of NNC (Dodds et al. 1997; Montana Department of Environmental Quality 2008b; Montana Department of Environmental Quality 2010; Paul 2008; Suplee et al. 2005; Suplee et al. 2008; Suplee et al. 2007; Varghese and Cleland 2005). Most of the work has focused on stream NNC development. Methods evaluated included ecoregion based and stressor response approaches.

Nebraska

Although Nebraska does not have any EPA approved NNC, they do have state adopted NNC for a majority of their reservoirs. The EPA recently failed to approve these NNC so the eventual fate of these values is uncertain (Nebraska Department of Environmental Quality 2008). These standards are outlined in Title 117 Chapter 4 which became effective on March 22, 2009. This table of values is found in *003.05 Nutrient Criteria for Lakes and Impounded Waters.*

Table 87. Existing numeric criteria in Nebraska.[1]

Waterbody Type	N	P	Chl-A	Clarity[2]
Lakes & Reservoirs	State adopted only	State adopted only	State adopted only	
Rivers & Streams				
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = For selected waterbody N/A=Not Applicable

[1] From Nebraska's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved August 2003). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for aquatic life uses.

[2] Source: EPA's (Nebraska Department of Environmental Quality 2009a; Nebraska Department of Environmental Quality 2009b; Nebraska Department of Environmental Quality 2009c; Nebraska Department of Environmental Quality 2009d; United States Environmental Protection Agency 2008b; United States Environmental Protection Agency 2010e).

The regulations states that the following criteria associated with various nutrient classifications shall apply to lakes or impounded waters according to codes listed in Chapter 6. Where no classification has been specified for a lake or impounded water, criteria associated with the statewide default classification shall apply. Criteria are based on seasonal averages from April 1 through September 30. The listed criteria are shown in Table 88. Nebraska has a very abbreviated Nutrient Criteria Development Plan (Nebraska Department of Environmental Quality 2008).

Table 88. State adopted nutrient criteria for reservoirs and lakes in Nebraska. Note, these are not EPA approved. From:(Nebraska Department of Environmental Quality 2009b; Nebraska Department of Environmental Quality 2009c)

Lake or Impounded Waters Classification:	Codes	Total Phosphorus (ug/l)	Total Nitrogen (ug/l)	Chlorophyll a (ug/l)
Reservoirs:	R1	54	1310	7
	R2	54	1310	7
	R3	112	570	8
	R4	1050	1980	5
	R5	69	660	24
	R6	54	1310	7
	R7	37	610	7
	R8	38	610	11
	R9	62	570	8
	R10	38	520	9
	R11	131	600	11
	R12	134	1460	44
	R13	143	1540	16
	R14	134	1460	44
	R15	133	1460	44
	R16	111	1070	30
	R17	134	1460	44
	R18	139	1460	44
	R19	873	1980	5
	R20	746	1980	5
	R21	709	1980	5
	R22	873	2760	14
Sandpits:	SP	95	1240	49
SandHills:	SH	3000	38960	341
Statewide Default:	SW	564	2300	29

Nevada

The state of Nevada has site specific criteria for rivers, streams, lakes and reservoirs Table 89. These site specific criteria are dependent on waterbody type and designated use classification.

Table 89. Existing Numeric Criteria for Nevada. [1]

Waterbody Type	N	P	Chl-a	Clarity[2]
Lakes & Reservoirs	W	W	W	W3,4
Rivers & Streams	W	W		W3,4
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = For selected waterbody N/A=Not Applicable

[1] From Nevada's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved May 2007). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes. If a state/territory has criteria for the protection of drinking water or human health, those criteria may be found on the tabs for either statewide or site-specific criteria.

[2] Source: EPA's (United States Environmental Protection Agency 2008b)

[3] Includes turbidity and suspended solids.

[4] For selected waters and uses.

The information in this section shows state adopted, EPA-approved site specific nutrient criteria for Nevada's waterbodies. Criteria on this page apply only to the waterbodies listed below. Criteria applicable to all waterbodies within the state are found on the "Statewide Criteria" tab. For more information, refer to the Nevada water quality standards. The following information reflects Nevada's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved May 2007)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_nv.cfm.).

NAC 445A.124 Class A waters: Description; beneficial uses; quality standards. (NRS 445A.425, 445A.520).

1. Class A waters include waters or portions of waters located in areas of little human habitation, no industrial development or intensive agriculture and where the watershed is relatively undisturbed by man's activity.
2. The beneficial uses of class A waters are municipal or domestic supply, or both, with treatment by disinfection only, aquatic life, propagation of wildlife, irrigation, watering of livestock, recreation including contact with the water and recreation not involving contact with the water.
3. The quality standards for class A waters* are:

Table 90. Water quality standards including NNC for class A waters in Nevada*.

Item	Specifications
Floating solids, sludge deposits, or taste- or odor-producing substances.	None attributable to man's activities.
Total phosphorus (as P): In any stream at the point where it enters a reservoir or lake. In any reservoir or lake. In a stream or other flowing water.	 ≤ 0.05 mg/L. ≤ 0.025 mg/L. ≤ 0.10 mg/L.

*Class A waters listed in subsection 4.

NAC 445A.125 Class B waters: Description; beneficial uses; quality standards. (NRS 445A.425, 445A.520)

1. Class B waters include waters or portions of waters which are located in areas of light or moderate human habitation, little industrial development, light-to-moderate agricultural development and where the watershed is only moderately influenced by man's activity.

2. The beneficial uses of class B water are municipal or domestic supply, or both, with treatment by disinfection and filtration only, irrigation, watering of livestock, aquatic life and propagation of wildlife, recreation involving contact with the water, recreation not involving contact with the water, and industrial supply.

3. The quality standards for class B waters* are:

Table 91. Water quality standards including NNC for class B waters* in Nevada.

Item	Specifications
Odor-producing substances.	Only such amounts which will not impair the palatability of drinking water or fish or have a deleterious effect upon fish, wildlife or any beneficial uses established for waters of this class.
Total phosphorus (as P).	≤ 0.10 mg/L.

*Class B waters listed in subsection 4.

NAC 445A.126 Class C waters: Description; beneficial uses; quality standards. (NRS 445A.425, 445A.520)

1. Class C waters include waters or portions of waters which are located in areas of moderate-to-urban human habitation, where industrial development is present in moderate amounts, agricultural practices are intensive and where the watershed is considerably altered by man's activity.

2. The beneficial uses of class C water are municipal or domestic supply, or both, following complete treatment, irrigation, watering of livestock, aquatic life, propagation of wildlife, recreation involving contact with the water, recreation not involving contact with the water, and industrial supply.

3. The quality standards for class C waters* are:

Table 92. Water quality standards including NNC for class C waters* in Nevada.

Item	Specifications
Total phosphorus (as P).	≤ 0.33 mg/L.

*Class C waters listed in subsection 4.

NAC 445A.147 Carson River: West Fork at the state line. (NRS 445A.425, 445A.520) **Standards of Water Quality**

Carson River

Control Point at the West Fork at the state line. The limits of this table apply only to the West Fork at the state line.

Table 93. Water quality standards including NNC for the Carson River at the West Fork, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .016 S.V. : ≤ .033	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	A-Avg. : ≤ 0.4 S.V. : ≤ 0.5	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	A-Avg. : ≤ 15 --	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	A-Avg. : ≤ 3 S.V. : ≤ 5	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b]. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.148 Carson River: Bryant Creek near the state line. (NRS 445A.425, 445A.520). **Standards of Water Quality Carson River**
Control Point at Bryant Creek near the state line. The limits of this table apply only to Bryant Creek near the state line.

Table 94. Water quality standards and NNC for Bryant Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .036 S.V. : ≤ .05	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	A-Avg. : ≤ 0.6 S.V. : ≤ 1.0	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b.] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.149 Carson River: East Fork at the state line. (NRS 445A.425, 445A.520) **Standards of Water Quality Carson River**
Control Point at the East Fork at the state line. The limits of this table apply only to the East Fork at the state line.

Table 95. Water quality standards and NNC for the East Fork Carson River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .03 S.V. : ≤ .065	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.5 S.V. : ≤ 1.1	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	A-Avg. : ≤ 5 S.V. : ≤ 8	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.150 Carson River: East Fork at Highway 395, south of Gardnerville. (NRS 445A.425, 445A.520)

Standards of Water Quality

Carson River Control Point for East Fork at Highway 395, south of Gardnerville (Riverview). The limits of this table apply from Riverview Mobile Home Park to the state line.

Table 96. Water quality standards and NNC for the East Fork at Highway 395 Carson River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.4 S.V. : ≤ 0.5	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b]. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.151 Carson River: East Fork at Muller Lane. (NRS 445A.425, 445A.520)

Standards of Water Quality

Carson River: Control Point at the East Fork at Muller Lane. The limits of this table apply only from East Fork at Muller Lane to Highway 395, south of Gardnerville (Riverview Mobile Home Park).

Table 97. Water quality standards and NNC for Control Point at East Fork at Muller Lane of Carson River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.5 S.V. : ≤ 0.8	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.152 Carson River at Genoa Lane. (NRS 445A.425, 445A.520)
Standards of Water Quality

Carson River: Control Point at Genoa Lane. The limits of this table apply from Genoa Lane to the East Fork at Muller Lane and to the West Fork at the state line.

Table 98. Water quality standards and NNC for Carson River Control Point at Genoa Lane, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.8 S.V. : ≤ 1.3	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.153 Carson River at Cradlebaugh Bridge. (NRS 445A.425, 445A.520)
Standards of Water Quality

Carson River: Control Point at Cradlebaugh Bridge. The limits of this table apply from Cradlebaugh Bridge to Genoa Lane.

Table 99. Water quality standards and NNC for Carson River control point at Cradlebaugh Bridge, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.85 S.V. : ≤ 1.2	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.154 Carson River at Mexican Ditch Gage. (NRS 445A.425, 445A.520)

Standards of Water Quality

Carson River: Control Point at Mexican Ditch Gage. The limits of this table apply from Mexican Ditch Gage to Highway 395, at Cradlebaugh Bridge.

Table 100. Water quality standards and NNC for Carson River control point at Mexican ditch gage, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.8 S.V. : ≤ 1.3	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b.] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.155 Carson River near New Empire. (NRS 445A.425, 445A.520)

Standards of Water Quality

Carson River: Control Point near New Empire. The limits of this table apply from New Empire to the Mexican Ditch Gage.

Table 101. Water quality standards and NNC for the Carson River at the control point near New Empire, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.3 S.V. : ≤ 1.7	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.156 Carson River at Dayton Bridge. (NRS 445A.425, 445A.520)

Standards of Water Quality

Carson River: Control Point at Dayton Bridge. The limits of this table apply from Dayton Bridge to New Empire.

Table 102. Water quality standards and NNC for the Carson River at the control point at Dayton Bridge, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.1	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.2 S.V. : ≤ 1.6	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	A-Avg. : ≤ 12 S.V. : ≤ 25	S.V. : ≤ 50	Aquatic life[b] and municipal or domestic supply.

[b] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.157 Carson River at Weeks. (NRS 445A.425, 445A.520)

Standards of Water Quality

Carson River: Control Point at Weeks (Ft. Churchill). The limits of this table apply from the U.S. Highway 95 Bridge at Weeks to the Dayton Bridge.

Table 103. Water quality standards and NNC for the Carson River at the control point at Weeks, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	A-Avg. : ≤ 0.1	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.6 S.V. : ≤ 1.1	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L		S.V. : ≤ 80	Aquatic life.[b]
Turbidity - NTU	A-Avg. : ≤ 25 --	S.V. : ≤ 50	Aquatic life[b] and municipal or domestic supply.

[b.] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.158 Carson River at Lahontan Dam. (NRS 445A.425, 445A.520)
Standards of Water Quality

Carson River: Control Point at Lahontan Dam. The limits of this table apply from Lahontan Dam to the U.S. Highway 95 bridge at Weeks (Ft. Churchill).

Table 104. Water quality standards and NNC for the Carson River at the control point at Lahontan Dam, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- --	S.V. : ≤ 0.06	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.3 S.V. : ≤ 1.7	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Aquatic life,[b] municipal or domestic supply,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	A-Avg. : ≤ 15 S.V. : ≤ 27	S.V. : ≤ 50	Aquatic life[b] and municipal or domestic supply.

[b.] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.160 West Walker River at the state line. (NRS 445A.425, 445A.520)
Standards of Water Quality
West Walker River: Control Point at the West Walker River at the state line. The limits of this table apply only to the West Walker River at the state line.

Table 105. Water quality standards and NNC for West Walker River at the control point at the state line, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average	-- --	≤ 0.1 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 0.6 mg/L ≤ 0.9 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Annual Average Single Value	≤ 60 mg/L	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

[b.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.161 Topaz Lake. (NRS 445A.425, 445A.520)
Standards of Water Quality
Topaz Lake: Control Point at Topaz Lake. The limits of this table apply at various points in Topaz Lake.

Table 106. Water quality standards and NNC for Topaz Lake, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average Single Value	-- --	≤ 0.05 mg/L ≤ 0.10 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 0.6 mg/L ≤ 1.0 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Annual Average Single Value	≤ 6.0 mg/L ≤ 9.0 mg/L	≤ 25 mg/L	Propagation of aquatic life.
Turbidity Annual Average Single Value	≤ 3.0 NTU ≤ 5.0 NTU	c	Propagation of aquatic life and municipal or domestic supply, or both.

c. Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.162 West Walker River near Wellington. (NRS 445A.425, 445A.520)

Standards of Water Quality

West Walker River: Control Point at the West Walker River near Wellington. The limits of this table apply from the West Walker River near Wellington to the West Walker River at the state line.

Table 107. Water quality standards and NNC for the West Walker River at Wellington, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average Single Value	≤ 0.07 mg/L ≤ 0.10 mg/L	≤ 0.1 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 0.6 mg/L ≤ 1.0 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	--	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

[b.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.163 West Walker River above confluence with East Walker River at Nordyke Road. (NRS 445A.425, 445A.520)

Standards of Water Quality

West Walker River: Control Point at the West Walker River above the confluence with the East Walker River at Nordyke Road. The limits of this table apply to the West Walker River above its confluence with the East Walker River to the control point mentioned in NAC 445A.162 (near Wellington).

Table 108. Water quality standards and NNC for the West Walker River above confluence with East Walker River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average Single Value	≤ 0.15 mg/L	≤ 0.10 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 1.0 mg/L ≤ 1.2 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	--	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

[b.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.164 Sweetwater Creek. (NRS 445A.425, 445A.520)

Standards of Water Quality

Sweetwater Creek: Control Point at Sweetwater Creek. The limits of this table apply to Sweetwater Creek from its confluence with the East Walker River to the state line.

Table 109. Water quality standards and NNC for Sweetwater Creek to state line, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average	-- --	≤ 0.1 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrate ≤ 0.25 mg/L ≤ 0.45 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	≤ 45 mg/L	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

b. Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.165 East Walker River at the state line. (NRS 445A.425, 445A.520)
Standards of Water Quality

East Walker River: Control Point at the East Walker River at the state line. The limits of this table apply only to the East Walker River at the state line.

Table 110. Water quality standards and NNC for the East Walker River at the state line, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average	--	≤ 0.1 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 0.8 mg/L ≤ 1.4 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	≤ 30 mg/L	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

[b.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.1655 East Walker River at Bridge B-1475. (NRS 445A.425, 445A.520)
Standards of Water Quality

East Walker River at Bridge B-1475: Control Point at the East Walker River at Bridge B-1475. The limits of this table apply only from the East Walker River at Bridge B-1475 to the East Walker River at the state line.

Table 111. Water quality standards and NNC for the East Walker River at Bridge B-1475, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average	-- --	≤ 0.10 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 0.9 mg/L ≤ 1.7 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	--	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

[b.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.166 East Walker River south of Yerington. (NRS 445A.425, 445A.520)
Standards of Water Quality
East Walker River: Control Point at the East Walker River south of Yerington above the confluence with the West Walker River (Nordyke Road). The limits of this table apply to the East Walker River South of Yerington above its confluence with the West Walker River to the East Walker River at Bridge B-1475.

Table 112. Water quality standards and NNC for the East Walker River at Yerington, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average Single Value	--	≤ 0.16 mg/L ≤ 0.39 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 0.9 mg/L ≤ 1.7 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	--	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

[b.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.167 Walker River at inlet to Weber Reservoir. (NRS 445A.425, 445A.520)

Standards of Water Quality

Walker River: Control Point at the Walker River at the inlet to Weber Reservoir. The limits of this table apply to the Walker River from the inlet to Weber Reservoir to the confluence of the West Walker River and the East Walker River.

Table 113. Water quality standards and NNC for the Walker River at the inlet to Weber Reservoir, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average Single Value	--	≤ 0.26 mg/L ≤ 0.40 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 1.2 mg/L ≤ 1.5 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ 1[c]mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	--	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	d	Propagation of aquatic life and municipal or domestic supply, or both.

[c.] The nitrite beneficial use standard is ≤0.06 mg/L from February through June when Lahontan cutthroat trout are present in the reach from Walker Lake to the Weber Reservoir.
[d.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.168 Walker River at Schurz Bridge. (NRS 445A.425, 445A.520)
Standards of Water Quality
Walker River: Control Point at Schurz Bridge. The limits of this table apply from the inlet to Walker Lake to Weber Reservoir.

Table 114. Water quality standards and NNC for Walker River at Schurz Bridge, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average Single Value	-- ≤ 0.17 mg/L ≤ 0.23 mg/L		Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrogen ≤ 1.2 mg/L ≤ 1.5 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ 1 mg/L[c]	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	≤ 60 mg/L	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	d	Propagation of aquatic life and municipal or domestic supply, or both.

c. The nitrite beneficial use standard is ≤0.06 mg/L from February through June when Lahontan cutthroat trout are present.
d. Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.169 Desert Creek. (NRS 445A.425, 445A.520)
Standards of Water Quality

Desert Creek: Control Point at Desert Creek. The limits of this table apply to Desert Creek from its confluence with the West Walker River to the state line.

Table 115. Water quality standards and NNC for Desert Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) Annual Average Single Value	≤ 0.13 mg/L	≤ 0.1 mg/L	Propagation of aquatic life, recreation involving contact with the water, municipal or domestic supply, or both, and recreation not involving contact with the water.
Nitrogen Species (as N) Annual Average Single Value Single Value	Total Nitrate ≤ 0.20 mg/L ≤ 0.27 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ .06 mg/L	Municipal or domestic supply, or both, propagation of aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids Single Value	--	≤ 80 mg/L	Propagation of aquatic life.
Turbidity Single Value	--	b	Propagation of aquatic life and municipal or domestic supply, or both.

[b.] Increase in turbidity must not be more than 10 NTU above natural conditions.

NAC 445A.1696 Walker Lake. (NRS 445A.425, 445A.520)

Standards of Water Quality

Walker Lake: Control Point at Walker Lake. The limits of this table apply to Walker Lake.

Table 116. Water quality standards and NNC for Walker Lake, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Suspended Solids Single Value	--	≤ 25 mg/L	Propagation of aquatic life.
Nitrogen Species (as N) Single Value Single Value	Total Inorganic Nitrogen: ≤ 0.3 mg/L	Nitrate: ≤ 90 mg/L Nitrite: ≤ 0.06 mg/L	Propagation of aquatic life and propagation of wildlife.
Total Phosphorus (as P) Single Value	--	≤ 0.82 mg/L	Propagation of aquatic life.

NAC 445A.171 Chiatovich Creek. (NRS 445A.425, 445A.520)
Standards of Water Quality
Chiatovich Creek: Control Point above highway maintenance station. The limits of this table apply above the highway maintenance station.

Table 117. Water quality standards and NNC for Chiatovich Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .04 S.V. : ≤ .06	A-Avg. : ≤ 0.1 --	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ .6 S.V. : ≤ .8	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Municipal or domestic supply,[b] aquatic life,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	--	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.172 Indian Creek. (NRS 445A.425, 445A.520)
Standards of Water Quality
Indian Creek: Control Point near center of Section 9, T.2 S., R.34 E. The limits of this table apply above the center of Section 9, T.2 S., R 34 E.

Table 118. Water quality standards and NNC for Indian Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	-- S.V. : ≤ 0.13	A-Avg. : ≤ 0.1 --	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Nitrate S.V. : ≤ 0.45	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Municipal or domestic supply,[b] aquatic life,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	--	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.173 Leidy Creek. (NRS 445A.425, 445A.520)
Standards of Water Quality

Leidy Creek: Control Point at hydroelectric plant. The limits of this table apply above the hydroelectric plant.

Table 119. Water quality standards and NNC for Leidy Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .013 S.V. : ≤ .03	A-Avg. : ≤ 0.1 --	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Nitrate A-Avg. : ≤ 0.18 S.V. : ≤ 0.22	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Municipal or domestic supply,[b] aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife[b] and recreation not involving contact with the water.
Suspended Solids - mg/L	--	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b.] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.175 Virgin River at Mesquite. (NRS 445A.425, 445A.520)
Standards of Water Quality
Virgin River: Control Point at Mesquite. The limits of this table apply from Mesquite to the Arizona state line (near Littlefield, Arizona).

Table 120. Water quality standards and NNC for the Virgin River at Mesquite, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.1	Aquatic life[b] and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.9 S.V. : ≤ 1.6	Nitrate S.V. : ≤ 90 Nitrite S.V. : ≤ 5.0	Aquatic life,[b] watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Turbidity - NTU	-- --	e	Aquatic life.[b]

b. The most restrictive beneficial use.
e. Increase in turbidity must not be more than 10 NTU above natural conditions.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.176 Virgin River at the state line near Littlefield. (NRS 445A.425, 445A.520)
Standards of Water Quality
Virgin River: Control Point at the state line (near Littlefield, Arizona). The limits of this table apply at the Arizona-Nevada state line (near Littlefield, Arizona).

Table 121. Water quality standards and NNC for the Virgin river at the state line, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .06 S.V. : ≤ 0.1	A-Avg. : ≤ 0.1 --	Aquatic life[b] and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 2.4 S.V. : ≤ 3.2	Nitrate S.V. : ≤ 90 Nitrite S.V. : ≤ 5.0	Aquatic life,[b] watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Turbidity - NTU	-- --	e	Aquatic life.[b]

b.The most restrictive beneficial use.
e. Increase in turbidity must not be more than 10 NTU above natural conditions.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.177 Virgin River at Riverside. (NRS 445A.425, 445A.520)
Standards of Water Quality
Virgin River: Control Point at Riverside. The limits of this table apply from the river mouth at Lake Mead to Mesquite.

Table 122. Water quality standards and NNC for the Virgin River at Riverside, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.1	Aquatic life[b] and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 2.9 S.V. : ≤ 6.1	Nitrate S.V. : ≤ 90 Nitrite S.V. : ≤ 5.0	Aquatic life,[b] watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Turbidity - NTU	-- --	e	Aquatic life.[b]

b. The most restrictive beneficial use.
e. Increase in turbidity must not be more than 10 NTU above natural conditions.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.178 Beaver Dam Wash. (NRS 445A.425, 445A.520)

Standards of Water Quality

Beaver Dam Wash: Control Point above Schroeder Reservoir. The limits of this table apply above Schroeder Reservoir.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .01 S.V. : ≤ .013	A-Avg. : ≤ 0.05 --	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Nitrate S.V. : ≤ .22	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Municipal or domestic supply,[b] aquatic life,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	--	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.179 Snake Creek. (NRS 445A.425, 445A.520)

Standards of Water Quality

Snake Creek: Control Point above fish hatchery. The limits of this table apply above the fish hatchery.

Table 123. Water quality standards and NNC for Snake Creek above the fish hatchery, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .05 S.V. : ≤ .08	A-Avg. : ≤ 0.1	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Nitrate A-Avg. : ≤ .22 S.V. : ≤ .44	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Municipal or domestic supply,[b] aquatic life,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	--	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

[b.] The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.180 Smoke Creek. (NRS 445A.425, 445A.520)
Water Quality Standards for Smoke Creek

Table 124. Water quality standards and NNC for Smoke Creek at the control point approximately 30 miles east of Susanville, California in Nevada.

Phosphates (PO_4) - mg/L
Annual Average.. not more than.......... 0.5
Single Value... not more than.......... 0.7
Nitrates (NO_3) - mg/L
Single Value... not more than.......... 5.0
Turbidity - Turbidity must not exceed that characteristic of natural conditions by more than 10 Jackson Units.

NAC 445A.181 Bronco Creek. (NRS 445A.425, 445A.520)
Water Quality Standards for Bronco Creek

Table 125. Water quality standards and NNC for Bronco Creek at Hirschdale Road, Nevada.

Phosphates (PO_4) - mg/L
Annual Average.. not more than.......... 0.3
Single Value... not more than.......... 0.4
Nitrates (NO_3) - mg/L
Single Value... not more than.......... 2.0
Turbidity - Turbidity must not exceed that characteristic of natural conditions by more than 10 Jackson Units.

NAC 445A.182 Gray Creek. (NRS 445A.425, 445A.520)
Water Quality Standards Gray Creek

Table 126. Water quality standards and NNC for Gray Creek at, Hirschdale Road, Nevada.

Phosphates (PO_4) - mg/L
Annual Average.. not more than.......... 0.3
Single Value.. not more than.......... 0.4
Nitrates (NO_3) - mg/L
Single Value.. not more than……… 3.0
Turbidity - Turbidity must not exceed that characteristic of natural conditions by more than 10 Jackson Units.

NAC 445A.184 Truckee River at the state line. (NRS 445A.425, 445A.520)
Standards of Water Quality

Truckee River: Control Point at the state line. The limits of this table apply only at the California-Nevada state line.

Table 127. Water quality standards and NNC for the Truckee Riever at the state line, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ 0.03	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Ortho Phosphate (P) - mg/L	S.V. : ≤ 0.01	S.V. : ≤ 0.05	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.3 S.V. : ≤ 0.43	Nitrate S.V. : ≤ 2.0 Nitrite S.V. : ≤ .04	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Turbidity - NTU	A-Avg. : ≤ 5.0 S.V. : ≤ 9.0	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.
Suspended Solids - mg/L	A-Avg. : ≤ 15.0	S.V. : ≤ 25	Aquatic life.[b]

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.185 Truckee River at Idlewild. (NRS 445A.425, 445A.520)
Standards of Water Quality

Truckee River: Control Point at Idlewild. The limits of this table apply from the control point at Idlewild to the state line control point.

Table 128. Water quality standards and NNC for the Truckee River at Idlewild, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ 0.05	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Ortho Phosphate (P) – mg/L	S.V. : ≤ 0.02	S.V. : ≤ 0.05	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.3 S.V. : ≤ 0.43	Nitrate S.V. : ≤ 2.0 Nitrite S.V. : ≤ .04	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Turbidity - NTU	A-Avg. : ≤ 6.0 S.V. : ≤ 9.0	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.
Suspended Solids - mg/L	A-Avg. : ≤ 15.0	S.V. : ≤ 25	Aquatic life.[b]

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.186 Truckee River at East McCarran. (NRS 445A.425, 445A.520) **Standards of Water Quality**

Truckee River: Control Point at East McCarran Boulevard Bridge. The limits of this table apply from the East McCarran control point to the Idlewild control point.

Table 129. Water quality standards and NNC for the Truckee River at East McCarran Boulevard Bridge, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ 0.05	A-Avg. : ≤ 0.10	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Ortho Phosphate (P) – mg/L	S.V. : ≤ 0.02	S.V. : ≤ 0.05	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 0.3 S.V. : ≤ 0.43	Nitrate S.V. : ≤ 2.0 Nitrite S.V. : ≤ .04	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Turbidity - NTU	A-Avg. : ≤ 6.0	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.
Suspended Solids - mg/L	A-Avg. : ≤ 15.0	S.V. : ≤ 25	Aquatic life.[b]

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.187 Truckee River at Lockwood Bridge. (NRS 445A.425, 445A.520)
Standards of Water Quality
Truckee River: Control Point at Lockwood Bridge. The limits of this table apply from the control point at Lockwood to the East McCarran control point.

Table 130. Water quality standards and NNC for the Truckee River at Lockwood Bridge, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.05	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	--	TN A-Avg. : ≤ 0.75 TN S.V. : ≤ 1.2	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Turbidity - NTU	--	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.
Suspended Solids - mg/L	A-Avg. : ≤ 25.0	S.V. : ≤ 50	Aquatic life.[b]

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.188 Truckee River at Derby Dam. (NRS 445A.425, 445A.520)
Standards of Water Quality
Truckee River: Control Point at Derby Dam. The limits of this table apply from Derby Dam to the Lockwood Bridge control point.

Table 131. Water quality standards and NNC for the Truckee River at Derby Dam, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.05	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	--	TN A-Avg. : ≤ 0.75 TN S.V. : ≤ 1.2 Nitrate S.V. : ≤ 2.0 Nitrite S.V. : ≤ .04	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Turbidity - NTU	A-Avg. : ≤ 8.0	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.
Suspended Solids - mg/L	A-Avg. : ≤ 24.0 S.V. : ≤ 40.0	S.V. : ≤ 50	Aquatic life.[b]

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.189 Truckee River at Wadsworth Gage. (NRS 445A.425, 445A.520)
Standards of Water Quality
Truckee River: Control Point at Wadsworth Gage. The limits of this table apply from the Wadsworth Gage control point to Derby Dam.

Table 132. Water quality standard and NNC for the Truckee River at Wadsworth Gage, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.05	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	--	TN A-Avg. : ≤ 0.75 TN S.V. : ≤ 1.2 Nitrate S.V. : ≤ 2.0 Nitrite S.V. : ≤ .04	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Turbidity - NTU	--	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.
Suspended Solids - mg/L	A-Avg. : ≤ 25.0	S.V. : ≤ 50	Aquatic life.[b]

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.190 Truckee River at Pyramid Lake. (NRS 445A.425, 445A.520)
Standards of Water Quality
Truckee River: Control Point at Pyramid Lake. The limits of this table apply from the mouth of the Truckee River at Pyramid Lake to the Wadsworth Gage control point.

Table 133. Water quality standards and NNC for the Truckee River at Pyramid Lake, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.05	Aquatic life,[b] water contact recreation,[b] municipal or domestic supply and noncontact recreation.
Nitrogen Species (N) - mg/L	--	TN A-Avg. : ≤ 0.75 TN S.V. : ≤ 1.2 Nitrate S.V. : ≤ 2.0 Nitrite S.V. : ≤ .04	Aquatic life,[b] water contact recreation,[b] municipal or domestic supply and noncontact recreation.
Turbidity - NTU	--	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.
Suspended Solids - mg/L	A-Avg. : ≤ 25.0	S.V. : ≤ 50	Aquatic life.[b]

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.191 Lake Tahoe. (NRS 445A.425, 445A.520)

Standards of Water Quality

Lake Tahoe: Control Point: Existing sampling points.

Table 134. Water quality standards and NNC for the Lake Tahoe, Nevada.

Soluble Phosphorus - µg/L

Annual Average.. not more than.........7.0

Total Nitrogen (as N) - mg/L

Annual Average.. not more than.......0.25

Single Value... not more than.......0 .32

Total Soluble Inorganic Nitrogen - µg/L

Annual Average.. not more than.......25.0

Nitrite (as N) - mg/L

Single Value... not more than.......0 .06

Algal Growth Potential - The mean annual algal growth potential at any point in the lake must not be greater than twice
the mean annual algal potential at a limnetic reference station and using analytical methods determined jointly with the Environmental Protection Agency, Region IX.

Plankton Count - number per ml

Average (June through September)... not to exceed.....100.0

Single Value... not to exceed.....500.0

Clarity - The vertical extinction coefficient must be less than 0.08 per meter when measured at any depth below the first
meter. Turbidity must not exceed 3 NTU at any point of the lake too shallow to determine a reliable extinction coefficient.

Turbidity - To minimize turbidity levels in Lake Tahoe and tributary streams and control erosion:

1. The discharge of solid or liquid waste materials including soil, silt, clay, sand and other organic and earthen materials to Lake Tahoe or any tributary thereto is prohibited.
2. The discharge of solid or liquid waste materials including soil, silt, clay, sand and other organic and earthen materials to lands below the high water rim of Lake Tahoe or along any tributary to Lake Tahoe in a manner which will cause the discharge of the waste materials to Lake Tahoe or any tributary thereto is prohibited.
3. The placement or man-made disturbance of material below the high water rim of Lake Tahoe or along any tributaries to Lake Tahoe in a manner which will cause the discharge of solid or liquid waste materials including soil, silt, clay, sand and other organic and earthen materials to Lake Tahoe or any tributary thereto is prohibited.

NAC 445A.1915 Tributaries to Lake Tahoe. (NRS 445A.425, 445A.520)
Standards of Water Quality: Lake Tahoe Tributaries.
The following standards apply to all tributaries to Lake Tahoe located in Nevada.

Table 135. Water quality standards and NNC for Lake Tahoe tributaries, Nevada.

Total Phosphates (as P) - mg/L	
Annual Average	not more than.......0.05
Nitrate (as N) - mg/L	
Single Value	not more than.......10.0
Nitrite (as N) - mg/L	
Single Value	not more than.......0.06
Total Suspended Solids - mg/L	
Single Value	not more than.......25.0
Turbidity - NTU	
Single Value	not more than.......10.0

NAC 445A.1917 Standards to maintain higher quality waters within tributaries to Lake Tahoe. (NRS 445A.425, 445A.520) The water quality of any tributary to Lake Tahoe which is higher than any applicable standard must be maintained at that higher quality. The following requirements to maintain existing higher quality waters apply at the following control points.

Table 136. Water quality standards to maintain higher quality waters within Lake Tahoe tributaries, Nevada.

Control Point	Total Phosphates (as P) - mg/L	Total Nitrogen (as N) - mg/L	Total Suspended Solids, mg/L	Turbidity, NTU
E. Fork Incline Cr. at Ski Incline *a		SV: 1.1 AA: 0.4		
W. Fork Incline C. at State Hwy. 431 *b		SV: 0.9 AA: 0.5	SV: N/A AA: 8.0	SV: 3.0 AA: 20
Incline Creek at Lakeshore Drive *c		SV: 1.8 AA: 1.2		
E. Fork Third Cr. at State Hwy. 431 *d	SV: AA: 0.045	SV: 0.5 AA: 0.3	SV: N/A AA: 20.0	SV: 3.0 AA: 2.0
Third Creek at Lakeshore Drive *e		SV: 1.4 AA: 1.0		
Wood Creek at Lakeshore Drive *f		SV: 0.7 AA: 0.5		
Second Creek at Second Creek Dr. *g		SV: 0.3 AA: 0.2		
Second Creek at Lakeshore Drive *h		SV: 0.6 AA: 0.3		
First Creek at Dale and Knotty Pine Dr. *i	SV: AA: 0.043	SV: 0.3 AA: 0.2		SV: 4.0 AA: 20
First Creek at Lakeshore Drive *j		SV: 0.6 AA: 0.3		SV: 9.0 AA: 8.0
Glenbrook Creek *k	SV: 0.060 AA: N/A	SV: 0.5 AA: 0.5	SV: 22.0 AA: N/A	
Logan House Creek *l	SV: 0.035 AA: 0.035	SV: 0.5 AA: 0.5	SV: 11.0 AA: N/A	
Eagle Rock Creek *m	SV: 0.050	SV: 0.2	SV: 12.0	

Control Point	Total Phosphates (as P) - mg/L	Total Nitrogen (as N) - mg/L	Total Suspended Solids, mg/L	Turbidity, NTU
	AA: 0.045	AA: 0.3	AA: 12.0	
Edgewood Creek at Palisades	SV: 0.100	SV: 0.6	SV: N/A	
Drive *n	AA: N/A	AA: 0.6	AA: N/A	
Edgewood Creek at Stateline	SV: 0.065	SV: 0.4	SV: 17.0	
*o	AA: N/A	AA: N/A	AA: N/A	

FOOTNOTES

a. Control point at the East Fork of Incline Creek at the ski resort. The standards specified in the table apply to the East Fork of Incline Creek from the ski resort to the origin of the East Fork of Incline Creek.
b. Control point at the West Fork of Incline Creek at State Highway 431. The standards specified in the table apply to the West Fork of the Incline Creek from State Highway 431 to the origin of the West Fork of Incline Creek.
c. Control point at Incline Creek at Lakeshore Drive. The standards specified in the table apply to Incline Creek from the confluence with Lake Tahoe to the ski resort in the East Fork of Incline Creek and to State Highway 431 in the West Fork of Incline Creek.
d. Control point at the East Fork of Third Creek at State Highway 431. The standards specified in the table apply from the East Fork of Third Creek at State Highway 431 to the origin of the East Fork of Third Creek.
e. Control point at Third Creek at Lakeshore Drive. The standards specified in the table apply to Third Creek from the confluence with Lake Tahoe to State Highway 431 in the East Fork of Third Creek and to the origin of the West Fork of Third Creek.
f. Control point at Wood Creek at Lakeshore Drive. The standards specified in the table apply to Wood Creek from the confluence with Lake Tahoe to the origin of Wood Creek.
g. Control point at Second Creek at Second Creek Drive. The standards specified in the table apply to Second Creek from Second Creek Drive to the origin of Second Creek.
h. Control point at Second Creek at Lakeshore Drive. The standards specified in the table apply to Second Creek from the confluence with Lake Tahoe to Second Creek Drive.
i. Control point at First Creek at Dale and Knotty Pine Drives. The standards specified in the table apply to First Creek from Dale and Knotty Pine Drives to the origin of First Creek.
j. Control point at First Creek and Lakeshore Drive. The standards specified in the table apply to First Creek from the confluence with Lake Tahoe to Dale and Knotty Pine Drives.
k. Control point on Glenbrook Creek which is located 100 feet from the mouth of Glenbrook Creek at Glenbrook. The standards specified in the table apply to Glenbrook Creek from the confluence with Lake Tahoe to the origin of Glenbrook Creek.
l. Control point on Logan House Creek which is located 0.3 miles upstream from U.S. Highway 50. The standards specified in the table apply to Logan House Creek from the confluence with Lake Tahoe to the origin of Logan House Creek.
m. Control point on Eagle Rock Creek which is located 0.2 miles upstream from the confluence with Edgewood Creek. The standards specified in the table apply to Eagle Rock Creek from the confluence with Edgewood Creek to the origin of Eagle Rock Creek.
n. Control point on Edgewood Creek at Palisades Drive which is located 50 feet downstream from the culvert at Palisades Drive. The standards specified in the table apply to Edgewood Creek from the control point upstream to the origins of Edgewood Creek.
o. Control point on Edgewood Creek at Stateline which is located on the upstream side of the culvert on U.S. Highway 50. The standards specified in the table apply to Edgewood Creek from the confluence with Lake Tahoe upstream to the control point on Edgewood Creek at Palisades Drive.

NAC 445A.192 Colorado River below Davis Dam. (NRS 445A.425, 445A.520)
Standards of Water Quality

Colorado River: Control Point below Davis Dam. The limits of this table apply from the state line below Davis Dam to Lake Mohave Inlet.

Table 137. Water quality standards and NNC for the Colorado River below Davis Dam, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .02 S.V. : ≤ .03	A-Avg. : ≤ 0.05 --	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Nitrate A-Avg. : ≤ 1.1 S.V. : ≤ 1.6	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Municipal or domestic supply,[b] aquatic life,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	--	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.193 Colorado River below Hoover Dam. (NRS 445A.425, 445A.520)
Standards of Water Quality
Colorado River: Control Point below Hoover Dam. The limits of this table apply from Lake Mohave Inlet to Hoover Dam.

Table 138. Water quality standards and NNC for the Colorado River below Hoover Dam, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	A-Avg. : ≤ .02 S.V. : ≤ .033	A-Avg. : ≤ 0.05 --	Aquatic life,[b] recreation involving contact with the water,[b] municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.0 S.V. : ≤ 1.5	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ .06	Municipal or domestic supply,[b] aquatic life,[b] recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Suspended Solids - mg/L	--	S.V. : ≤ 25	Aquatic life.[b]
Turbidity - NTU	-- --	S.V. : ≤ 10	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.195 Lake Mead excluding area covered by NAC 445A.197. (NRS 445A.425, 445A.520)
Lake Mead

Table 139. Water quality standards and NNC for Lake Mead, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses as Designated in NAC 445A.194 (most stringent use listed first)
Chlorophyll *a* – μg/L	b		Recreation involving contact with water, propagation of aquatic life, including, without limitation, a warm-water fishery, recreation not involving contact with water and municipal or domestic supply, or both.
Nitrogen Species as N Single Value	Total Inorganic Nitrogen: 95% of Samples ≤ 4.5 mg/L	Nitrate: ≤ 10 mg/L Nitrite: ≤ 1 mg/L	Municipal or domestic supply, or both, watering of livestock, propagation of aquatic life, including, without limitation, a warm-water fishery, and propagation of wildlife.
Suspended Solids Single Value	--	≤ 25 mg/L	Propagation of aquatic life, including, without limitation, a warm-water fishery, and recreation not involving contact with water.
Turbidity Single Value	f	≤ 25 NTU	Propagation of aquatic life, including, without limitation, a warm-water fishery, municipal or domestic supply, or both, recreation involving contact with water and recreation not involving contact with water.

b. The requirements for chlorophyll a are:
(1) Not more than one monthly mean in a calendar year at Station LWLVB 1.85 may exceed 45 μg/L. "Station LWLVB 1.85" is located at the center of the channel at a distance of 1.85 miles into Las Vegas Bay from the confluence of the Las Vegas Wash with Lake Mead.
(2) The mean for chlorophyll a in summer (July 1-September 30) must not exceed 40 μg/L at Station LWLVB 1.85, and the mean for 4 consecutive summer years must not exceed 30 μg/L. The sample must be collected from the center of the channel and must be representative of the top 5 meters of the channel. "Station LWLVB 1.85" is located at the center of the channel at a distance of 1.85 miles into Las Vegas Bay from the confluence of the Las Vegas Wash with Lake Mead.
(3) The mean for chlorophyll a in the growing season (April 1-September 30) must not exceed 16 μg/L at Station LWLVB 2.7 and 9 μg/L at Station LWLVB 3.5. "Station LWLVB 2.7" is located at a distance of 2.7 miles into Las Vegas Bay from the confluence of the Las Vegas Wash with Lake Mead. "Station LWLVB 3.5" is located at a distance of 3.5 miles into Las Vegas Bay from the confluence of the Las Vegas Wash with Lake Mead.
(4) The mean for chlorophyll a in the growing season (April 1-September 30) must not exceed 5 μg/L in the open water of Boulder Basin, Virgin Basin, Gregg Basin and Pierce Basin. The single value must not exceed 10 μg/L for more than 5 percent of the samples.
(5) Not less than two samples per month must be collected between the months of March and October. During the months when only one sample is available, that value must be used in place of the monthly mean.
f. Turbidity must not exceed that characteristic of natural conditions by more than 10 Nephelometric Units.
⇒The Commission recognizes that, the at the inlets to Lake Mead localized violations of standards may occur.

NAC 445A.197 Lake Mead from 1.2 miles into Las Vegas Bay from confluence of Las Vegas Wash with Lake Mead. (NRS 445A.425, 445A.520) Control point at 1.2 miles into Las Vegas Bay from the confluence of the Las Vegas Wash with Lake Mead. Inner Las Vegas Bay.

Table 140. Water quality standards and NNC for Lake Mead 1.2 miles into Las Vegas Bay, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses as Designated in NAC 445A.196 (most stringent use listed first)
Nitrogen Species as Single Value	Total Inorganic Nitrogen: 95% of Samples ≤ 5.3 mg/L	Nitrate: ≤ 90 mg/L Nitrite: ≤ 5 mg/L	Propagation of aquatic life, including, without limitation, a warm-water fishery, watering of livestock and propagation of wildlife.
Suspended Solids Single Value	--	≤ 25 mg/L	Propagation of aquatic life, including, without limitation, a warm-water fishery, and recreation not involving contact with water.
Turbidity Single Value	d	≤ 25 NTU	Propagation of aquatic life, including, without limitation, a warm-water fishery, and recreation not involving contact with water.

d. Turbidity must not exceed that characteristic of natural conditions by more than 10 Nephelometric Units.
⇒The Commission recognizes that, because of discharges of tributaries, localized violations of standards may occur in the inner Las Vegas Bay.

NAC 445A.199 Las Vegas Wash from Telephone Line Road to confluence of discharges from City of Las Vegas and Clark County wastewater treatment plants. (NRS 445A.425, 445A.520) Control point at Telephone Line Road. The limits in this table apply from Telephone Line Road to the confluence of the discharges from the City of Las Vegas and Clark County wastewater treatment plants, which encompasses the City of Henderson wastewater treatment plant discharge.

Table 141. Water quality standards and NNC for Upper Las Vegas Wash, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Use as Designated in NAC 445A.195 (most stringent use listed first)
Nitrogen Species as N Single Value	Total Inorganic Nitrogen: 95% of Samples ≤ 20 mg/L	Nitrate: ≤ 100 mg/L Nitrite: ≤ 10 mg/L	Watering of livestock and propagation of wildlife.
Suspended Solids Single Value		≤ 135 mg/L[c]	Propagation of aquatic life, excluding fish.

c. Total suspended solids standard does not apply when flows are greater than 110 percent of average flow as measured at the nearest gage. “Average flow” is defined as the 12-month rolling average of the average monthly flow.

NAC 445A.201 Confluence of Las Vegas Wash with Lake Mead to Telephone Line Road. (NRS 445A.425, 445A.520) The limits in this table apply from the confluence of the Las Vegas Wash with Lake Mead to Telephone Line Road.

Table 142. Water quality standards and NNC for the Lower Las Vegas Wash, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses as Designated in NAC 445A.195 (most stringent use listed first)
Nitrogen Species as N Single Value	Total Inorganic Nitrogen: 95% of Samples ≤ 17 mg/L	Nitrate: ≤ 100 mg/L Nitrite: ≤ 10 mg/L	Watering of livestock and propagation of wildlife.
Suspended Solids Single Value		≤ 135 mg/L[c]	Propagation of aquatic life, excluding fish.

c. Total suspended solids standard does not apply when flows are greater than 110 percent of average flow as measured at the nearest gage. "Average flow" is defined as the 12-month rolling average of the average monthly flow.

NAC 445A.203 Humboldt River near Osino. (NRS 445A.425, 445A.520)
Standards of Water Quality
Humboldt River: Control Point near Osino. The limits in this table apply from the control point near Osino to the upstream source of the main stem.

Table 143. Water quality standards and NNC for the Humboldt River near Osino, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	Apr. – Nov. Seasonal Avg. : ≤ 0.1	Aquatic life (warm-water fishery),[b] bathing and recreation involving contact with the water, municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.5 Apr. – Nov. S.V. : ≤ 2.4	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Municipal or domestic supply,[b] propagation of wildlife, irrigation, watering of livestock and aquatic life (warmwater fishery).
Suspended Solids - mg/L	--	Annual Median : ≤ 80[e]	Aquatic life (warm-water fishery).[b]
Turbidity - NTU	--	S.V. : ≤ 50	Aquatic life (warm-water fishery),[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
e. The maximum allowable point source discharge is S.V. ≤ 80 mg/L of suspended solids.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.204 Humboldt River at Palisade Gage. (NRS 445A.425, 445A.520)
Standards of Water Quality
Humboldt River: Control Point at the Palisade Gage. The limits of this table apply from the control point at Palisade Gage upstream to the Osino control point.

Table 144. Water quality standards and NNC for the Humboldt River at Palisade Gage, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	Apr. – Nov. Seasonal Avg. : ≤ 0.1	Aquatic life (warm-water fishery),[b] bathing and recreation involving contact with the water, municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.4 Apr. – Nov. S.V. : ≤ 2.4	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Municipal or domestic supply,[b] propagation of wildlife, irrigation, watering of livestock and aquatic life (warmwater fishery).
Suspended Solids - mg/L	--	Annual Median : ≤ 80[e]	Aquatic life (warm-water fishery).[b]
Turbidity - NTU	--	S.V. : ≤ 50	Aquatic life (warm-water fishery),[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
e. The maximum allowable point source discharge is S.V. ≤ 80 mg/L of suspended solids.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.205 Humboldt River at Battle Mountain Gage. (NRS 445A.425, 445A.520). **Standards of Water Quality,** Humboldt River: Control Point at the Battle Mountain Gage. The limits of this table apply from the control point at Battle Mountain Gage upstream to the Palisade Gage control point.

Table 145. Water quality standards and NNC for the Humboldt River at Battle Moutain Gage, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	Apr. – Nov. Seasonal Avg. : ≤ 0.1	Aquatic life (warm-water fishery),[b] bathing and recreation involving contact with the water, municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.9 Apr. – Nov. S.V. : ≤ 4.0	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Municipal or domestic supply,[b] propagation of wildlife, irrigation, watering of livestock and aquatic life (warmwater fishery).
Suspended Solids - mg/L	--	Annual Median : ≤ 80[e]	Aquatic life (warm-water fishery).[b]
Turbidity - NTU	--	S.V. : ≤ 50	Aquatic life (warm-water fishery),[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
e. The maximum allowable point source discharge is S.V. ≤ 80 mg/L of suspended solids.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.206 Humboldt River at crossing of State Highway 789. (NRS 445A.425, 445A.520)

Standards of Water Quality

Humboldt River: Control Point where State Highway 789 crosses the Humboldt River. The limits of this table apply from the control point where State Highway 789 crosses the Humboldt River upstream to the Battle Mountain Gage control point.

Table 146. Water quality standards and NNC for the Humboldt River at SH 789, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	Apr. – Nov. Seasonal Avg. : ≤ 0.1	Aquatic life (warm-water fishery),[b] bathing and recreation involving contact with the water, municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 2.9 Apr. – Nov. S.V. : ≤ 3.7	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Municipal or domestic supply,[b] propagation of wildlife, irrigation, watering of livestock and aquatic life (warmwater fishery).
Suspended Solids - mg/L	--	Annual Median : ≤ 80[e]	Aquatic life (warm-water fishery).[b]
Turbidity - NTU	--	S.V. : ≤ 50	Aquatic life (warm-water fishery),[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
e. The maximum allowable point source discharge is S.V. ≤ 80 mg/L of suspended solids.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.207 Humboldt River at Imlay. (NRS 445A.425, 445A.520)

Standards of Water Quality

Humboldt River: Control Point at Imlay. The limits of this table apply from the control point at Imlay upstream to the Comus Gage control point.

Table 147. Water quality standards and NNC for the Humboldt River at Imlay, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	Apr. – Nov. Seasonal Avg. : ≤ 0.1	Aquatic life (warm-water fishery),[b] bathing and recreation involving contact with the water, municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 2.4 Apr. – Nov. S.V. : ≤ 2.9	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Municipal or domestic supply,[b] propagation of wildlife, irrigation, watering of livestock and aquatic life (warmwater fishery).
Suspended Solids - mg/L	--	Annual Median : ≤ 80[e]	Aquatic life (warm-water fishery).[b]
Turbidity - NTU	--	S.V. : ≤ 50	Aquatic life (warm-water fishery),[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
e. The maximum allowable point source discharge is S.V. ≤ 80 mg/L of suspended solids.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.208 Humboldt River at Woolsey. (NRS 445A.425, 445A.520) Standards of Water Quality

Humboldt River: Control Point at Woolsey. The limits of this table apply from the control point at Woolsey upstream to the Imlay control point.

Table 148. Water quality standards and NNC for the Humboldt River at Woolsey, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	Apr. – Nov. Seasonal Avg. : ≤ 0.1	Aquatic life (warm-water fishery),[b] bathing and recreation involving contact with the water, municipal or domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	--	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Municipal or domestic supply,[b] propagation of wildlife, irrigation, watering of livestock and aquatic life (warmwater fishery).
Suspended Solids - mg/L	--	Annual Median : ≤ 80[e]	Aquatic life (warm-water fishery).[b]
Turbidity - NTU	--	S.V. : ≤ 50	Aquatic life (warm-water fishery),[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
e. The maximum allowable point source discharge is S.V. ≤ 80 mg/L of suspended solids.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.210 Muddy River at Glendale Bridge. (NRS 445A.425, 445A.520)
Standards of Water Quality
Muddy River: Control Point at Glendale Bridge. The limits of this table apply from the Glendale Bridge upstream to the river source.

Table 149. Water quality standards and NNC for the Muddy River at Glendale Bridge, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.1	Aquatic life,[b] recreation not involving contact with the water, and municipal or domestic supply.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.3 S.V. : ≤ 1.4	Nitrate S.V. : ≤ 10 Nitrite S.V. : ≤ 1.0	Municipal or domestic supply,[b] aquatic life, recreation involving contact with the water, watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Turbidity - NTU	-- --	e	Aquatic life[b] and municipal or domestic supply.

b. The most restrictive beneficial use.
e. Increase in turbidity must not be more than 10 NTU above natural conditions.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.211 Muddy River at Overton. (NRS 445A.425, 445A.520)
Standards of Water Quality
Muddy River: Control Point at Overton. The limits of this table apply from the mouth of the river at Lake Mead to the Glendale Bridge.

Table 150. Water quality standards and NNC for the Muddy River at Overton, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.3	Aquatic life,[b] recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 1.3 S.V. : ≤ 1.8	Nitrate S.V. : ≤ 90 Nitrite S.V. : ≤ 5.0	Aquatic life,[b] watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Turbidity - NTU	--	e	Aquatic life[b].

b. The most restrictive beneficial use.
e. Increase in turbidity must not be more than 10 NTU above natural conditions.
From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.212 Meadow Valley Wash. (NRS 445A.425, 445A.520)
Standards of Water Quality
Meadow Valley Wash
Control Point at confluence with Muddy River. The limits of this table apply from the confluence of the Meadow Valley Wash with the Muddy River to the bridge above Rox.

Table 151. Water quality standards and NNC for the Muddy River at Meadow Valley Wash, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphates (as P) - mg/L	--	A-Avg. : ≤ 0.1	Aquatic life,[b] recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Total Nitrogen A-Avg. : ≤ 2.0 S.V. : ≤ 3.3	Nitrate S.V. : ≤ 90 Nitrite S.V. : ≤ 5.0	Aquatic life,[b] watering of livestock, propagation of wildlife and recreation not involving contact with the water.
Turbidity - NTU	--	e	Aquatic life[b].

b. The most restrictive beneficial use.
e. Increase in turbidity must not be more than 10 NTU above natural conditions.
From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.215 Big Goose Creek. (NRS 445A.425, 445A.520)
Standards of Water Quality
Big Goose Creek: Control Point at Ranch.

Table 152. Water quality standards and NNC for the Big Goose Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.216 Salmon Falls Creek. (NRS 445A.425, 445A.520)
Standards of Water Quality
Salmon Falls Creek: Control Point at Highway 93 south of Jackpot.

Table 153. Water quality standards and NNC for the Salmon Falls Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.217 Shoshone Creek. (NRS 445A.425, 445A.520)
Standards of Water Quality
Shoshone Creek: Control Point: Jackpot to Delaplain Road.

Table 154. Water quality standards and NNC for Shoshone Creek, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.218 Jarbidge River: East Fork. (NRS 445A.425, 445A.520)
Standards of Water Quality
East Fork Jarbidge River: Control Point at the Nevada-Idaho state line.

Table 155. Water quality standards and NNC for the East Fork Jarbidge River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.219 Jarbidge River upstream from Jarbidge. (NRS 445A.425, 445A.520)
Standards of Water Quality
Jarbidge River: Control Point upstream from Jarbidge at bridge.

Table 156. Water quality standards and NNC for the Jarbidge River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	S.V. < 0.05	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.220 Jarbidge River downstream from Jarbidge. (NRS 445A.425, 445A.520)

Standards of Water Quality

Jarbidge River: Control Point downstream from Jarbidge at bridge.

Table 157. Water quality standards and NNC for the Jarbidge River at bridge, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	S.V. < 0.05	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.221 Bruneau River: West Fork. (NRS 445A.425, 445A.520)

Standards of Water Quality

Bruneau River: Control Point at Diamond "A" Road.

Table 158. Water quality standards and NNC for the Bruneau River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 "A-Avg." or "A.A." defined. (NRS 445A.425, 445A.520) "A-Avg." or "A.A." means annual average.
NAC 445A.11768 "S.V." defined. (NRS 445A.425, 445A.520) "S.V." means single value.

NAC 445A.222 Owyhee River: East Fork above Mill Creek. (NRS 445A.425, 445A.520)

Standards of Water Quality

Owyhee River: Control Point above Mill Creek.

Table 159. Water quality standards and NNC for the Owyhee River, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.223 Owyhee River: East Fork south of Owyhee. (NRS 445A.425, 445A.520)

Standards of Water Quality

Owyhee River: Control Point at New China Dam.

Table 160. Water quality standards and NNC for Owyhee River at New China Dam, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.224 Owyhee River: East Fork, Nevada-Idaho state line. (NRS 445A.425, 445A.520)

Standards of Water Quality

Owyhee River: Control Point at the Nevada-Idaho state line.

Table 161. Water quality standards and NNC for the Owyhee river at the Nevada-Idaho state line, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, water contact recreation, municipal and domestic supply, noncontact recreation.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, water contact recreation, noncontact recreation.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

NAC 445A.225 Owyhee River: South Fork. (NRS 445A.425, 445A.520)

Standards of Water Quality

South Fork Owyhee River: Control Point at Petan Access Road.

Table 162. Water quality standards and NNC for the Owyhee River at Petan Access Road, Nevada.

Parameter	Requirements to Maintain Existing Higher Quality	Water Quality Standards for Beneficial Uses	Beneficial Uses
Total Phosphorus (as P) - mg/L	--	< 0.1	Aquatic life, recreation involving contact with the water, municipal and domestic supply and recreation not involving contact with the water.
Nitrogen Species (as N) - mg/L	Nitrate S.V. < 1.0	Nitrate S.V. : < 10 Nitrite S.V. : < 0.06	Municipal and domestic supply, aquatic life, recreation involving contact with the water and recreation not involving contact with the water.
Suspended Solids - mg/L	-- --	S.V. : < 25	Aquatic life, and municipal and domestic supply.
Turbidity - NTU	--	S.V. : < 10	Aquatic life, and municipal and domestic supply.

From NAC 445A.11704 Definitions.
NAC 445A.11708 “A-Avg.” or “A.A.” defined. (NRS 445A.425, 445A.520) “A-Avg.” or “A.A.” means annual average.
NAC 445A.11768 “S.V.” defined. (NRS 445A.425, 445A.520) “S.V.” means single value.

New Hampshire

New Hampshire does not have any current NNC (Comstock et al. 2008; Edwarson 2010; New Hampshire Department of Environmental Services 1999; Trowbridge 2009; United States Environmental Protection Agency 1988b; Unknown 2010). However, it does have a Nutrient Criteria Development Plan (New Hampshire Department of Environmental Services 2002; Unknown 2010). This planning document has not been revised since 2002, however recently in 2010 the New Hampshire Department of Environmental Services (NHDES) presented their most current modified strategy for development of NNC (Unknown 2010). A summary of their findings are presented below.

NHDES using the reference waterbody/ecoregion approach found that **r**egionally derived numeric nutrient thresholds based on EPA recommended frequency distribution approach lower than those derived by individual states; NH - 0.009 – 0.015 mg/L; and often too low to be enforceable. They examined reference stream data from Vermont, Maine and New York along with potential indicators used by those states. That is the values would implicate that most waterbodies were not meeting designated uses. Their best initial best estimate of low end of range of numeric TP is 0.020 – 0.035 mg/L and based on 75th – 90th percentile of assessment waterbody units (Aus) without known dissolved oxygen impairment. The NHDES assumed that the upper end of TP numeric threshold is equal to the New York State derived biological response estimate (0.065 mg/L) until additional data becomes available. Therefore NHDES is currently assuming the best estimate of interim criterion = 0.030 mg/L TP.

NHDES was currently conducting stress-response studies to develop relationships between nutrients and stream/river macroinvertebrates and algae. Ultimately, NHDES felt that proposed numeric nutrient criteria will likely be based on multiple lines of evidence that include 1) distribution of nutrient data and stress/response relationships. At the time of the 2010 presentation the NHDES felt that a reasonable target for establishment of interim numeric nutrient criteria would likely be the end of 2010. As of this time there does not appear to be any draft NNC or proposed NNC for this state. The NHDES also estimated that final proposed numeric nutrient criteria would likely be released by the end of 2013.

New Jersey

New Jersey does have site specific NNC for nitrogen and chlorophyll-a and clarity for lakes/reservoirs and rivers and streams. In addition, statewide NNC exist for phosphorus for both lakes/reservoirs and rivers and streams (Table 163).

Table 163. Existing Numeric Criteria for New Jersey.[1]

Waterbody Type	N	P	Chl-A	Clarity[2]
Lakes & Reservoirs	W[3]	S	W[4]	W[5]
Rivers & Streams	W[3]	S		W[5]
Estuaries				W[5]
Wetlands				

S = Statewide   W = For selected waterbody   N / A=Not Applicable
[1] From New Jersey's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved May 2010). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes. If a state/territory has criteria for the protection of drinking water or human health, those criteria may be found on the tabs for either statewide or site-specific criteria.
[2] Source: EPA's (New Jersey Department of Environmental Protection 2010; United States Environmental Protection Agency 2008b)
[3] Criteria for Nitrate-N for Pinelands (PL) waters and their designated uses.
[4] Established pursuant to the TMDL Report for the non-tidal Passaic River basin addressing phosphorus impairments dated April 28, 2008.
[5] Turbidity.

The following information reflects New Jersey's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved May 2010) and found in their state water quality standards (New Jersey Department of Environmental Protection 2010). The regulations are presented below. After examining the New Jersey web page these NNC appear to be current ((New Jersey Department of Environmental Protection 2010). In general, for lakes *phosphorus as total P shall not exceed 0.05 mg/l, at any lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water, except where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3,* (Approved in 1974). For streams *phosphorus as total P shall not exceed 0.1 mg/l in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses* (Approved in 1981). The specific language is presented verbatim below.

7:9B-1.14 Surface water quality criteria

(b) Surface water quality criteria for PL* waters are as follows:

1. These waters shall be maintained as to quality in their existing state or that quality necessary to attain or protect the designated uses, whichever is more stringent.

i. For Nitrate-Nitrogen a level of 2 mg/L shall be maintained in the surface waters unless it is shown that a lower level must be maintained to protect the existing surface water quality.

2. The water quality criteria for existing discharges are the water quality criteria contained in "Surface Water Quality Standards" as adopted in March 1981, except that:

i. The criteria for Nitrate-Nitrogen and pH promulgated in N.J.A.C. 7:9B- 1.14(b)1 for PL waters apply instead of the 1981 criteria, and;

ii. The criteria for phosphorus, bacterial quality, and toxic substances promulgated in N.J.A.C. 7:9B-1.14(c) through (g) apply instead of the 1981 criteria, as though the freshwater portions of the PL waters were classified as FW2* and the saline portions were classified as SE1*.

7:9B-1.14(d) General Surface Water Quality Criteria for FW2, SE and SC Waters: (Expressed as Maximum concentrations unless otherwise noted)

Turbidity (Nephelometric Turbidity Unit-NTU)
Maximum 30-day average of 15 NTU, a maximum of 50 NTU at any time. FW2, SE3
Maximum 30-day average of 10 NTU, a maximum of 30 NTU at any time. SE1, SE2
Levels shall not exceed 10.0 NTU. SC

*Surface water classifications explained: *From 7:9B-1.4 Definitions*

"PL" means the general surface water classification applied to Pinelands Waters. "Pinelands waters" means all waters within the boundaries of the Pinelands Area, except those waters designated as FW1 in N.J.A.C. 7:9B-1.15(j), as established in the Pinelands Protection Act (N.J.S.A. 13:18A-1 et seq.) and shown on Plate 1 of the "Comprehensive Management Plan" adopted by the New Jersey Pinelands Commission in November 1980.

"FW2" means the general surface water classification applied to those fresh waters that are not designated as FW1 or Pinelands Waters.
From 7:9B-1.12 Designated uses of FW1, PL, FW2, SE1, SE2, SE3, and SC waters

In all "SE1" waters the designated uses are: (1) Shellfish harvesting in accordance with N.J.A.C. 7:12; (2) Maintenance, migration and propagation of the natural and established biota; (3) Primary contact recreation; and (4) Any other reasonable uses.

Site-Specific Criteria Derived from TMDL Studies

Through its TMDL study, the New Jersey Department of Environmental Protection (NJDEP) determined that the in-stream numeric criterion (0.1 mg/L) does not apply to streams because monitoring and simulation demonstrated that phosphorus is not rendering the waters unsuitable for the designated uses. Absent watershed or site specific criteria, the applicable phosphorus criteria at the critical locations of the Wanaque Reservoir and the Dundee Lake are a numeric criterion of 0.05 mg/L of total phosphorus. As a result, NJDEP established watershed criteria for chlorophyll- *a*, which are expressed as seasonal averages (June 15 – September 1), of 20 µg/L and 10 µg/L of chlorophyll-*a* for Dundee Lake and the Wanaque Reservoir, respectively. The TMDL document provides appropriate analysis to demonstrate that these site-specific criteria, once met, are sufficient to protect the applicable designated uses in these waters (*Source: July 2008 EPA Approval Letter for New Jersey Water Quality Standards).* New Jersey is beginning to consider updating its NNC based on more modern methodology (Laidlaw 2010a).

New Jersey Nutrient Criteria Enhancement Plan states that "significant data and research developments have recently expanded the knowledge base about the general and site specific factors that cause or contribute to nutrient impairment in New Jersey's waters since these criteria were promulgated" (Cohen et al. 2009).

New Mexico

New Mexico currently only has limited site specific NNC for TP in selected rivers, focused on protection of aquatic life uses (Lemon 2011; New Mexico Environment Department 2006; New Mexico Environment Department 2009; New Mexico Water Quality Control Commission 2005; United States Environmental Protection Agency 1988c). The information below shows EPA-approved site-specific nutrient criteria for New Mexico's waterbodies. This information reflects New Mexico's water quality standards posted to the Water Quality Standards Repository as of November 2010 (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_nm.cfm) (EPA-approved December 2006)(New Mexico Water Quality Control Commission 2005). A review of the most current water quality standards adopted by New Mexico in 2011 and approved by EPA later on indicates that there has not been any new NNC proposed and/or adopted by the State and/or approved by EPA (ftp://ftp.nmenv.state.nm.us/www/swqb/Standards/2011/20.6.4NMAC-IntegratedStandards-CWAStatus2011-04-18.pdf)((New Mexico Environment Department 2011).

Excerpt for current New Mexico water quality standards pertaining to site specific NNC (New Mexico Environment Department 2011).

20.6.4.109 Rio Grande Basin - Perennial reaches of Bluewater creek, Rio Moquino, Seboyeta creek, Rio Paguate, the Rio Puerco above the village of Cuba and all other perennial reaches of tributaries to the Rio Puerco including the Rio San Jose in Cibola county from the USGS gaging station at Correo upstream to Horace springs.

A. Designated Uses: coldwater aquatic life, domestic water supply, fish culture, irrigation, livestock watering, wildlife habitat and primary contact.

B. Criteria:

(1) In any single sample: pH shall be within the range of 6.6 to 8.8, temperature 20°C (68°F) or less and *total phosphorus (as P) 0.1 mg/L*. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

20.6.4.123 Rio Grande Basin - Perennial reaches of the Red river upstream of the mouth of Placer creek, all perennial reaches of tributaries to the Red river, and all other perennial reaches of tributaries to the Rio Grande in Taos and Rio Arriba counties unless included in other segments.

A. Designated Uses: domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and secondary contact.

B. Criteria:

(1) In any single sample: specific conductance 400 umhos/cm or less (500 umhos or less for the Rio Fernando de Taos) and pH within the range of 6.6 to 8.8, temperature 20°C (68°F) or less. For the Red river in this segment, *total phosphorus (as P) less than 0.1 mg/L*. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

20.6.4.129 Rio Grande Basin - Perennial reaches of the Rio Hondo.

A. Designated Uses: domestic water supply, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and secondary contact.

B. Criteria:
(1) In any single sample: specific conductance 400 umhos/cm or less, pH within the range of 6.6 to 8.8, *total phosphorus (as P) less than 0.1 mg/L* and temperature 20°C (68°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

20.6.4.208 Pecos River Basin - Perennial reaches of the Rio Peñasco and its tributaries above state highway 24 near Dunken, perennial reaches of the Rio Bonito downstream from state highway 48 (near Angus), the Rio Ruidoso downstream of the U.S. highway 70 bridge near Seeping Springs lakes, perennial reaches of the Rio Hondo upstream from Bonney canyon and perennial reaches of Agua Chiquita.

A. Designated Uses: fish culture, irrigation, livestock watering, wildlife habitat, coldwater aquatic life and secondary contact.

B. Criteria:
(1) In any single sample: pH within the range of 6.6 to 8.8, temperature 30°C (86°F) or less and *total phosphorus (as P) less than 0.1 mg/L*. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

20.6.4.209 Pecos River Basin - Perennial reaches of Eagle creek above Alto reservoir, perennial reaches of the Rio Bonito and its tributaries upstream of state highway 48 (near Angus) and perennial reaches of the Rio Ruidoso and its tributaries upstream of the U.S. highway 70 bridge near Seeping Springs lakes.

A. Designated Uses: domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, municipal and industrial water supply and secondary contact.

B. Criteria:
(1) In any single sample: specific conductance 600 umhos/cm or less in Eagle creek, 1,100 umhos or less in Bonito creek, and 1,500 umhos or less in the Rio Ruidoso, pH within the range of 6.6 to 8.8, *total phosphorus (as P) less than 0.1 mg/L* and temperature 20°C (68°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

20.6.4.404 San Juan River Basin - The Animas river from Estes Arroyo upstream to the New Mexico-Colorado line.

A. Designated Uses: coldwater aquatic life, irrigation, livestock watering, wildlife habitat, municipal and industrial water supply and secondary contact.

B. Criteria:
(1) In any single sample: pH within the range of 6.6 to 8.8, temperature 20°C (68°F) or less and *total phosphorus (as P) 0.l mg/L or less*. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

20.6.4.406 San Juan River Basin - Navajo reservoir in New Mexico.

A. Designated Uses: coldwater aquatic life, warmwater aquatic life, irrigation storage, livestock watering, wildlife habitat, municipal and industrial water storage and primary contact.

B. Criteria:
(1) At any sampling site: pH within the range of 6.6 to 8.8, temperature 20°C (68°F) or less and *total phosphorus (as P) 0.1 mg/L or less*. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

20.6.4.407 San Juan River Basin - Perennial reaches of the Navajo and Los Pinos rivers in New Mexico.

A. Designated Uses: coldwater aquatic life, irrigation, livestock watering, wildlife habitat and secondary contact.

B. Criteria:
(1) In any single sample: pH within the range of 6.6 to 8.8, temperature 20°C (68°F) or less and *total phosphorus (as P) 0.1 mg/L or less*. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

The State of New Mexico has a Nutrient Criteria Development Plan which was adopted in 2005 (New Mexico Environment Department 2006). The Nutrient Criteria

Development Plan for the New Mexico Environment Department Surface Water Quality Bureau (NMSWQB) is summarized below. NMSWQB will develop nutrient threshold values for different waterbody types and different classes within each type. Waterbodies were prioritized as follows: 1) streams, 2) rivers, 3) lakes and reservoirs, and 4) wetlands. The initial step proposed in the Plan was to compiled nutrient data for New Mexico from EPA's Storage and Retrieval System (STORET), USGS, and NMSWQB. In addition, the agency planned to collect additional data from Federal, State, Tribal, and local water quality agencies and universities. The next step was to identify data gaps, and additional required data that can be collected through additional nutrient criteria development projects as well as regular water quality surveys. In addition to data on primary (TN, TP, chlorophyll-*a*, total suspended solids (TSS), and turbidity) and secondary (Dissolved Oxygen (DO), pH, benthic macroinvertebrates, periphyton, and Ash Free Dry Mass (AFDM)) nutrient variables, NMSWQB planned to gather data on classification parameters such as geology, elevation, watershed size, and stream order.

The NMSWQB planned to conduct statistical analyses to classify waterbodies and determine threshold values for select variables. Once threshold values are established, they will be tested and refined before proposing for adoption into the water quality standards (WQS) or inclusion in assessment protocols. Numeric TN and TP criteria will be adopted into the state water quality standards while threshold values for the other variables (DO, pH, and chlorophyll-*a*) will incorporated into the *weight-of-evidence approach* used in the assessment protocol. NMSWQB envisioned using different variables depending on waterbody type and this suite of variables would be used to determine impairment. For example, periphyton chlorophyll-*a* and TP would likely be used in streams while plankton chlorophyll a and Soluble Reactive Phosphate (SRP) may be used in reservoirs, a *trophic index* may be used for lakes that includes a number of variables, and a *weight-of-evidence approach* will be used to determine impairment for streams and rivers. The variables selected will be those that show the best relationship with indicators of impairment and will include at a minimum TN, TP, and chlorophyll-*a*. At the time of the publication of the Nutrient Criteria Development Plan, three general approaches for criteria development had been developed and discussed in the various EPA Guidance manuals. These included (1) identification of reference sites for each waterbody class based on best professional judgment or percentile selections of data plotted as frequency distributions, (2) use of predictive relationships, and (3) application and/or modification of established nutrient/algal thresholds. NMSWQB indicated that they would explore the use of the different approaches as needed for different waterbody types. This would hopefully produce criteria and translator values of greater scientific validity and account for waterbody classes with no available reference conditions or insufficient data to conduct robust statistical analysis. NMSWQ intended to work with the EPA Regional Technical Advisory Group (RTAG), which would serve to review the criteria, threshold values, and data analysis used in their development. Final draft NNC would be subjected ultimately to public review and comment.

The New Mexico Environment Department (NMED) has developed protocol for assessing nutrient levels and impairment in wadeable perennial streams (New Mexico Environment Department 2009). This document establishes an assessment protocol for determining nutrient impairment status of wadeable perennial streams. This methods uses multiple approaches and lines of evidence to evaluate whether aquatic life uses are being impaired by excess nutrients. This includes previously published EPA nutrient ecoregion values, bioassays, and symptoms of nutrient overenrichment including large diurnal fluctuations in dissolved oxygen and pH. An example of the data types collected is listed below (New Mexico Environment Department 2009).

An Assessment Unit will be determined to be not supporting if **three or more** of the following indicators are present.

(if not all of the indicators have been measured, the presence of two of the following indicators will be assessed as not supporting). Check all indicators that exceed the threshold values below.

1. Total nitrogen is above the ecoregion/ALU threshold in >15% of samples

2. Total phosphorus is above the ecoregion/ALU threshold in >15% of samples

3. Dissolved Oxygen threshold is exceeded
o ( ) determined to be **not supporting** using the assessment protocol for Data Collected with Continuous Recording Devices
o ( ) >15% of grab samples exceeded 120%
o ( ) >15% of grab samples are below the applicable standard

4. pH threshold is exceeded
o ( ) determined to be **not supporting** using the assessment protocol for large pH data sets
o ( ) >15% of grab samples exceeds appropriate criterion

5. The Algal Bioassay indicates moderately high or high algal production

6. Chlorophyll *a* ecoregion threshold is exceeded

New York

New York has an existing ambient water quality guidance value of 20 μg/L for phosphorus, established for classes A, AA, A-S, and B waters for which the letter “P” (ponds, lakes, and reservoirs) appears in the Water Index Number, excluding Lake Champlain (Izabela Wojtenko EPA Region 2, and Scott Stoner New York State Department of Environmental Conservation pers.com.)(New York Department of Environmental Conservation 1998; New York Department of Environmental Conservation 2008b). New York’s guidance values are based on a long-established practice of translation of its narrative standards, and are authorized in their state regulations at 6 NYCRR 702.15. Guidance values including this one for phosphorus are compiled in Division of Water Technical and Operational Guidance Series (TOGS) No. 1.1.1. Therefore New York’s current nutrient standards for protection of aquatic life, involves a combination of numerical criteria for nitrites and the use of narrative nutrient criteria and numerical “guidance” values of phosphorus for specific waterbodies.

The New York Department of Environmental Conservation (NYSDEC) standards are both narrative (e.g., "none in amounts that will impair ...") and numeric (e.g., "0.001 µg/L") and are promulgated in their water quality standards regulation 6 NYCRR Part 703(New York Department of Environmental Conservation 1998; New York Department of Environmental Conservation 2008b). Numeric guidance values are derived in the absence of a standard and compiled in the Division of Water technical and operational guidance series (TOGSS) 1.1.1 and its addenda. Ambient standards and guidance values apply to the waterbodies and are supported by technical documents, called "Fact Sheets" that are available from their program. The NYSDEC defines various waterbodies in which these narrative criteria and guidance values apply. One of these is the special class freshwater systems. They are defined in §701.3 which refers to Class AA-Special (AA-S) fresh surface waters. They are defined below. Only sections pertinent to nutrient criteria are listed.

§701.3 Class AA-Special (AA-S) fresh surface waters:

(a) The best usages of Class AA-S waters are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. *The waters shall be suitable for fish, shellfish, and wildlife propagation and survival.*

(d) *These waters shall contain no phosphorus and nitrogen in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages.*

(f) There shall be no increase in turbidity that will cause a substantial visible contrast to natural conditions.

However, the NYSDEC has applied the guidance values to most freshwater systems denoted by the classifications of A, A-S, AA, AA-S, B, and C. Currently an aquatic chronic criteria of nitrite-nitrogen level of 100 µg/L is applied to all of these waterbody types with the exception of trout waters (T or TS) in which case the standard is 20 µg/L for trout waters. For the waters of the Great Lakes System, the department substitutes a guidance value for the aquatic Type standard if so determined under section 702.15(c) of this Title.

Application of narrative nutrient criteria are guided in part by Technical & Operational Guidance Series (TOGS), including the *1.1.1* Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations(New York Department of Environmental Conservation 1998).* The DEC has set a limit on total phosphorus for waterbodies ponds, lakes and reservoirs classified as A, A-S, AA, AA-S, B 20 excluding Lake Champlain. The DEC uses site-specific values for Lake Champlain, Ontario and Erie that tier back to specific classifications. In many cases this is the same as the total phosphorus levels listed for ponds, lakes and reservoirs. These standards were based on aesthetic effects for primary and secondary contact recreation. The waterbody-specific values for phosphorus in these lakes are

• Lakes Erie and Ontario: The Lake Erie target TP concentration is divided up by basin, with the Western Basin equal to 15 µg/L and the Central and Eastern basins equal 10 µg/L. Lake Ontario's target is 10 µg/L. These target P numbers for Erie and Ontario are in supporting 3 documents to the Great Lakes Water Quality Act.

• Lake Champlain (NY side): Main Lake - 10 µg/L, South Lake - 25-54 µg/L, remainder of lake - 14 µg/L. These values are from the VT-NY Agreement and were also used in the phosphorus TMDL.

• New York City Watershed reservoirs: 15 µg/L for terminal reservoirs. This value (plus the statewide guidance value of 20 µg/L) was used in the reservoir phosphorus TMDLs.

• Waters of the Forest Preserve: Natural conditions.

New York State has an active Nutrient Standards Plan that was revised and updated 2-1-2008 (New York Department of Environmental Conservation 2008a). This document updates the revised plan dated 1-18-06, which updated the original plan dated 9-29-04. The document describes New York’s existing approach to addressing nutrient over-enrichment, along with the plan to refine it in response to the U.S. Environmental Protection Agency (USEPA)’s requirements that states adopt nutrient criteria for lakes and reservoirs, and for rivers and streams. They further state that when the USEPA publishes nutrient criteria for other waterbody types (estuaries and coastal marine waters and their wetlands) applicable to New York, New York will work with USEPA to determine the most appropriate nutrient criteria for these waters. They discussed the published recommended EPA criteria for lakes, reservoirs, rivers and streams (Gibson et al. 2000; United States Environmental Protection Agency 2000h; United States Environmental Protection Agency 2001h). They state that several ecoregions are included within New York. The “Level III” ecoregions within New York are 58, 59, 60, 61, 62, 67, 83, and 84. The aggregate ecoregions are VII, VIII, XI, and XIV. They describe the USEPA recommendation for states to establish criteria for both nutrients [nitrogen (N), and phosphorus (P) and response variables (chlorophyll a and/or water clarity)].

They argued that state adoption of the USEPA’s criteria recommendations as standards is one option to meeting USEPA’s requirements. Derivation and adoption of state-specific standards for nutrients is another option. They state that New York does not believe that the USEPA criteria are necessarily appropriate for New York’s waters, and they intend therefore to derive its own, state-specific criteria for nutrients for both ponded and flowing waters, as detailed below. New York believes that these criteria, based on data solely from New York State, will more accurately represent nutrient levels necessary to protect the designated uses (best uses) of New York’s waters.

There are three basic elements of NY’s approach that include human health/potable water sources, contact recreation, and aquatic life support. They are listed below.

1.a. Human Health - Lakes and Reservoirs
1.b. Human Health - Flowing Waters

2.a. Recreation - Lakes and Reservoirs
2.b. Recreation - Flowing Waters

3.a. Aquatic Life - Lakes and Reservoirs
3.b. Aquatic Life - Wadeable Flowing Waters
3.c. Aquatic Life - Non-Wadeable Flowing Waters

New York's approach is summarized in the table 14 below. To accomplish this New York has and may be continuing to conduct several projects in support of these three elements. These projects and objectives were funded in part with support from EPA. The descriptions below were taken almost verbatim from the Nutrients Standard Plan (New York Department of Environmental Conservation 2008a).

Table 164. New York's approach to developing numerical nutrient water quality standards (Excerpt from 2008 New York Nutrient Standards Plan.

Targeted Uses to be protected	Applicable Water body Type	Additional research to be completed	Proposal as part of the First administrative action in 2009	Proposal as part of the Second administrative action in 2012*
Human Health (water source)	Lakes/Reservoirs	none	X	
Human Health (water source)	Flowing	Sept. 30, 2009		X
Recreation	Lakes/Reservoirs	none	X	
Recreation	Flowing	2011*		X
Aquatic Life	Lakes/Reservoirs	2011*		X
Aquatic Life	Flowing (wadeable)	none	X	
Aquatic Life	Flowing (non-wadeable)	2008	X	

* Contingent upon sufficient federal funding to complete the work in a timely manner, as well as DEC staff availability, in consideration of other priorities and requests from the EPA.

Human Health/Potable Water Supply: Lake and Reservoir Studies (selected waterbodies)

In support of development of criteria to protect human health and sources of potable water supply New York initiated studies to address specific questions. The focus of these investigations was lakes and reservoirs; (Classes A, A-S, AA, AA-S). For lakes and reservoirs classified as sources of potable water supply (the A classes), research is ongoing to evaluate the relation between nutrients (and related response variables) and the production of disinfection byproducts (DBPs) and algal toxins, and to derive nutrient criteria for ponded Class “AA” and “A” waters. The criteria will be extended to ponded waters of Classes 5 A-S and AA-S. Additional research is being conducted to determine equivalent criteria for flowing water systems of Classes A, AA, A-S, and AA-S. Because nearly all freshwater systems in New York State are phosphorus-limited rather than nitrogen-limited, the nitrogen criteria would only apply when it can be demonstrated that a waterbody is nitrogen limited. Therefore the state believes it would retain a narrative standard rather than develop a numeric value(s) for nitrogen under most circumstances. However, New York did state it would consider whether it would be appropriate to also establish some form of numeric criteria for a nitrogen-limited system.

The basic experimental design employed by the State of New York consisted of collections of <u>paired measurements</u> of nutrient related indices (total phosphorus and chlorophyll-*a*) and human health related indices (disinfection byproduct formation potentials and algal toxins). Their plan was to assess the relationship between nutrient related parameters and human health related indices. Any correlative relationships will then be compared to applicable ambient water quality standards and/or drinking water standards to determine appropriate nutrient related standards for the protection of human health.

Their project consisted of the following tasks: (a) collection of water column samples from a number of Class “AA” and “A” lakes and reservoirs within New York State, (b) analysis of water samples for nutrient related parameters (total phosphorus, chlorophyll a, water clarity), disinfection byproduct formation potential, and algal toxins, (c) selected analysis of water samples for phytoplankton identification and enumeration, (d) compilation of water purveyor system information regarding DBP levels in water supply distribution systems, and (e) analysis of all data to determine appropriately protective nutrient criteria.

The field component of their project was conducted from May through October of 2004, with additional supplemental field investigations occurring during 2007 as part of a follow-up study. They collected ambient water samples from approximately 20 lakes and/or reservoirs. Targeted waters were selected to encompass a relatively broad range of trophic conditions and represent a number of the Level III Ecoregions found in New York State and surrounding region. Their project included development of a technical report detailing the findings and conclusions of the study, which was targeted for completion by September 30, 2009 although we cannot determine if a report has been completed. An interim Project Summary dated August 20, 2007 is available from the agency.

The *human-health lakes* project takes an <u>effects-based</u> approach to establishing nutrient criteria. Criteria will be developed for total phosphorus (TP) and chlorophyll-*a*. A criterion will also be developed for water clarity based on the results of the study. The criteria will be based on relationships between nutrient indices (chlorophyll a and TP) and related human health indices (DBPFP and algal toxins), with the goal of establishing threshold levels of the former to prevent exceedances of the latter in drinking water supplies. These relationships were to be defined by the study. Criteria based on the results of this study will be proposed as guidance values as outlined in the “Introduction and Overview”section of the New York State Nutrients plan. Although the study was conducted on Class AA and A waters, the criteria derived are expected to be appropriate for all ponded surface waters classified as sources of potable water supply. Thus, any criteria derived will also be adopted for Class AA- Special and A-Special waters.

The extension of study results to moving waters (rivers and streams) is questionable given the differences between ponded and moving water systems. In brief, the concern expressed by NYSDEC was that in ponded systems the nutrients present have a significantly better opportunity to "build-out" organic matter by prompting algal growth, whereas, in moving systems the "build-out" of organic matter at a particular point in the system is more limited as the nutrient moves past the point. Thus, the ultimate nutrient criteria for ponded systems would likely be more restrictive than for flowiing water systems, although this would also need to consider downstream concerns as well (e.g., ponded water supply source).

In 2007, USEPA provided New York and New Jersey with funding to initiate a Paleolimonology Project designed to: (a) define and refine nutrient-related reference conditions, (b) define reasonable target nutrient concentrations with respect to restoration efforts, (c) verify ecoregional delineations, (d) evaluate water quality trends, and (e) assess dissolved oxygen dynamics within regional lakes. The project involved the development and/or extension of inferential models for the purpose of estimating historical water quality conditions with respect to trophic indices (primarily phosphorus) and dissolved oxygen. Inferential models to assess historical trophic conditions will be based on sedimentary diatoms, while estimates of historical dissolved oxygen conditions will be based on sedimentary remains of Chironomids. The project also built upon previous paleolimnology studies conducted as part of the USEPA Environmental Monitoring and Assessment Program (EMAP). According the NYSDEC the initial phase of the project had proceeded well, however, additional funding was necessary to fully complete the goals of this project. Subsequent work would involve a continuation of ongoing work with the already established team of researchers, and this effort would substantially increase the Sstate’s efforts on all ponded water criteria.

In 2007, USEPA provided supplemental follow up funding to extend efforts regarding nutrient criteria as they relate to potable waters. The follow-on project was designed to answer several remaining issues related to nutrient criteria for potable waters, as follows. The most important issue remaining is to determine how these relationships play out with respect to flowing water systems. NYSDEC felt that is was very unlikely that nutrient thresholds would be somewhat higher for flowing waters due to the fact that there is less opportunity for resident algae to fully utilize available nutrients in these systems, and therefore there is likely to be lower primary productivity per unit of nutrient than in ponded systems. The next phase of this overall study effort followed a similar experimental design as the earlier effort. NYSDEC planned to collect monthly samples on approximately 15 flowing water systems throughout New York State. At the time of the Nutrient Plan, the QAPP for the project has been completed and sample collection had been underway since May 2007. Additional work would be completed by September

30, 2009, which included completion of sample collection and analysis, as well as data analysis and report development.

In addition to the flowing water portion of the follow-on investigation, additional work was planned for the ponded systems in an effort to address certain unanswered questions on this category of waters. Additional work that was planned included: (a) sample collection on two additional ponded water sources to confirm applicability of existing relationships; (b) follow-up sampling will be conducted on two of the original systems to evaluate inter-annual variability for given parameters;

(c) addition of the parameters of true color and SUVA (specific UV absorbance) will be evaluated to assess the import of humic materials in the generation of THMs and to evaluate the value of surrogate measures, respectively;

(d) coupled samples will be collected from several lakes/reservoirs and their primary tributary to further investigate the nature of DBP precursor source categories (allochthonous verses autochthonous);

(e) spatial variability (both horizontal and vertical) within given systems will be assessed using synoptic longitudinal events and episodic discrete depth sampling events, respectively; and (f) investigation of probable removal capability of conventional water treatment processes for halogenated byproducts and algal toxins using paired raw water and finished water samples.

NYSDEC planned to release two individual reports at the conclusion of the follow-up investigations that will detail results from both efforts, one for ponded waters and one for flowing waters.

Criteria to Protect Primary Contact Recreation

Summary: Lakes and Reservoirs

For primary contact recreation for lakes and reservoirs, the perception data compiled by the Division of Water's Citizens Statewide Lake Assessment Program will be used to identify levels of phosphorus (as well as the response variables, water clarity and chlorophyll-*a* that correspond to unimpacted, impacted, and impaired uses. These criteria will be applied to Class B waters and likely to the A classes as well. NYSDEC would consider the extent to which these same criteria will be applied to Class C waters, or if separate criteria are more appropriate. Because nearly all freshwater systems in New York State are phosphorus-limited rather than nitrogen-limited, the nitrogen criteria would only apply when it can be demonstrated that a waterbody is nitrogen limited. Therefore NYSDEC concluded that they would likely retain a narrative standard rather than develop a numeric value(s) for nitrogen under most circumstances. New York State would consider whether it would be appropriate to also establish some form of numeric criteria for a nitrogen-limited system.

New York had recognized that existing approaches for establishing nutrient criteria, such as narrative standards, present guidance values, or the default 304(a) criteria, did not address the primary consequences of over-enrichment of surface waters- human use impairment- that has driven much of the need for developing nutrient criteria. NYSDEC recognized that one of most sensitive uses impaired by eutrophication is often related to the aesthetic quality of the water, such as primary contact recreation.

In recognition of the limitation of these approaches to protect the aesthetic quality of the water and the best use of recreation from nutrient over-enrichment, the USEPA strongly encouraged New York State to use of alternative or supplemental methods for assigning nutrient criteria through identification of reference conditions or reference waterbodies. The NYSDEC therefore completed a two year study for USEPA Regions I, II, and V involving the use of use impairment data linked with water quality data to identify reference conditions as part of the nutrient criteria development process. Data were evaluated from eight states and three USEPA regions, all collected in a similar manner using standardized lake perception surveys, spread over eight aggregate USEPA ecoregions, twenty-six level III USEPA ecoregions, and 200,000 samples.

Data were evaluated using a variety of methodologies to identify reference conditions, mostly consistent with historical methodologies used to identify intrastate ecoregions and the USEPA CALM methodology used to identify support of designated uses. CALM refers to "*Consolidated Assessment and Listing Methodology*". CALM provides a framework for states and other jurisdictions to document how they collect and use water quality data and information for environmental decision making and serves as a compendium of best practices. The primary purposes of these data analyses are to determine the extent that all waters are attaining water quality standards, to identify waters that are impaired and need to be added to the 303(d) list, and to identify waters that can be removed from the list because they are attaining standards. The CALM document is updated periodically as additional chapters are completed and existing chapters revised and is posted on the EPA web page: http://water.epa.gov/type/watersheds/monitoring/calm.cfm (United States Environmental Protection Agency 2002b).

Reference conditions were defined as the 75_{th} percentile of the reference dataset, consistent with the USEPA recommendations. One proposed methodology defines reference waterbodies as those that are "slightly impaired" at a frequency of <10%, consistent with the CALM methodology (as adapted by several states) for 10 "fully supporting" designated uses and historical precedent for utilizing use impairment data in identifying state guidance values. Reference conditions are calculated from the use impairment dataset using these definitions for reference waterbodies. Another methodology defines reference as corresponding to sampling conditions described as "could not be nicer" or (having) "very minor aesthetic problems,"while another method applies USEPA guidance encouraging the use of the "most protective....approach for reference condition calculations", using USEPA guidelines to identify "adequate" datasets. A "composite" methodology assigns the percentage of lakes meeting the criteria in previous methodologies to the entire USEPA nutrient dataset. A summary of the methodologies and the resulting reference condition calculations is available in the final report for this study provided to USEPA Regions I, II, and V.

New York intended to use these findings to identify supplemental calculations of reference conditions to be considered with the default 304(a) criteria to determine final nutrient criteria for waterbodies used for primary contact recreation (primarily Class B and C). These criteria will be established for Class B waters. Class C waters must have water quality suitable for primary contact recreation, but this is not a designated best use for Class C waters (6 NYCRR 701.8). Nonetheless, many (but not all) Class C waters are used for swimming. When the criteria to protect this use are derived, NYSDEC will consider the extent to which these same criteria should be applied to Class C waters. Because primary contact recreation is also a best use for Class A, A-S, AA, and AA-S waters, it is likely that these criteria will also apply to these waters. However, nutrient criteria for drinking water source protection are likely to be more stringent and will be the controlling criteria for these waters. Once the NYSDEC establishes guidelines for defining reference conditions and/or reference waterbodies, these guidelines will be applied to the methods presented in this study to derive supplemental reference condition calculations. It is expected that this will strengthen the final nutrient criteria adopted by New York State by providing a more diverse approach that considers a composite of a 1) frequency distribution/statistically based approaches (the default 304(a) criteria), 2) a threshold based approach (the existing narrative standard and guidance value) and 3) a use impairment based approach (the lake perception/use impairment study calculations).

NYSDEC felt they had sufficient information in hand to start answering these questions, and adequate resources in hand to do this. While some additional data collection would help to fill in some of the data gaps in some of the level III ecoregions (and the smaller aggregate ecoregions), and they did not yet have enough total nitrogen data to address numeric criteria for any of the ecoregions, the database should be large enough in most of the level III and aggregate ecoregions to only address questions related to TP, chlorophyll-*a*, and water clarity and their interactions.
The key decision about where NYSDEC will differentiate between unimpacted, impacted, and impaired waters was being addressed, and draft criteria would be developed starting in the winter of 2008. To date, we have not seen any evidence of this based on our review of available literature for New York. NYSDEC stated that further discussion of which criteria are appropriate for which water classes, would be undertaken in conjunction with and following the NNC derivation process. Extension/continuation of the Paleolimnology Project (see above) would also be beneficial to the future refinement of recreation criteria for ponded systems and the development of aquatic life criteria for ponded systems.

Summary Flowing Waters

The NYDEC planned to conduct field survey work during the 2008 field season, utilizing field perception surveys comparable to those used in the ponded waters assessments. They anticipated that these surveys would be limited to the large river systems that are capable of supporting contact recreation; criteria will be developed to define these systems. As with the ponded water systems, survey results will be paired with stressor (phosphorus and nitrogen) and response variables (chlorophyll-*a*, Secchi disk transparency, and turbidity) to evaluate correlations between these variables and perception responses. Definitions of acceptable impacts (the determination about where to "draw the line") adopted in the ponded water nutrient criteria development process would inform the process for identifying acceptable impacts in flowing waters. NYSDEC anticipated that the process for developing draft criteria for flowing waters will be lagged behind the criteria process for ponded waters for at least two years, to allow for sufficient data collection across ranges of large river systems and ecoregions to determine if these gradients need to be built into the draft criteria. They emphasized that adherence to the above schedule is contingent upon sufficient federal funding to complete the work in a timely manner, as well as NYDEC staff availability, in consideration of other priorities and requests from the EPA.   As previously stated we have not seen any new efforts by New York State to develop NNC in recent years.

Criteria to Protect Aquatic Life

Summary: Lakes and Reservoirs

NYSDEC planned to conduct research to evaluate the integrity of aquatic life in lakes and reservoirs in relation to eutrophication from phosphorus and nitrogen. Biological communities would be sampled in a subset of lakes from across NYS beginning in 2008 as part of the NYS ambient water quality monitoring program (lakes and reservoirs). As data was collected nutrient criteria will be inferred based on the relationships between nutrient concentrations and biological community integrity. This would be an ongoing project and sufficient data for drawing conclusions regarding nutrient criteria was not expected until after several years of sampling and data analysis has been conducted. NYSDEC emphasized that it was essential to emphasize that adherence to the above schedule was contingent upon sufficient federal funding to complete the work in a timely manner, as well as NYSDEC staff availability, in consideration of other priorities and requests from the EPA. NYSDEC also felt that extension/continuation of the Paleolimnology Project (see above) would also be beneficial to the future refinement of recreation criteria for ponded systems and the development of aquatic life criteria for ponded systems as well.

Summary: Wadeable Stream Nutrients and Biotic Community

For wadeable rivers and streams, levels of nutrient concentrations for both nitrogen and phosphorus, above which the aquatic invertebrate communities become degraded have been established as a result of research conducted throughout New York State. This work is summarized in (Smith et al. 2007). Based on the study results, NYSDEC felt that they could now derive an ambient nutrient standard or guidance value in terms of levels of nitrogen and phosphorus that would not cause impairment of the biotic community as measured by macroinvertebrates. In addition, this study developed a biotic index of nutrient enrichment for macroinvertebrates in New York State which is now used in the detection and prediction of water quality impact resulting from non-point source nutrient inputs. It also allowed New York State to associate ranges of nutrient concentration with changes in biotic communities. Therefore they felt that it is possible to identify levels of nutrients which cause perturbation and establish nutrient impairment criteria for wadeable streams. From ongoing studies, NYSDEC planned on continuing to refine nutrient criteria for wadeable streams through continued sampling of biological communities and water chemistries throughout the state.

At the time of the publication of the New York Nutrient Criteria Development Plan, a project funded by the EPA was about to begin in 2008 to incorporate nutrient criteria response variables missing from the dataset in (Smith et al. 2007). These additional response variables to be targeted in 2008 included a periphyton community data, Chlorophyll-a, and aesthetic value observations. This new data was meant to act as supplemental information in refining the guidance values for phosphorus and nitrogen which are expected to be proposed in 2009. As previously mentioned we have not observed any proposed NNC for phosphorus and nitrogen for New York State.

Non-Wadeable Streams and Rivers: Historical Data on Nutrients and Water Quality and RIBS Sampling Pilot Study

Summary

For non-wadeable rivers and streams, the NYSDEC planned to use Division of Water's historical record of statewide monitoring to supplement and complement ongoing research targeted at addressing aquatic life use impairment from nutrients in large rivers of New York State. This work is expected to be completed by September, 2008.

Details of Research and Products

The objective of this project was to develop effects-based aquatic life numeric nutrient criteria for non-wadeable rivers and streams in New York State. The strategy of the project was three-fold: 1) to develop background nutrient conditions for large rivers in the different aggregate ecoregions, 2) to determine effects of varying nutrient concentrations on algal and invertebrate communities, and 3) to develop numeric nutrient criteria based on the information gathered in research strategy items 1 and 2 immediately above. A review of the historical biological and water chemistry data collected during and after 1993 in large, non-wadeable rivers throughout New York State would be conducted by NYSDEC. USGS National Water Quality Assessment program data will also be utilized during this phase. NYSDEC planned to conduct biological water quality assessments to identify reference conditions and corresponding nutrient concentrations which do not cause impairment to aquatic life use. NYSDEC collected additional nutrient criteria response variable data over the summer seasons of 2006 and 2007 to supplement the historical data and provide information on additional response variables. This data set included macroinvertebrate and periphyton community data, algal biomass as chlorophyll-*a*, turbidity, secchi depth, and a full suite of nutrient and basic chemical parameters as well as basic habitat measurements. Based on the behavior of response variables to increasing levels of eutrophication, namely invertebrate and periphyton community data, and algal biomass as chlorophyll-a, nutrient criteria will be derived. NYSDEC indicated that NNC would likely be derived within a three-tiered framework similar to that planned for New York State wadeable streams and rivers. This framework consisted of a reference, acceptable, and unacceptable range of nutrients for the different nutrient ecoregions. NYSDEC claimed that the current project would fully support the goal of developing regional numeric nutrient criteria for both nitrogen and phosphorus that will be protective and scientifically defensible.

North Carolina

A combination of statewide and site specific NNC are used in North Carolina including chlorophyll-*a* (statewide) and clarity/turbidity (site specific)(Table 165). Statewide and site specific criteria listed below were obtained from the North Carolina NNC listed in their most current version of the state water quality standards and EPA web sites. It should be noted that there is little difference in the applicability of the statewide and site specific criteria due to the wide definitions used in the site specific criteria (i.e. applicability to waterbodies).

Table 165. Existing Numeric Criteria in North Carolina.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes & Reservoirs			S	W[3]
Rivers & Streams			S	W[3]
Estuaries			S	W[3]
Wetlands				

S = Statewide W = For selected waterbody N/A=Not Applicable

[1] From North Carolina's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved November 2007). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes. If a state/territory has criteria for the protection of drinking water or human health, those criteria may be found on the tabs for either statewide or site-specific criteria.

[2] Source: EPA's (North Carolina Department of Environment and Natural Resources 2007; United States Environmental Protection Agency 2008b)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_nc.cfm).

[3] Numeric turbidity criteria (measured in Nephelometric Turbidity Units) for selected waters.

The following information reflects North Carolina's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved November 2007). We checked the State of North Carolina water quality standards web site and found that this represents the most recently state adopted NNC (http://portal.ncdenr.org/web/wq/ps/csu)((North Carolina Department of Environment and Natural Resources 2007). The site specific standards are listed below. The designated uses that these NNC apply to are:

B: Primary Recreation, Fresh Water
C: Aquatic Life, Secondary Recreation, Fresh
CA: Critical Area

FWS: Future Water Supply Waters
HQW: High Quality Waters
N/A: Not Applicable/Out of State
NSW: Nutrient Sensitive Waters
ORW: Outstanding Resource Waters
SA: Market Shellfishing, Salt Water
SB: Primary Recreation, Salt Water
SC: Aquatic Life, Secondary Recreation, Salt
Sw: Swamp Waters
Tr: Trout Waters.

Classifications C (freshwater), Tr (trout waters), and SC (saltwater) aquatic life uses are the primary focus of the NNC listed below. Also, the size of reservoirs differentiates whether chlorophyll-*a* criteria.

Statewide Criteria

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters

(1) Best Usage of Waters. Aquatic life propagation and maintenance of biological integrity (including fishing, and fish), wildlife, secondary recreation, agriculture and any other usage except for primary recreation or as a source of water supply for drinking, culinary or food processing purposes;

(3) Quality standards applicable to all fresh surface waters.

(a) *Chlorophyll-a (corrected): not greater than 40 μg/L for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation not designated as trout waters, and not greater than 15 μg/L for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation designated as trout waters (not applicable to lakes and reservoirs less than 10 acres in surface area)*; the Commission or its designee may prohibit or limit any discharge of waste into surface water if, in the opinion of the Director, the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;

15A NCAC 02B .0220 Tidal Salt Water Quality Standards for Class SC Waters

(1) Best Usage of Waters. Aquatic life propagation and maintenance of biological integrity (including fishing, fish and functioning PNAs), wildlife, secondary recreation, and any other usage except primary recreation or shellfishing for market purposes.

(3) Quality standards applicable to all tidal salt waters:

(a) *Chlorophyll a (corrected): not greater than 40 μg/L in sounds, estuaries, and other waters subject to growths of macroscopic or microscopic vegetation*; the Commission or its designee may prohibit or limit any discharge of waste into surface waters if, in the opinion of the Director, the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;

15A NCAC 02B .0223 Nutrient Sensitive Waters

In addition to existing classifications, the Commission may classify any surface waters of the state as nutrient sensitive waters (NSW) upon a finding that such waters are experiencing or are subject to excessive growths of microscopic or macroscopic vegetation. Excessive growths are growths which the Commission determines impair the use of the water for its best usage as determined by the classification applied to such waters.

NSW may include any of all waters within a particular river basin as the Commission deems necessary to effectively control excessive growths of microscopic or macroscopic vegetation. For the purpose of this Rule, the term “nutrients” shall mean phosphorus or nitrogen or any other chemical parameter or combination of parameters which the commission determines to be contributing to excessive growths of microscopic or macroscopic vegetation. Those water additionally classified as nutrient sensitive shall be identified in the appropriate schedule of classifications as referenced in Section .0300 of this Subchapter. Nutrient strategies applicable to NSW shall be developed by the Commission to control the magnitude, duration, or frequencies of excessive growths of microscopic or macroscopic vegetation so that the existing and designated uses of the waterbody are protected or restored.

Site-specific Criteria

15A NCAC 02B .0211 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS C WATERS

(1) Best Usage of Waters. Aquatic life propagation and maintenance of biological integrity (including fishing, and fish), wildlife, secondary recreation, agriculture and any other usage except for primary recreation or as a source of water supply for drinking, culinary or food processing purposes;

(3) Quality standards applicable to all fresh surface waters.

(k) *Turbidity: the turbidity in the receiving water shall not exceed 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters and 10 NTU in streams, lakes or reservoirs designated as trout waters; for lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level cannot be increased*. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202 of this Section] recommended by the Designated Nonpoint Source Agency [as defined by Rule .0202 of this Section]. BMPs must be in full compliance with all specifications governing the proper design, installation, operation and maintenance of such BMPs;

15A NCAC 02B .0220 TIDAL SALT WATER QUALITY STANDARDS FOR CLASS SC WATERS

(1) Best Usage of Waters. Aquatic life propagation and maintenance of biological integrity (including fishing, fish and functioning PNAs), wildlife, secondary recreation, and any other usage except primary recreation or shellfishing for market purposes.

(3) Quality standards applicable to all tidal salt waters:

(l) *Turbidity: the turbidity in the receiving water shall not exceed 25 NTU; if turbidity exceeds this level due to natural background conditions, the existing turbidity level shall not be increased.* Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202(6) of this Section] recommended by the Designated Nonpoint Source Agency (as defined by Rule .0202 of this Section). BMPs must be in full compliance with all specifications governing the proper design, installation, operation and maintenance of such BMPs.

North Carolina has a Nutrient Criteria Implementation Plan (North Carolina Department of Environment and Natural Resources 2004; North Carolina Department of Environment and Natural Resources 2005). This Plan was originally written in 2004 and redrafted in 2005. Therefore the recommendations made in these documents are somewhat dated. More to the point, many of the proposed deadlines associated with drafting of NNC have past and in some cases are very late. We however present an abbreviated but for the most part verbatim account of these documents.

The North Carolina Department of Environment and Natural Resources (NCDENR) outlined their strategy for development of NNC in the Nutrient Implementation Plan. The NCDENR considered this as the second "phase" of Nutrient Criteria development and implementation, beyond their existing strategies, policies and regulations. North Carolina chose to divide the waters of the State into two subgroups.
These subgroups were defined as:
1. Non-Flowing Waters: The non-flowing waters category generally included:

a. Lakes – Lakes are defined as natural (not manmade)
geologic features, which impound water. In North Carolina, natural lakes are predominantly located within the Coastal Plains ecoregion and are generally shallow, elliptical lakes referred to as Carolina Bay Lakes.

b. Reservoirs – Reservoirs are manmade (not natural) fresh water impoundments.
North Carolina reservoirs may be used as sources for drinking water, energy production, flood control, commercial water use, aquatic life habitat, and/or recreation. Reservoirs are found throughout the State and are the dominant lake form in the Piedmont, Sandhills, and Mountain ecoregions.

c. Estuaries – Estuaries are natural coastal features where there is an interaction of fresh and salt waters. These waters are tidally influenced, which, in turn, periodically influences changes in salinity, nutrients, water depth, etc. Estuaries along the coast of North Carolina are predominantly drowned river valleys, which became inundated by the rising sea level during the last glacial retreat.

2. Flowing Waters: The flowing waters category includes rivers and streams.

As with most Nutrient Criteria Development Plans administered by other states the first step outlined in the North Carolina plan was the task of assembling an inventory of available data. According to NCDENR there were literally thousands of ambient observations that had been taken from approximately 423 stations located in over 150 water bodies grouped by ecoregion in North Carolina.
Measured parameters include chlorophyll-*a*, total nitrogen (TN), and total phosphorous (TP). The time frame for this data ranges from the early to mid 1980s to present. Data/water bodies were grouped according to the following regions in North Carolina: mountains, piedmont, sandhills, coastal plains, and estuaries

Based on this inventory the NCDENR assessed the data needs that could not be met by existing data based on the methods that might be used to develop NNC. These data gaps would be filled by subsequent targeted data collection to be completed according to a proposed schedule. Resource requirements for data evaluation and collection were delineated in a later section of the Plan.

Based on available data and potential approaches that might be used the NCDENR selected a variety of candidate parameters.

Selected Parameters

For the nonflowing waters category NCDWQ intended to pursue a phytoplankton measure as its primary approach for nutrient criteria development. Towards this end, NCDENR intended to develop new instream criteria for chlorophyll-*a* and site specific TN and TP optimization levels. The State of North Carolina has a predominance of reservoirs, with only six natural lakes. The inclusion of a water clarity parameter, therefore, was subject to further research and evaluation. Common non-algal turbidity has been historically and consistently identified in North Carolina's waters, making the use of a water clarity parameter an ineffective tool as a measurable response variable for nutrients in their State.

The selected parameters were proposed to be developed on a region specific basis. Therefore, the final proposed parameters would have a unique value for each of the following designated non-flowing water regions: e.g. mountains, piedmont, sandhills, coastal plains, and estuaries.

Parameter Type:

Chlorophyll a: At the time of the Plan, NCDENR envisioned adopting region specific, quantitative chlorophyll-*a* criteria. NCDENR believed that this action would require significant modifications to the current chlorophyll-*a* criteria language. The State intended to conduct a complete scientific evaluation and review in order to determine the most effective methodology available with which to implement a revised chlorophyll-*a* water quality standard for the control of nutrients. Anticipated outcomes of this review may lead to the incorporation of seasonal growing averages, instantaneous maximums, and frequency and distribution response criteria incorporated into the new, revised chlorophyll-*a* standard. As previously discussed, regionally specific chlorophyll-*a* criteria would be developed for the mountains, piedmont, sandhills, coastal plains, and estuary regions of North Carolina. Based upon the detailed evaluation and analysis of the relationship between TN, TP, chlorophyll a, and trophic status of the water two categories of quantitative chlorophyll-*a* parameters would be proposed for each of the five regions presented above. One category (the lower numeric value of the two) would represent a a threshold level that, if exceeded, would indicate that the water body in question had become "nutrient enriched" and in danger of eventually becoming impaired. These "nutrient enriched" water bodies would be designated as such and would be subject to the development and implementation of a nutrient management. This management strategy and its associated controls on point source and nonpoint source nutrient loading would be designed to *prevent* further nutrient enrichment and to *preclude* subsequent impairment of the river or stream in question. The second category (the higher value of the two) would be designated as the "impairment level" criteria. Exceedance of this impairment level criterion would indicate that the water body had become impaired and was not maintaining one or more of its designated uses. This "impairment level" chlorophyll-*a* criteria would be applicable for use support attainment and 303(d) listing decisions.

Total Nitrogen (TN) & Total Phosphorous (TP): Site specific
TN and TP control levels would be developed for those waters that are determined to be "nutrient enriched" under the provisions of this plan. When a specific water body equals or exceeds the "nutrient enriched" chlorophyll-*a* quantitative level, a "translation" process will be required for that specific water body. This translation process would address both the point and nonpoint source nutrient loading to the nutrient enriched waters and will result in the development of site specific TN and TP control levels that are sufficient to prevent the subsequent nutrient impairment of the water body in question.

The NCDENR believed that this management strategy and its associated controls on site specific point source and nonpoint source nutrient loading would allow NCDENR to *prevent* further nutrient enrichment, preclude subsequent impairment of the waters (exceedances of the impairment level chlorophyll-*a* criteria) and to *protect* all existing and designated uses.

Nutrient Translator

At the time of the Plan publication, NCDENR intended to implement the following actions in those non-flowing water bodies that become “nutrient enriched,” as described above.

a. NCDWQ would require optimization of TN and TP removal for major dischargers to non-flowing water bodies identified as “nutrient enriched.” These optimization levels will be established to *prevent* further nutrient degradation of the waters while the second part of this translation process is executed.

b. As a second step, the agency would develop and implement a comprehensive, site specific nutrient management strategy for all “nutrient enriched” waters. This strategy and its associated modeling would address both point and nonpoint nutrient sources and would detail the steps necessary to effectively control those sources in a manner that will prevent further nutrient enrichment and the impairment of the water body in question. NCDENR would implement the plans developed under this nutrient management strategy to the extent necessary to ensure that all designated and existing uses of the threatened waters remain *protected.* If necessary, nutrient management plans would be extended upstream to flowing waters in order to adequately protect a downstream non-flowing water body.

NCDENR intended to follow an overall approach for the establishment of nutrient criteria for non-flowing waters that would be based on the results of a comprehensive cause and effect based study and analysis. The goal of their research was to categorize the State’s non-flowing water bodies into the previously described five regions and then analyze and evaluate the relationship between TN and TP levels and chlorophyll-*a* levels, trophic state of the water body in question, and ultimately, designated use impairment. One goal of their proposed study was be to create a regional trophic state matrix that would compare and contrast the regional location of the non-flowing waters with their associated trophic state, ambient level of TN, TP, and chlorophyll-*a* levels. The results of this study would be utilized to establish regional, multileveled quantitative chlorophyll-*a* parameters and would be incorporated into the development and implementation of the nutrient “translator”.

At the time of the publication of the Plan, North Carolina anticipated adopting uniform nutrient parameters for all classifications of the non-flowing waters of a specific region, without consideration of designated use categories. They realized that further analysis and evaluation of results of the nutrient cause and effect study may indicate the need to implement site specific proactive criteria to prevent the occurrence of levels of response variables of identified concern. They concluded that different nutrient parameters would likely be adopted for the rivers and streams located in that same region.

NCDENR would prioritize waterbodies according to the appropriate timeline presented in the Nutrient Implementation Plan.NCDENR felt that the successful execution of the Nutrient Implementation Plan would result in the development of N and P control levels and translator guidance for all lakes, reservoirs, estuaries, rivers, and streams in the State that become “nutrient enriched.” It was felt that all of these steps and components could be completed by June 2011, which has not occurred.

NCDENR stated that outside Research Assistance for analysis of data and evaluation of relationship between TN & TP levels, and chlorophyll a levels, water body trophic state, and impairment would be needed through partnerships with university researchers and agencies. Field data collection would likely be needed to fill identified data gaps and support nutrient cause and effect study. The estimated cost of this activity was unknown at the time due to the fact that the scope and the extent of the data collection effort had yet to be determined.

NCDENR stated that benthic diatom and benthic invertebrates surveys and/or the Diatom Index Biotic Index would most likely be the primary nutrient parameter for flowing waters. These parameters will be quantitative and regionally specific. NCDENR stated that based upon the analysis of the relationship between the algal biomass, DIBI, TN, TP, and designated use impairment, region unique periphyton assessment criteria values would likely be established at two category levels for the rivers and streams of the State. These multileveled parameters will be implemented in a manner very similar to the methodology already proposed for the implementation of the chlorophyll-*a* parameters for North Carolina's non-flowing waters. The lower category value of the periphyton measurement will be established at a level that, if exceeded, would indicate that the river or stream in question was nutrient enriched and in danger of eventual impairment if no action is taken. Flowing waters exceeding this benchmark would be considered "nutrient enriched" and would be subject to the development and implementation of a nutrient management strategy. This management strategy and its associated controls on point source and nonpoint source nutrient loading would be designed to *prevent* further nutrient enrichment and to *preclude* subsequent impairment of the river or stream in question. The second tier (the higher value of the two categories) would be designated as the "impairment tier" criteria. Exceedance of this second category would indicate that the water body had become impaired and was not maintaining one or more of its designated uses. This "impairment tier" periphyton criterion would be applicable for use support attainment and 303(d) listing decisions.

A site specific nutrient translation process would be required whenever the "nutrient enriched" periphyton assessment value is exceeded in a river or stream. This translation process would address both the point and nonpoint source nutrient loading to the nutrient enriched waters and result in the development of site specific TN and TP control levels. The NCDENR felt that this management strategy and its associated controls on site specific point source and nonpoint source nutrient loading would prevent further nutrient enrichment, preclude subsequent impairment of the waters (exceedances of the impairment periphyton criteria) and to protect all existing and designated uses.

The NCDENR planned on implementing the following actions in those flowing waters that become "nutrient enriched," as described above:

a. Optimization of TN and TP removal will be required for all major point source dischargers to the waters in question. These levels would be established to prevent further nutrient degradation of the river or stream while the second part of this translation process is executed.

b. As a second step, the agency would develop and implement a comprehensive, site specific nutrient management strategy for all “nutrient enriched” flowing waters. This strategy and its associated modeling would address both point and nonpoint nutrient sources and would include the steps necessary to effectively control nutrient sources that will prevent further nutrient enrichment and impairment of the water body in question. NCDENR would implement the plans developed under this nutrient management strategy to the extent necessary to ensure that all designated and existing uses of the threatened waters remain protected.

To implement the proposed nutrient control strategy for flowing waters NCDENR stated that additional comprehensive research and analysis would be necessary (North Carolina Department of Environment and Natural Resources 2004; North Carolina Department of Environment and Natural Resources 2005). The proposed research would utilize multiple approaches, incorporating elements of both a 1) reference based approach and a 2) cause and effect study. NCDENR plans to conduct comprehensive algal assessments at selected sites along with the collection of data on levels of TN, TP, and chlorophyll-*a* and the attainment of designated uses at these locations. They planned to compare and contrast this information with similar data collected at sites identified as the minimally/least impacted rivers and streams within the same ecoregion. They anticipated that this analysis would provide insight into the relationship between the filamentous algae density, DIBI, TN, TP, chlorophyll-*a* levels, and designated use impairment in North Carolina’s rivers and streams on a regional basis. NCDENR planned on using this information to establish regional, multitiered, quantitative periphyton parameters and will be further used to develop and implement both elements of the nutrient translator for flowing waters. At the time, North Carolina anticipated adopting uniform nutrient parameters for all the classifications of the flowing waters of a specific region, irrespective of designated use categories.

NCDENR stated that the successful execution of their Nutrient Criteria Implementation Plan would result in the establishment of site specific nitrogen and phosphorus control levels and translator guidance for all lakes, reservoirs, estuaries, rivers, and streams in the State that are determined to be “nutrient enriched” under the guidelines of this plan. One important observation we made was that although the North Carolina Plan claimed to address estuarine nutrient criteria development, we did not see much detail if any explaining how these waterbody types would be addressed in relation to NNC development.

North Dakota

North Dakota does not have NNC but it does not a Nutrient Criteria Development Plan currently (Deutschman 2007; Houston Engineering 2008; North Dakota Department of Health 2011). The following information was synthesized from their Plan.

The North Dakota Department of Health (NDDH) contracted with a consultant to assemble the data needed to develop NNC and to develop their Nutrient Criteria Development Plan (Deutschman 2007). Their Plan was one of the most well documented and comprehensive ones reviewed. The first step conducted was a broad review and assessment of available literature and water quality data during the preparation of the nutrient criteria development plan. The literature reviewed included reports and information specific to North Dakota and other states which have or are developing nutrient criteria development plans, and EPA national guidance material. North Dakota surface water monitoring data, obtained from the NDDH, the United States Geological Survey (USGS) and from EPA, were reviewed and summarized. The objective for the literature and data review was to understand potential options (including benefits and limitations) for North Dakota in establishing an approach for developing nutrient criteria. A thorough statistical analysis of the data to develop the criteria is expected during the implementation of this plan. The analysis presented in their plan was primarily intended to understand the limitations of the available data and the need for collecting additional data when developing criteria.

The author of the Plan felt that the Nutrient Criteria Development planning documents from six states seemed especially applicable to North Dakota. Key components of the six nutrient criteria plans were summarized. Several factors were generally considered when assessing the relevance of a state's nutrient criteria plan to North Dakota, including similar water resources, geographic proximity, scientific rigor of the plan, and ability (based on staff and financial reseources) to implement the plan. The following state plans were identified as relevant to North Dakota:

1. California;
2. Colorado;
3. Florida;
4. Minnesota;
5. Montana; and
6. Utah.

Based upon their literature review, they concluded several items seemed relevant to developing nutrient criteria within North Dakota:

1. Omernick Level III or IV ecoregions represent a good spatial scale for developing nutrient criteria for streams and rivers;

2. Nutrient criteria should be seasonal, reflective of the temporal response of the resource;

3. The application of EPA's recommended approach of the 25th percentile for the monitoring data "population" can result in unduly restrictive criteria;

4. Using a 75th percentile concentration for sites identified as "reference" is preferred over the 25th percentile for the monitoring data "population"

recommended by EPA;

5. Nutrient concentrations established using regional stressor – response field studies tend to fall within a narrow band around the 85th percentile value using reference site data;

6. The selection of nutrient criteria based on a statistical approach (including EPA's recommended approach) is best supported by ground-truthed field data used to develop a site specific stressor – response relationship;

7. The nutrient criteria should ideally include some expression of uncertainty (e.g., confidence interval) which reflects the inherent variability of natural systems, both in terms of the stressor – response relationship and the beneficial use impairment;

8. Common sense should be applied when using a statistical approach (i.e., consideration given to censoring techniques, sample size, correlation among causal variables, the type of statistical distribution);

9. Many states preferdc the use of a reference approach, either to establish the form of the stressor – response relationship or for applying a statistical approach. However, identifying "reference" conditions for large river systems can be challenging;

10. Identifying the limiting causative factor(s) for some systems can be a challenge;

11. Spatially varying nutrient criteria on large lakes and reservoirs may be necessary to be protective and represent the naturally occurring longitudinal change in water quality;

12. Criteria weree intended to be regionally protective. Site-specific data developed through the completion of a total maximum daily load study may still be needed to protect a specific water body; and

13. Few states have actually implemented their criteria – so additional lessons can be learned.

The intent of their review was to incorporate the relevant lessons learned from the literature review into the North Dakota nutrient criteria development process (Deutschman 2007).

The authors of the Plan presented a proposed strategy for developing nutrient criteria for the State of North Dakota. The ability to implement this strategy will be largely based upon the availability of good quality surface water quality monitoring data to identify and verify reference sites and statistically defensible stressor – response relationships. Therefore, they pointed out that this approach should be considered "preliminary" with revisions necessary as more detailed information becomes available. The intent is to provide sufficient detail within the Plan to generally identify the anticipated criteria development approaches for lotic (i.e., rivers and streams) and lentic (i.e., lakes and reservoirs) systems. The author stated that there may be a need to collect additional data and so some assumptions were made in regards to reasonable future funding scenarios that would support this effort.

The authors pointed out the advantages and disadvantages to for development of regional versus site specific NNC. They pointed out that the advantages of developing the nutrient criteria across some larger geographic area are that 1) a lesser level of effort may be required to develop the criteria, because criteria are not developed individually for each water body using site specific data, and 2) there is greater consistency of the criteria when it is applied across a larger area. The disadvantage is that the criteria may be over or under protective of the resource's beneficial uses, because they are generalized.

The author evaluated two alternative spatial scales, ecoregions and major surface water hydrologic basin, have been considered for criteria development. They recommended that NNC use a nested approach of Level III ecoregions further subdivided by major surface water hydrologic basins for nutrient criteria development. The appropriateness of this classification system would be evaluated further once statistical analysis of the data began.

Large reservoirs weree expected to behave differently than most water features within their ecoregion. The water quality of large rivers and the mainstem reservoirs (Lake Sakakawea and Lake Oahe) are influenced considerably by the large amount of drainage area beyond the North Dakota border. Additionally, there are numerous perennial lotic systems which flow through more than one ecoregion. Using ecoregions alone, rather than a nested approach should be considered if the nested approach proves difficult.

The author of the Plan indicated that nutrient criteria should ideally be developed in a manner, which reflects the timing (when during the year) and duration (how long) of the beneficial use impairment. They pointed out that timing and duration of the beneficial use impairment may differ from the timing and duration of the factors leading to the impairment. For example, the timing and duration of an algal bloom in a lake or reservoir during the growing season may be caused by an episodic pulse in nutrient load in the spring. Nutrient criteria need to include a temporal component (i.e., the time of year they apply and any duration or recurrence or averaging period) associated with the criteria.

They pointed out in the Plan that the process and methods used to develop nutrient criteria should ideally be based upon a known and quantifiable stressor – response relationship. The preference is to establish criteria as an expression of the stressor variable where exceedance of some threshold results in an undesirable condition for the response variable.

The authors expected that conceptual ecological models (e.g., Causal Analysis / Diagnosis Information System or CADDIS; existing ecosystem water quality models) would provide the theoretical foundation for the stressor – response relationships.

Example models are presented for both lotic and lentic systems. The authors pointed out that conceptual models assist not only with identifying the stressor – response relationship, but also to reasonably ensure the proper stressor variables and metrics are identified and measured which best describe the system's response to nutrient enrichment.

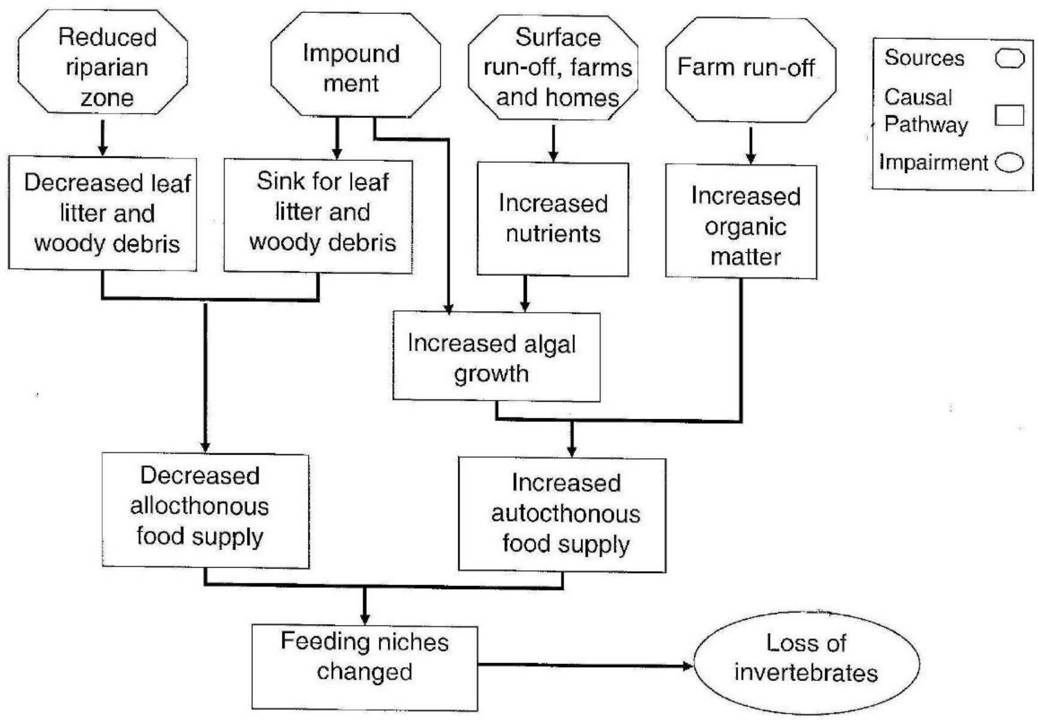


Figure 18. Conceptual model of nutrient dynamics and affects in Lotic ecosystems from CADDIS. Source: (Deutschman 2007)

Figure 18 shows an example conceptual model for a lotic system from CADDIS. They pointed out that there are are several additional sources for conceptual models that can be used for lotic systems. Some of these conceptual models include commonly used receiving water quality models such as QUAL2K, CEQUALW2 and WASP. Prior to selecting specific stressor–response variables for developing the nutrient criteria for lentic systems, a conceptual model using currently available information will be finalized. Ideally, this conceptual model will recognize the uniqueness of the prairie aquatic ecosystem. A similar conceptual model is presented for lotic systems below (Figure 19).

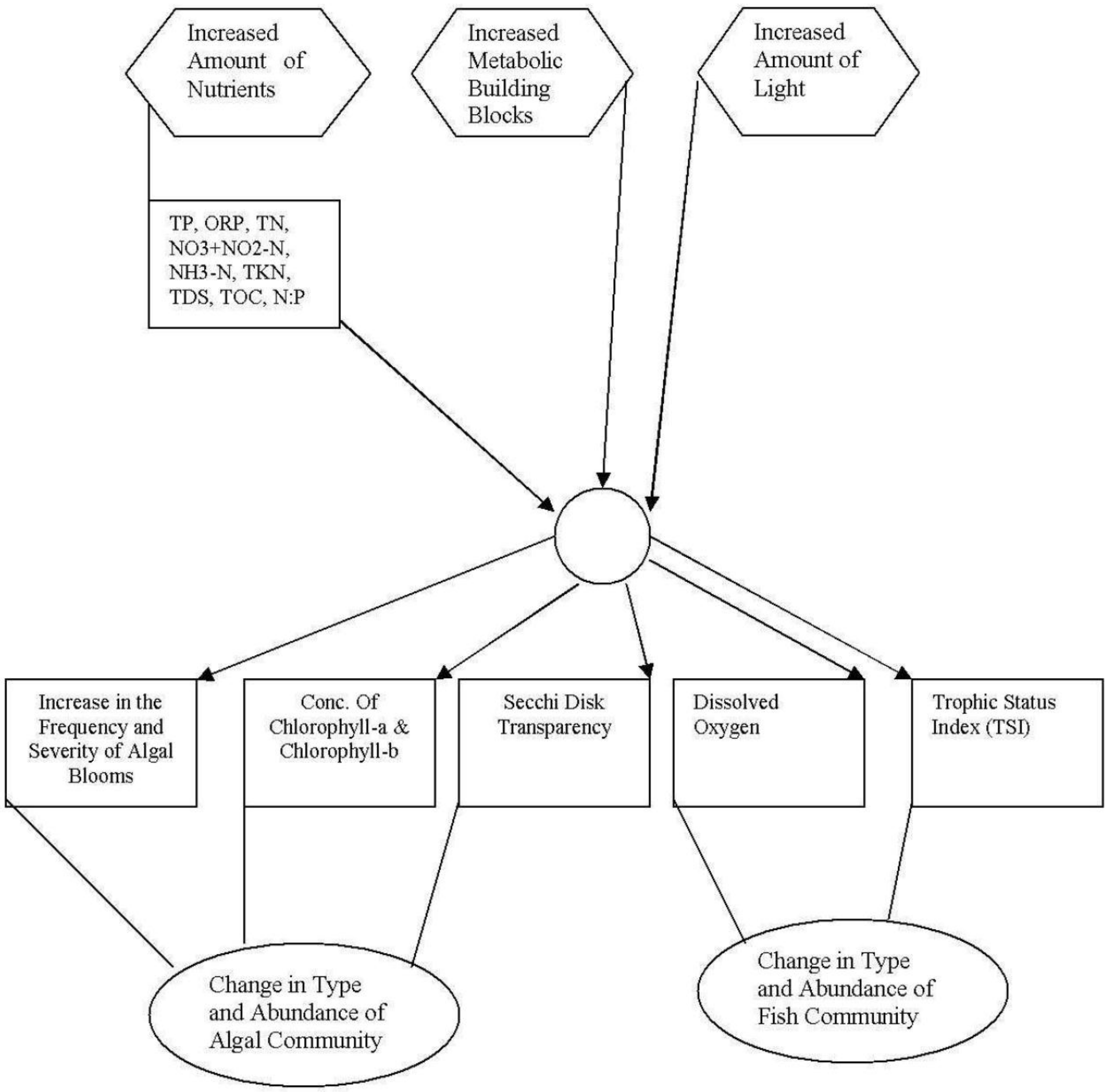


Figure 19. Conceptual model of nutrient dynamics and affects on lentic systems using CADDIS model. From: (Deutschman 2007)

The authors pointed out that the ultimate biological response to excess nutrients varies depending upon the physical and hydrologic characteristics of a water body. The actual metrics used to quantify the physical and hydrologic characteristics can vary. However, the metrics often involve an expression of light penetration, flow regime, and abiotic factors such as habitat, salinity, or acidity. Classifying water bodies is intended to enable the development of nutrient criteria which best reflects the likely response of water bodies which are similar in nature. For the purpose of developing nutrient criteria, a process is needed to classify water bodies with regard to their landscape setting and the resulting physical and chemical characteristics within each geographic area. Based upon preliminary considerations, the following water body classification system was recommended in the North Dakota Plan:

1) Reservoirs and Lakes (Lentic Systems)

a. Reservoir

i. Large River Reservoirs (e.g., Lake Sakakawea, Lake Oahe, Jamestown Reservoir, Lake Ashtabula)

ii. Small and Medium River Reservoirs (e.g., Sweet Briar Dam, McDowell Dam, Crown Butte Reservoir)

b. Natural Lakes

i. Shallow Lakes (e.g., Lake Haskins, Green Lake, Powers Lake)
ii. Non-shallow Lakes (e.g., Devils Lake)

c. Wetlands

2) Rivers and Streams (Lotic Systems)

a. Perennial
i. Wadeable
ii. Non-wadeable (i.e., large)

b. Intermittent / Ephemeral

The recommended approach for classifying lentic water bodies further included variables such as meandepth (derived from surface area and volume), maximum depth, fetch, open water area, overflow rate, and hydraulic residence time. Two other important metrics, which may be considered or developed in the event the proposed metrics are insufficient to classify lentic systems, are the mixing characteristics (e.g., polymictic versus dimictic) and dominant stable state (vis-a-vis clear macrophyte dominated state for shallow lake systems).

The recommended approach for classifying lotic water bodies included the metrics of flow regime (likely frequency and magnitude of discharge) and drainage area at the watershed mouth. The National Hydrography Dataset (NHD) is anticipated to be the primary tool for the initial classification of lotic systems. A careful evaluation of the decision process used to define a stream within the NHD as perennial or intermittent is needed to ensure the distinctions between lotic systems (perennial and intermittent) are appropriate and suitable for nutrient criteria development within North Dakota. An alternative classification metric, which proved to be useful in Montana, is stream order. The ability to develop nutrient criteria using the preliminary water body classification system depends upon the amount of water quality data available for the parameters of interest. Subsequent analysis of sample size by geographic area and water resource type is needed.

The following preliminary definitions are presented for the purpose of classifying water bodies and determining the amount of water quality data available by water body type.

Lentic Systems - Lentic systems are generally considered as standing water systems. This concept is quite broad, encompassing bodies of standing water with widely differing spatial (size) and temporal (seasonal) characteristics.

The authors pointed out that the categories and labels used to describe features such as wetlands, ponds, and lakes are somewhat arbitrary, often informal, and are primarily constructed to help manage the standing water systems. For this plan, a lentic system included a lake, reservoir or wetland.

For the purpose of this plan, the following criteria are used to distinguish a lake system from other lentic systems:

1. Surface area of 10 acres (4 hectares) or more;

2. A maximum depth which is not less than 3.3 feet (1 meter); and

3. A minimum non-vegetated, contiguous open water area of 1,000 m2 or more.

The standing water forming a lake is not artificially created or increased in depth by obstructing a watercourse through the use of a dam or other man-made obstruction.

Shallow Lake - A shallow lake is a natural lake, characterized by standing water, where light penetrates to the bottom sediments to potentially support rooted plant growth throughout the water body. The lack of consistent thermal stratification during the summer and the tendency to exhibit alternative turbid and clear stable states are also common characteristics of this class of water.

Non-shallow Lake - A non-shallow lake is characterized by both a shallow shoreline area that may potentially support rooted plant growth and a deeper portion where sunlight does not penetrate to the bottom. These water bodies frequently stratify into distinct thermal layers during the summer.

Reservoir - Reservoirs are artificial (man-made) lentic systems. At a minimum, reservoirs must meet the first three conditions defined for a lake system. In addition, the following criteria are used to distinguish reservoirs from other lentic systems:

1. Existence of a control structure to actively regulate water levels and discharge; and

2. Generally shorter hydraulic residence time (generally less than 1 year) because of a larger drainage area to surface area ratio compared to a lake.

Wetland – A lentic system that is inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

Lotic systems – Lotic systems are generally flowing water systems. More specifically, they can be characterized by the presence of a unidirectional gravity induced current. As with lentic systems, there is substantial variability in the types of lotic systems. For this plan, a lotic system will include wadeable and non-wadeable streams or rivers.

Wadeable Stream or River - A wadeable stream or river is a lotic system which can generally be traversed on foot and exhibits a depth such that it can be “sampled” without the use of a boat during summer base flow conditions. These lotic systems can be further classified according to the temporal nature of their flow regime as either perennial or intermittent.

Non-Wadeable Stream or River - A non-wadeable stream or river is a lotic system which can not be traversed on foot and exhibits a depth such that “sampling” can only be conducted with the use of a boat during summer base flow conditions. These lotic systems are typically perennial.

Perennial Stream or River - These systems are generally considered those which have flowing water throughout most of the year during the open water season (generally > 90% of the time) during a typical year. These systems may periodically have no observable flow, but this generally occurs only during extreme drought. The stream bed seasonally intersects the water table. Groundwater is typically the source of base flow and runoff from rainfall is a supplemental source of water for stream flow. Perennial streams and rivers are generally 3rd order or greater.

Intermittent Stream or River - These systems are generally considered those which only periodically have flowing water during the open water season, during most years. These systems may not convey water at all, unless under periods of extremely high precipitation. The stream bed seasonally intersects the water table. Runoff from rainfall is a supplemental source of water for stream flow. These streams and rivers may be 2nd, 3rd or 4th order.

Ephemeral stream: An ephemeral stream has flowing water only for a short duration during spring runoff or after precipitation events in a typical year. Ephemeral stream beds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from spring runoff or rainfall is the primary source of water for stream flow. An ephemeral stream is generally 1st or 2nd order.

The purpose for developing regional nutrient criteria is to broadly protect water bodies from the enrichment of nutrients due to human effects, thereby protecting designated beneficial uses (e.g., recreation, drinking water supply, aquatic life). Nutrient concentrations within a water body fluctuate across some range in response to naturally occurring factors such as varying loads resulting from a range of precipitation and runoff conditions. The biological response will mirror this natural fluctuation. It is expected that water bodies in “ecological balance” can experience a range of nutrient concentrations (either daily, seasonally or annually), while still supporting beneficial uses. The regional nutrient criterion must also either implicitly or explicitly incorporate an acceptable range of concentrations bounding that criterion. The authors pointed out that finding locations which represent reference conditions can be challenging

A nutrient criterion is not intended to represent a single threshold from which beneficial use impairment can be determined. A criterion is a regionally-derived value based upon the classification of several or many similar water bodies. The process to ascertain beneficial use impairment is procedurally more rigorous in North Dakota. A common thread is that some of the stressor variables are the same as the core and supplemental indicators, which the State uses in beneficial use determination.

The nutrient criteria, once established, should be based on regional information intended to establish maximum acceptable nutrient levels for water bodies of different types across the State. The NDDH uses additional factors to list specific waters as impaired and place them on the Section 303(d) list of impaired waters needing TMDLs. For those water bodies which are impaired by nutrients, a specific total maximum daily load study (TMDL) must be performed to determine how a water body can be improved (i.e., nutrient levels reduced) to meet its beneficial uses. It should be recognized that there may be the need on a site specific basis (i.e., TMDL where the regional criteria are not sufficient, either too restrictive or not restrictive enough) to establish site specific criteria. In these cases, the site specific criteria would be adopted into the State's water quality standards prior to TMDL implementation.

It is recommended that there also be a process to evaluate and define a translator mechanism during the nutrient criteria development process. This translator mechanism would allow established nutrient criteria to be adjusted in order to address impaired water bodies. The translator mechanism would essentially be a method or process allowing the “conversion” from the numeric criteria developed for a region to a site specific criteria or goal.

A wide range of definitions have been used to describe reference condition. Ideally, a location selected to represent reference conditions reflects pristine conditions, devoid of any human influence. The following definitions are applicable to developing nutrient criteria:

Pristine - The biological condition exhibited by an aquatic resource in absence of human disturbance, as characterized by the types and abundance of species. The biological condition prior to Euro-American settlement is generally assumed to be “pristine”.

Minimally Impacted Conditions - The biological condition exhibited by an aquatic resource in the presence of minimal human disturbance, as characterized by the types and abundance of species. The biological condition following Euro-American settlement is generally assumed to be impacted. An analysis of the condition of the landscape within the contributing drainage area is typically characterized by minimal agricultural and urban influences. It is generally assumed that these conditions do not actually occur in North Dakota.

Least Impacted Condition - The biological condition exhibited by an aquatic resource characterized by the least amount of human disturbance available in a region for a water body class, as characterized by the types and abundance of species. The definition of least impacted conditions has the same meaning as “regional reference site” as defined within 2.b.(6) of 33-16-02.1-08 General Water Quality Standards of North Dakota Century Code. The biological condition following Euro-American settlement is generally assumed to be impacted. An analysis of the condition of the landscape within the contributing drainage area is typically characterized by the smallest amount of agricultural and urban influences. The least impacted condition may or may not be the minimally impacted condition.

Regional reference sites (2.b.(6) of 33-16-02.1-08 General Water Quality Standards of North Dakota Century Code) means sites or water bodies which are determined by the department to be representative of sites or water bodies of similar type (e.g.,hydrology and ecoregion) and are least impacted with respect to habitat, water quality, watershed land use, and riparian and biological condition. Regional reference sites are used to describe regional reference condition.

Using the least impacted reference condition to establish the nutrient criteria is recommended. Efforts are ongoing within the State to establish a suite of candidate reference sites and/or reaches, which can be used for multiple purposes, including the development of biological criteria, suspended and beded sediment (SABS) criteria, and nutrient criteria.

The EMAP Western Pilot Project effort identified 21 reference sites within a single Level III ecoregion for North Dakota. Further identification of reference sites are expected as part of a planned biological monitoring effort for the Red River of the North Basin, catalyzed by the International Red River Board (IRRB) (Fritz 2004).

Recommended definitions of reference conditions as developed for the IRRB are similar to those described above. The NDDH anticipates establishing a reference site network, with one of the purposes being the development of nutrient criteria. Important data to be collected at the reference sites include nutrient concentrations and cause-affect relationships for nutrient response.

Recommended Approaches for Nutrient Criteria Development

The preliminary recommendations are based upon the current understanding of data availability, the desired philosophy of the NDDH, and the need for a method tied to the biological response of the resource to excess nutrients. The approach ultimately selected and implemented may be different from that recommended, as additional information and data are collected and analyzed. The approach ultimately selected must result in nutrient criteria which are technically and scientifically defensible, can be reasonably implemented within state law and rule, and are acceptable to society. Preliminary North Dakota recommended approaches were provided for lotic and lentic systems separately, because of their differing response to excess nutrients.

The "EPA Approach"

At the time of the Plan preparation EPA had outlined three approaches from which States could develop their nutrient criteria. The first two approaches are based on descriptive statistics defining the 75th percentile concentration for reference sites, or the 25th percentile concentration of non-reference sites, to identify the numeric criterion for a parameter.

Regionally recommended nutrient criteria by the EPA were summarized in the Planalong with criteria based on previous North Dakota analyses. The use of statistical methods and the selection of percentile concentrations as an approach for determining nutrient criteria were not recommended for North Dakota, without some linkage to the stressor-response relationships. The author stated that some noteworthy drawbacks to a purely statistical based method include:

· Percentiles of data do not consider the environmental context of a resource. For instance, this method would apply the same numeric criterion to all perennial streams, regardless of size (e.g., Missouri River versus the Maple River);

· The "arbitrary" choice of a percentile rank may in fact establish a numeric criterion lower than the least impacted or minimally impacted conditions; and

· Use of a statistically based approach is not tied to the stressor-response relationship, and does not address the ability of a percentile-derived criterion to protect beneficial uses.

While the EPA technical guidance manuals provide excellent information, they do not specifically relate the recommended approach to the beneficial use. These uses vary from state to state. North Dakota recognizes four beneficial uses for water bodies. This plan for developing criteria is based upon establishing nutrient criteria protecting the most "stringent" beneficial use, which in most cases will be aquatic life. The recommended approaches assume that criteria developed to be protective aquatic life are also protective of all other beneficial uses (e.g., drinking water, supply, recreation).

Proposed Approach for Lentic Systems

As previously illustrated Figure 19 presents a conceptual ecological model showing the response of lentic systems to excess nutrient concentrations. This model suggests potential causative ecological endpoints (i.e., response variables) include the frequency and severity of algal blooms, the concentrations of chlorophyll-*a*, some measure of water clarity, dissolved oxygen concentrations and Trophic Status Index (TSI) score. The conceptual model further suggests that the applicable causative variables are those that limit primary production.

An initial evaluation of the following causative variables as potential nutrient criterion was recommended:

· Total phosphorus
· Orthophosphate or dissolved phosphorus
· Total nitrogen
· Nitrate plus nitrite nitrogen
· Nitrogen to phosphorus ratio
· Ammonia nitrogen
· Total Kjeldhal nitrogen
· Total organic carbon
· Dissolved organic carbon
· Total dissolved solids

The use of an indicator like the Trophic Status Index (TSI), which combined several trophic characteristics, should also be considered. Statistical analysis of the response and causative variables will be used to select the final parameters. Those parameters which have the strongest predictive relationship with the ecological endpoints will be the most useful to establish as criteria. Confounding factors such as salinity concentrations should be incorporated into the analysis to determine if modifications to the lentic system classification method are needed.

Expectations are that a detailed analysis of the various forms of nitrogen is not needed. Rather, the response to total nitrogen or inorganic nitrogen may be sufficient to describe the response of the ecological system.

Use of the open water season is recommended as the temporal scale for the development of nutrient criteria in lentic systems. The specific temporal scale over which nutrient criteria are applied should be confirmed during the course of nutrient criteria development.

Use of the average water column concentration taken in the deepest (often middle) portion of a lake or reservoir is recommended as the spatial scale for the nutrient criteria. An alternative approach is expressing the criteria as a value representative of the surface mixed layer. Horizontal variation in larger lakes and reservoirs is also likely. Therefore, for larger lakes and reservoirs the nutrient criteria may need to be established longitudinally or for specific embayments.

One important guiding principle is that the nutrient criteria should ideally be based on a definable cause – effect relationship. The recommended approach for developing nutrient criteria for lakes and reservoirs is based on establishing regionally defensible cause (i.e., load) – effect (i.e., eutrophication response) relationships. These relationships should incorporate the important causative and response variables and ideally incorporate the frequency and duration of the conditions causing beneficial use impairment (e.g., algal bloom frequency and duration). The approach requires establishing a threshold defining an "algal bloom" correlated to the impairment in aquatic life (or another beneficial use such as recreation). Figure 20 presents the recommended method for developing the nutrient criteria for lakes and reservoirs. Expectations are that the method would be applied using appropriate spatial and temporal scales. The approach is based upon developing and applying regional eutrophication load-response models, tied to dissolved oxygen levels and the impact to aquatic life. The approach depends upon the ability of the NDDH to establish eco-region appropriate lake and reservoir trophic goals. These goals may be established based upon reference conditions, or the desired trophic state using best professional judgment. The approach essentially consists of using models to "back-calculate" regional nutrient loads based upon the established goals. The regional model will need to be applied on a geographically representative sample of lakes and reservoirs to establish the regional load. The regional load will then require translation into concentration or yield for some distance upstream, while considering the appropriate runoff conditions (e.g.,average runoff year). The recommended criteria developed using this technique needs to be compared to the method developed for lotic systems, with the most stringent applied. An alternative method may be used if the ability to establish goals using the desired trophic state or data limitations prohibits the use of the recommended method. The alternative approach is the use of descriptive statistics for the concentrations of the causal variables correlated to the response condition leading to beneficial use impairment. This approach is is the recommended approach for lotic systems.

According to the Plan a significant issue for North Dakota was the lack of monitoring data relating to lakes which reflects reference conditions. The EPA is undertaking a National Lake Survey utilizing a probabilistic site selection approach, so it is possible that this gap may be addressed through pending efforts. However, four groups of lentic systems are proposed for North Dakota's nutrient criteria, so any data reflecting expected condition may only apply to certain types of lentic systems (e.g., shallow lake). Another data gap is the lack of a Trophic Status Index (TSI) model specific to the state. Carlson's TSI model is currently utilized by the NDDH to assess eutrophication in lentic systems. A major drawback to using Carlson's TSI is that it was developed for lakes that are primarily phosphorus limited. Because most North Dakota lakes and reservoirs have an abundance of phosphorus, this model should be modified or otherwise adapted for conditions in North Dakota to provide a tool to establish causative variable criteria from endpoints such as Secchi depth transparency.

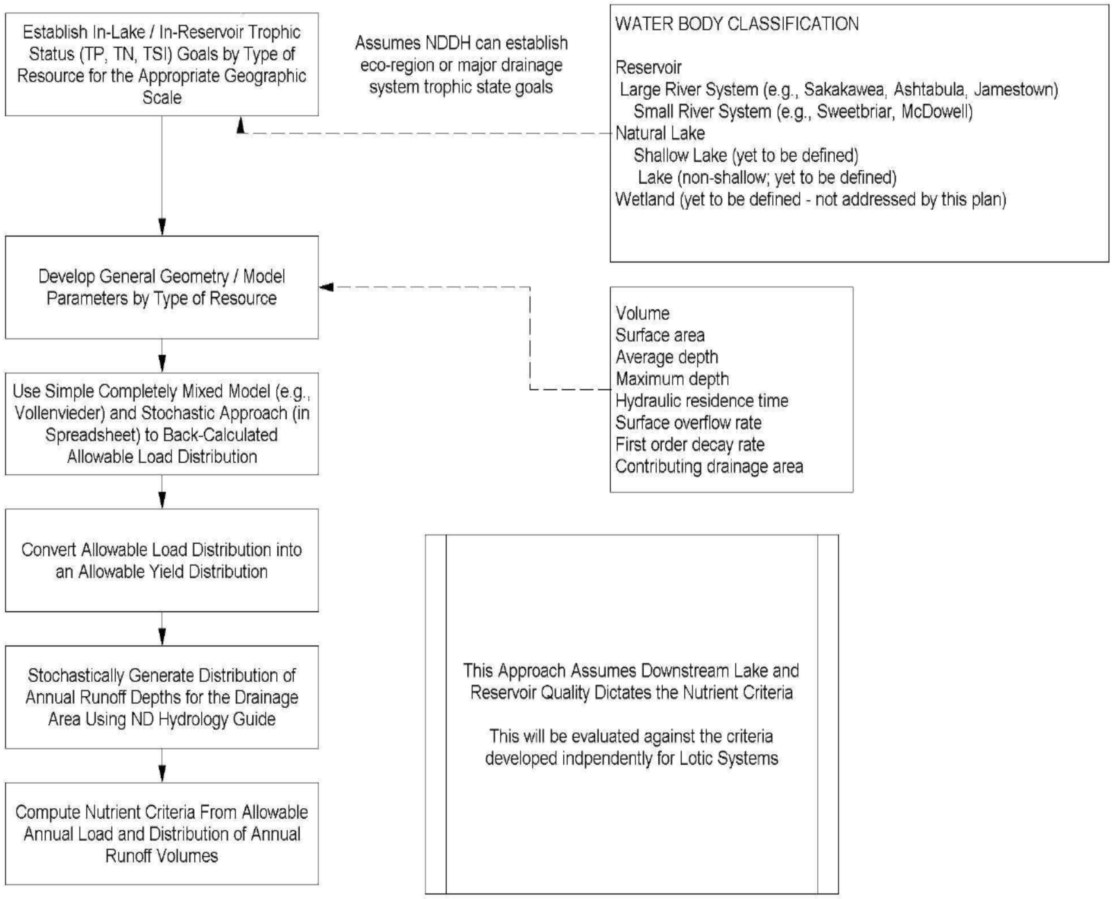


Figure 20. Conceptual approach for development of lentic NNC in North Dakota. Source: (Deutschman 2007).

An additional challenge is how to convert a regionally defined loads into nutrient concentrations in the streams and rivers entering the lake or reservoir and how to modify the concentrations moving upstream in the drainage area. Much of the available data is more than 5 years old, and therefore has been subject to varying and changing data collection and analytical techniques. While the National Lakes Survey will assess lakes statewide, only a single measurement will be collected from each lake. The authors recommended that additional funding should be used to sample the National Lakes Survey lakes additional times, sufficient to develop cause – affect relationships.
The authors concluded that considerable paired total phosphorus, total nitrogen and chlorophyll-*a* data are available within the NDDH database for lentic systems, with the exception of Level III ecoregion 48. However, no chlorophyll-a data were available within the remaining datasets for lentic systems. The NDDH data should initially be used to evaluate potential cause – affect relationships.

Proposed Approach for Lotic Systems

Figure 21 presents a conceptual ecological model showing the response of lotic systems to excess nutrient concentrations. This model suggests potential ecological endpoints (i.e., response variables) include the frequency and severity of algal blooms, the concentrations of chlorophyll-*a*, and various metrics associated with the aquatic community (e.g., fish, macroinvertebrates, periphyton). The conceptual model further suggested that the applicable causative variables are those that limit primary production.

Several ecological indicators are used by the NDDH in assessing whether a stream or river attains the beneficial use for aquatic life. The ecological endpoints are also our response "targets" for the nutrient criteria. These ecological endpoints include the macroinvertbrate assemblage, the types and abundance of fish, the algae and diatom assemblages and plant biomass as characterized by macrophyte density and algal biomass (epiphyton, periphyton, phytoplankton). The pigment chlorophyll-a is typically used to quantify algal biomass. Excess nutrients, through biological processes, can also affect the magnitude of and daily variation in the amount of dissolved oxygen.

Unless light (or some other physical or chemical characteristic) does not limit primary productivity, an excess of nutrients within perennial rivers and streams leads to an increase in the biomass of epiphytic algae. The increase in epiphytic algae is generally less in turbid lotic systems compared to clear water systems. The authors pointed out that current understanding of the response to excess nutrients within intermittent streams is less clear and therefore, will be more challenging to describe.

Ecological endpoints typically include some characteristic of the ecological community, population distribution or dynamic, or the abundance and distribution of specific organisms. While there are substantial efforts to characterize ecological endpoints, the variability within the available data presently makes it uncertain as to which metric will best reflect the response of a stream to human impacts and changes in nutrients. Various macroinvertebrate endpoints or metrics are recommended as the response variables for excess nutrients within rivers and streams (based upon a conceptual model). These metrics may include total taxa richness, EPT taxa, the Hilsenhoff Biotic Index (HBI), and the Index of Biotic Integrity (IBI). Algal biomass, the concentration of dissolved oxygen, and pH may also be evaluated as potential response variables.

Many efforts have been implemented to collect data on response variables in lotic systems. Similarly, data for numerous causative variables, including nutrients, have been collected over time. Cursory evaluations of various project data suggest that both total phosphorus and total nitrogen, respectively, can be related to changes in macroinvertebrate composition. Lotic systems are known to respond to increasing concentrations of various nutrients including nitrogen, phosphorus; the metabolic building block carbon (e.g., CO_2); and light. The nature of the response may be linear or nonlinear.An initial evaluation of the following causative variables as potential nutrient criterion is recommended:

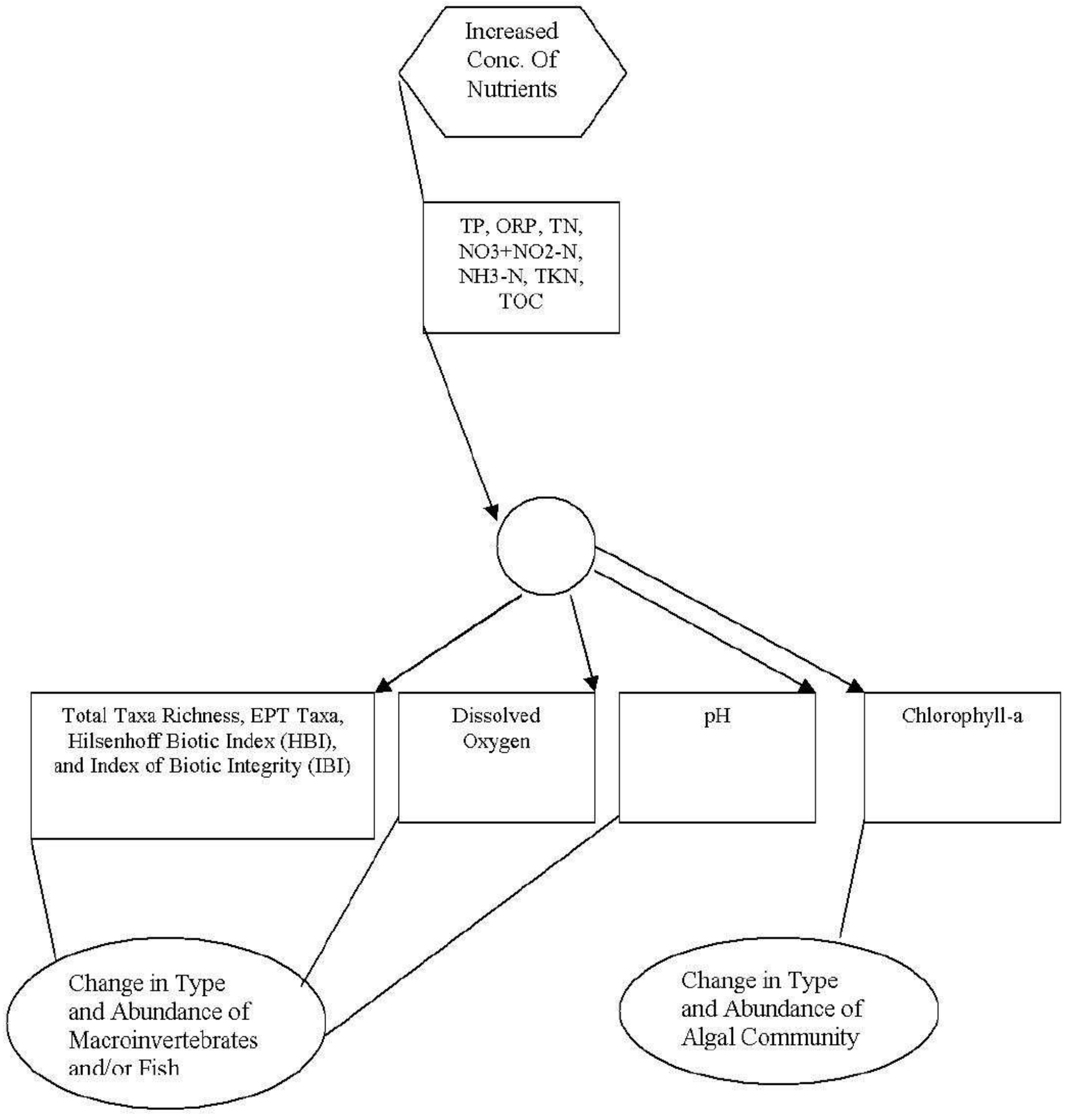


Figure 21. Conceptual Model that will be used to guide data collection, analysis and development of NNC in lotic systems in North Dakota (*from CADDIS*). Source: (Deutschman 2007).

· Total phosphorus
· Orthophosphate or dissolved
phosphorus
· Total nitrogen
· Nitrate plus nitrite nitrogen
· Ammonia nitrogen
· Total Kjeldhal nitrogen
· Dissolved organic carbon
· Total organic carbon

Statistical analysis of the response and causative variables based upon the conceptual model will be used to select the final parameters. Those parameters which have the strongest predictive relationship with the ecological endpoints will be the most useful to establish as criteria. Expectations are that a detailed analysis of the various forms of nitrogen is unneeded. Rather, the response to total nitrogen or inorganic nitrogen is sufficient to describe the response of the ecological system.

Defining the temporal scale for the nutrient criteria can help guide future data collection efforts. There are several options for defining the temporal scale for lotic system nutrient criteria, including daily, weekly, monthly, seasonal, and annual (load based). The temporal scale will depend in large part on whether the lotic system is perennial or intermittent. The magnitude of nutrient concentrations during base flow will differ inherently from those occurring storm or event flows. When determining the temporal scale of the nutrient criteria, the frequency of in-stream concentrations and the duration over which the concentrations occur should be considered.

The nutrient criteria may need to consider a weekly or even shorter temporal scale if dissolved oxygen or pH is used as the response variable(s). Excess nutrients can lead to increased epiphytic algae and an increase in the amplitude of the diel variation in dissolved oxygen. Low dissolved oxygen during the early morning in some streams and rivers can lead to aquatic life impairment.

The author of the Plan expected that nutrient criteria would be developed by Level III ecoregion and major drainage basin and separately for perennial and intermittent streams and rivers. Further separation of the large non-wadable river systems from other non-wadeable perennial streams was likely.

Recommended Criteria Development Method

The use of a ***reference approach*** to establish the nutrient criteria for lentic systems is recommended. The recommended approach consists of:

1. Refining the conceptual model (Figure 18) for each lotic system of interest (i.e., intermittent and perennial wadeable and non-wadeable streams) to reasonably ensure the identification of the stressor and response variables, as well as the causative mechanism for the response to excess nutrients and the ecological endpoints;

2. Using existing or newly collected biological data (e.g., fish population characteristics, macroinvertebrate abundance / diversity, periphyton abundance /diversity) to test / validate the ecological endpoints described by the conceptual model. Use the reference sites to establish the desired conditions for the ecological endpoints;

3. Subdivide the resource according to the appropriate water body classification for lotic systems;

4. Use landscape scale features to identify candidate reference sites or reaches, stratified by Level III ecoregion and major drainage basin, which represent least impacted conditions and the nutrient condition gradient. Previous work completed in the Sheyenne River Basin suggests that less than 60% of the upstream land use in agriculture is necessary to define a site or reach as "reference." Additional analysis will be needed to confirm this early conclusion;

5. Evaluate the ability to use various surrogate response variables across the nutrient gradient, for the ecological endpoints of interest (e.g., relate pH and dissolved oxygen dynamics to the ecological response endpoints);

6. Use existing or newly collected chemical concentration data, specifically for the causative variables, and evaluate potential statistically significant relationships between the causative variable (stressor) and the various fish, macroinvertebrate, and periphyton ecological endpoints (i.e., response variables);

7. Determine the ecological endpoint(s) which best supports criteria development; and

8. Establish nutrient criteria for causative variables based on thresholds established for the ecological endpoints;

Two additional steps may be completed, should the recommended approach prove challenging:

9. Compute descriptive statistics (including the 85th percentile values) for the causative variables at various temporal scales. In the absence of statistically significant relationships between the causative and response variables, anecdotally identify the relationship between the descriptive statistics for the The reference approach takes into account a range of disturbances defined as least impacted and, therefore, a range in the stressor-response relationship.

10. In the absence of a definable relationship, use the 85th percentile concentration for the reference condition.

A potential issue relates to situations when lotic systems discharge into lentic systems. The criteria set forth to protect the beneficial uses in a particular river or stream reach may not necessarily also be protective for conditions in downstream resources (i.e., a lake or reservoir). The role of a translator mechanism is important in this context. This would potentially allow for adjustments (i.e. more stringent) to nutrient criteria in lentic systems such that it would "agree" with the criteria established for lotic systems, thus protecting the beneficial uses in both systems.

A second substantive issue identified in the plan was the availability of fish, macroinvertebrate and periphyton data needed to develop the various response variable metrics. These data need to be specific to reference sites or reaches and across nutrient gradients within the geographic region of interest. Based upon a cursory review of the available macroinvertebrate data, additional data will need to be collected for reference reaches.

Large non-wadeable river systems present unique technical challenges requiring a set of causative variables which may be different than for smaller wadeable perennial systems. Large river system ecology can differ considerably from smaller systems. These challenges include how reference conditions are defined, sampling challenges and a generally greater importance of allocthanous than autocthanous energy inputs. The need to collaborate with other state, provincial, and federal agencies will also be a challenge.

The authors provided data on the the availability of paired nutrient concentration data (i.e., causal variable) and differing potential response variables, by monitoring effort / program and ecoregion for lotic and lentic systems. They found that there were few paired total phosphorus, total nitrogen and chlorophyll-*a* data are available within the NDDH database for lotic systems.

Bsed on the findings and recommendations of the Plan, the NDHH prioritized their waterbodies and attempted to develop NNC for lakes and reservoirs first (Deutschman 2007; Houston Engineering 2008)

Following publication of the Nutrient Criteria Plan the State of North Dakota commissioned a follow-up Plan for lakes and reservoirs that was conducted by Houston Engineering, Inc. (HEI) which was completed in 2008 (Houston Engineering 2008). A verbatim summary of their major findings are listed below.

The authors evaluated several metrics for use in classifying lentic systems in North Dakota. The selected metric was developed internally to HEI and were: (surface area / drainage area) * volume = acre-feet. The metric used in this nutrient criteria development process was found to be the most suitable, for several reasons.

• The modeling output displayed a difference in the median results for the model response variables (in-lake TP concentrations, Secchi depths, and chlorophyll-*a* concentrations) between the four groups that were established for lakes and reservoirs and the confidence intervals about the median values did not overlap. Box-plot analysis of modeling results did display some overlap of the interquartile ranges between the groups. This is expected, however, because of the overlap in the range of the physical characteristics for the groups that underpinned the computation of the metric.

• There was an observed inverse relationship between in-lake TP concentrations water body class. In-lake TP concentration decreased with an increase in class value. It was expected that this classification system will work for the other planning regions in North Dakota. The metric is based upon descriptive water body physical characteristics and the model tool is unbiased with regard to area where descriptive data is collected.The authors also conducted modeling studies to evaluate the potential response of various levels of nutrient loading on lake trophic status and response. They felt that their study modeling results were determined to be “reasonable” for the following reasons:

• The modeling results for the water bodies appear to reflect, and compare with, regional data that has been measured by the USGS and the State in the URRB regional pilot study area for water yield and in-lake TP concentrations.

• There was an observed direct relationship between the amount of cultivated agriculture and watershed yield where, as the amount of cultivated agricultural land use increased, the predicted unit runoff and TP unit load increased.

Although the model they used was determined to be reasonable, it was discovered that there were limitations and issues with regard to the modeling approach that was selected.

• Strong confidence exists for estimations of lentic system TP concentrations using the CNET model. However, a limitation is that the CNET model is a “beta” version and equations that underlie the calculation of chlorophyll-a concentrations and Secchi depths need refinement. This limitation was discovered upon a side by - side comparison with the BATHTUB model (the precursor to CNET).

• The evaluation of landlocked lakes was not included within this study. Water balance issues were encountered when executing the model. Instabilities occurred in the model when watershed inflows were less than evaporation (which is typical for landlocked lakes).

• The robustness of the model and confidence in the classification system can be greatly enhanced using an improved dataset. Many water bodies did not have physical attribute or morphometric data (i.e., volume and drainage area). This led to low predictive power of the regression equations used for estimating these attributes for other water bodies. There also was a lack of water quality data available for water bodies, which constrained the model calibration and verification processes. The model results were calibrated through evaluation of data for water bodies in aggregate rather than by lake and reservoir class.

• Water yields were found to be reasonably consistent with USGS data. However, an assumption to acknowledge in the CNET model is that watershed runoff includes all delivered water (such as base flow), and the model approach did not account for regional abstractions (such as wetlands). Further, it is important to acknowledge that although the model was executed on a daily time step, watershed runoff results should only be examined in aggregate (annually).

• Ideally, total phosphorus yields would be tied back to Clean Water Act Section 319 watershed assessment and implementation projects or TMDL development projects in North Dakota. This should be considered during model refinement but these data were not available at the time of this study. From review of the model results, it was found that the TP yields were generally lower than what would be expected based on professional judgment.

The authors concluded that the results of their regional pilot study supported the proposed classification system (Houston Engineering 2008). However, they acknowledged that the results suggest (based on median annual TP concentrations) that lakes in “Class I”, that is smaller lakes, are substantially eutrophic even under land use conditions of minimal agricultural cultivation, while lakes in “Class IV”, which are the larger lakes, maintain a mesotrophic conditions even when the landscape is in full agricultural production. Furthermore, the results from “agricultural land use condition adjustment” suggested that reservoirs do not ever obtain a condition better than a eutrophic state. Data collected to implement class-specific model calibrations would help address this limitation. The authors of the lake/reservoir Nutrient Criteria Development Plan concluded that models are useful tools to help answer questions or use in predicting past or future conditions. For developing nutrient criteria for North Dakota’s lentic systems, the absence of sufficient data about reference water bodies across the State supports the need for a regional model used to develop criteria (Houston Engineering 2008).

Ohio

Currently, the State of Ohio lacks NNC (Ohio Environmental Protection Agency 2010b). However, the Ohio EPA (OHEPA) does have an approved Nutrient Criteria Development Plan (Ohio Environmental Protection Agency 2006; Ohio River Valley Water Sanitation Commission 2002). The official beneficial designated uses of the State of Ohio are listed in Table 166. There are 7 levels of designated uses that pertain to aquatic life use. The following information is extracted from the Ohio Nutrient Criteria Development Plan (Ohio Environmental Protection Agency 2006; Ohio River Valley Water Sanitation Commission 2002).

A synthesis of the Ohio Nutrient Criteria Development Plan is presented below (Ohio Environmental Protection Agency 2006). The Ohio Plan is relatively brief and written in outline format. This is reflected in its title “*Outline of Methodology to Establish Scientifically Defensible Nutrient Water Quality Standards”*. It begins by providing a preface of the EPA’s position and guidance on NNC development at the time of the drafting of the Ohio Plan. The OHEPA notes that a recent memo authored by Geoff Grubb memo dated (December 4, 2001) explained USEPA’s preference that States adopt nutrient standards by 2004 (Grubbs 2001b). They also noted that because of the process for developing standards may differ significantly between states, EPA stated that some States may not have to adopt standards by 2004 as long as evaluations of progress show that standards development is well underway and the State’s efforts are consistent with its plan for developing and adopting nutrient criteria. If however EPA felt that a State’s plan is not appropriate or if a State has not adopted standards by 2004, the EPA may exercise their authority under section 303(c)(4)(B) of the Clean Water Act and find that promulgation of nutrient criteria for the State is necessary to meet the requirements of the Clean Water Act.

Table 166. Summary of Ohio's beneficial use designations. From: (Ohio Environmental Protection Agency 2010b).

Summary of Ohio's Beneficial Use Designations (OAC 3745-1-07) - April 2004

Beneficial Use Designation	Key Attributes, or why a water would be designated the beneficial use	Practical Impacts (comparisions to Warmwater Habitat baseline)
Designations for the protection of aquatic life		
Coldwater Habitat 91 waterbodies	native cold water or cool water species; put-and-take trout stocking	more stringent ammonia, cyanide, dissolved oxygen, phenol, pH, silver, and temperature criteria; may result in additional wastewater treatment requirements
Exceptional Warmwater Habitat 386 waterbodies	unique and diverse assemblage of fish and invertebrates	more stringent temperature, dissolved oxygen, and ammonia criteria; may result in additional wastewater treatment requirements
Seasonal Salmonid Habitat 19 waterbodies	supports lake run steelhead trout fisheries	more stringent ammonia, cyanide, dissolved oxygen, phenol, pH, silver, and temperature; slightly more restrictive chlorine disinfection practices
Warmwater Habitat 2,930 waterbodies	typical assemblages of fish and invertebrates, similar to least impacted reference conditions	baseline regulatory requirements in line with Clean Water Act "fishable goal" expectations
Limited Warmwater Habitat 72 waterbodies	temporary designations based on 1978 WQS and not subjected to use attainability analysis; being phased out	exempt from TDS criteria and may also be exempt from pH, iron and zinc criteria as well
Modified Warmwater Habitat 143 waterbodies	tolerant assemblages of fish and macro-invertebrates, but otherwise similar to WWH; irretrievable condition precludes complete recovery to reference condition	less restrictive requirements for dissolved oxygen and ammonia; may result in less restrictive wastewater treatment requirements
Limited Resource Waters 163 waterbodies	fish and macroinvertebrates severely limited by physical habitat or other irretrievable condition	less restrictive aquatic life criteria for majority of pollutants; may result in less restrictive wastewater treatment requirements
Designations for the protection of recreational activities		
Bathing Waters	bathing beach with lifeguards/bath house; greatest potential exposure to bacteria	lowest risk of swimmer's illness after exposure; greater disinfection of wastewater
Primary Contact Recreation	water depth allows full body immersion; high proximity to residential areas; intermediate potential exposure to bacteria	intermediate risk of swimmer's illness after exposure; baseline level of disinfection
Secondary Contact Recreation	water depth precludes full body immersion; low proximity to residential areas; lowest potential exposure to bacteria	greatest risk of swimmer's illness after exposure; slightly less disinfection of wastewater
Designations for the protection of water supplies		
Public Water Supply	all waters within 500 yards of all public water supply surface water intakes, all publicly owned lakes and reservoirs, all privately owned lakes and reservoirs used as a drinking water source, all emergency water supplies	maintain or improve potable water supplies, reduce water treatment costs; upstream dischargers may face more stringent limits in order to meet PWS criteria at point of water withdrawal
Agricultural Water Supply	water used, or potentially used, for livestock watering and/or irrigation	limited impact; as a practical matter other standards are generally protective of this use, except for a limited number of heavy metals in unique situations
Industrial Water Supply	water used for industrial purposes	no impact; no criteria contained in rule; criteria may be established on case specific basis but as a practical matter this has never been needed because other standards are protective of this use.

The OHEPA pointed out should the EPA promulgate standards, the criteria promulgated would be based on EPA's published recommendations derived using a reference site approach. For the two Ohio level III ecoregions the target values for TP would be 0.0625 mg/l and 0.0700 mg/l, respectively, and would be applied to all streams regardless of drainage area or designated aquatic life use. In contrast, target values identified by OHEPA analyses of Ohio EPA's databases suggested that a tiered approach based on stream size and designated aquatic life use would be equally protective while offering less stringent criteria in most circumstances. For example, they cite the TP targets identified by OHEPA for a Warmwater Habitat (WWH) designated headwater stream in the same area is 0.07 mg/l, approximately the same as the level III target, but that for a small river it is 0.17 mg/l, an order of magnitude difference. OHEPA also noted that states developing their own standards would have the advantage of added flexibility in how standards are applied toward making 303d listing decisions, such that a measured nutrient concentration exceeding the numeric target would not necessarily demonstrate impairment. For this to occur, they quoted a portion the Geoff Grubbs memo that stated , "States should quantify response variables to know what it is they're trying to attain." Those response variables can be a combination of factors including chlorophyll-*a*, turbidity, and, in the case of Ohio, biological criteria. The task was to scientifically demonstrate the relationship between the causal elements and the response variables. Because the Ohio water quality "ECOS" databases lack information on chlorophyll-a, a cause-and-effect relationship between nutrients and biological criteria can only be inferred. However, they pointed out that studies in Ohio streams showed there was strong evidence to support this relationship between nutrients and other biological indicators (Miltner and Rankin 1998).

(Miltner and Rankin 1998) tested the relationship between primary nutrients and biotic integrity in rivers and streams using biological, physical and chemical information collected since 1982 from similar locations in streams throughout Ohio using standards procedures. They found that there was a negative correlation between nutrients, especially total phosphorus, and biotic integrity. The deleterious effect of increasing nutrient concentration on fish communities in low order streams was detectable when nutrient concentrations exceeded background conditions (TN and TP > 0.61 mg/L and 0.06 mg/L respectively.

The OHEPA provided multiple literature citations demonstrating a direct positive relationship between nutrient concentration and periphytic biomass, as measured by chlorophyll-*a*, in temperate, boreal and arctic streams (Biggs 2000a; Dodds et al. 2002). However, they pointed out that at that time few studies had examined the effects of that relationship on higher trophic levels or indirect effects on water quality. OHEPA had demonstrated secondary effects of excessive algal abundance on diel dissolved oxygen concentrations and higher trophic levels by measuring dissolved oxygen hourly with synoptically collected biological samples. Again, however, chlorophyll-*a* had not been measured concurrently. OHEPA stated that addressing this information gap would give a definitive, scientifically defensible basis for developing nutrient water quality standards using response variables as indicators of impairment.

The OHEPA stated that the objective of the Plan was to establish a link between average seasonal nutrient concentration, algal biomass during the late summer or early fall low-flow period as measured by chlorophyll-*a*, and the health of higher trophic levels as measured by various benthic and fish community indices. This study would also consider the variation in nutrient effects explained by flow and habitat (solar irradiance being one aspect of habitat). The anticipated outcome of the study will be a data set that has the following variables: Multimetric scores (e.g. IBI, ICI, QHEI) and associated information, including riparian width, as a measure of habitat quality, hourly dissolved oxygen concentrations, routine water quality parameters (dissolved oxygen, pH, conductivity, temperature, chemical oxygen demand, alkalinity, chloride, nitrate-nitrite nitrogen, total Kjeldahl nitrogen (TKN), ammonia nitrogen, low-level detection of total phosphorus, dissolved phosphorus, total non-filtrable residue, and total filtrable residue), measures of chlorophyll-*a* from the water column and periphyton, and a qualitative measure of the percent of daylight hours where direct sunlight can reach the wetted channel. See Table 167 for a matrix of existing parameters and parameters to be collected during the proposed study. Total inorganic nitrogen (TIN) would be expressed as the sum of nitrate, nitrite and ammonia nitrogen.

Intra-seasonal variation would be minimized by collecting chlorophyll-*a* samples no sooner than two weeks following any significant rainfall or high flow event. Spatial variation within a stream reach would be minimized by collecting periphyton from cobble-sized substrates in riffles. Methodology for collecting periphyton samples and determining chlorophyll-*a* concentration will follow standardized protocol documented in various studies. All of the previous studies followed the same general methodology as described in the Plan. Basically the investigator would scrape a known area (~ 2.84 cm2 for this study) of periphyton from each of several rocks (fifteen rocks for this study) within a representative reach of stream, typically a riffle-run complex, filter the sample on 1.2 micron glass fiber filters in the field (filters can then be frozen on dry ice for no more than 30 days), and extract the chlorophyll-*a* using a known quantity (10-15 ml) of either 95 percent ethanol or 90 percent acetone. The amount of chlorophyll-*a* in a sample would be determined using EPA Method 445. Initial calibration of the fluorometer would be conducted using a know standard. Sampling sites would be chosen within river basins and pre-scheduled for surveys to support Total Maximum Daily Load (TMDL) development. Sites would reflect a range of stream sizes, habitat quality and anthropogenic enrichment, and would optimally be located on streams with USGS gauging stations. Samples would be collected once during the late summer or early fall season as that is when stream flows in Ohio are lowest and temperatures highest, hence any secondary effects from excessive algal abundance (e.g., wide D.O. swings) are likely to be most pronounced. Because sampling will be largely confined to pre-scheduled TMDL basins, the number of sites sampled in any given basin would necessarily be constrained by the basin size, heterogeneity (or lack thereof), and the need to avoid introducing autocorrelation to the data set from sampling too heavily in any one basin.

Table 167. Matrix of causal and response variables for nutrient criteria for rivers and streams in Ohio. Source: (Ohio Environmental Protection Agency 2006).

Waterbody Type	Available Data	Data Set Information	Causal variables			Response variables				
			NOx, NH_3, TKN	TP	Habitat*	Turbidity (as TSS for existing data)	Hourly D.O.	Chl_a	Fish	Macro-invert-ebrates
Rivers and Streams	Existing data: the number of sites where all parameters were collected is indicated for each.	State-wide for streams and rivers, period of coverage 1981-1998. Data from 1999 - 2001 yet to be linked in the database. Yes, since 1999.	1,788	1,788	1,788	1,788	<100	0	1,788	1,448
	Planned data collection: Four field seasons, the total number of sites and samples per site for each parameter is indicated; see Table 2 for a breakdown of sampling sites by stream size.		20 -25 sites, 4- 6 samples per site	20 -25 sites, 4-6 samples per site	20 - 25 sites, 1 sample per site	20 -25 sites, 4- 6 samples per site	20 - 25 sites, One 48hr sample per site (contingent on stream size - physical placement)	20 - 25 sites, 1water column and 1 periphyton sample per site	20 - 25 sites, 1 sample per site	20 - 25 sites, 1 sample per site
Lakes and Reservoirs	Ohio EPA to adopt the Ambient Water Quality Criteria Recommendations for Lakes and Reservoirs applicable to Ohio's ecoregions.									

Nutrient Criteria for Lakes

As an interim measure, OHEPA planned to adopt the Ambient Water Quality Criteria recommendations for Lakes and Reservoirs (USEPA) applicable to Ohio's ecoregions. OHEPA was in the initial stages of formulating a Lakes Monitoring Program. As data became available through in-house sampling, or from other credible data sources, nutrient criteria for lakes would be refined to suite particular classes of lakes. The OHEPA was developing a lake definition and uses to be assigned to lakes. The new uses would replace the Exceptional Warmwater Habitat Use which was previously assigned to all lakes as a default use category. The OHEPA had not come to a decision about a new definition or uses, as of June 21, 2006. The existing definitions used are listed below.

"Lake" was defined as a waterbody of the state that is a natural or constructed, permanent pooled or impounded area connected to other surface waters. The term excludes naturally impounded areas less than 5 acres (2 hectares) in size that are predominantly vegetated with rooted or non-rooted aquatic macrophytes. The lake boundary is inclusive of any associated wetlands which included fringing wetlands, lacustrine fens, bogs, other wetlands, or areas with submersed and floating aquatic macrophytes, that are contiguous with open water.

"Lakes" are classified as follows:

(1) Natural lakes - Permanent pooled waters of the state that formed without human intervention. These lakes included, and are not limited to kettle lakes formed from glacial outwash.

(2) Constructed lakes - Permanent impounded waters of the state that were formed by human intervention. These lakes include, and are not limited to dammed streams, up-ground reservoirs, quarry ponds, and post-construction sediment ponds.

The possible general lake uses included:

1) Public Drinking Water Supply
2) Fish Consumption
3) Body Contact
4) Agricultural/Wildlife Water Supply Water Storage Capacity
5) Aesthetics - free from nuisance conditions, TSS, etc.
6) General Aquatic Life Use (based on trophic state)

These uses would apply to all lakes whether sampled or not. The lake definition and lake uses would be finalized and outlined in a white paper that OHEPA would be completed by the end of 2006.

If the proposed study is not carried out, the back-up by OHEPA would be to adopt USEPA's recommended criteria based on ecoregional reference ranges. At the time of the publication of the their Plan, Ohio was on track to develop nutrient water quality criteria for headwaters and wadeable streams. For larger rivers (i.e., those > 200 mi^2 in drainage area) a separate large river study may be necessary to accrue sufficient sample size within a time-span where all data are comparable and valid.

In order to accomplish this OHEPA planned on partnering with USGS to augment data collection in 2007, as well as expand large river collections to outside of the priority TMDL basins in 2007. OHEPA had, however, been using biocriteria to identify segments of large rivers impaired by nutrients, and assigning permit limits for nutrients based on TMDLs in those affected waterbodies, and so had a de facto fall-back method. The methodology for how reference-range based nutrient criteria were defined ad hoc in these cases was described in a separate document attached to the Plan entitled the "*Legal and Technical Basis for Nutrient Target Values Used in TMDL Projects*". Reference ranges for nutrients had been previously defined for Ohio rivers and streams and have been described in Ohio TMDL guidance documents. The proposed study, piloted in 2003, began with full field seasons in 2004 and 2005. Based on the pace of sampling in 2004 and 2005, OHEPA concluded that additional time would be needed to accrue sufficient data for larger rivers. The agency proposed three levels of stratification by stream size including: 1) headwaters, 2) wadeable streams, and 3) rivers with drainage areas greater than or equal to 200 mi2 (hereafter known as larger rivers). Results from 2004 and 2005 suggested that headwaters and wadeable streams function similarly with respect to nutrient enrichment; therefore, OHEPA recommended collapsing these two categories into one stratum, hereafter referred to as "smaller streams". Pending further results in 2006 and 2007, ecoregions OHEPA stated that they may add more levels of stratification for smaller streams (headwaters and wadeable). The geographic scope (i.e., stratified by ecoregion or simply stream size) of nutrient criteria would depend on stratification levels. At the time of the release of the Plan, OHEPA expected to generate statewide criteria stratified by stream size. After additional data collection supports the theory that ecoregions explain a significant proportion of variation in the data, the OHEPA will consider additional criteria stratification by ecoregion.

The ultimate objective of these studies were to establish a link between average seasonal nutrient concentration (either TP, TN, or both), algal biomass as measured by chlorophyll a, habitat quality, and the health of higher trophic levels as measured by multimetric community (e.g. IBI and ICI) scores in rivers and streams. Application of the ensuing results into a water quality rule package would take the form of a hierarchical decision tree as conceptualized in Figure 22. Entry into the decision tree occurred at two points: 1) one assumes the status of aquatic life use attainment is known through biological monitoring, or 2) one assumes some data for causal and response variables are available. Entry at either point can result in a waterbody being listed as impaired by nutrients if certain conditions are met; however, the later entry point carried a high error rate for falsely concluding that a waterbody is impaired when it is not. OHEPA stated that the more variation that can be explained between causal and response variables, the lower this error rate would be. Entry at either point carries a low chance of error in the opposite direction, that is, of falsely concluding that a waterbody is neither impaired nor threatened when it is.

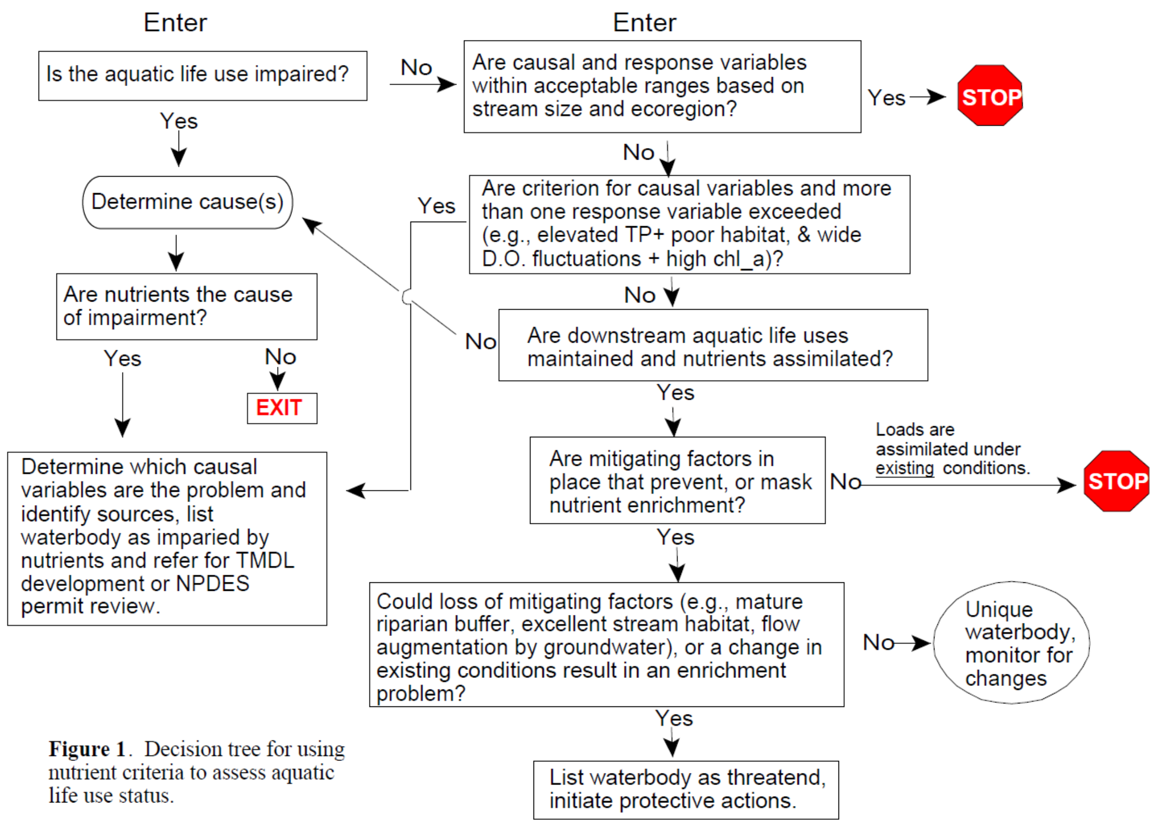


Figure 22. Alternate method proposed by OHEPA to address nutrient related impairment if NNC are not developed. Source: (Ohio Environmental Protection Agency 2006).

OHEPA determined that individual criterion for causal or response variables, stratified by stream size, would form the conditional statement for determining whether the aquatic life use of a waterbody is either impaired or threatened. The criterion would be based on the results of the nutrient study that was underway at the time of the drafting of the Nutrient Criteria Development Plan. Criteria for the causal variables total phosphorus (TP) or total inorganic nitrogen (TIN [NOx +NH3]), or both would be developed pending results of the study. The OHEPA pointed out that TP and TIN show a high degree of multicollinearity in samples collected over previous years of their study, and showed no additive or interaction effects (i.e., a non-linear model doesn't help to explain any additional variation). However, they found that TP and TIN were weakly correlated based on historical OHEPA data. An analysis of the historic data had shown that TP is a better predictor of biological integrity than is TIN, and showed a much stronger correlation with dissolved oxygen fluctuation (Miltner and Rankin 1998). They further pointed out that D.O. flux is a direct manifestation of algal productivity. Collectively, these results are consistent with TP acting as the limiting nutrient in Ohio streams, and therefore the likely focus of future nutrient criteria development. Data would continue to be collected for nitrogen, and criteria developed based on future study outcomes. OHEPA also planned to evaluate potential downstream effects of nutrient enrichment caused by nitrogen by assessment through biological and water quality surveys, along with subsequent determinations of causes and sources of impairment.

Because Ohio uses numeric biological criteria to judge attainment/non-attainment of aquatic life uses, every waterbody that is genuinely impaired due to nutrient enrichment from nitrogen will need to be identified, listed, and have a TMDL developed for nitrogen as a pollutant. Criteria for response variables, based on their study results, will likely be developed for dissolved oxygen variation and periphytic chlorophyll-*a* for headwaters and wadeable streams, and dissolved oxygen variation and either periphytic or sestonic chlorophyll-*a* or both for larger rivers. Criteria for biological response variables already exist in Ohio water quality standards. OHEPA planned to adopt USEPA's ecoregional recommendations for all lakes and reservoirs or some modification of this based on more current data. OHEPA anticipated that a rule package would be developed in 2008 and submitted in 2009 along with the smaller streams rule package. To our knowledge this has not yet occurred.

The OHEPA has conducted additional research and subsequently published more recent technical guidance for development of NNC for lakes and rivers in Ohio since publication of the Nutrient Criteria Plan in 2006 (Miltner 2011; Miltner 2010; Skalski and Anderson 2010). In addition, draft proposed NNC for lakes and streams and rivers are being reviewed by the public and EPA (Ohio Environmental Protection Agency 2010a; Ohio Environmental Protection Agency 2010c). These draft proposals are reviewed by (Miltner 2011). He recently summarized the current status of NNC development in Ohio. He indicated that several methods will likely be used in the end to derive the final recommended NNC for streams and rivers. This included a weight of evidence approach for rivers and streams which is then "rarified" or translated into a single ***trophic index criterion*** (TIC) (Bob Miltner pers.com.). Specifically, numerical scores are assigned to causal (TP, DIN) and response variables (benthic chlorophyll-*a*, 24 h DO range, 24 h minimum DO, fish and macroinvertebrate community indices) and the sum of the component score identifies where along a continuum of enrichment a particular waterbody is located. Mr. Miltner stated that this is essentially a "work-around" to deal with the issue of independent applicability of each method (B. Miltner pers.com.). He suggested that NNC will demand a "weight of evidence approach" but, that in their opinion, EPA currently has not developed a good method to incorporate multiple lines of evidence in a quantitative fashion. Important steps and components of the most current State of Ohio's nutrient criteria development strategy and proposal for lotic waters are outlined below from (Miltner 2011) include:

1) Conducting observational studies tracing effects of nutrients
    - a) Nutrients to benthic chlorophyll
        - • as mediated by canopy cover
    - b) Benthic chlorophyll to dissolved oxygen
        - •24 hour range
        - •absolute daily minimum
    - c) Dissolved oxygen to macroinvertebrates and fish
        - • existing water quality standards for D.O.
2) Identify change points/thresholds at each step
    - • Use of CART with bootstrapping, linear regression
3) Implementation
    - • Weight of evidence and independent application
        - - How to balance the two?
        - - What is reasonable potential?

Several lines of evidence and analytical tools were used to derive multiple metrics of nutrient assessment including 1) Structural equation modeling, 2) Logistic regression, 3) Quantile Regression, and 4) Threshold Indicator Taxa Analysis (TITAN)(Baker and King 2010; Miltner 2011). The method of (Baker and King 2010), i.e. (TITAN) was a new technique for detecting changes in taxa distributions along an environmental gradient over space or time, and assess synchrony among taxa change points as evidence for community thresholds. This technique allows the analysts to deconstruct communities to assess synchrony of taxon-specific change points, TITAN provides a sensitive and precise alternative to existing methods for assessing community thresholds. TITAN can be used to identify reference conditions and to support development of numerical regulatory criteria. The graphical examples of each step used in developing the proposed NNC multimetric approach for streams and rivers are listed below (Figure 24-Figure 32, Table 167-Table 169).

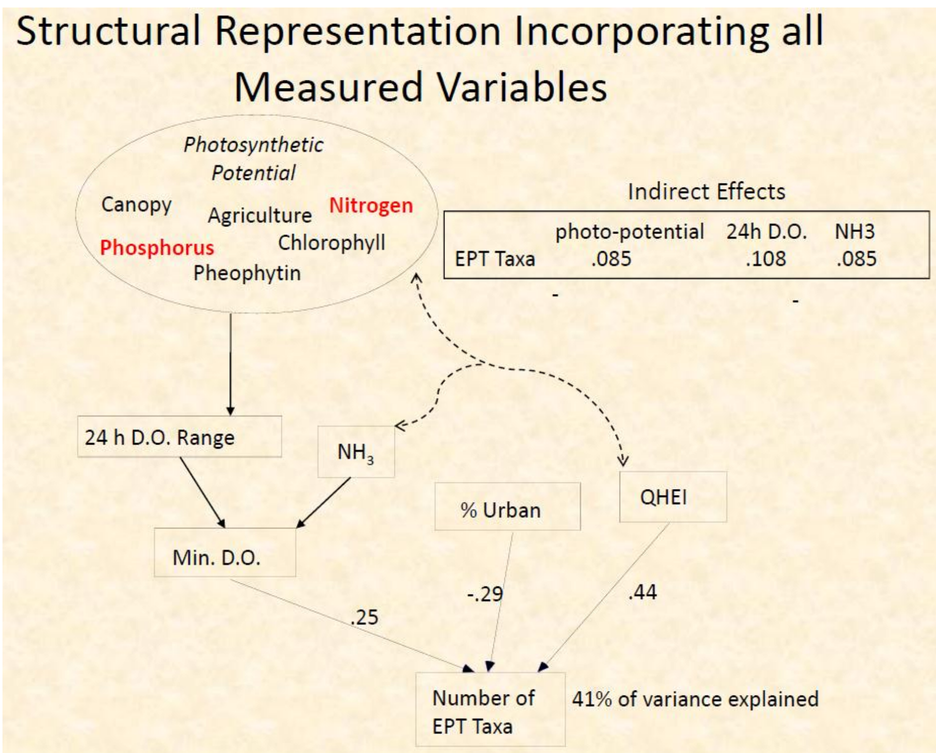


Figure 23. Summary of structural equation modeling used to assemble predictive models linking stressors with community indices for development of river and stream NNC in Ohio. Qualitative habitat evaluation index (QHEI) Ephemoptera+Plecoptera+Trichoptera Index (EPT). Source:(Miltner 2011).

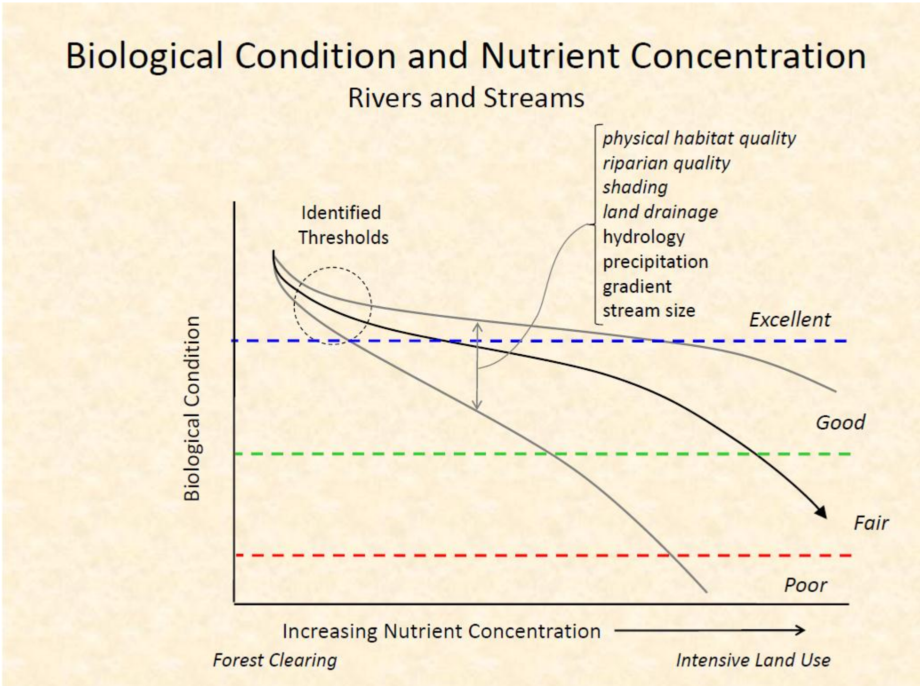
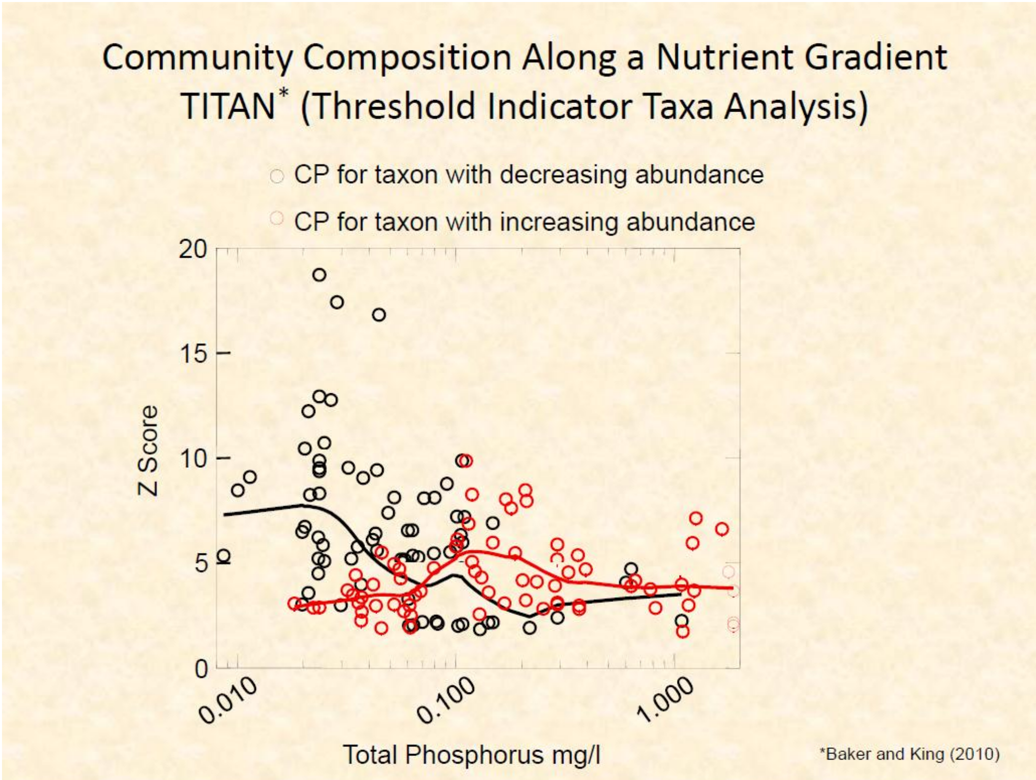


Figure 24. Example of relationship of modifier variables influencing the relationship of biological condition and nutrient levels in streams and rivers in Ohio, and associated thresholds as determined by various predictive models. Source: (Miltner 2011).



TITAN analysis

Figure 25. Example of use of TITAN analysis to detect community shift in relation to nutrient concentration in lotic systems in Ohio (Baker and King 2010). Source: (Miltner 2011).

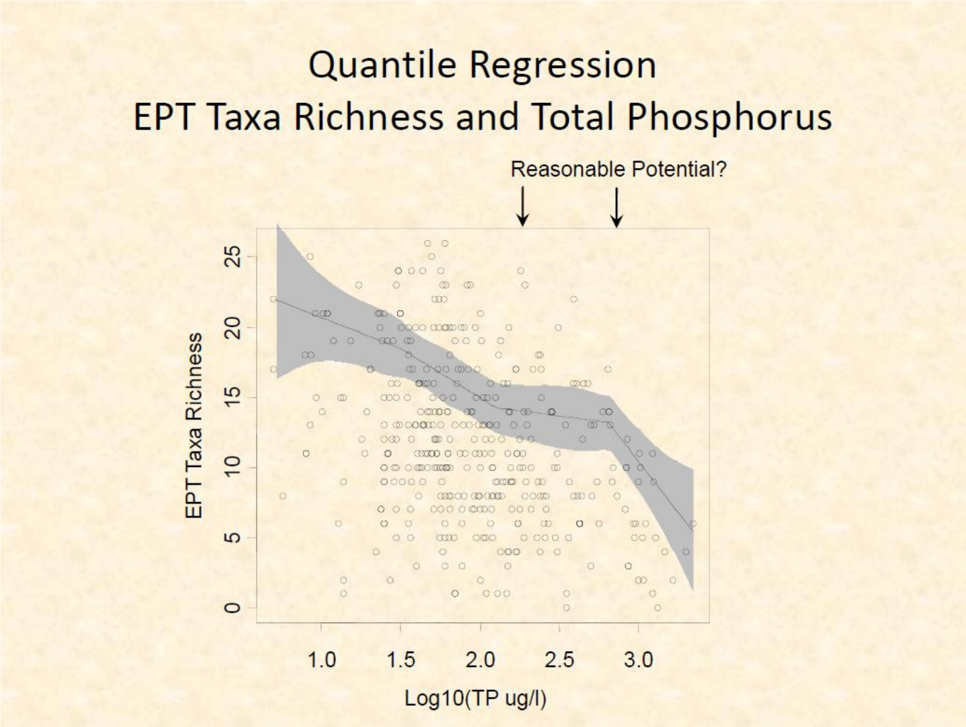


Figure 26. Example of quantile regression of EPT Taxa Richness (response variable) versus Log10 TP concentration in Ohio lotic systems that was used to derive NNC. Source: (Miltner 2011).

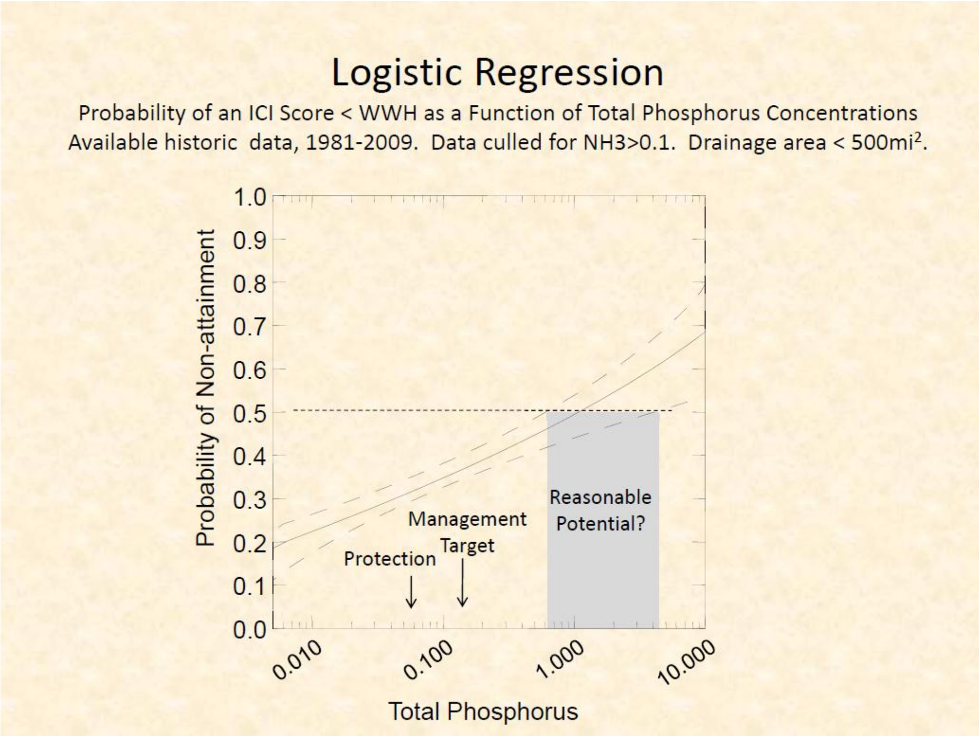


Figure 27. Example of logistic equation used to describe potential relationships between total P and non-attainment status. Source: (Miltner 2011).

Table 168. Matrix of reasonable potential thresholds used to determine nutrient caused impairment of aquatic life uses in Ohio rivers and streams. Source: (Miltner 2011).

Matrix of Reasonable Potential Thresholds

	ICI	EPT	IBI
DIN (quantile)	3.2	3.1	2.91 mg/l
DIN (logistic)	NS	NS	Varies by QHEI[1]
TP (logistic)	Varies by QHEI[2]	Varies by QHEI[3]	Varies by QHEI[4]
TP (quantile)	0.31	0.13	0.159 mg/l

1 For QHEI < median, probability of non-attainment > 0.5 when DIN> ~ 2.1 mg/l ;
when QHEI > 74, probability of non-attainment > 0.5 when DIN > ~ 9.5 mg/l;
2 For QHEI < median, probability of non-attainment > 0.5 when TP > ~ 0.6 - 3.0 mg/l
3 For QHEI < median, probability of non-attainment > 0.5 when TP > ~ 0.3 mg/l
4 For QHEI < median, probability of non-attainment > 0.5 when TP> ~ 0.159 mg/l ;
when QHEI > 74, probability of non-attainment > 0.5 when TP > ~ 0.457 mg/l

Table 169. Example of weight of evidence implementation of draft stream and river water quality standards in Ohio. Source: (Miltner 2011).

Weight of Evidence Implementation of Draft Water Quality Standards

Integrating Multiple Benchmarks & Thresholds into a Single Numeric Scale - The Trophic Index Criterion

Causal Link or Rationale for Nutrient WQS	TP	DIN	Chl a	24 H & Min D.O.	Fish & Bugs	TIC	Narrative
Nutrients to Chlorophyll	≤0.04	≤0.44	≤120	≤6 range >5 min	≥50	19	Acceptable (8 - 19)
Chl a & D.O. to Aquatic Life	>0.1	<1.0	>182	>7 range >4 min	>38	7	Threatened (4 - 7)
Logistic & Quantile Regression	>0.3	>3.0	>320	>9 range >4 min	36	1	Impaired (0 - 3)
Respective sub-scores	4		4	5	6	19	Acceptable
	1		1	1	4	7	Threatened
	0		0	0	1	1	Impaired

In summary the major conclusions that OHEPA arrived at while deriving draft Stream/River NNC are listed.

- Measurable changes to stream systems occur along a nutrient gradient

- However, complexity of relationship precludes adoption of a single numeric criterion and independent application

- Also, exceeding a threshold or change point does not equate to impairment.

- This necessitates inclusion of response indicators (e.g., benthic chlorophyll, dissolved oxygen) in water quality standard

In contrast to development to streams and rivers, the proposed assessment method for lake NNC is rather straightforward in comparison (Bob Miltner pers.coms.). (Ohio Environmental Protection Agency 2011). The criteria used to assess the nutrient response parameters is described in (Ohio Administrative Code) *OAC Chapter 3745-1-43, Table 43-12* and are summarized in (
Table 170) of this report.
The primary nutrient response parameters include chlorophyll-*a* and dissolved oxygen. The determination of the appropriate chlorophyll-*a* criterion from *OAC Chapter 3745-1, Table 43-12* based on lake type and ecoregion. All valid data points are pooled from surface grabs for each sampling event and a median value is computed. The lake fails the assessment if the median value is greater than the criterion. If there are separate results from both grab and composite samples, it is acceptable to compute an average for that particular sampling event to use in the calculation.

For dissolved oxygen (DO) in-situ profile data is used and readings compiled from each depth increment to calculate an average value for each sampling event. The analyst then only uses results from the epilimnion if the lake is thermally stratified. The lake fails the assessment if more than 10% of the average values are less than 6.0 mg/L.

Secondary nutrient response parameters including secchi depth and pH can also be used to assess whether a lake is impaired for nutrients. For secchi depth the appropriate criterion is obtained from *OAC Chapter 3745 Table 43-12*, based on lake type and ecoregion. The data points are then pooled from each sampling event and a median value is computed. The lake fails the assessment if the median value is greater than the criterion.

In-situ profile data for pH is compiled from each depth increment to calculate a median value for each sampling event. Only results from the epilimnion are used if the lake is thermally stratified. The lake fails the assessment if more than 10% of the median values are either less than 6.5 or greater than 9.0 S.U.

Criteria used to assess the nutrient causative parameters are listed in *OAC Chapter 3745-1-43, Tables 43-4 and 43-12* and summarized in
Table 170 below. Determine the appropriate total phosphorus criterion from *OAC Chapter 3745-1, Table 43-12* based on lake type and ecoregion. Pool all valid data points

obtained from surface grabs for each sampling event and compute a median value. The lake fails the assessment if the median value is greater than the criterion.

Total nitrogen is calculated from the sum of total kjeldahl nitrogen and nitrate-nitrite nitrogen. Determine the appropriate criterion from *OAC Chapter 3745-1,Table 43-12* based on lake type and ecoregion. Pool all valid data points obtained from surface grabs for each sampling event and compute a median value. The lake fails the assessment if the median value is greater than the criterion.

Before collecting a sample for NNC, the collector has to determine the appropriate ammonia nitrogen outside mixing zone (OMZA) criterion from *OAC Chapter 3745-1,Table 43-4* that applies to each surface grab sample based on field temperature and pH. Then the user must compare the concentration from each sample to the specific criterion that applies. The lake fails the assessment if more than 10% of the readings are greater than the criterion.

Table 170. Parameters tested during a standard lake sampling event and respective numeric criteria. [1] T-Nitrogen=T-Kjeldahl Nitrogen + Nitrate-Nitrite (Note: Criteria used to assess the base aquatic listed parameters are listed in OAC Chapter 3745-1, Tables 42-1, 42-3, 42-5, 43-4, 43-12). [1]From: *Criteria used to assess the base aquatic life parameters are listed in OAC Chapter 3745-1, Tables 42-1 and 42-3.*

Parameter	Criterion	Assessment Method
Primary Nutrient Response Parameters		
Chlorophyll a (µg/L)	tiered (Table 43-12)[1]	Median > criterion
Dissolved oxygen (mg/L)	6.0 (Table 43-12)	More than 10% < 6.0
Secondary Nutrient Response Parameters		
Secchi depth (m)	tiered (Table 43-12)	Median > criterion
pH (SU)	6.5 – 9.0 (Table 43-12)	More than 10% 6.5 < pH > 9.0
Nutrient Causative Parameters		
T-Phosphorus (µg/L)	tiered (Table 43-12)	Median > criterion
T-Nitrogen[1] (µg/L)	tiered (Table 43-12)	Median > criterion
Ammonia (mg/L)	calculated (Table 43-4)	More than 10% > OMZA
Base Aquatic Life Parameters		
T-Dissolved Solids (mg/L)	1,500 (Table 42-5)[1]	More than 10% > 1,500
Specific Conductivity	2,400 (Table 42-5)	More than 10% > 2,400

Parameter	Criterion	Assessment Method
(µS/cm)		
Arsenic (µg/L)	150 (Table 42-1)[1]	More than 10% > 150
Mercury (µg/L)	0.91 (Table 42-1)	More than 10% > 0.91
Selenium (µg/L)	5.0 (Table 42-1)	More than 10% > 5.0
Cadmium (µg/L)	calculated (Table 42-3)[1]	More than 10% > OMZA
Chromium (µg/L)	calculated (Table 42-3)	More than 10% > OMZA
Copper (µg/L)	calculated (Table 42-3)	More than 10% > OMZA
Lead (µg/L)	calculated (Table 42-3)	More than 10% > OMZA
Nickel (µg/L)	calculated (Table 42-3)	More than 10% > OMZA
Zinc (µg/L)	calculated (Table 42-3)	More than 10% > OMZA

The nutrient indicator is classified as full support if all of the response and causative parameters pass individual assessment. The nutrient indicator is classified as full support Best professional judgment must be used for lakes that fall into this category to determine if results are caused by natural or anthropomorphic conditions. This might require a review of other sources credible data or additional monitoring. The nutrient indicator is classified as impaired if either primary response parameter fails individual assessment. A TMDL will be developed for lakes classified as impaired unless there is compelling evidence that it's caused by natural conditions.

Base Aquatic Life Indicator

Criteria used to assess the base aquatic life parameters are listed in *OAC Chapter 3745-1, Tables 42-1 and 42-3*. Data is obtained from surface grab samples. Assessment of standard base aquatic life parameters listed below.

1) Total Dissolved Solids, Arsenic, Mercury and Selenium

Compare individual readings to the Outside Mixing Zone Average criterion. The lake fails the assessment if more than 10% of the readings are greater than the appropriate criterion for any of the parameters.

2) Cadmium, Chromium, Copper, Lead, Nickel and Zinc

Compare individual readings to the Outside Mixing Zone Average criterion computed based on the sample hardness. The lake fails the assessment if more than 10% of the readings are greater than the appropriate criterion for any of the parameters.

3) Herbicides, Organochlorine Insecticides, Semi-Volatile Organic Compounds, PCBs

Compare individual readings to the Outside Mixing Zone Average criterion. The lake fails the assessment if more than 10% of the readings are greater than the appropriate criterion for any of the parameters.

Base Aquatic Life Indicator Status

The base aquatic life indicator is classified as either full support or impaired. The indicator is considered impaired if any one of the individual parameters exceeds criteria in more than 10% of the samples.

Based on the most recent information received from the OHEPA, the State of Ohio appears to be very close to proposal and adoption of NNC for their surface waters. The status of lake and reservoir NNC however, appears to be more certain and more likely to be adopted before stream and river NNC.

Oklahoma

The State of Oklahoma does have NNC for selected lakes, reservoirs, streams and rivers (Oklahoma Department of Environmental Quality 2010; Oklahoma Water Resources Board 2010)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ok.cfm,http://www.owrb.ok.gov/quality/standards/standards.php) Table 171. Oklahoma recently adopted new water quality standards and implementation rules that impact interpretation of NNC *(OAC 785:45 and 785:46)(Oklahoma Water Resources Board 2011a; Oklahoma Water Resources Board 2011b).* To our knowledge these are still under review by EPA.

Table 171. Existing numeric nutrient criteria for Oklahoma.[1]

Waterbody Type	N	P	Chl-A	Clarity[2]
Lakes & Reservoirs		W		W[3]
Rivers & Streams		W		W[3]
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = for selected waterbody N/A=Not Applicable

[1] From Oklahoma's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved November 2008). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for support of aquatic life uses. This has been update for July 2011, adopted State standards, but not EPA approved (noted with)(Oklahoma Water Resources Board 2011a).

[2] Source: EPA's (Oklahoma Water Resources Board 2011a; United States Environmental Protection Agency 2008b)

[3] Turbidity criteria for the use of fish and wildlife propagation.

Designations of beneficial uses for a waterbody in Oklahoma are listed below (Oklahoma Water Resources Board 2011a).

(1) EWS - Emergency Water Supply beneficial use
(2) PPWS - Public and Private Water Supply beneficial use
(3) F&W Prop. - Fish and Wildlife Propagation beneficial use
    (A) WWAC - Warm Water Aquatic Community subcategory
    (B) HLAC - Habitat Limited Aquatic Community subcategory
    (C) CWAC - Cool Water Aquatic Community subcategory
    (D) Trout - Trout Fishery (put and take) subcategory
(4) Ag - Agriculture beneficial use
(5) Rec - Recreation beneficial use
    (A) PBCR - Primary Body Contact beneficial use
    (B) SBCR - Secondary Body Contact beneficial use
(6) Nav – Navigation beneficial use
(7) Aes - Aesthetics beneficial use

The language presented below was extracted from the most recent version of Oklahoma's state water quality standards and applies to all waterbodies within the state (unless a waterbody type or designated use is noted

Part 3. Beneficial Uses and Criteria to Protect Uses

785:45-5-9. General narrative criteria

(c) Taste and Odor. Taste and odor producing substances from other than natural origin shall not interfere with the production of a potable water supply by modern treatment methods or produce abnormal flavors, colors, tastes and odors in fish flesh or other edible wildlife, or result in offensive odors in the vicinity of the water, or otherwise impair any beneficial use.

(d) Nutrients. Nutrients from point source discharges or other sources shall not cause excessive growth of periphyton, phytoplankton, or aquatic macrophage communities which impairs any existing or designated beneficial use.

785:45-5-19. Aesthetics

(a) To be aesthetically enjoyable, the surface waters of the state must be free from floating materials and suspended substances that produce objectionable color and turbidity.

(b) The water must also be free from noxious odors and tastes, from materials that settle to form objectionable deposits, and discharges that produce undesirable effects or are a nuisance to aquatic life.

(c) The following criteria apply to protect this use:

(1) Color. Surface waters of the state shall be virtually free from all coloring materials which produce an aesthetically unpleasant appearance. Color producing substances, from other than natural sources, shall be limited to concentrations equivalent to 70 Platinum-cobalt true color units.

785:45-5-25. Implementation Policies for the Antidegradation Policy Statement

(d) The thirty (30) day geometric mean total phosphorus concentration in waters designated "Scenic River" in Appendix A of this Chapter ***shall not exceed 0.037 mg/L.*** This subsection (d) applies in addition to, and shall be construed so as to be consistent with, any other provision of this Chapter which may be applicable to such waters. Such criterion became effective July 1, 2002 and shall be implemented as authorized by state law through Water Quality Standards Implementation Plans and other rules, permits, settlement agreements, consent orders, compliance orders, compliance schedules or voluntary measures designed to achieve full compliance with the criterion in the stream by June 30, 2012.

The State of Oklahoma does have an EPA approved Nutrient Criteria Development Plan (Oklahoma water Resources Board 2006). This Plan represented the latest update to the Nutrient Criteria Development Plan for Oklahoma, developed by the Oklahoma Water Resources Board and submitted to EPA Region VI. This document integrates three different documents previously reviewed by EPA including the Nutrient Criteria Development Plan (of 2002), the June 2006 update, and the June 2, 2006 transmittal letter. In this plan, the OWRB outlines its long-term strategy for development of nutrient criteria in Oklahoma. The strategy is broken down into three phases, including: Phase One, development of Scenic Rivers criteria; Phase Two, development of nutrient criteria for lakes; and Phase Three, development of nutrient criteria for streams. At the time of publication of the Plan, OWRB had completed Phase One with the promulgation of the .037 mg/l total phosphorus criterion for Scenic Rivers, approved by EPA in 2004. OWRB expanded on this with promulgation of an assessment protocol for this criterion in 2005. The OWRB began to implement Phase Two with promulgation of a 0.010 mg/l chlorophyll-*a* criterion to protect the Public and Private Water Supply beneficial use on Sensitive Water Supplies, as well as Lake Wister and Tenkiller Ferry Reservoir. From here, OWRB planned to focus on nutrient criteria development for other lakes and then streams in Oklahoma. As of the most recent revisions of the 2011 water quality standards Oklahoma has not developed any new NNC. There were however recent changes to implementation procedures that includes some numeric “translators” for assessing water quality impairment due to nutrients (Oklahoma Water Resources Board 2011b).

The OWRB acknowledged that development of viable TSI criteria or chlorophyll-*a* criteria for the remainder of Oklahoma’s lakes will be very difficult. They expressed concern in their Plan about their ability and technical resources needed to develop viable conversions from TSI criteria to allowable phosphorus loading. Loading must be obtained in order to implement TSI criteria through TMDL. Viable statewide or even viable ecoregional nutrient criteria for streams will be difficult to develop.

OWRB acknowledged that critical limiting factors for criteria development were data availability and basic research to lay as a foundation for criteria (Oklahoma water Resources Board 2006). They stated the available guidance outside of that published for each ecoregion based upon percentiles was scarce. Literature available to help establish nutrient and chlorophyll criteria based upon protecting beneficial uses was limited. The first task of criteria development will be to review the available research published to build a technical basis.

Stream data in Oklahoma suitable to establish nutrient criteria are very limited. Periphyton collections are limited to only a few special studies have been conducted (Oklahoma Water Resources Board 2004). Most Oklahoma stream has been collected from periphytometers constructed from glass rods or glass slides. These apparatus assess short-term algae growth rather than the algae standing crop. Also available on a limited basis, are sestonic algae concentration and diurnal dissolved oxygen monitoring. The lack of sites with a full complement of long-term nutrient, diurnal dissolved oxygen, periphyton, fish and invertebrate data over a range of perceived impairments is of major consequence. Additional funds will be required in order to complete criteria development where extensive modeling and data collection are required.

OWRB stated that nutrient criteria for streams that are not Scenic Rivers is of lower priority compared to lake criteria (Oklahoma water Resources Board 2006). Lakes are more sensitive than streams, and beneficial use impairment on lakes has more and greater long-term consequences. Therefore, OWRB planned on allocating resources primarily to on lakes criteria development over the next few years.

Oregon

The State of Oregon currently has state adopted and EPA approved NNC for lakes, reservoirs, rivers, streams and estuaries (Table 172). The existing NNC are listed below.

Table 172. Existing numeric criteria for Oregon.[1.]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes & Reservoirs		W	S	
Rivers & Streams		W	S	
Estuaries			S	
Wetlands				

S = Statewide W = for selected waterbody N / A=Not Applicable
[1] From Oregon's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved July 2007). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for aquatic life use protection.
[2] Source: EPA's (Oregon Department of Environmental Quality 2007; United States Environmental Protection Agency 2008b) http://arcweb.sos.state.or.us/pages/rules/oars_300/oar_340/340_041.html

The existing designated beneficial uses for the purposes for water quality standards in Oregon include:

domestic water supply,

fishing,
industrial water supply,
boating,
irrigation,
water contact recreation,
livestock watering,
aesthetic quality,
fish and aquatic life,
hydropower,
wildlife and hunting and,
commercial navigation and transportation.

The NNC for Oregon waters include chlorophyll-*a* for lakes/reservoirs, rivers/streams and estuaries and total phosphorus in selected lakes/reservoirs and rivers/streams, which are listed below verbatim.

340-041-0007 Statewide Narrative Criteria(Oregon Department of Environmental Quality 2007) and (http://arcweb.sos.state.or.us/pages/rules/oars_300/oar_340/340_041.html).

(1) Notwithstanding the water quality standards contained in this Division, the highest and best practicable treatment and/or control of wastes, activities, and flows must in every case be provided so as to maintain dissolved oxygen and overall water quality at the highest possible levels and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor, and other deleterious factors at the lowest possible levels.

(2) Where a less stringent natural condition of a water of the State exceeds the numeric criteria set out in this Division, the natural condition supersedes the numeric criteria and becomes the standard for that water body. However, there are special restrictions, described in OAR 340-041-0004(9)(a)(D)(iii), that may apply to discharges that affect dissolved oxygen.

(11) The creation of tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life or affect the potability of drinking water or the palatability of fish or shellfish may not be allowed;

(14) Aesthetic conditions offensive to the human senses of sight, taste, smell, or touch may not be allowed;

340-041-0019
Nuisance Phytoplankton Growth

(1)(a) The following values and implementation program must be applied to lakes, reservoirs, estuaries and streams, except for ponds and reservoirs less than ten acres in surface area, marshes and saline lakes:

(b) The following average Chlorophyll-*a* values must be used to identify water bodies where phytoplankton may impair the recognized beneficial uses:

(A) Natural lakes that thermally stratify: 0.01 mg/L;

(B) Natural lakes that do not thermally stratify, reservoirs, rivers and estuaries: 0.015 mg/L;

(C) Average Chlorophyll-*a* values may be based on the following methodology (or other methods approved by the Department): A minimum of three samples collected over any three consecutive months at a minimum of one representative location (e.g., above the deepest point of a lake or reservoir or at a point mid-flow of a river) from samples integrated from the surface to a depth equal to twice the secchi depth or the bottom (the lesser of the two depths); analytical and quality assurance methods must be in accordance with the most recent edition of Standard Methods for the Examination of Water and Wastewater.

Basin-Specific Criteria (Mid Coast Basin) 340-041-0225

Water Quality Standards and Policies for this Basin
(3) Nutrients in Clear Lake Watershed. In order to preserve the existing high quality water in Clear Lake north of Florence for use as a public water supply source requiring only minimal filtration, it is the policy of the Environmental Quality Commission to protect the Clear Lake watershed including both surface and groundwater, from existing and potential contamination sources with the following requirements:

(a) The total phosphorus maximum annual loading discharged into Clear Lake may not exceed 241 pounds per year from all sources.
(b) The total phosphorus maximum annual loading for the Clear Lake watershed may be deemed exceeded if the median concentration of total phosphorus from samples collected in the epilimnion between May 1 and September 30 exceed nine micrograms per liter during two consecutive years.
(c) Of the total phosphorus loading of 241 pounds per year specified in section (1) of this rule, 192 pounds per year will be considered current background and Department reserve and is not available to other sources.
(d) The total phosphorus maximum annual loading discharged into Collard Lake may not exceed 123 pounds per year.

Basin-Specific Criteria (Willamette) 340-041-0345

Water Quality Standards and Policies for this Basin
(5) In order to improve water quality within the Yamhill River subbasin to meet the existing water quality standard for pH, the following special rules for total maximum daily loads, waste load allocations, load allocations and program plans are established:

(a) After completion of wastewater control facilities and program plans approved by the Commission under this rule and no later than June 30, 1994, no activities may be allowed and no wastewater may be discharged to the Yamhill River or its tributaries without the authorization of the Commission that cause the monthly median concentration of total phosphorus to exceed 70 µg/1 as measured during the low flow period between approximately May 1 and October 31*** of each year;

***Precise dates for complying with this rule may be conditioned on physical conditions (i.e., flow, temperature) of the receiving water and may be specified in individual permits or memorandums of understanding issued by the Department. The Department may consider system design flows, river travel times, and other relevant information when establishing the specific conditions to be inserted in the permits or memorandums of understanding.

Pennsylvania

Pennsylvania currently does not possess NNC (Brown 2007; Paul and Zheng 2007; Pennsylvania Department of Environmental Protection 2006; Pennsylvania Department of Environmental Protection 2010). However, the State does have an EPA approved Nutrient Criteria Development Plan (Pennsylvania Department of Environmental Protection 2004). A summary of their proposed NNC development approach is provided verbatim below.

Criteria Development Process
A. Rivers and Streams Conceptual Approach

According to the 2004 Nutrient Criteria Development Plan, Pennsylvania's preferred method of nutrient criteria development was an effects-based approach. At that time, Pennsylvania planned on participating in the EPA funded periphyton study aimed at the development of response-based nutrient criteria. The study was supposed to define relationships between response variables (periphyton chlorophyll-*a* and dissolved oxygen) and causal variables (nutrients).
Additionally, periphyton data collected at USGS NAWQA sites would be used to augment the data collected in the above study. Diurnal DO data would also be collected following protocol developed for a EPA periphyton study so that comparable results would be obtained. Since there was considerable uncertainty associated with defining such a relationship, Pennsylvania also planned on exploring additional backup methods (Reference Station and Response-Based approaches) as well. Pennsylvania planned on exploring the two methods outlined in the EPA the Nutrient Criteria Technical Guidance Manuals for Rivers and Streams, and Lakes and Reservoirs, that is, the two data distribution analysis methods for the setting of criteria reference values, namely the "All Streams" and "Reference Stream" approaches (Gibson et al. 2000; United States Environmental Protection Agency 2000h). Pennsylvania was exploring the possibility of utilizing the "Reference Stream" approach to develop criteria for rivers and streams based on a more specific regional basis than those proposed by EPA. EPA Region III had contracted ENSR to incorporate all available water quality monitoring data into a Region

III specific database. Pennsylvania received the final database in December 2003, over a year later than anticipated when previous milestones/schedules were proposed in draft Nutrient Criteria Development Plans. Dates were pushed up one year except for the final regulation, where the year was taken out of the final rulemaking process. A critical step in the Reference Stream approach is to develop a method by which "reference" stations are selected. Reference stations were defined for this purpose as those stations that show minimal anthropogenic impacts. An ArcView interface was being developed for the recently finalized ENSR Nutrient Database to allow for simpler querying of the database and defining the required elements of a reference station.

B. Lakes Conceptual Approach

Pennsylvania had not yet committed to a specific approach to criteria development for lakes. The "Reference Station" approach being tested on the State's free-flowing waters remained an alternative. However, Pennsylvania noted that there was much more historic literature and data linking specific nutrient and chlorophyll-*a* levels to lake over-enrichment that could also be used in the criteria setting process in conjunction with available monitoring data from Pennsylvania lakes. Therefore, there was a higher probability of developing stressor response models for use in lakes and reservoirs. Additionally, trophic status indices, such as that proposed by (Carlson 1977), remained a viable alternative for setting criteria for lakes in conjunction with the other methods listed.

More recently the Pennsylvania Department of Environmental Protection (PDEP) summarized more recent efforts to develop NNC (Brown 2007). In that presentation PDEP describes their most current efforts to develop NNC recommendations in streams using various methods. They describe several methods and projects including:

• Continued Sampling periphyton biomass, water column chemistry, field chemistry, algal species counts state-wide,
• Conducting focused surveys at eight fixed water quality monitoring stations sampled 2-3 times in each of their six regions plus and additional $\approx$ 100 TMDL related study sites,
• designing and conducting nutrient releasing substrata study and,
• initiating macroinvertebrate studies evaluating impacts associated with elevated nutrients.

(Brown 2007) mentioned that based literature and several studies there appears to be a range of values the that appear to represent endpoints or thresholds where excessive algal can be caused by elevated levels of P and N. They found that models relate in-stream P (and N) concentrations to periphyton biomass (Chl-A) produce several plausible endpoints. Several studies have identified a range of conditions, (50 to 150 mg/m^2) where periphyton achieve nuisance accumulations.

Recent studies commissioned by Region 3 EPA, to develop draft NNC for the northern Piedmont region of Pennsylvania have been completed (Paul and Zheng 2007). Using a variety of approaches they came up with a range of potential endpoints and potential NNC (Table 173).

Table 173. Summary of candidate endpoints for southeastern Pennsylvania for each of the analytical approaches discussed in (Paul and Zheng 2007).

	Approach	TP Endpoint (μg/L)
Reference Approach		**2-37**
	Reference Site 75th Percentile	16-17
	All Sites 25th Percentile	17
	Modeled Reference Expectation	2-37
Stressor-Response		**36-64**
	Conditional Probability – EPT taxa	38
	Conditional Probability - % Clingers	39
	Conditional Probability - % Urban Intolerant	64
	Conditional Probability - Diatoms TSI	36
Other Literature		**13-100**
	USEPA Recommended Regional Criteria	37
	USEPA Regional Criteria Approach – Local Data	40-51
	Algal Growth Saturation	25-50
	Nationwide Meta-Study TP-Chlorophyll	21-60
	USGS Regional Reference Study	20
	USGS National Nutrient Criteria Study	13-20
	New England Nutrient Criteria Study	40
	Virginia Nutrient Criteria Study	50
	New Jersey TDI	25-50
	Delaware Criteria	50-100

Puerto Rico

Puerto Rico has NNC for TIN, TP and Chlorophyll-*a* in selected waterbodies Table 174

Table 174. Existing Numeric Criteria for Puerto Rico.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs		S		W[3]
Rivers and Streams		S		W[3]
Estuaries	S	S		W[3]
Wetlands				W[3]

S = Statewide W = for selected waterbody N/A=Not Applicable

[1] From Puerto Rico's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved August 2010). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for aquatic life uses[2] Source: EPA's (Commonwealth of Puerto Rice Environmental Quality Board 2010b; United States Environmental Protection Agency 2008b)

[3] Turbidity criteria for class SB, SC and SD waters and their designated uses.

The NNC for phosphorus in Puerto Rico is defined as a TP value that shall not exceed 1 mg/L upstream of drinking water reservoirs or estuarine waters except by permission of board. In addition, TIN shall not exceed 5.0 mg/L in estuaries and marine waters. A nutrient related turbidity NNC is also defined as not to exceed (NTE) 10 NTU in estuarine/marine waters, while the value is NTE 50 NTU in all other waterbodies including reservoirs, streams and wetlands, unless natural turbidity is higher.

Puerto Rico has a current federally approved Nutrient Criteria Development Plan (Commonwealth of Puerto Rice Environmental Quality Board 2010a; Commonwealth of Puerto Rico Environmental Quality Board 2008). We have extracted pertinent sections of that document and present it in the following text. According to the list of Impaired Waters for Puerto Rico, all reservoirs on the island are impaired for aquatic life use. The Puerto Rico Environmental Quality Board (PREQB) has identified low dissolved oxygen as the major cause of this impairment. Their report identifies nutrients as one of the primary causative agents of the eutrophication that may contribute to the observed dissolved oxygen values. However, quantitative information to support this is not available. PREQB points out that, nutrients have yet to be officially identified as a major cause of impairment in Puerto Rico. The fact that nutrients are not regarded as a major cause of pollution in Puerto Rico may be due to the lack of adequate standards that allow for the identification of nutrient impaired waters.

PREQB has funded several studies to evaluate the current status of water quality in reservoirs and streams and rivers. The next step is to initiate studies to evaluate potential thresholds associated with perceived nutrient impairment. PREQB appears to be focusing on the lakes and reservoirs. The primary nutrient they anticipate developing NNC is TP and TN. In general, the reservoirs of Puerto Rico were widely distributed in terms of their nutritional status. A preliminary ranking of the trophic status of the reservoirs was performed based on the trophic state index (TSI) approach developed by Carlson (Carlson 1977). According to the TSI developed for total phosphorous (TP) out of a total of nineteen reservoirs, six fell in the mesotrophic category twelve ranked in the eutrophic group, whereas one ranked in the hypereutrophic category. Overall, a significant difference between the concentration of nutrients at the riverine (entrance) and the lacustrine (near dam) sections of the reservoirs was observed with higher nutrient and chlorophyll-*a* levels observed at the entrance. Here, the relationship between chlorophyll-*a* values and nutrients was also stronger. Estimates of reference conditions for TP, TKN, TN, and chlorophyll-*a* were 17.0 μg/L, 0.26 mg/L, 0.36 mg/L, and 2.87 μg/L, respectively, similar to values proposed by EPA for other ecoregions of the USA. The large difference between the referenced-based value for phosphorus (17.0 μg/L) and the current water quality standard (1,000) μg/L TP) was very noticeable.

PREQB conducted a series of in-situ nutrient response studies at Lago Guajataca to identify the limiting nutrient for phytoplankton growth in our reservoirs. Both nitrogen and phosphorus were shown to be limiting factors to aquatic biomass growth. The result contrasted with observations from temperate lakes, where phosphorus has been identified as the sole controlling factor to algae growth. A highly significant correlation among nutrients, as well as between nutrients and lake productivity (chlorophyll-*a*) was observed during the monitoring period. A relationship between the concentration of total phosphorus (TP) in the reservoir versus. the total nitrogen (TN)/TP ratio resulted in two populations defined by a change point (17.1 μg/L) that is remarkably similar to the reference-based value derived for TP (17.0 μg/L). These results, according to PREQB demonstrate the importance of controlling loadings of both nutrients (N and P) into lakes of Puerto Rico.

PREQB is also in the process of funding a second phase of a study evaluating rivers and streams to determine reference conditions and proposed nutrient criteria. PREQB stated that the evaluation of historical USGS database suggests that both N and P limitation occurs in tropical rivers but P limitation occurs in majority of the cases. Therefore, at the moment TP will be the parameter which appears to need regulation. They concluded that is will be necessary to gather more information to evaluate if there is a need to also regulate N. After all of the appropriate information is collected, PREQB will look into different options for the next steps of the criteria derivation process. The expectation is that appropriate criteria will be developed and adopted at that time. However, if additional data is deemed necessary, the next step may include the identification of an ecological target condition for impairment. The aforementioned step would require a process of searching for funds to develop the proposal project, which could have duration of one year. Also, two additional years are required to complete the project mentioned. This means, that overall time period is three years.

In summary, the PREQB continues to evaluate various approaches to development of NNC for lakes and rivers but acknowledges the fact that they may not have many nutrient related problems. The two primary approaches they are evaluating are stressor-response methods and reference waterbody approaches.

Rhode Island

Rhode Island currently possesses NNC for phosphorus in lakes and reservoirs (Table 175). A current Nutrient Criteria Development Plan was released in 2007 (Rhode Island Department of Environmental Management 2007b). An excerpt from the water quality regulations highlighting NNC are listed below verbatim with additional summary information (Rhode Island Department of Environmental Management 2010).

Table 175. Existing numeric criteria for Rhode Island.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs		S		
Rivers and Streams				
Estuaries				
Wetlands				

S = Statewide W = for selected waterbody N/A=Not Applicable

[1] From Rhode Island's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved July 2010). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for aquatic life use protection.

[2] Source: EPA's (Rhode Island Department of Environmental Management 2010; United States Environmental Protection Agency 2008b);
http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_ri.cfm ;
http://www.dem.ri.gov/pubs/regs/regs/water/h20q09a.pdf

The designated water uses in Rhode Island are listed below.

Freshwaters

Class AA@ - These waters are designated as a source of public drinking water supply (PDWS) or as a tributary within a public drinking water supply watershed (the terminal reservoir of the PDWS are identified in Appendix A), for primary and secondary contact recreational activities and for fish and wildlife habitat. These waters shall have excellent aesthetic value.

Class A - These waters are designated for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good excellent aesthetic value.

Class B* - These waters are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.

Class B1* - These waters are designated for primary and secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges. However all Class B criteria must be met.

Class C - These waters are designated for secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These water shall have good aesthetic value.

@ Class AA waters used for public drinking water supply may be subject to restricted recreational use by State and local authorities.
* Certain Class B and B1 waterbody segments may have partial use designations assigned to them as noted in rule 8.B.(3).

Seawaters

Class SA*@ - These waters are designated for shellfish harvesting for direct human consumption, primary and secondary contact recreational activities, and fish and wildlife habitat. They shall be suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value.

Class SB* - These waters are designated for primary and secondary contact recreational activities; shellfish harvesting for controlled relay and depuration; and fish and wildlife habitat. They shall be suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value.

Class SB1* - These waters are designated for primary and secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges. However all Class SB criteria must be met.

Class SC - These waters are designated for secondary contact recreational activities, and fish and wildlife habitat. They shall be suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value.

@ Some Class SA waters contain Closed Safety Zones which are waters in the vicinity of an approved sanitary discharge which may be impacted in the event of complete failure of treatment and are therefore, currently prohibited to shellfishing. Although shellfishing use is restricted, all SA criteria must be met.
* Certain Class SA, SB and SB1 waterbody segments may have partial use designations assigned to them as noted in rules 8.B(3).

The following text excerpt from the Rhode Island water quality standards contains information on current NNC.

Rule 8. Surface Water Quality Standards – State of Rhode Island(Rhode Island Department of Environmental Management 2010)

D. Water Quality Criteria - The following physical, chemical and biological criteria are parameters of minimum water quality necessary to support the surface water use classifications of rule 8.B. and shall be applicable to all waters of the State.

(1). General Criteria - The following minimum criteria are applicable to all waters of the State, unless criteria specified for individual classes are more stringent:
(d). Nutrients - Nutrients shall not exceed the limitations specified in rule 8.D.(2) and 8.D.(3) and/or more stringent site-specific limits necessary to prevent or minimize accelerated or cultural eutrophication.

(2). Class-specific Criteria for Freshwaters – (see Table 1 in Rhode Island Regulations)

(3). Class-specific Criteria for Seawaters – (see Tables 2 and 3 in Rhode Island Regulations)

Table 176. Rhode Island Nutrient Criteria (Table 1. 8.D.(2) Class-Specific Criteria) – Fresh Waters.

<table>
<tr><th>Criterion</th><th>Class AA[1]</th><th>Class A</th><th>Class B, B1, B(a), B1(a)</th><th>Class C</th></tr>
<tr><td>2. Sludge deposits, solid refuse, floating solids, oil, grease, scum</td><td colspan="3">None allowable.</td><td>None in such amounts that would impair any usages specifically assigned to this class.</td></tr>
<tr><td>6. Taste and odor</td><td colspan="2">None other than of natural origin and none associated with nuisance algal species.</td><td colspan="2">None in such concentrations that would impair any usages specifically assigned to this class nor cause taste or odor in edible portions of fish.</td></tr>
<tr><td>10. Nutrients</td><td colspan="4">a. Average Total Phosphorus shall not exceed 0.025 mg/L in any lake, pond, kettlehole or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria, except as naturally occurs, unless the Director determines, on a site-specific basis, that a different value for phosphorus is necessary to prevent cultural eutrophication.
b. None in such concentration that would impair any usages specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedance of the criterion of 10(a) above in a downstream lake, pond, or reservoir. New discharges of wastes containing phosphates will not be permitted into or immediately upstream of lakes or ponds. Phosphates shall be removed from existing discharges to the extent that such removal is or may become technically and reasonably feasible.</td></tr>
</table>

[1]Class AA waters used for public drinking water supply may be subject to restricted recreational use by State and local authorities.

Table 177. Rhode Island Nutrient Criteria (TABLE 2. 8.D.(3) Class-Specific Criteria) – Sea Waters.

<table>
<tr><th>Criterion</th><th>Class SA, SA(b)</th><th>Class SB, SB1, SB(a), SB1(a)</th><th>Class SC</th></tr>
<tr><td>2. Sludge deposits, solid refuse, floating solids, oil, grease, scum</td><td colspan="2">None allowable.</td><td>None in such amounts that would impair any usages specifically assigned to this class.</td></tr>
<tr><td>6. Taste and odor</td><td>None allowable except as naturally occurs.</td><td colspan="2">None in such concentrations that would impair any usages specifically assigned to this class nor cause taste or odor in edible portions of fish or shellfish.</td></tr>
<tr><td>10. Nutrients</td><td colspan="3">None in such concentration that would impair any usages specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication. Shall not exceed site-specific limits if deemed necessary by the Director to prevent or minimize accelerated or cultural eutrophication. Total phosphorus, nitrates and ammonia may be assigned site-specific permit limits based on reasonable Best Available Technologies. Where waters have low tidal flushing rates, applicable treatment to prevent or minimize accelerated or cultural eutrophication may be required for regulated nonpoint source activities.</td></tr>
</table>

A summary of the the Rhode Island Department of Environmental Management (RIDEM) Nutrient Criteria Development Plan is summarized below (Rhode Island Department of Environmental Management 2007b). Like many of the other state's plans, the Rhode Island Plan begins by summarizing the existing EPA technical guidance and options available at the time of the publication of the plan. RIDEM then goes on to describe the future approach and timeline it will take to develop NNC.

One of RIDEM's goals was to address over-enrichment in the rivers that actually have nutrient related impairments. The RIDEM's intention was to develop nutrient criteria for riverine systems that will address real problems of nutrient over-enrichment in rivers of the state. The RIDEM anticipated that these criteria would later prevent nutrient over-enrichment, allow for identification of rivers that are impaired by nutrients, and set goals for loading estimates.

The RIDEM proposed to implement a phased approach to developing NNC for Rhode Island rivers and streams. The proposed to first evaluate the currently available data and subsequently collect new data, utilizing several of the approaches presented by EPA in the Technical Guidance Manuals. They would also utilize their own state-specific information which they believe would allow for development of more precise numeric nutrient criteria for Rhode Island rivers and streams. This process would include several key steps.

Initially, the currently available data for all rivers will be evaluated using a frequency distribution approach. For the sites with currently available data, identification of reference streams will be attempted using land use, biological data and Best Professional Judgment (BPJ). For each parameter for which there is currently data available, a frequency distribution for reference rivers and a frequency distribution for all rivers will be plotted. Various percentiles of both sets of data will be calculated for review.

The RIDEM also planned to utilize data that has been compiled to classify streams according to physical factors (land use, stream order, geology, etc), hydrology (slope, velocity, elevation, etc), point source location, etc. If possible, an attempt would be made to classify the streams based on nutrient gradients (measured nutrient concentrations and algal biomass) to help identify similarities within stream system types. A trophic classification scheme, based upon the "Dodds et al approach" outlined in the EPA technical guidance manual, will be evaluated. Potential existing sources of data and information to classify streams included Digital Elevation Models (DEM) data, Fish and Wildlife data (bottom type, canopy cover), GIS data (stream order, landuse, soil types), USGS and (Natural Resource Conservation Service) NRCS data for stream hydrology (velocity, slope, elevation) information, and the RIDEM baseline monitoring programs (chemical and biological) for information on bottom substrate type and flow. They also concluded that additional data may have to be collected to allow for classification of the rivers and streams.

The rivers and streams for which there is data will be sorted into the classes as determined above. Reference streams within each class will be identified. Frequency distributions of "reference" and all rivers will be generated to evaluate potential criteria ranges for each class of streams.

The RIDEM felt that their agency would have to collect additional data on the candidate variables. At that time they had historical data for TN, TP and turbidity in some rivers of the state. A majority of this data was however confined to the larger streams of the state which had significant wastewater treatment facility (WWTF) discharges. The RIDEM planned on investigating the addition of TN at the 25 chemical "baseline" stations. These stations would likely be sampled quarterly for water chemistry and are analyzed for other conventional (including TP and turbidity) parameters. At that time, the RIDEM did not have data for chlorophyll-*a* in rivers. Evaluation of the suitability of sampling for chlorophyll-*a* will be discussed given the concerns of macrophyte growth in RI rivers. Current observations at that time indicated that water column and periphyton levels of chlorophyll-*a* may not reveal the actual ambient conditions. Instead, macrophyte growth from sediment-to-plant cycling may be more of an issue related to nutrients loadings.

Observations of macrophyte growth at stations where TP and TN are collected may be attempted. The RIDEM planned on investigating the addition of turbidity sampling at the five USGS gaging stations located within Rhode Island. In addition, monitoring of 24 hour DO and pH levels may be added to supplement the nutrient data. The agency envisioned collecting data over the course of a year to capture seasonal conditions. In addition to the collection of data on the candidate variables, the agency also planned on collecting data on supplementary physical factors of the rivers and streams to allow for stream classification.

Once data is collected the agency planned on analyzing both new and existing historical data. The data will be evaluated using frequency distributions of reference rivers and all rivers. The data would be sorted into various classes and the frequency distributions for each class that is determined. The data will be evaluated for relationships between the critical response variables (turbidity, Chl-A, pH, DO) and observed nutrient (TP, TN) concentrations. A final evaluation of the data would be based upon Best Professional Judgement, EPA's proposed criteria, and designated use attainment. Using all of the collected information and the subsequent review of the data, the RIDEM would then be prepared to propose nutrient criteria for rivers and streams.

For lakes, RIDEM proposed to maintain the TP criteria of 25 μg/l for lakes. RIDEM planned to examine the associated Carlson Index ranges for secchi depth and chlorophyll-*a* in conjunction with 13 years of Rhode Island lakes data to establish a criteria for each parameter. Their "URI Watershed Watch Program" had collected TN data on lakes in the state for over 13 years. The agency planned on reviewing the TN data relative to the levels of the other 3 nutrient criteria parameters and the trophic status information. They planned to construct a regression model that would relate TN to TP to assist in establishing a TN criteria.

The agency planned to attempt to classify the lakes of the state to better facilitate development of NNC. Physical characteristics, independent of most anthropogenic sources, including lake size, depth, color and inherent characteristics such as reservoirs or impoundment situations, would be used to classify the lakes. All of this data including water quality data would be entered into a database to assist in the evaluation and development of criteria This information would be used to determine reference lakes within each class and impaired lakes within each class using the BPJ of state lakes experts and volunteer perception information.. In addition, a evaluation of frequency distributions of reference lakes data and frequency distribution of all lakes data will be conducted to develop a potential criteria range. The data generated from this reference approach would be used as supplemental information in the development of criteria for TN, chlorophyll-*a*, and secchi depth. The RIDEM planned to utilize all information generated from the different approaches for evaluation and development of NNC for TN, chlorophyll-*a*, and secchi depth.

South Carolina

South Carolina currently has stated adopted and federally approved NNC for selected lakes and reservoirs and other waterbodies (Table 178)(South Carolina Department of Health and Environmental Control 2008). In addition, they possess a Nutrient Criteria Development Plan (South Carolina Department of Health and Environmental Control 2007).

Table 178. Existing numeric criteria for South Carolina.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs	W	W	W	W[3]
Rivers and Streams				W[3]
Estuaries				W[3]
Wetlands				W[3]

S = Statewide   W = for selected waterbody   N/A=Not Applicable

[1] From South Carolina's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved October 2004). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for Aquatic Life uses. Currently there are no state adopted, but not federally approved NNC.

[2] Source: EPA's (South Carolina Department of Health and Environmental Control 2008; United States Environmental Protection Agency 2008b)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_sc.cfm.) (http://www.scdhec.gov/environment/water/regs/r61-68.pdf.)

[3] Numeric turbidity criteria (measured in Nephelometric Turbidity Units) apply to Outstanding National Resource Waters, Outstanding Resource Waters, freshwater trout waters and shellfish harvesting waters only.

The following information reflects South Carolina's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved October 2004) and currently listed on the South Carolina web site (http://www.scdhec.gov/environment/water/regs/r61-68.pdf)(South Carolina Department of Health and Environmental Control 2008).

The designated waterbody uses are listed below.

1) Outstanding National Resource Waters (ONRW) are freshwaters or saltwaters which constitute an outstanding national recreational or ecological resource

2) Outstanding Resource Waters (ORW) are freshwaters or saltwaters which constitute an outstanding recreational or ecological resource or those freshwaters suitable as a source for drinking water supply purposes with treatment levels specified by the Department

3) Trout Waters. The State recognizes three types of trout waters: Natural; Put, Grow, and Take; and Put and Take.

a. Natural (TN) are freshwaters suitable for supporting reproducing trout populations and a cold water balanced indigenous aquatic community of fauna and flora.

b. Put, Grow, and Take (TPGT) are freshwaters suitable for supporting growth of stocked trout populations and a balanced indigenous aquatic community of fauna and flora.

c. Put and Take (TPT) are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department.

4) Freshwaters (FW) are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department.

5) Shellfish Harvesting Waters (SFH) are tidal saltwaters protected for shellfish harvesting and uses listed in Class SA and Class SB.

Class SA are tidal saltwaters suitable for primary and secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption and uses listed in Class SB.

Class SB are tidal saltwaters suitable for primary and secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption.

The following text is the verbatim language extracted from South Carolina’s regulations that describe the current state adopted and federally approved NNC. There are no NNC that are state adopted only or currently proposed.

E. General Rules and Standards Applicable to All Waters

11. In order to protect and maintain lakes and other waters of the State, consideration needs to be given to the control of nutrients reaching the waters of the State. Therefore, the Department shall control nutrients as prescribed below.

b. Numeric nutrient criteria for lakes are based on an ecoregional approach which takes into account the geographic location of the lakes within the State and are listed below. These numeric criteria are applicable to lakes of 40 acres or more. Lakes of less than 40 acres will continue to be protected by the narrative criteria.

(1) For the Blue Ridge Mountains ecoregion of the State, ***total phosphorus shall not exceed 0.02 mg/L, chlorophyll a shall not exceed 10 µg/L, and total nitrogen shall not exceed 0.35 mg/L.***

(2) ***For the Piedmont and Southeastern Plains ecoregions of the State, total phosphorus shall not exceed 0.06 mg/L, chlorophyll a shall not exceed 40 µg/L, and total nitrogen shall not exceed 1.50 mg/L.***

(3) ***For the Middle Atlantic Coastal Plains ecoregions of the State, total phosphorus shall not exceed 0.09 mg/L, chlorophyll a shall not exceed 40 µg/L, and total nitrogen shall not exceed 1.50 mg/L.***

G. CLASS DESCRIPTIONS, DESIGNATIONS, AND SPECIFIC STANDARDS FOR SURFACE WATERS.

Quality Standards for Trout Waters

i. Turbidity. Not to exceed 10 Nephelometric Turbidity Units (NTUs) or 10% above natural conditions provided existing uses are maintained.

Quality Standards for Freshwaters

h. Turbidity * Not to exceed 50 NTUs provided existing uses are maintained.
* Lakes only Not to exceed 25 NTUs provided existing uses are maintained.

Quality Standards for Shellfish Harvesting Waters

i. Turbidity not to exceed 25 NTUs provided existing uses are maintained

Quality Standards for Class SA Waters

i. Turbidity not to exceed 25 NTUs provided existing uses are maintained.

Quality Standards for Class SB Waters

i. Turbidity not to exceed 25 NTUs provided existing uses are maintained.

South Carolina federally accepted Nutrient Criteria Development Plan delineates the most recent approach for development of NNC in that state (South Carolina Department of Health and Environmental Control 2007). According to the South Carolina

Department of Health and Environmental Control (SCDHEC), South Carolina was the first state in Region 4 to promulgate and adopt numeric nutrient criteria for lakes based upon a modification of the current EPA guidelines. SCDHEC prioritized the stages and remaining waterbody types for which NNC will be developed. The SCDHEC began the process of promulgating numeric nutrient criteria for its waters with the adoption of numeric nutrient criteria for lakes of forty acres or more in the 2001 triennial review of the water quality standards regulation, South Carolina Regulation 61-68 Water Classifications and Standards (R.61-68). The SCDHEC prioritized its lakes for numeric nutrient criteria development. SCDHEC adopted an ecoregional approach for classification of these waters and modified EPA's Approach to Criteria Development as outlined in the Technical Guidance Documents that are specific to the waterbody types to reflect attributes specific to South Carolina's lakes. SCDHEC indicated that they were currently gathering additional data and information on their estuaries, as well as reviewing data and information on our rivers and streams. It was their intent to have all of our State's waters covered by numeric nutrient criteria. South Carolina's waters have classified uses that support all of the fishable/swimmable goals of the Clean Water Act.

South Carolina had adopted all four of the USEPA nutrient criteria parameters for use with lakes, but will determine through the development process if all four are necessary for each additional type of waters. Phosphorus has largely been implicated as the cause of over-enrichment in freshwater systems and implicated recently as the limiting factor in marine systems as well, thus South Carolina will likely develop and adopt phosphorus criteria for all classes of waters. Criteria will be set based on evaluations of relationships between total phosphorus (TP) and various response variables (e.g., chlorophyll a, dissolved oxygen (DO), and biological indices). The extent or value of developing nitrogen criteria for all South Carolina waters will be examined further. SCDHEC will determine whether nitrogen criteria are needed for all waters by evaluating relationships between nitrogen concentrations and in-stream biological parameters (e.g., chlorophyll-*a*, and biological indices).

South Carolina planned on evaluating the utility of chlorophyll-a criteria (both periphyton and/or phytoplankton based) by examining relationships between chlorophyll a and nutrients in lotic and lentic waters. South Carolina had already adopted turbidity criteria for all of its waters based on waterbody types and also their classified uses. SCDHEC also planned on evaluating the use of biological indices and macroinvertebrate data to determine its utility for setting nutrient criteria. The SCDHEC was also considering the use of dissolved oxygen data and information as it relates to productivity or algal biomass.

South Carolina's nutrient standards would be based on use protection using State-specific data and not just simply a statistical evaluation of the national dataset. They anticipated translating their existing narrative water quality standards in association with any applicable numeric nutrient criteria adopted as an assurance of coverage for all of the waters of the State. If necessary, SCDHEC would include a mechanism reference in the water quality standards. Where necessary, SCDHEC would develop numeric nutrient criteria to protect specified uses of the waters of the State.

Prior to drafting the 2008 Nutrient Criteria Development Plan, South Carolina had generated a significant amount of data and information on their lakes of 40 acres or more through our Section 314 program and planned to continue to monitor the trophic status of these waters. South Carolina planned to utilize EPA's technical guidance or modifications thereof to refine and develop criteria for other waters of the State. The actual approaches used would most likely depend on the result of the analysis of available data and future data collections and would use only data specific to South Carolina waters. The approaches used would likely include either effect-based (correlating nutrient levels with measurable water quality or biological effects or impairments utilizing available data and data to be collected, findings in published literature, and historical information) or reference-based (utilizing a percentile of the frequency distribution of all sites for different water body types based on site-specific data and ecoregions).

All of South Carolina's estuaries lie within Nutrient Ecoregion XIV. During criteria development, SCDHEC will determine if it is appropriate to have one set of indicators for all estuarine waters or to include several sets. Recently, SCDHEC had expanded its analysis of estuarine eutrophication indicators, as well as spatial coverage for estuarine sampling. Approximately 24,000 observations have been collected from 1990 to 2007; however, the agency felt additional sampling, especially for chlorophyll-*a*, was needed to ensure sufficient data for appropriate classification of estuaries. The agency planned to collect additional nitrogen, phosphorus, chlorophyll-*a*, and turbidity data from tidal creeks and open waters using both fixed and random sampling designs. The SCDHEC intended to adopt numeric nutrient criteria for estuaries during the next triennial review of the water quality standards in mid 2007. Based on our review we did not see any evidence of this occurring.

South Carolina's rivers and streams lie within Nutrient Ecoregions IX, XI, and XIV. SCDHEC's river and stream monitoring program has traditionally included phosphorus, nitrogen, turbidity and biological community analyses, with extensive spatial coverage across ecoregions and stream classes. Over 120,000 observations have been collected from 1990 to 2007. This data and information will be analyzed and used to develop numeric nutrient criteria for South Carolina rivers and streams according to EPA guidance. The relationships between nutrients and designated uses of these waterbodies will be evaluated. SCDHEC intended that numeric nutrient criteria for rivers and streams be adopted in the next triennial by mid 2007. Based on our review we did not see any evidence of this occurring.

SCDHEC intended to use all available appropriate data to develop NNC. Most data available were from state sources retrieved from STORET while some state data may be used that is not in the National Nutrient Database. Other data will be reviewed as provided by external sources (USGS, studies, etc) and also from continued data collection by SCDHEC and/or other state or federal agencies.
Data collection will be conducted by SCDHEC staff according to SCDHEC Standard Operating Procedures. Statistical analyses would be performed by staff using appropriate software. SCDHEC staff had gathered information from various sources regarding

historical and current studies of nutrients in South Carolina estuaries, rivers and streams. This information may be used for background or baseline determinations.

Algal growth potential tests (AGPTs) had been conducted by SCDHEC at selected sites from South Carolina estuaries. SCDHEC staff also collected physicochemical data (DO, pH, salinity, secchi depth, etc.), nutrient samples (total ammonia, total nitrate/nitrite, TKN, and total phosphorus) and chlorophyll a samples concurrently at these sites. SCDHEC staff have reviewed and consulted on the results of AGPT study and data analysis of nutrient relationships (e. g. causal versus response indicators) in estuaries. This study was conducted in 2003 with a preliminary report due in May 2004.

SCDHEC anticipated that additional data will be needed to develop NNC. Although several continuing and new sampling initiatives were mentioned in the Nutrient Criteria Development Plan, not all represented specific efforts for the expressed purpose of developing nutrient criteria. However they noted that resources to collect these types of data were not available from state funds and external grants would need to be secured to collect additional data.

These future studies and efforts would include:

a. Further assessments of relationships between nutrient (TP and TN) concentrations and impairment of designated uses in more waters throughout the state.

b. Seasonal effects of nutrients.

c. The importance of flow, turbidity, substrate, and light in moderating the effects of nutrients.

d. Additional resources to collect, compile, and analyze data from future collection efforts.

e. Development of criteria protective of designated uses

f. Coordination with continued application of narrative criteria

g. Developing a system for evaluating exceedences of nutrient criteria for assessment

h. Exploring the role of modeling and assessing effluents on nutrient loading

i. Consideration of how to evaluate downstream effects.

The SCDHEC intended that numeric nutrient criteria for estuaries and rivers and streams be adopted in the next triennial review of the water quality standards which should be concluded by mid 2007. Based on our review to date this has not been accomplished.

South Dakota

South Dakota currently does not have NNC (South Dakota Department of Environment and Natural Resources ; South Dakota Department of Environment and Natural Resources 2003; South Dakota Department of Environment and Natural Resources 2010). In addition, South Dakota does not have a Nutrient Criteria Development Plan.

Tennessee

Tennessee currently has NNC for chlorophyll-*a* in lakes and reservoirs (Tennessee Department of Environment and Conservation 2007a)(http://www.state.tn.us/ environment/wpc/publications/)(Table 179).

Table 179. Existing numeric criteria for Tennessee.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs			W	
Rivers and Streams				
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = for selected waterbody N/A=Not Applicable

[1] From Tennessee's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved March 2008). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes. If a state/territory has criteria for the protection of drinking water or human health, those criteria may be found on the tabs for either statewide or site-specific criteria.

[2] Source: EPA's (United States Environmental Protection Agency 2008b)

Standards Reference: (García et al. 2011; Tennessee Department of Environment and Conservation 2001a; Tennessee Department of Environment and Conservation 2001b; Tennessee Department of Environment and Conservation 2003a; Tennessee Department of Environment and Conservation 2003b; Tennessee Department of Environment and Conservation 2004; Tennessee Department of Environment and Conservation 2007a; Tennessee Department of Environment and Conservation 2007b; Tennessee Department of Environment and Conservation 2007c; United States Environmental Protection Agency 1988d). http://www.state.tn.us/environment/wpc/publications/.

Site-specific Criteria

The following information reflects Tennessee's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved March 2008). There are not currently state adopted, but not EPA approved NNC for Tennessee. Also, there are no proposed NNC. The following text is taken verbatim from the current water quality standards for this state.
Designated Uses are outlined in Tennessee's water quality standards and are summarized and listed below (Tennessee Department of Environment and Conservation 2007c).

Domestic Water Supply - DWS
Industrial Water Supply - IWS
Fish and Aquatic Life - FAL
Trout Stream - TS

Naturally Reproducing Trout Stream - NRTS
Recreation - REC
Livestock Watering and Wildlife - LWW
Irrigation - IRR
Navigation - NAV

The existing NNC are listed below.

1200-4-3-.03 Criteria for Water Uses.

(3) Fish and Aquatic Life.

(4) Recreation.

(i) Nutrient Response Criteria for Pickwick Reservoir: those waters impounded by Pickwick Dam on the Tennessee River. The reservoir has a surface area of 43,100 acres at full pool, 9,400 acres of which are within Tennessee. Chlorophyll-*a* (corrected, as described in Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998): the mean of the photic-zone (See definition)* composite chlorophyll-*a* samples collected monthly April through September shall not exceed 18 µg/L, as measured over the deepest point, main river channel, dam forebay.

* Definition
1200-4-3-.04 Definitions in Addition to the Meanings Provided in the Water Quality Control Act (T.C.A. §§69-103), Terms Used in These Rules Shall Have the Meanings Provided Below.
(9) Photic-Zone – the region of water through which light penetrates and where photosynthetic organisms live.

In addition to this NNC, Tennessee does use "numeric translators" that are used to translate narrative criteria for nutrients into comparable numeric screening values to evaluate relationships with and attainment of designated uses (Gregory Denton, State of Tennessee pers. com.)(Tennessee Department of Environment and Conservation 2001a). Currently a waterbody is impaired if the nutrient translator values are exceeded, and there is biological impairment as evaluated by benthic communities. They are currently evaluating the use of phytoplankton indices.

The State of Tennessee does have a current federally accepted Nutrient Criteria Development Plan (Tennessee Department of Environment and Conservation 2007b). This is very comprehensive plan detailing the approach their state will take to develop NNC. The Tennessee Department of Environment and Conservation (TNDEC) has divided their approach for development of NNC based on waterbody type. The three waterbody types they have focused on are lakes and reservoirs, wadeable streams, and non-wadeable streams. In addition, they further classify lakes and reservoirs into separate subcategories and evaluate wadeable streams into first order and greater than first order streams. Highlights of their plan are quoted verbatim and/or summarized below.

Wadeable Streams

For wadeable streams, TNDEC has selected an approach to criteria development that blends recommendations from EPA with the state's own primary research into nutrient levels in various parts of the state. The Tennessee Ecoregion Project began in 1993 when Tennessee, decided to subregionalize and update the national Level III ecoregions that were developed in 1986. During the delineation process, maps containing information on bedrock and surface geology, soil, hydrology, physiography, topography, precipitation, land use and vegetation were reviewed. Interagency cooperation widened the base of maps, information and resources available to delineate subregions. Much of this information was digitized to produce draft maps of ecoregion and subregion boundaries. Ecoregion delineation culminated in 1997 with the publication of a map outlining 25 Level IV ecoregions.

Tennessee has been researching nutrient levels in wadeable streams since 1995 and had used these data to develop nutrient criteria as outlined in the document *Development of Regionally-Based Interpretations of Tennessee's Narrative Nutrient Criterion*, (Tennessee Department of Environment and Conservation 2001a). This document is referenced as a "translator" (along with other scientifically defensible data) in Tennessee's narrative nutrient criterion, which became a state rule in January 2004. The nutrient criterion is tied-in with the biological criteria for an effects-based approach.

The guidelines are based on data collected primarily from 1996 to 1999, consisting of chemical, physical and biological samples collected in least-impacted, yet representative, streams in 25 Level IV ecological subregions across the state. Data continues to be collected from these streams on the five-year watershed cycle. Several studies described below had been conducted to develop and refine the regionalized nutrient criteria guidelines at the time of the publication of their Plan.

Ecoregion Reference Stream Study

Three hundred and fifty-three potential reference sites were evaluated as part of the ecoregion project. The reference sites were chosen to represent the best attainable conditions for all streams with similar characteristics in a given subregion. Reference conditions represented a set of expectations for physical habitat, general water quality and the health of the biological communities in the absence of human disturbance and pollution.

Inner Nashville Basin Probabilistic Monitoring Study

In 2001, 104(b)(3) grant monies were awarded to extend a probabilistic study of water quality in the Inner Nashville Basin (ecoregion 71i). The focus of this phase of the study was to explore the relationship between nutrient levels and the biological community (Tennessee Department of Environment and Conservation 2003b). The metric with the strongest response to total phosphorus was EPT richness. The percent chironomids and oligochaetes (%OC) was the biometric most affected by nitrate+nitrite concentrations.The relationships between nutrients and macroinvertebrate biometrics were strengthened when percent canopy was included as a variable. Data show the absence of canopy played a significant role in the response of macroinvertebrates to elevated nutrient levels.

Update of Tennessee Macroinvertebrate Index for Wadeable Streams

In 2006, the state revised the Tennessee Macroinvertebrate Index as part of the annual Quality System Standard Operating Procedure (QSSOP) review and the triennial review of Water Quality Standards. In an effort to make the index more sensitive to nutrient and sediment impairment, the percent dominant taxon metric was replaced with the percent nutrient tolerant metric presented in a paper on determining nutrient impairment using biological and other non-chemical indicators in Kentucky (Brumley et al. 2004).

First Order Streams

TNDEC has developed nutrient guidelines for larger wadeable streams which are currently being applied to first order streams although the response variable (macroinvertebrates) has been adjusted. The existing biocriteria does not apply to first order streams in all bioregions. When first order test streams are sampled, an upstream or watershed reference is collected at the same time. The division is gathering this information into a first order reference database. When enough data are available, a multi-metric index and regional expectations specific to first order streams will be developed. This will help fine-tune the existing wadeable stream nutrient criteria to these smaller systems.

Periphyton

Tennessee has found that the macroinvertebrate index has proven to be a reliable assessment tool for nutrient impairment. When possible, generally as part of special studies, the State has conducted rapid periphyton density surveys as a supplement to the macroinvertebrate surveys. The first priority has been to get baseline data on reference streams. At least one and typically two or more, periphyton density surveys have been completed on every reference stream with suitable substrate. Preliminary estimates of background levels of microalgae and macroalge have been made.

Ecoregion delineation updates

Three of Tennessee’s existing subecoregions have been further divided into five Level IV ecoregions while the nomenclature has changed on three others.

Non-wadeable streams and rivers

Non-wadeable streams and rivers are covered under the general narrative nutrient criteria for fish and aquatic life in the 2004 water quality standards. Now that regional guidelines have been developed for wadeable streams and rivers, Tennessee is beginning to focus on non-wadeable flowing water. Because Tennessee strongly felt that nutrient criteria should consider the cause/effect relationships. Therefore biological guidelines for non-wadeable streams will be developed at the same time as NNC.

Lakes and Reservoirs

Lakes and reservoirs are covered under the general narrative nutrient criterion for fish and aquatic life established in the 2003 emergency rule and promulgated in the 2004 Water Quality Standards. Tennessee intended to work closely with Trinity Valley Authority (TVA), USACE, USGS, neighboring states and other agencies to develop more specific reservoir criteria. It is unlikely that Tennessee will choose to adopt EPA’s national criteria recommendations for lakes and reservoirs. Instead, for large lakes and reservoirs, the state will seek to develop site-specific goals. The State planned on utilizing the findings of the national lake and reservoir study. As with nutrient development in wadeable streams, cause and effect relationships will be used.

Wetlands

At this time, the TNDEC is uncertain what approach might be best for nutrient criteria development for wetlands. It may be possible to select reference quality wetlands based on wetland functions. The TNDEC was reviewing EPA’s December 2006 draft guidance, which was subsequently finalized and published (United States Environmental Protection Agency 2008a). At the time of the Nutrient Criteria Plan publication the TNDEC was planning to utilize the EPA guidance document along with consultation with state wetlands experts and appropriate resource agencies to develop a strategy for future NNC development. The TNDEC stated that additional funding would be needed to accomplish this task.

Since publication of the Nutrient Criteria Development Plan, several nutrient criteria related studies have been completed to gather more information on the distribution of nutrients in Tennessee’s waterbodies and possible relationships with response variables (García et al. 2011; Tennessee Department of Environment and Conservation 2009a; Tennessee Department of Environment and Conservation 2009b; Tennessee Department of Environment and Conservation 2010).

Texas

Since TCEQ water quality standards program staff are very familiar with Texas water quality standards, we provide only a very brief synopsis of current NNC information for this state. NNC were adopted by Texas in 2010 for selected reservoirs, and were recently approved by EPA in 2011 ((Flores 2011; Texas Commission on Environmental Quality 2010h; Texas Commission on Environmental Quality 2011). The NNC were for selected reservoirs and consisted of chlorophyll-a NNC. The standard is defined as a value of the median of monitoring data that will not exceed NNC for chlorophyll-a. The NNC varies with each reservoir: (5.00-53.05 μg/L Chl-A). Various approaches were considered while developing the reservoir NNC. This included ecoregion reference approach, Trophic State Indices, modeling and stressor-response models (Lower Colorado River Authority 2009; Texas Commission on Environmental Quality 2008b; Texas Commission on Environmental Quality 2009; Texas Commission on Environmental Quality 2010a; Texas Commission on Environmental Quality 2010c; Texas Commission on Environmental Quality 2010f; Texas Parks and Wildlife Department 2007). The final approach used involved historical sampling data and NNC set at the upper parametric prediction interval (Texas Commission on Environmental Quality 2010h).

Recent studies involving whole stream and mesocosm level community studies of stream periphyton versus nutrient loading and concentrations have been conducted under EPA funding using stressor response approach, change point analysis, and TITAN type analysis (King et al. 2009; King and Winemiller 2009). Texas does have a mutually recognized Nutrient Criteria development plan (Texas Commission on Environmental Quality 2006). The agency is currently considering various approaches for development of stream, river and estuarine NNC.

Utah

Utah currently does not have NNC (United States Environmental Protection Agency 1988e; Utah Department of Environmental Quality 2006; Utah Department of Environmental Quality 2011)(http://www.rules.utah.gov/publicat/code/r317/r317-002.htm). The state does have a Nutrient Criteria Development Plan (Miller 2005). In addition, draft summary guidance on their most current strategy for development of NNC is outlined in (Utah Department of Environmental Quality 2011).

The following information is taken from the Nutrient Criteria Development plan (Miller 2005). Nuisance algae problems have been documented in Utah and throughout the United States for many years. Impacts occur as a result of excess biomass, although specific impacts may vary substantially between lentic (lake) and lotic (flowing) environments and the individual species that develop dominance. Lake environments support free-living algae (phytoplankton) that exist in the water column. Most wadeable streams that have stable substrates support benthic attached algae (periphyton). Primary production in deeper, or turbid streams, where adequate light does not reach the bottom, is usually provided by phytoplankton. Biomass is usually measured by its chlorophyll a content,
because this is the dominant algal pigment. It is reported as μg L-1 (in water samples) or mg m^2 for periphyton.

At the time of Utah's Nutrient Criteria Development Plan publication EPA had been encouraging states to incorporate NNC into their rules. However, EPA guidelines recognize the influence of local and regional conditions and have therefore suggested a probabalistic approach based on the top 25% (waterbodies with the lowest nutrient concentrations) among a list of ***reference sites*** for specific waterbody types; or to select a value based on the (bottom) 25th percentile of nutrient concentrations ***among all waterbodies*** of the same type and ecoregion in order to establish reference condition and hence, the appropriate numeric standard for that region. Utah believed that both of these approaches do not fully represent local or site-specific stream or lake/reservoir conditions. Therefore, Utah proposed additional approaches in their plan. In addition to nutrients, the Division planned to develop appropriate standards for algal biomass in streams and lakes/reservoirs.

The Utah Department of Environmental Quality (UTDEQ) had been conducting extensive water quality monitoring (including nutrients) of Utah's streams and lakes prior to 2007. Approximately 97% of lake/reservoir surface acres are presently assigned beneficial uses and undergo biannual monitoring in order to determine their respective support status. In this assessment, the Division uses its narrative values as weight of evidence if excessive algal biomass (chlorophyll-*a*) is apparent or if hypolimnetic dissolved oxygen approaches the 24-hr dissolved oxygen standard. UTDEQ's plan for implementing nutrient and algal biomass standards for lakes and reservoirs is to establish a sub-classification system within their existing beneficial use designation. Because only four of Utah's 132 priority lakes are natural lakes, this subclassification system will focus on reservoirs. Reservoirs are uniquely different from natural lakes. These differences include beneficial use classification, basin morphometry, fluctuating depth and residence time, and requirement for a conservation pool.

UTDEQ planned to use these characteristics, in addition to ecoregion, to stratify or group reservoirs with similar characteristics. Our goal is to develop nutrient and chlorophyll-*a* standards for individual subclasses of reservoirs. However, because of the highly variable nature of reservoirs, UTDEQ believed that this may not be possible on an ecoregional or other large-scale basis. Alternatively, UTDEQ also planned on proceeding to establish site-specific criteria values with the priority placed on reservoirs that have already been placed on their 303(d) list.

UTDEQ believed that derivation of numeric nutrient and algal biomass criteria will be difficult for streams as well. This is because there are other significant environmental factors that influence algal growth in streams. Therefore, UTDEQ planned on developing appropriate methodology and a supportive database that demonstrate that a waterbody is being impacted by excess nutrients and algae. UTDEQ planned to focus on two major approaches to meet these data needs and appropriate decision points. First, UTDEQ planned on establishing a network of reference sites which includes about 100 candidate sites under investigation thus far. Many of these sites were identified previously during the Western EMAP Pilot Study. UTDEQ have adopted this protocol as part of the decision-making process for determining reference condition. As with the reservoir classification system, UTDEQ planned on stratifying the stream database according to groups with similar characteristics (i.e. ecoregion, Rosgen stream type, stream order, phytoplankton vs periphyton-based primary production, etc.), as well as watershed-scale attributes such as land use and urbanization. This effort will allow development of multiple metrics and indices that can be used to identify thresholds of significant adverse changes in the aquatic community. After ecoregional and physicochemical variables have been accounted for, nutrient concentrations can then be accurately related to these thresholds of adverse change. In addition to developing a reference network of sites, UTDEQ will be performing special studies on specific streams/watersheds. In these studies, they stated that they will 1) measure physicochemical and biological attributes (i.e. periphyton species composition and biomass, macroinvertebrate species composition), in relation to upstream/downstream gradients; 2) compare this data to a parallel (control) stream of the same order; or the magnitude and rate of change following chemical P removal. This effort will result in development of site-specific numeric criteria in support of TMDL implementation as well as useful data for their reference condition database.

The following summary of the most current approach to NNC development is taken verbatim from: *Draft: Nutrient Water Quality Standards: An Adaptive and Collaborative Approach to Developing Nutrient Criteria to Protect Aquatic Life Uses*, March 22, 2011 (Utah Department of Environmental Quality 2011)

Rationale for Non-Traditional Approach

o Pathways between nutrients and designated uses are numerous and complex
o Site-specific characteristics are important
o Much variance exists among regional, numeric criteria
o Disagreements over what N & P criteria are appropriate are common

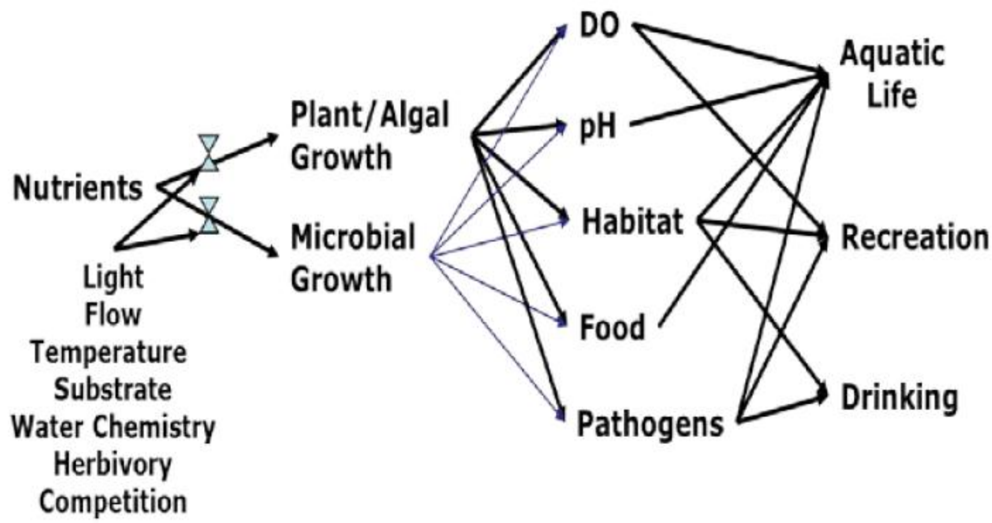


Figure 28. Pathways between nutrients and designated uses. Source: (Utah Department of Environmental Quality 2011).

A Path Toward Defensible Water Quality Nutrient Protections

o Establish regional indicators for N & P (multiple lines of evidence, models)
o Establish nutrient-specific biological and functional responses for streams and lakes(ecology study)
o Identify waters with evidence of nutrient-related degradation
o Either immediately promulgate indicators to numeric criteria or create a variance (fixed-time) and study plan for verifying regional numbers

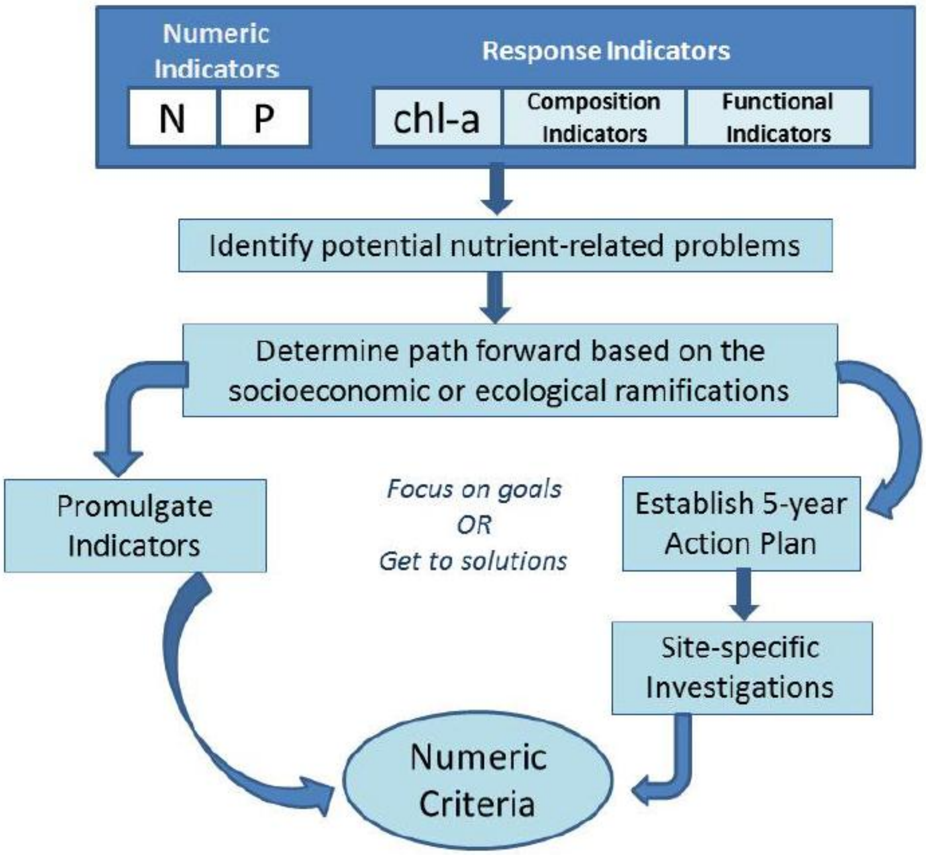


Figure 29. Potential paths toward development of defensible numeric nutrient criteria in Utah. Source: (Utah Department of Environmental Quality 2011)

Multiple Lines of Evidence to Determine Phosphorous and Nitrogen Regional WQ Indicators

o Multiple models are being developed to determine regional criteria
o Goal is to develop thresholds—water quality indicators for N, P, and algae growth (e.g., Chl-a)
o Indicators serve as WQ screening values until problems are identified

o A range of numbers will be established to bracket values that may result from site-specific studies for aquatic life, recreation, and drinking water uses

Detecting Deleterious Nutrient Effects

o DWQ is conducting studies to develop indicators that quantify ecological responses to nutrients
o Indicators will be both structural (changes to biological composition) and functional (changes to ecosystem process)
o Examples of structural indicators include: bug nutrient indicator metrics & diatom indicator metrics; these are direct measures of the effects of nutrients to aquatic life uses
o Examples of functional indicators include: nutrient spiraling, organic matter characterization, nutrient diffusing substrates (N vs P limitation), leaf pack decomposition (microbe responses), and whole stream metabolism
o These measures will be used in concert with chemical indicators to identify waters with potential nutrient-related problems
o Ultimately, thresholds will be established for aquatic life, recreation and drinking water uses; the CWA require the use of the most protective value

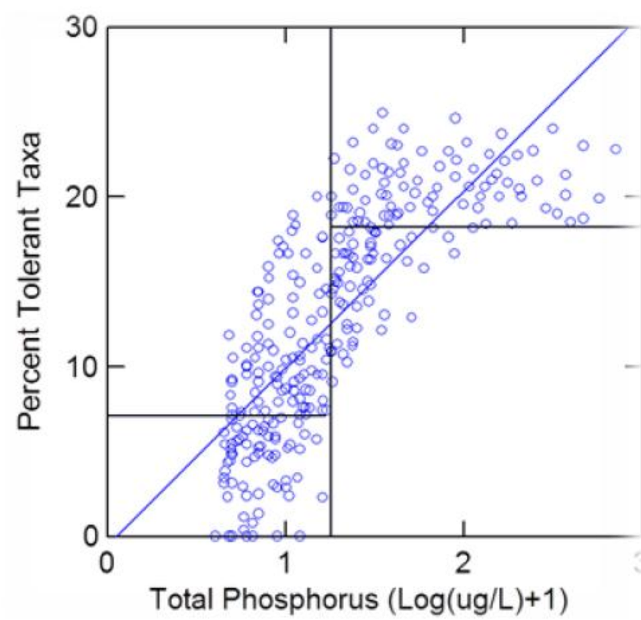


Figure 30. Example of use of stressor response relationships between TP and indicator taxa in Utah (Utah Department of Environmental Quality 2011).

Development of Numeric Site-Specific Criteria

o DWQ will work with scientists from EPA and academia to develop a site-specific criteria manual
o The manual will include field, lab, and analytical methods
o Stakeholder potentially affected by a nutrient impairment will be encouraged to work with DWQ to conduct the research to determine if regional indicators are appropriate criteria for a specific waterbody

Protecting High Quality Waters

o We cannot allow waters to become degraded before instigating management actions
o The Clean Water Act addresses this concern with antidegradation rules and regulations
o For any new discharge or expansion of an existing discharge, Utah rules require DWQ to permit the least degrading, feasible alternative
o DWQ is conducting an economic study to better define "feasible" in the context of a communities ability to pay
o Nutrients would always be evaluated when quantifying which treatment alternative are the least degrading.

Vermont

Currently Vermont has numeric criteria for nitrate-nitrogen in its lakes and rivers (http://www.nrb.state.vt.us/wrp/publications/wqs.pdf). In addition, Vermont has limited TP criteria for Lake Champlain and Lake Memphremagog and for streams above 2,500 feet in elevation. Most of these criteria were adopted in 1998.

Figure 31. Existing Numeric Criteria for the State of Vermont[1].

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs	S	W		S
Rivers and Streams	S	S		S
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide   W = For selected waterbody   N/A=Not Applicable
[1] From Vermont's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved May 2008). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for aquatic life use support.
[2] Source: EPA's "State Adoption of Numeric Nutrient Standards (1998-2008)."

The language presented below comes directly from state water quality standards and applies to all waterbodies within the state (unless a waterbody type or designated use is noted). The following information reflects Vermont's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved May 2008). We also checked the state web site and found this to be the most recent water quality standards (http://www.nrb.state.vt.us/wrp/publications/wqs.pdf)(Vermont Natural Resources Board 2008).

The designated beneficial uses of waterbodies in Vermont are listed below.

Table 180. Designated uses for waterbodies in Vermont. Source: (Vermont Department of Environmental Conservation 2006b).

Designated Uses	Class A(1) – Ecological Waters	Class A(2) – Public Water Supplies	Class B Waters
Aquatic Biota, Wildlife & Aquatic Habitat	√	√	√
Aesthetics	√	√	√
Swimming & Other Primary Contact Recreation	√		√
Boating, Fishing & Other Recreation Uses	√		√
Public Water Supplies		√	√
Irrigation of Crops & Other Agricultural Uses			√

Excerpts from the State of Vermont's water quality standards are listed below.

Statewide Criteria

Chapter 3 Determination of Criteria

Section 3-01 Water Quality Criteria and Indices – General

B. General Criteria

The following water quality criteria shall be achieved in all waters, regardless of their classification:

2. Phosphorus

a. All waters - general policy

In all waters, total phosphorus loadings shall be limited so that they will not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses.

b. Upland Streams

In addition to compliance with the general policy above, for all streams above 2,500 feet in elevation, **total phosphorus shall not exceed 0.010 mg/L at low median monthly flow.**

d. Lakes, ponds, or reservoirs that have drainage areas of less than 40 square miles and a drainage area to surface area ratio of less than 500:1, and their tributaries.

(1) In addition to compliance with the general policy above, there shall be no significant increase over currently permitted phosphorus loadings. Discharges to tributaries **shall not increase in-stream conditions by more than 0.001 mg/L at low median monthly flow**. Indirect discharges to lakes, ponds, or reservoirs **shall not increase total dissolved**

phosphorus as measured in the groundwater 100 feet from the mean water level of the lake, pond, or reservoir by more than 0.001 mg/L.

(2) Applicable basin plans, other applicable plans, permit limitations, and other measures adopted or approved by the Secretary, may define "no significant increase" so as to allow new or increased discharges of phosphorus, only when the permit for such discharges provides for a corresponding reduction in phosphorus loadings to the receiving waters in question.

3. Nitrates

a. General Policy

In all waters nitrates shall be limited so that they will not contribute to the acceleration of eutrophication, or the stimulation of the growth of aquatic biota, in a manner that prevents the full support of uses.

b. Lakes, Ponds and Reservoirs not including Riverine Impoundments

Not to exceed 5.0 mg/L as NO_3-N regardless of classification.

c. All Other Waters

(1) **Not to exceed 0.20 mg/L, as nitrate-nitrogen (NO_3-N) at flows exceeding low median monthly flows**, in Class A(1) and A(2) waters above 2,500 feet altitude, National Geodetic Vertical Datum.

(2) **Not to exceed 2.0 mg/L as NO3-N at flows exceeding low median monthly flows,** in Class A(1) and A(2) waters at or below 2,500 feet altitude, National Geodetic Vertical Datum.

(3) **Not to exceed 5.0 mg/L as NO3-N at flows exceeding low median monthly flows**, in Class B waters.

6. Taste and Odor
None that would prevent the full support of any designated uses or existing use or have an adverse effect on the taste or odor of fish.

7. Color
None that would prevent the full support of uses.

Section 3-02 Class A(1) Ecological Waters

A. Management Objectives
Managed to achieve and maintain waters in a natural condition, compatible with the following designated uses:

1. Aquatic Biota, Wildlife, and Aquatic Habitat - consistent with waters in their natural condition.

2. Aesthetics - water character, flows, water level, bed and channel characteristics, and flowing and falling waters in their natural condition.

3. Swimming and Other Primary Contact Recreation - highest quality in waters, in their natural condition with negligible risk of illness or injury from conditions that are a result of human activities.

4. Boating, Fishing, and Other Recreational Uses - highest quality as compatible with waters in their natural condition.

B. Water Quality Criteria for Class A(1) Ecological Waters
The following water quality criteria shall be achieved in all Class A(1) ecological waters.

1. **Turbidity - None in such amounts or concentrations that would prevent the full support of uses, and not to exceed 10 NTU (nepholometric turbidity units) as an annual average under dry weather base-flow conditions.**

Section 3-03 Class A(2) Public Water Supplies

A. Management Objectives
Water managed for public water supply purposes to achieve and maintain waters with a uniformly excellent character and a level of water quality that is compatible with the following designated uses:

1. Aquatic Biota, Wildlife, and Aquatic Habitat - high quality aquatic biota and wildlife sustained by high quality aquatic habitat necessary to support their life-cycle and reproductive requirements.

2. Aesthetics - water character, flows, water level, and bed and channel characteristics consistently exhibiting aesthetic value.

3. Swimming and other primary contact recreation - in waters that pose negligible risk of illness due to conditions that are a result of human activities, but managed as necessary for consistency with use as a public water supply.

4. Boating, Fishing, and Other Recreational Uses - suitable for good quality boating, fishing, and other recreational uses.

5. Public Water Supplies - highly suited as a source for public water supply with disinfection, and filtration when necessary.

B. Water Quality Criteria for Class A(2) Public Water Supplies

The following water quality criteria shall be achieved in all Class A(2) public water supplies.

1. **Turbidity - None in such amounts or concentrations that would prevent the full support of uses, and not to exceed 10 NTU (nepholometric turbidity units) as an annual average under dry weather base-flow conditions**.

Section 3-04 Class B Waters

A. Management Objectives
Class B waters shall be managed to achieve and maintain a level of quality that fully supports the following designated uses:

1. Aquatic Biota, Wildlife, and Aquatic Habitat - aquatic biota and wildlife sustained by high quality aquatic habitat with additional protection in those waters where these uses were sustainable at a higher level based on Water Management Type designation.

2. Aesthetics - water character, flows, water level, bed and channel characteristics, exhibiting good aesthetic value and, where attainable, excellent aesthetic value based on Water Management Type designation.

3. Public water supply - Suitable for use as a source for a public water supply with filtration and disinfection.

4. Irrigation of crops and other agricultural uses - suitable, without treatment, for irrigation of crops used for human consumption without cooking and suitable for other agricultural uses.

5. Swimming and other primary contact recreation - suitable for swimming and other forms of water based recreation where sustained direct contact with the water occurs and, where attainable, suitable for these uses at very low risk of illness based on Water Management Type designation.

6. Boating, fishing and other recreational uses - Suitable for these uses with additional protection in those waters where these uses are sustainable at a higher level based on Water Management Type designation.

B. Water Quality Criteria for Class B waters
In addition to the criteria specified in ' 3-01 of these rules, the following criteria shall be met in all Class B waters:

1. Turbidity - The following criteria shall be achieved: a. **In Cold Water Fish Habitat waters - None in such amounts or concentrations that would prevent the full support of uses, and not to exceed 10 NTU (nepholometric turbidity units) as an annual average under dry weather base-flow conditions; and b. In Warm Water Fish Habitat waters - None in such amounts or concentrations that would prevent**

the full support of uses, and not to exceed 25 NTU (nepholometric turbidity units) as an annual average under dry weather base-flow conditions.

Site-specific Criteria

Chapter 3 Determination of Criteria
Section 3-01 Water Quality Criteria and Indices – General
B. General Criteria

The following water quality criteria shall be achieved in all waters, regardless of their classification:
2. Phosphorus
c. Lake Champlain and Lake Memphremagog

(1) It is the policy of the State of Vermont to accomplish those net reductions in current phosphorus loadings to Lake Champlain and Lake Memphremagog that are necessary to achieve the in-lake total phosphorus concentration criteria specified in Table 181 (Table 3 in regulation) below. To support this policy, the following requirements shall apply.

(2) In the watersheds of Lake Champlain and Lake Memphremagog, there shall be no significant increase over currently permitted phosphorus loadings. “No significant increase” may be defined by the Secretary, as part of the applicable basin plans, other applicable plans, permit limitations, or other measures to allow new or increased discharges of phosphorus, only when the permit for such discharges provides for a corresponding reduction in phosphorus loadings from other sources within the watershed of the same lake segment.

(3) All discharges into each of the lake segments identified below, or into tributaries within the basin, shall comply with the applicable basin plans, other applicable plans, permit limitations and any other measures adopted or approved by the Secretary reasonably designed to achieve the following criteria:

Table 181. Site specific numeric nutrient criteria in Vermont (Table 3 State Water Quality Standards)(Vermont Natural Resources Board 2008).

Lake Segment (See Appendix B Vermont Water Quality Standards)[1]	Phosphorus Criterion (mg/L as P)
Lake Champlain	
Main Lake	0.010
Malletts Bay	0.010
Burlington Bay	0.014
Shelburne Bay	0.014
Northeast Arm	0.014
Isle La Motte	0.014
Otter Creek	0.014
Port Henry	0.014
St. Albans Bay	0.017
Missisquoi Bay	0.025
South Lake A	0.025
South Lake B	0.054
Lake Memphremagog	
Main Lake	0.014
South Bay	0.025

[1]The above criteria shall be achieved as the annual mean total phosphorus concentration in the photosynthetic depth (euphotic) zone in central, open water areas of each lake segment.

According to EPA Region 1, many northeastern states including Vermont, Maine and New Hampshire have historically used narrative nutrient criteria "translator" values documented in their implementation guidance documents (T. Stover, pers.com.)(Vermont Department of Environmental Conservation 2006b). Many have adopted in part the EPA CALM guidance procedural methods (Edwarson 2010; Rhode Island Department of Environmental Management 2007a; United States Environmental Protection Agency 2002a).

Recently in 2009 Vermont initiated rulemaking for nutrient criteria for streams in 2009 (Laidlaw 2010). These draft criteria have submitted to EPA as well for review although they have not been adopted(United States Environmental Protection Agency 2008b). The proposed streams criteria are: TP 10µg/L- 44 µg/L and TN 0.3 – 0.75 mg/L (Table 182). Large rivers and lakes > 20 acres have not been addressed. Vermont also proposed new lake numeric nutrient standards (Table 183). However, no specific timeline for rulemaking has been established.

Table 182. Proposed numeric nutrient criteria for Vermont streams.

			Aesthetics Criteria				Aquatic Life Criteria		
Variable	Units	Stream Type[a]	A1 Natural Condition	A2, B1 No worse than excellent	B2 No worse than very good	B, B3 No worse than good	A1 Natural Condition	B1 No more than minor change	A2, B, B2, B3 No more than moderate change
Low-flow TP	mg/L	SHG	0.013[b]	0.020	0.030	0.044	0.010[c]	0.020	0.035
		MHG	0.011[b]	0.020	0.030	0.044	0.010[c]	0.020	0.035
		WWMG	0.022[b]	0.020	0.030	0.044	0.020	0.030	0.050
Low-flow TN	mg/L	SHG	0.33[b]	--	0.50	0.85	0.30	0.50	0.75
		MHG	0.28[b]	--	0.50	0.85	0.30	0.50	0.75
		WWMG	0.35[b]	--	0.50	0.85	0.50	0.75	0.75

[a] SHG = small high-gradient; MHG = medium high-gradient; WWMG = warm-water medium-gradient.
[b] Derived from the 75[th] percentile of the reference stream distribution (Figure 7).
[c] The existing TP criterion of 0.010 mg/L in the Vermont Water Quality Standards for streams above 2,500 feet elev: such streams as A(1) unless specifically classified as A(2).

Table 183. Proposed numeric nutrient criteria for selected Vermont Lakes. Source: (Laidlaw 2010).

		Aesthetics Criteria			Aquatic Life Criteria		
Variable	Units	A1 Natural Condition	A2, B1 No worse than excellent	B, B2, B3 No worse than good or very good	A1 Natural Condition	B1 No more than minor change	A2, B, B2, B3 No more than moderate change
Spring TP	mg/L	0.012[a] 0.016[b]	0.014	0.024	0.012[a] 0.016[b]	0.014	0.024
Spring TN	mg/L	0.36	0.40	0.48	0.36	--	--
Summer TP	mg/L	0.014	0.014	0.024	0.014	--	--
Summer Secchi	m	3.8	3.8	2.4	3.8	--	--
Summer Chl	mg/L	0.005	0.009	0.016	0.005	--	--

[a]Applies to lakes in the Northeastern Highlands and Northeastern Coastal Zone sub-ecoregions.
[b]Applies to lakes in the Eastern Great Lakes and Hudson Lowlands sub-ecoregions.

Virgin Islands

The U.S. Virgin Islands (USVI) Code established the Department of Planning and Natural Resources (VIDPNR) as the environmental protection/regulatory agency. The Virgin Islands currently possesses NNC for phosphorus and clarity in estuaries (Table 184) (United States Virgin Islands Department of Planning and Natural Resources 2010a). In addition, the Virgin Islands also has an approved Nutrient Criteria Development Plan (**United States Virgin Islands Department of Planning and Natural Resources** 2010b). An excerpt of the Virgin Islands current NNC is listed below.

Table 184. Existing numeric criteria for the Virgin Islands.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs	N/A	N/A	N/A	N/A
Rivers and Streams	N/A	N/A	N/A	N/A
Estuaries		S		S
Wetlands	N/A	N/A	N/A	N/A

S = Statewide W = for selected waterbody N/A=Not Applicable
[1] From Virgin Islands' water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved June 2010) for aquatic life use protection.
[2] Source: EPA's (United States Environmental Protection Agency 2008b; United States Virgin Islands Department of Planning and Natural Resources 2010a).

The USVI has three designated use classes of water. This includes:

1. Class A: Best usage of waters: Preservation of natural phenomena requiring special conditions (e.g. natural reefs, spawning areas),

2. Class B: Best usage of waters: For maintenance and propagation of desirable species of aquatic life (including threatened and endangered species listed pursuant to section 4 of the federal Endangered Species Act) and for primary contact recreation (swimming, water skiing, etc,

3. Class C:
• Best usage of waters: For maintenance and propagation of desirable species of aquatic life (including threatened and endangered species listed pursuant to section 4 of the federal Endangered Species Act) and for primary contact recreation (swimming, water skiing, etc.).

The current state adopted and federally approved water quality standards and NNC are listed below.

Statewide Criteria

§186-1. General water quality criteria
(a) All waters of the U.S. Virgin Islands shall meet generally accepted aesthetic qualifications and shall be capable of supporting diversified aquatic life. "Waters" of the U.S. Virgin Islands shall be defined, as follows, as in by Title 12, Chapter 7, Section

182(f) of the Virgin Islands Code: “Waters of the United States Virgin Islands” means all waters within the jurisdiction of the United States Virgin Islands including all harbors, streams, lakes, ponds, impounding reservoirs, marshes, water-courses, water-ways, wells, springs, irrigation systems, drainage systems and all other bodies or accumulations of water, surface and underground, natural or artificial, public or private, situated wholly or partly within or bordering upon the United States Virgin Islands, including the territorial seas, contiguous zones, and oceans.”

(b) Biocriteria: The Territory shall preserve, protect, and restore water resources to their most natural condition. The condition of these waterbodies shall be determined from measures of physical, chemical, and biological characteristics of each waterbody class, according to its designated use. As a component of these measures, the Territory may consider the biological integrity of the benthic communities living within waters. These communities shall be assessed by comparison to reference conditions(s) with similar abiotic and biotic environmental settings that represent the optimal or least disturbed condition for that system. Such reference conditions shall be those observed to support the greatest community diversity, and abundance of aquatic life as is expected to be or has been historically found in natural settings essentially undisturbed or minimally disturbed by human impacts, development, or discharges. This condition shall be determined by consistent sampling and reliable measures of selected indicator communities of flora and/or fauna and may be used in conjunction with other measures of water quality. Waters shall be of a sufficient quality to support a resident biological community as defined by metrics based upon reference conditions. These narrative biological criteria shall apply to fresh water, wetlands, estuarine, mangrove, seagrass, coral reef and other marine ecosystems based upon their respective reference conditions and metrics.

(c) These waters shall be free of substances attributable to municipal, industrial, or other discharges or wastes as follows:

(6) Exotic or aquatic nuisance species.

§186-2. Class A

(a) Best usage of waters: Preservation of natural phenomena requiring special conditions, such as the Natural Barrier Reef at Buck Island, St. Croix and the Under Water Trail at Trunk Bay, St. John. These are outstanding natural resource waters that cannot be altered except towards natural conditions. No new or increased dischargers shall be permitted.

(b) Quality criteria: Existing natural conditions shall not be changed. The biological condition shall be similar or equivalent to reference condition for biological integrity. In no case shall Class B water quality standards be exceeded.

§186-3. Class B

(a) Best usage of waters: For maintenance and propagation of desirable species of aquatic life (including threatened, endangered species listed pursuant to section 4 of the federal Endangered Species Act and threatened, endangered and indigenous species listed pursuant Title 12, Chapter 2 of the Virgin Islands Code) and for primary contact recreation (swimming, water skiing, etc.). This Class allows minimal changes in structure of the biotic community and minimal changes in ecosystem function. Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.

(b) Quality criteria: The biological condition shall reflect no more than a minimal departure from reference condition for biological integrity. The following criteria apply at and beyond the boundary of the applicable mixing zone as specified in section 186-5(f) or 186-6, as the case may be.

(5) Phosphorus: **Phosphorus as total P shall not exceed 50 ug/L in any water**s.

(7) Suspended, colloidal, or settleable solids: None from wastewater sources which will cause disposition or be deleterious for the designated uses shall be present in any waters.

(11) Color and turbidity: (A) Except for Class B waters listed in section 186-11(b)(1)(A), a **Secchi disc shall be visible at a minimum depth of one (1) meter. For waters where the depth does not exceed one (1) meter, the bottom must be visible.**

§186-4. Class C
(a) Best usage of waters: For maintenance and propagation of desirable species of aquatic life (including threatened and endangered species listed pursuant to section 4 of the federal Endangered Species Act and threatened, endangered and indigenous species listed pursuant Title 12, Chapter 2 of the Virgin Islands Code) and for primary contact recreation (swimming, water skiing, etc.). This Class allows for evident changes in structure of the biotic community and minimal changes in ecosystem function. Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa (community structure) are allowed but sensitive-ubiquitous taxa remain common and abundant; ecosystem functions are fully maintained through redundant attributes of the system.
(b) Quality criteria: The biological condition shall reflect no more than a minimal departure from reference condition as observed at the least disturbed reference site(s) within Class C waters. The following criteria apply at and beyond the boundary of the applicable mixing zone as specified in section 186-5(f) or section 186-6, as the case may be.

(5) Phosphorus: Phosphorus as total P shall not exceed 50 ug/L in any waters.

(7) Suspended, colloidal, or settleable solids: None from wastewater sources which will cause disposition or be deleterious for the designated uses shall be present in any waters.

(**11) Color and turbidity: A Secchi disc shall be visible at a minimum depth of one (1) meter.**

Nutrient Criteria Development Plan

As mentioned earlier, the Virgin Islands possesses a mutually agreed upon (EPA and Virgin Island) Nutrient Criteria Development Plan (United States Virgin Islands

Department of Planning and Natural Resources 2010b). The details and content of this recent revision of the plan are included below.

By August 2001, EPA had published the *Technical Guidance Manual for Estuarine and Coastal Marine Waters* (United States Environmental Protection Agency 2001j). This manual provided states, tribes and other authorized jurisdictions with methods for developing nutrient water quality criteria for estuarine and coastal marine waters. While this guidance does not present nutrient criteria for a specific estuaries or coastal waters, it constitutes EPA's scientific recommendations regarding defensible approaches for developing regional nutrient criteria.

In the process of nutrient criteria development, USVI planned to follow recommendations included in the 2001 Guidance document. The Virgin Island Department of Planning and Natural Resources (DPNR) first planned on establishing a range of nutrient (phosphorus and nitrogen) concentrations in reference and impacted waters. Reference sites would be determined as DPNR continued to work on the development of nutrient criteria. Second, DPNR would analyze data to establish 75th percentile values for class A, B, and C waters. These values would become a significant component in the process of nutrient criteria development. Once the data is analyzed, DPNR would determine if it was necessary to develop different nutrient criteria for the water classes (A, B, and C) as relates to estuarine and coastal criteria. Once criteria are developed, it would be incorporated into the WQS revision process.

The DPNR had planned on conducting several projects that would comprise their Nutrient Standards Plan. They estimated that these projects would be completed at various times over the next several years. DPNR noted that EPA had previously recommended that states establish criteria for both nutrients [nitrogen (N), and phosphorus (P)] along with response variables (chlorophyll a and/or water clarity). DPNR believed that their numerical values, based on historical data as well as data collected presently and in the future, will accurately represent not-to-be-exceeded nutrient levels necessary to protect the designated uses (best uses) of our waters. However, given the technical and resource constraints, DPRNR expected criteria development would take time depending on resources. Before numerical standards can be adopted, DPNR stated that further research must be conducted which included multi-year sample collection.

Enhanced water quality monitoring project

The DPNR outlined their process of selected monitoring sites using previously conducted research and GIS. They spelled out the number of sites and seasonality and types of parameters. This included temperature, salinity, pH, dissolved oxygen, turbidity, TKN, TP. At the time of analysis the University of the Virgin Islands (UVI) did not have the capability to analyze TN. UVI however eventually acquired analytical equipment which allowed for TN analysis. They also described their planned statistical analysis including multiple linear regression to examine possible correlations between nutrient concentration and routine water quality parameters.

The proposed experimental design was reviewed by an EPA-contracted statistician, at the request of the Nutrient Work Group. They recommended that DPNR explore the use of non-parametric statistical tests (e.g. rank sum tests. They anticipated that this study would be completed during a 2-year project to be untaken by UVI.

Relate Nutrient Concentration to Coral Health – to be completed by December 2010

In addition to examining nutrient concentrations in varying waterbody types, the USVI's Nutrient Criteria Development Program would attempt to examine the relationship between nutrients concentrations in the water column and its relationship with coral reef health. Relating coral reef condition to ambient water quality will help U.S. EPA and USVI establish methods that support the mandates of the Clean Water Act. This in turn would enhance reef sustainability. In 2007, Bill Fisher of Office of Research and Development's (ORD's) Gulf Ecology Division published the Stony Coral Rapid Bioassessment Protocol for use in the USVI. The bioassessment surveys were completed by the ORD for St. Croix in November to December 2007 and for St. John's and St. Thomas Islands in February to March 2009. They planned two more monitoring events being scheduled before the project is completed. DPNR anticipated the data collection to be completed by December 2010 and statistical data analysis completed by June 2011. Results of this study will be a significant component during the development of nutrient criteria to protect sensitive coral reef ecosystems.

Summary

DPNR believed that evaluation of the results of the above referenced efforts would facilitate better decision making and result in scientifically numeric nutrient criteria development. They also stated that additional sampling, more site-specifically focused studies, etc. may be needed. The Virgin Island's goal was to adopt NNC by 2015 with EPA approval in 2016.

Virginia including Chesapeake Bay Regional Criteria

Virginia has NNC for phosphorus, chlorophyll-a and clarity for selected waterbodies (Virginia State Water Control Board 2011)(Table 185). In addition, Virginia has a mutually agreed to Nutrient Criteria Development Plan (Virginia Department of Environmental Quality 2006). In addition to the information and publications obtained from EPA and the State of Virginia web sites, we also obtained additional information from Virginia Department of Environmental Quality (VADEQ) staff member Mr. David Whitehurst (D. Whitehurst pers. com.).

Current nutrient criteria apply broadly to two categories of waterbodies including lakes and reservoirs and Chesapeake Bay (Whitehurst pers.com.). The state numeric nutrient criteria regulations that apply to Virginia are cited below.

Chesapeake Bay criteria – 9VAC25-260-185
James River site specific criteria - 9VAC25-260-310(bb).
Lake and Reservoir criteria – 9VAC25-260-187

Table 185. Existing numeric nutrient criteria in Virginia.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs		W	W	
Rivers and Streams				
Estuaries			W	W[3]
Wetlands				

S = Statewide W = For selected waterbody N ⁄ A=Not Applicable

[1] From Virginia's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved December 2009). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes for protection of aquatic life.

[2] Source: EPA's "State Adoption of Numeric Nutrient Standards (1998-2008)", http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_va.cfm#existing, (http://www.deq.state.va.us/wqs/)

[3] Virginia has numeric DO and clarity criteria to protect designated uses from the impacts of nutrients and suspended sediment in the Chesapeake Bay and its tidal tributaries. For the Chesapeake Bay, submerged aquatic vegetation (SAV) restoration acreage is a surrogate clarity indicator since clarity will determine the ability for SAVs to thrive and expand into known historic habitat.

Chesapeake Bay and James River

Numeric criteria to protect designated uses from the impacts of nutrients and suspended sediment in the Chesapeake Bay and its tidal tributaries were adopted in 2005. For the Chesapeake Bay, submerged aquatic vegetation (SAV) restoration acreage is a surrogate clarity indicator since clarity will determine the ability for SAVs to thrive and expand into known historic habitat. Chlorophyll-*a* criteria apply to the tidal James River (adopted in 2006).

The Chesapeake Bay include numeric criteria for dissolved oxygen, acres of submerged vegetation, percent light transmission, water clarity in acres, and narrative chlorophyll-*a*. This includes a spatial and temporal aspect implementation/assessment of these criteria (see 9VAC25-260-185). In addition, there is a James River site specific criteria that includes NNC for chlorophyll-*a* that includes spatial and temporal implementation/assessment aspect.

Attainment of these criteria, are assessed through comparison of the generated cumulative frequency distribution of the monitoring data to the applicable criteria reference curve for each designated use. If the monitoring data cumulative frequency curve is contained inside the reference curve, then the segment is in attainment of the designated use.

The development of the Chesapeake Bay NNC are based on a region wide TMDL that was performed to control eutrophication and hypoxia(United States Environmental Protection Agency 2010c). There are numerous supporting technical documents for Chesapeake Bay nutrient criteria (Anderson et al. 2002; United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2004; United States Environmental Protection Agency 2007; United States Environmental Protection Agency 2010b; United States Environmental Protection Agency 2010c).

These include the *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries (Regional Criteria Guidance) April 2003* which was the foundation document defining Bay water quality criteria and recommended implementation procedures for monitoring and assessment. *The Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability October 2003* defined the five tidal water designated uses to be protected through the published Bay water quality criteria. Six addendum documents have been published since April 2003 addressing detailed issues involving further delineation of tidal water designated uses, Chesapeake Bay Program analytical segmentation schemes, detailed criteria attainment and assessment procedures, and Chesapeake Bay numerical chlorophyll a criteria (United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2004; United States Environmental Protection Agency 2007; United States Environmental Protection Agency 2010b; United States Environmental Protection Agency 2010c). All of these documents and any future reports are available at the Chesapeake Bay Program web site at: Chesapeake Bay Program. The citations to these documents are also provided in our bibliography along copies of these documents in our database.

Documents that formed the basis for the tidal portions of the James River site-specific criteria are located at the Virginia web site. The web links are located below.

Chlorophyll-*a* Numerical Criteria for the Tidal James River November 30, 2004
James River Alternatives Analysis June 23, 2005

James River Alternatives Analysis
http://www.deq.virginia.gov/wqs/documents/James_River_Chlorophyll_study/JAA_Final_Report_6_23_05.pdf

VADEQ Technical Report
http://www.deq.virginia.gov/wqs/documents/James_River_Chlorophyll_study/James_chl_a_criteria_tech_doc_2004.pdf

Site-specific Criteria – Chesapeake Bay

The information that follows includes the EPA-approved site-specific nutrient criteria for Virginia's waterbodies that are designed to support aquatic life use. The following information reflects Virginia's water quality standards posted to the Water Quality Standards Repository as of November 2010 (EPA-approved December 2009) and on their most current edition of their State water quality standards (Virginia State Water Control Board 2011).

9 VAC 25-260-185 Criteria to protect designated uses from the impacts of nutrients and suspended sediment in the Chesapeake Bay and its tidal tributaries.

Table 186. Dissolved oxygen criteria associated with nutrient management in Chesapeake Bay. From: 9VAC 25-260-185 A. Dissolved Oxygen.

Designated Use	Criteria Concentration/ Duration	Temporal Application
Migratory fish spawning and nursery	7-day mean ≥ 6 mg/L (tidal habitats with 0-0.5 ppt salinity)	February 1 – May 31
	Instantaneous minimum ≥ 5 mg/L	
Open-water[1]	30 day mean ≥ 5.5 mg/L (tidal habitats with 0-0.5 ppt salinity)	year-round
	30 day mean ≥ 5 mg/L (tidal habitats with >0.5 ppt salinity)	
	7 day mean ≥ 4 mg/L	
	Instantaneous minimum ≥ 3.2 mg/L at temperatures <29°C Instantaneous minimum ≥ 4.3 mg/L at temperatures ≥ 29°C	
Deep-water	30 day mean ≥ 3 mg/L	June 1 – September 30
	1 day mean ≥ 2.3 mg/L	
	Instantaneous minimum ≥ 1.7 mg/L	
Deep-channel	Instantaneous minimum ≥ 1 mg/L	June 1 – September 30

[1] In applying this open-water instantaneous criterion to the Chesapeake Bay and its tidal tributaries where the existing water quality for dissolved oxygen exceeds an instantaneous minimum of 3.2 mg/L, that higher water quality for dissolved oxygen shall be provided antidegradation protection in accordance with section 30 subsection A.2 of this chapter.

B. Submerged Aquatic Vegetation and Water Clarity

If the submerged aquatic vegetation (SAV) acres in this subsection are met in any individual Chesapeake Bay Program segment as described in subsection D of this section, then the shallow-water submerged aquatic vegetation use is met in that segment. If the SAV acres in this subsection are not met in any individual Chesapeake Bay Program segment, then the water clarity criteria shall apply to the water clarity acres in that segment. If these water clarity criteria are met to the bottom water-sediment interface for the number of water clarity acres in that segment, then the shallow-water submerged aquatic vegetation use is met; regardless of the number of acres of SAV in that segment.

Table 187. Designated uses and NNC for water clarity, SAV and water clarity-acres in Chesapeake Bay.

Designated Use	Chesapeake Bay Program Segment	SAV Acres[1]	Water Clarity Criteria (percent light-through-water)[2]	Water Clarity Acres[1]	Temporal Application
Shallow-Water Submerged Aquatic Vegetation Use	CB5MH	7,633	22%	14,514	April 1 - October 31
	CB6PH	1,267	22%	3,168	March 1 - November 30
	CB7PH	15,107	22%	34,085	March 1 - November 30
	CB8PH	11	22%	28	March 1 - November 30
	POTTF	2,093	13%	5,233	April 1 - October 31
	POTOH	1,503	13%	3,758	April 1 - October 31
	POTMH	4,250	22%	10,625	April 1 - October 31
	RPPTF	66	13%	165	April 1 - October 31
	RPPOH	0	-	0	-
	RPPMH	1700	22%	5000	April 1 - October 31
	CRRMH	768	22%	1,920	April 1 - October 31
	PIAMH	3,479	22%	8,014	April 1 - October 31
	MPNTF	85	13%	213	April 1 - October 31
	MPNOH	0	-	0	-
	PMKTF	187	13%	468	April 1 - October 31
	PMKOH	0	-	0	-
	YRKMH	239	22%	598	April 1 - October 31
	YRKPH	2,793	22%	6,982	March 1 - November 30
	MOBPH	15,901	22%	33,990	March 1 - November 30
	JMSTF2	200	13%	500	April 1 - October 31
	JMSTF1	1000	13%	2500	April 1 - October 31
	APPTF	379	13%	948	April 1 - October 31
	JMSOH	15	13%	38	April 1 - October 31
	CHKOH	535	13%	1,338	April 1 - October 31
	JMSMH	200	22%	500	April 1 - October 31
	JMSPH	300	22%	750	March 1 -

Designated Use	Chesapeake Bay Program Segment	SAV Acres[1]	Water Clarity Criteria (percent light-through-water)[2]	Water Clarity Acres[1]	Temporal Application
					November 30
	WBEMH	0	-	0	-
	SBEMH	0	-	0	-
	EBEMH	0	-	0	-
	LAFMH	0	-	0	-
	ELIPH	0	-	0	-
	LYNPH	107	22%	268	March 1 - November 30
	POCOH	0	-	0	-
	POCMH	4,066	22%	9,368	April 1 - October 31
	TANMH	13,579	22%	22,064	April 1 - October 31

[1] The assessment period for SAV and water clarity acres shall be the single best year in the most recent three consecutive years. When three consecutive years of data are not available, a minimum of three years within the most recent five years shall be used.
[2] Percent Light through Water = 100e(-KdZ) where Kd is water column light attenuation coefficient and can be measured directly or converted from a measured secchi depth where Kd = 1.45/secchi depth. Z = depth at location of measurement of Kd.

C. Chlorophyll-*a*

Table 188. Narrative chlorophyll-a criteria for Virginia waters.

Designated Use	Chlorophyll-*a* Narrative Criterion	Temporal Application
Open Water	Concentrations of Chlorophyll *a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in undesirable or nuisance aquatic plant life, or render tidal waters unsuitable for the propagation and growth of a balanced, indigenous population of aquatic life or otherwise result in ecologically undesirable water quality conditions such as reduced water clarity, low dissolved oxygen, food supply imbalances, proliferation of species deemed potentially harmful to aquatic life or humans or aesthetically objectionable conditions.	March 1 - September 30

Part VII
Special Standards and Scenic Rivers Listings.
9 VAC 25-260-310. Special standards and requirements.

The special standards are shown in small letters to correspond to lettering in the basin tables. The special standards are as follows:

aa. The following site-specific dissolved oxygen criteria apply to the tidal Mattaponi and Pamunkey Rivers and their tidal tributaries because of seasonal lower dissolved oxygen concentration due to the natural oxygen depleting processes present in the extensive surrounding tidal wetlands. These criteria apply June 1 - September 30 to Chesapeake Bay segments MPNTF, MPNOH, PMKTF, PMKOH and are implemented in accordance with subsection D of 9 VAC 25-260-185. These criteria supercede the open-water criteria listed in subsection A of 9 VAC 25-260-185.

Table 189. Dissolved oxygen criteria for compliance with nutrient standards in selected Virginia tidal rivers.

Designated use	Criteria Concentration/Duration	Temporal Application
Open-Water	30 day mean ≥ 4.0 mg/L	June 1 - September 30
	Instantaneous minimum ≥ 3.2 mg/L at temperatures < 29°C Instantaneous minimum ≥ 4.3 mg/L at temperatures ≥ 29°C	

bb. The following site specific numerical Chlorophyll a criteria apply March 1 - May 31 and July 1 - September 30 [as seasonal means] to the tidal James River (excludes tributaries) segments JMSTF2, JMSTF1, JMSOH, JMSMH, JMSPH and are implemented in accordance with subsection D of 9 VAC 25-260-185.

Table 190. Chlorophyll-*a* numeric criteria for the James River, Virginia.

Designated use	Chlorophyll *a* ug/L	Chesapeake Bay Program Segment	Temporal Application
Open-Water	10	JMSTF2	March 1 – May 31
	15	JMSTF1	
	15	JMSOH	
	12	JMSMH	
	12	JMSPH	
	15	JMSTF2	July 1 – September 30
	23	JMSTF1	
	22	JMSOH	
	10	JMSMH	
	10	JMSPH	

cc. For Mountain Lake in Giles County, Chlorophyll-*a* shall not exceed 6 µg/L at a depth of 6 meters and orthophosphate-P shall not exceed 8 µg/L at a depth of one meter or less.

dd. For Lake Drummond, located within the boundaries of Chesapeake and Suffolk in the Great Dismal Swamp, chlorophyll a shall not exceed 35 µg/L and total phosphorus shall not exceed 40 µg/L at a depth of one meter or less.

Freshwater Systems

For reservoirs numeric criteria for chlorophyll-*a* and TP are assessed from sampling locations in the lacustrine portion of the reservoir where observations are evenly distribution over seven months from April 1 to October 31 (Whitehurst per.com.). These criteria are applied to a specific list of reservoirs. These were adopted by the State and approved by EPA to protect aquatic life and recreational designated uses from the impacts of nutrients in 2007. In summary the criteria for cold water are: TP –0.02 mg/l (median), Chl-A: 0.025 mg/l (based on the 90th percentile) and for warm water lakes it is: TP –0.04 mg/l (median), Chl-A 0.035 mg/l (based on the 90th percentile). Site specific NNC (chlorophyll-a and TP) also exist for two natural lakes in Virginia.

Supporting documentation for lakes/reservoir nutrient criteria are located at this web site link to Virginia: Freshwater Nutrient Criteria Development.

The report entitled AAC Report 2005 provides the basis for reservoir nutrient criteria in Virginia. There are also a number of documents related to freshwater nutrient criteria development in Virginia including the status of current work for non-tidal streams and rivers. Other technical support documents are listed below and most are included in the bibliography (Rowe 2006; Virginia Water Resources Research Center 2008; Walker et al. 2007).

AAC Report 2005 - http://www.deq.virginia.gov/wqs/pdf/AAC05report.pdf

AAC Lake Dissolved Oxygen Responses - http://www.deq.virginia.gov/wqs/pdf/AACLAKEDO.pdf

AAC 2005 Report Addendum 1 - http://www.deq.virginia.gov/wqs/documents/Nutrient_Criteria/AAC_Report_Addendum_5_26_05.doc

AAC 2005 Report Addendum 2 - http://www.deq.virginia.gov/wqs/documents/Nutrient_Criteria/AAC_Addendum2_2005.doc

9 VAC 25-260-187. Criteria for man-made lakes and reservoirs to protect aquatic life and recreational designated uses from the impacts of nutrients.

A. The criteria in Section B apply to the man-made lakes and reservoirs listed in that section. Additional man-made lakes and reservoirs may be added as new reservoirs are constructed or monitoring data become available from outside groups or future agency monitoring.

B. Whether or not algicide treatments are used, the chlorophyll-*a* criteria apply to all waters on the list. The total phosphorus criteria apply only if a specific man-made lake or reservoir received algicide treatment during the monitoring and assessment period of April 1 through October 31.

The 90th percentile of the chlorophyll-*a* data collected at one meter or less within the lacustrine portion of the manmade lake or reservoir between April 1 and October 31 shall not exceed the chlorophyll-*a* criterion for that water body in each of the two most recent monitoring years that chlorophyll-*a* data are available. For a water body that received algicide treatment, the median of the total phosphorus data collected at one meter or less within the lacustrine portion of the man-made lake or reservoir between April 1 and October 31 shall not exceed the total phosphorus criterion in each of the two most recent monitoring years that total phosphorus data are available.

Table 191. Numeric nutrient criteria for selected reservoirs in Virginia.

Man-Made Lake or Reservoir Name	Location	Chlorophyll-*a* (μg/L)	Total Phosphorus (μg/L)
Able Lake	Stafford County	35	40
Airfield Pond	Sussex County	35	40
Amelia Lake	Amelia County	35	40
Aquia Reservoir (Smith Lake)	Stafford County	35	40
Bark Camp Lake (Corder Bottom Lake, Lee/Scott/Wise Lake)	Scott County	35	40
Beaver Creek Reservoir	Albemarle County	35	40
Beaverdam Creek Reservoir (Beaverdam Reservoir)	Bedford County	35	40
Beaverdam Reservoir	Loudoun County	35	40
Bedford Reservoir (Stony Creek Reservoir)	Bedford County	35	40
Big Cherry Lake	Wise County	35	40
Breckenridge Reservoir	Prince William County	35	40
Briery Creek Lake	Prince Edward County	35	40
Brunswick Lake (County Pond)	Brunswick County	35	40
Burke Lake	Fairfax County	60	40
Carvin Cove Reservoir	Botetourt County	35	40
Cherrystone Reservoir	Pittsylvania County	35	40
Chickahominy Lake	Charles City County	35	40
Claytor Lake	Pulaski County	25	20
Clifton Forge Reservoir (Smith Creek Reservoir)	Alleghany County	35	20
Coles Run Reservoir	Augusta County	10	10
Curtis Lake	Stafford County	60	40
Diascund Creek Reservoir	New Kent County	35	40
Douthat Lake	Bath County	25	20
Elkhorn Lake	Augusta County	10	10
Emporia Lake (Meherrin Reservoir)	Greensville County	35	40
Fairystone Lake	Henry County	35	40
Falling Creek Reservoir	Chesterfield County	35	40
Fort Pickett Reservoir	Nottoway/Brunswick County	35	40
Gatewood Reservoir	Pulaski County	35	40
Georges Creek Reservoir	Pittsylvania County	35	40
Goose Creek Reservoir	Loudoun County	35	40
Graham Creek Reservoir	Amherst County	35	40
Great Creek Reservoir	Lawrenceville	35	40

Man-Made Lake or Reservoir Name	Location	Chlorophyll-*a* (µg/L)	Total Phosphorus (µg/L)
Harrison Lake	Charles City County	35	40
Harwood Mills Reservoir	York County	60	40
Hidden Valley Lake	Washington County	35	40
Hogan Lake	Pulaski County	35	40
Holiday Lake	Appomattox County	35	40
Hungry Mother Lake	Smyth County	35	40
Hunting Run Reservoir	Spotsylvania County	35	40
J. W. Flannagan Reservoir	Dickenson County	25	20
Kerr Reservoir, Virginia portion (Buggs Island Lake)	Halifax County	25	30
Keysville Reservoir	Charlotte County	35	40
Lake Albemarle	Albemarle County	35	40
Lake Anna	Louisa County	25	30
Lake Burnt Mills	Isle of Wight County	60	40
Lake Chesdin	Chesterfield County	35	40
Lake Cohoon	Suffolk City	60	40
Lake Conner	Halifax County	35	40
Lake Frederick	Frederick County	35	40
Lake Gaston, (Virginia portion)	Brunswick County	25	30
Lake Gordon	Mecklenburg County	35	40
Lake Keokee	Lee County	35	40
Lake Kilby	Suffolk City	60	40
Lake Lawson	Virginia Beach City	60	40
Lake Manassas	Prince William County	35	40
Lake Meade	Suffolk City	60	40
Lake Moomaw	Bath County	10	10
Lake Nelson	Nelson County	35	40
Lake Nottoway (Lee Lake, Nottoway Lake)	Nottoway County	35	40
Lake Pelham	Culpeper County	35	40
Lake Prince	Suffolk City	35	40
Lake Robertson	Rockbridge County	35	40
Lake Smith	Virginia Beach City	60	40
Lake Whitehurst	Norfolk City	60	40
Lake Wright	Norfolk City	60	40

Man-Made Lake or Reservoir Name	Location	Chlorophyll-*a* (μg/L)	Total Phosphorus (μg/L)
Laurel Bed Lake	Russell County	35	40
Lee Hall Reservoir (Newport News Reservoir)	Newport News City	60	40
Leesville Reservoir	Bedford County	25	30
Little Creek Reservoir	Virginia Beach City	60	40
Little Creek Reservoir	James City County	25	30
Little River Reservoir	Montgomery County	35	40
Lone Star Lake F (Crystal Lake)	Suffolk City	60	40
Lone Star Lake G (Crane Lake)	Suffolk City	60	40
Lone Star Lake I (Butler Lake)	Suffolk City	60	40
Lunga Reservoir	Prince William County	35	40
Lunenburg Beach Lake (Victoria Lake)	Town of Victoria	35	40
Martinsville Reservoir (Beaver Creek Reservoir)	Henry County	35	40
Mill Creek Reservoir	Amherst County	35	40
Modest Creek Reservoir	Town of Victoria	35	40
Motts Run Reservoir	Spotsylvania County	25	30
Mount Jackson Reservoir	Shenandoah County	35	40
Mountain Run Lake	Culpeper County	35	40
Ni Reservoir	Spotsylvania County	35	40
North Fork Pound Reservoir	Wise County	35	40
Northeast Creek Reservoir	Louisa County	35	40
Occoquan Reservoir	Fairfax County	35	40
Pedlar Lake	Amherst County	25	20
Philpott Reservoir	Henry County	25	30
Phelps Creek Reservoir (Brookneal Reservoir)	Campbell County	35	40
Ragged Mountain Reservoir	Albemarle County	35	40
Rivanna Reservoir (South Fork Rivanna Reservoir)	Albemarle County	35	40
Roaring Fork	Pittsylvania County	35	40
Rural Retreat Lake	Wythe County	35	40
Sandy River Reservoir	Prince Edward County	35	40
Shenandoah Lake	Rockingham County	35	40

Man-Made Lake or Reservoir Name	Location	Chlorophyll-*a* (µg/L)	Total Phosphorus (µg/L)
Silver Lake	Rockingham County	35	40
Smith Mountain Lake	Bedford County	25	30
South Holston Reservoir	Washington County	25	20
Speights Run Lake	Suffolk City	60	40
Spring Hollow Reservoir	Roanoke County	25	20
Staunton Dam Lake	Augusta County	35	40
Stonehouse Creek Reservoir	Amherst County	60	40
Strasburg Reservoir	Shenandoah County	35	40
Stumpy Lake	Virginia Beach	60	40
Sugar Hollow Reservoir	Albemarle County	25	20
Swift Creek Reservoir	Chesterfield County	35	40
Switzer Lake	Rockingham County	10	10
Talbott Reservoir	Patrick County	35	40
Thrashers Creek Reservoir	Amherst County	35	40
Totier Creek Reservoir	Albemarle County	35	40
Townes Reservoir	Patrick County	25	20
Troublesome Creek Reservoir	Buckingham County	35	40
Waller Mill Reservoir	York County	25	30
Western Branch Reservoir	Suffolk City	25	20
Wise Reservoir	Wise County	25	20

Monitoring data used for assessment shall be from sampling location(s) within the lacustrine portion where observations are evenly distributed over the seven months from April 1 through October 31 and are in locations that are representative, either individually or collectively, of the condition of the man-made lake or reservoir.

Virginia has an approved nutrient criteria plan (Department of Environmental Quality Commonwealth of Virginia 2004). Text from that document is included below. In that document the State outlines their preferred approach. The preferred approach was to develop and use effects based criteria (Figure 38). The Plan states that effect-based criteria will be considered as well as other options, including the development of nutrient criteria that reflect localized conditions and protect specific designated uses utilizing processes outlined in the EPA Technical Guidance Manuals (USEPA 2000 - 2001) or other scientifically defensible methods and appropriate water quality data (such as the current collaborative effort to develop nutrient criteria for the Chesapeake Bay). This effort will also involve an evaluation of the applicability of Virginia's current regulatory program (Nutrient Enriched Waters) for controlling nutrients in state surface waters by water body type (estuaries, lakes and reservoirs, rivers and streams). Appendices A through E of the Plan describe Virginia's regulatory designations of these Nutrient Enriched Waters. Designations are based upon an evaluation of local water quality data for one or more indicators of nutrient enrichment (chlorophyll-a, total phosphorus and dissolved oxygen fluctuations); the waters are protected from further enrichment by a companion regulation for control of total phosphorus from point sources. This evaluation will consider expansion of the existing State approach to include designations of additional waters experiencing nutrient enriched problems and to address such issues as total nitrogen, watersheds and non-point sources. If the concept of Nutrient Enriched Waters is not incorporated into the final approach selected by the State, a plan will have to be developed to transition from the existing regulatory Nutrient Enriched Waters listings to the new regulatory approach by sequentially deleting currently designated Nutrient Enriched Waters as the Commonwealth adopts nutrient criteria for those waters.

If effects based criteria cannot be developed, a reference condition-based criteria refined for Virginia from either the EPA Region III regional database or Virginia STORET database at ecoregion Level IV supplemented with new 2000-2002 Virginia CEDS monitoring data will be used. Virginia may consider the choice of a percentile other than those suggested in 304(a) criteria documents and technical guidance manuals.

General Schematic of Virginia Proposed Plan:

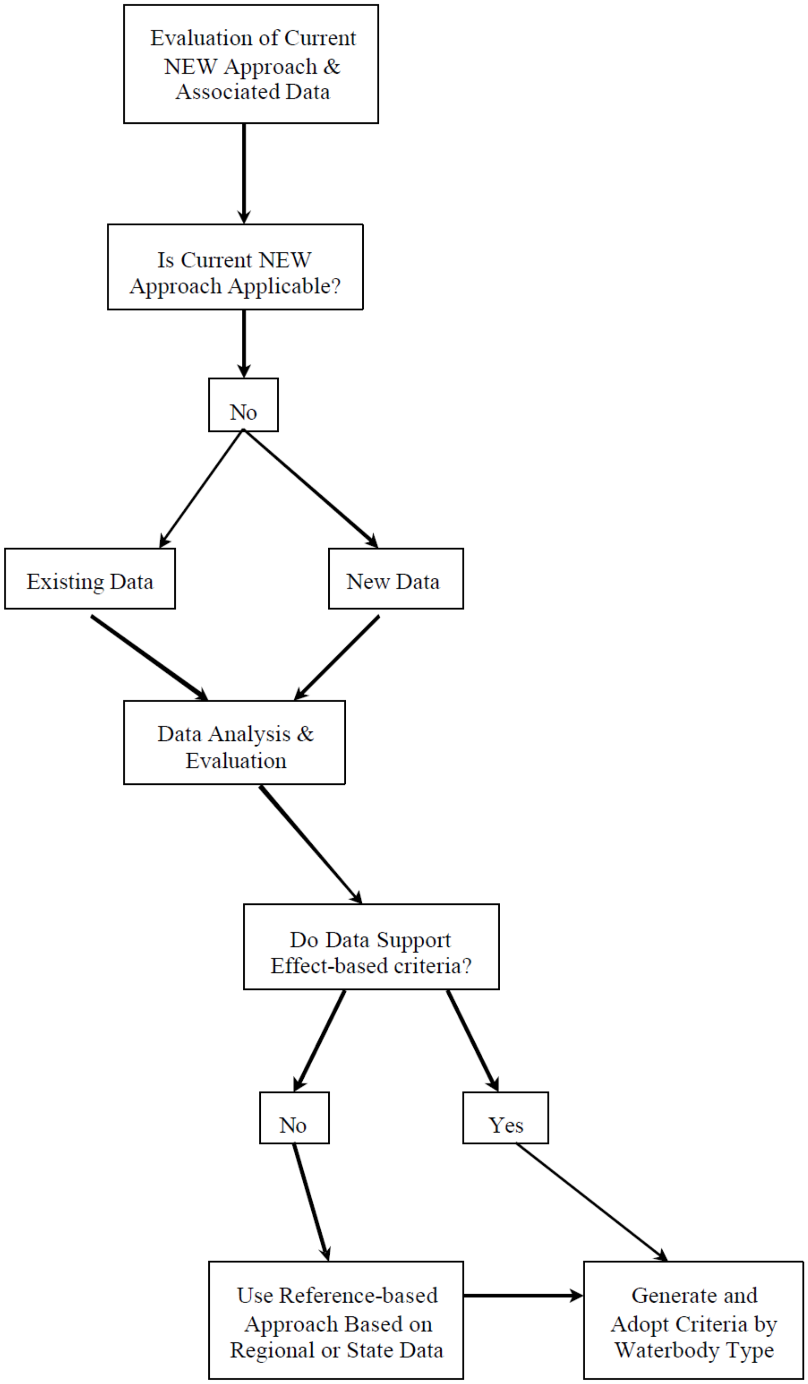


Figure 32. Proposed nutrient criteria development plan (Department of Environmental Quality Commonwealth of Virginia 2004).

Since publication of the Nutrient Criteria plan, NNC have been published for reservoirs and lakes and for the Chesapeake Bay and tidal portions of selected rivers. These were previously described. The plan is to submit draft criteria for wadeable streams in 2012 and nonwadeable streams in 2013.

Numeric nutrient criteria for wadeable & non-wadeable streams/rivers under development. The following documents are found at:
http://www.deq.virginia.gov/wqs/rule.html#NUT2

AAC Literature Review for Rivers & Streams
AAC Report 2006
AAC Rivers & Streams Report 12/2006
Weight of Evidence Screening Value Approach to Nutrient Criteria Development for Wadeable Streams
Freshwater Nutrient Criteria for Non-wadeable Streams in Virginia: Fish Community Assessment, Phase I
Nutrient Criteria Development in VA - ASWPICA presentation
AAC Final Report 2009 - Wadeable Streams
AAC Final Report 2009 - Non-Wadeable Rivers
AAC Final Report 2010

One of the most important documents produced by the State of Virginia were the two comprehensive literature reviews compiled for lakes and streams (Walker et al. 2006; Walker et al. 2007). These two documents may be very useful in assembling appropriate methods and potential threshold values for streams in Texas.

Washington

The State of Washington currently has NNC for phosphorus in selected lakes, reservoirs and rivers and streams (Table 192)(Washington State Department of Ecology ; Washington State Department of Ecology 1997; Washington State Department of Ecology 2004; Washington State Department of Ecology 2006). These criteria were in effects since 1997. A description of the criteria were extracted from the current state water quality standards and are listed below.

Table 192. Existing numeric criteria for Washington State.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs		W		
Rivers and Streams		W		
Estuaries				
Wetlands				

S = Statewide W = for selected waterbody N/A=Not Applicable
[1] From Washington's 1997 water quality standards posted to the Water Quality Standards Repository as of November 2010 for support of aquatic life uses. Review of state documents indicates that there are no proposed or state only adopted NNC currently.
[2] Source: EPA's (United States Environmental Protection Agency 2008b).
http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_wa.cfm
http://www.ecy.wa.gov/programs/wq/swqs/index.html, http://www.ecy.wa.gov/pubs/0610091.pdf

The following information reflects Washington's 2006 and 1997 water quality standards posted to the EPA Water Quality Standards Repository as of November 2010.

WAC 173-201A-030 General water use and criteria classes.

The following criteria shall apply to the various classes of surface waters in the state of Washington:

(1) Class AA (extraordinary).
(a) General characteristic. Water quality of this class shall markedly and uniformly exceed the requirements for all or substantially all uses.
(c) Water quality criteria:
(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

(2) Class A (excellent).
(a) General characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.
(c) Water quality criteria:
(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

(3) Class B (good).
(a) General characteristic. Water quality of this class shall meet or exceed the requirements for most uses.
(c) Water quality criteria:
(viii) Aesthetic values shall not be reduced by dissolved, suspended, floating, or submerged matter not attributed to natural causes, so as to affect water use or taint the flesh of edible species.

(4) Class C (fair).
(a) General characteristic. Water quality of this class shall meet or exceed the requirements of selected and essential uses.
(c) Water quality criteria - marine water:
(vii) Aesthetic values shall not be interfered with by the presence of obnoxious wastes, slimes, aquatic growths, or materials which will taint the flesh of edible species.

(5) Lake class.
(a) General characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.
(c) Water quality criteria:
(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Site-specific Criteria

The information on this tab shows EPA-approved site-specific nutrient criteria for Washington's waterbodies. Criteria on this page apply only to the waterbodies listed below. Criteria applicable to all waterbodies within the state are found on the "Statewide Criteria" tab. For more information, refer to the Washington water quality standards. WAC 173-201A-030 General water use and criteria classes.

The following criteria shall apply to the various classes of surface waters in the state of Washington:

(6) Establishing lake nutrient criteria.
(a) The following table shall be used to aid in establishing nutrient criteria:
(Ch. 173-201A-030, Table 1)

Table 193. Site specific lake nutrient criteria for the State of Washington (Ch. 173-201A-030, Table 1).

Coast Range, Puget Lowlands, and Northern Rockies Ecoregions:		
Trophic State	**If Ambient TP (ug/L) Range of Lake is:**	**Then criteria should be set at:**
Ultra-oligotrophic	0-4	4 or less
Oligotrophic	>4-10	10 or less
Lower mesotrophic	>10-20	20 or less
	Action value >20 lake specific study may be initiated	
Cascades Ecoregion:		
Trophic State	**If Ambient TP (ug/L) Range of Lake is:**	**Then criteria should be set at:**
Ultra-oligotrophic	0-4	4 or less
Oligotrophic	>4-10	10 or less
	Action value >10 lake specific study may be initiated	
Columbia Basin Ecoregion:		
Trophic State	**If Ambient TP (ug/L) Range of Lake is:**	**Then criteria should be set at:**
Ultra-oligotrophic	0-4	4 or less
Oligotrophic	>4-10	10 or less
Lower mesotrophic	>10-20	20 or less
Upper mesotrophic	>20-35	35 or less
	Action value >35 lake specific study may be initiated	

Lakes in the Willamette, East Cascade Foothills, or Blue Mountain ecoregions do not have recommended values and need to have lake-specific studies in order to receive criteria as described in (c)(i) of this subsection.

WAC 173-201A-130 Specific classifications—Freshwater.

(107) Spokane River from Long Lake Dam (river mile 33.9) to Nine Mile Bridge (river mile 58.0). Special conditions: (a) The average euphotic zone concentration of total phosphorus (as P) shall not exceed 25 mg/L during the period of June 1 to October 31.

Nutrient Criteria Development Plan

The State of Washington also has a mutually accepted Nutrient Criteria Development Plan (Washington State Department of Ecology 2004). In their Plan the Washington State Department of Ecology (WSDEP) document the use of an their technical advisory committee In the Plan they state that the technical advisory committee recommended adopting TP criteria based on ecoregional action levels. A combination of background conditions and trophic states were used to arrive at the proposed action value for each ecoregion. The method recommended a range of TP values. A land-use development level of 0 percent to 25 percent was used to develop the near background condition. The TP values within the 50th to 75th percentiles were used to bracket the range. This range provided protection and allowed some level of development to occur while protecting beneficial uses at near-natural conditions.

The final ecoregional action values were developed by choosing values that occurred where the recommended ranges of the background conditions and trophic boundaries overlapped. Lakes in ecoregions that do not have action values (Eastern Cascades Foothills and Willamette Valley ecoregions) were quite different from lakes in neighboring ecoregions and should be studied individually to establish criteria.
The criteria were determined by a minimum level of sampling or a more comprehensive lake-specific study. The minimum level of sampling consists of a mean of four or more samples taken from the epilimnion (near lake surface) during the months of June through September in one or more years. Samples would be spread throughout the season. If existing TP levels are at or below ecoregional action levels, the criterion could be set at or below the trophic states into which they fit.

If the TP concentrations were higher than the ecoregional action value, then attainment of the ecoregional action value would be recommended. These lakes would receive priority for comprehensive lake-specific studies according to the five-year rotation of WSDEP's statewide watershed approach. They would also be listed on the latest revision to the impaired water body (303[d]) list. Existing and potential characteristic uses would be determined and if they were attainable (as determined following EPA's Section 314 Clean Lakes Guidance), the TP criteria for achieving those uses would be the recommended goals. If characteristic uses were not achievable, then higher TP criteria could be recommended that would be protective of the remaining uses. The criteria should not be intended for lakes or ponds with surface areas less than five acres or ponds entirely contained on private property that do not drain to other lakes and streams. Studies to develop lake-specific criteria should be allowed where citizens or affected parties feel criteria are not protective enough or are too protective. These studies would involve the public and affected entities, require public hearings, and require plans to be approved by the WSDEP. Past studies may be accepted if they have gathered the necessary information as outlined in the discussion of the lake-specific approach. Whenever possible, these actions will be coordinated with WSDEP's watershed-basin approach.

WSDEP used the process described previously and the resulting committee recommendations to develop lake nutrient criteria. These were converted into the existing

NNC that were adopted in 2006. The lake nutrient criteria adopted by the state of Washington are found at Section 30 paragraph (6) of Chapter 173-201A of the Washington Administrative Code that is described earlier in this section.

WSDEP also provided guidance for development of NNC for riverine systems from excess nutrients. This guidance and description of results to date are presented below verbatim. WSDEP examined periphyton growth, chlorophyll-*a*, nitrogen, and total phosphorous levels in ecoregions on the west and east sides of the state. However WSDEP's researchers were unable to find a predictive relationship between excess production and eutrophication and measured nutrient concentrations. Flow rates, shading, and available light were also confounding factors in eutrophication processes in streams and rivers. Thus, efforts to develop statewide nutrient criteria for river and stream systems were curtailed. Ecology has chosen an alternative pathway for the control of nutrient concentrations in riverine systems that rely on other indicators and triggers for trophic health, and more water body specific modeling to select nutrient threshold values. Washington State has established aquatic life criteria for pH and dissolved oxygen, which serve as sensitive indicators of riverine eutrophication. While these dissolved oxygen values were set to provide a high level of protection and support for metabolic function, they also set a standard that cannot be attained in rivers with nuisance algal growth. In establishing permit limits or in establishing load and wasteload allocations through TMDLs or water clean up plans, the role of nutrients in affecting oxygen levels is evaluated and protective limits established where nutrients are interfering with attainment of the daily minimum oxygen levels. Thus compliance plans for the dissolved oxygen criteria examine the influence of BOD, nutrients, and temperature to ensure the trophic health of the water body is maintained or restored.

The second key indirect indicator of river eutrophication is the state's pH criteria. The criteria set ranges of acceptable pH, which eutrophic streams typically violate, that if exceeded cause the water body to be evaluated for potential impairment. The carbon dioxide used for photosynthesis by aquatic plants and algae results in increases in the pH of waters where such plant production is high. While the pH criteria are less sensitive indicators of trophic health than the dissolved oxygen criteria in use by the state, they do provide an important supplementary trigger for initiating necessary water body investigations. Excess nutrients in the state are identified by increasing trends in pH concentrations and by exceedences of the upper pH levels established for the water bodies.

WSDEP determined in their Plan that due to a lack of data in estuaries and the known highly complex relationship between nutrients and trophic health in marine systems, statewide criteria were not recommended for marine waters. WDEP chose an alternative pathway for the control of nutrient concentrations in marine systems that relies on other indicators and triggers for trophic health, and more water body specific modeling to select nutrient threshold values. These alternative triggers function as described for riverine systems. The interrelationship between nutrient concentrations in marine systems, however, is even more complex than in fresh water systems. Due to tides, stratification and potential changes in the limiting nutrient form (phosphorous versus

nitrogen) with depth and location, and the non-linear contributions from freshwater streams and rivers, the setting of statewide nutrient criteria in marine waters were too problematic at the time of the publication of the Plan.
WDEP has begun the process of developing sophisticated models for its marine waters that can be used to account for the complex variables that affect compliance with water quality standards. A primary driver in marine waters for setting the agency's priorities will be the failure to comply with dissolved oxygen criteria. Several large sectors of Puget Sound have been modeled to date with the focus on where problems with dissolved oxygen and excess algal production have been found to exist. These models are priority as they not only help the state protect and restore the trophic health to its waters, but because they are the best tool to use to ensure that all water quality standards will be met in this complex marine environment.

West Virginia

West Virginia has no federally approved or state adopted NNC (Hansen et al. 2006; Laidlaw 2010a; Rowe 2006; West Virginia Coal Association et al. 2006; West Virginia Department of Environmental Protection 2009). From 2008 to 2010, the state had adopted NNC for TOP and chlorophyll-a in lakes and reservoirs. These NNC applied to all lakes with a retention time of ≥ 14 days and all other lakes will be covered under future rivers/streams NNC development (United States Environmental Protection Agency 2008b) http://www.dep.wv.gov/WWE/Programs/wqs/Pages/default.aspx, http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_wv.cfm. However, EPA has never approved these NNC. Therefore starting in 2010 the State decided to not enforce the current state adopted NNC until EPA approves(West Virginia Department of Environmental Protection 2010). EPA had deffered approval because the warmwater criteria may not be protective enough(West Virginia Department of Environmental Protection 2010). The current (Effective since July 1, 2008) water quality standards are found in 47CRS2 - Requirements Governing Water Quality Standards(West Virginia Department of Environmental Protection 2009). However, on their web page they state *"the following sections are no longer in effect: Section 8.3, Section 2.2, Appendix F. Additionally, Section 7.2d.16.2 was not acted upon by the EPA and is no longer effective. The current state adopted NNC for West Virginia are described below"*. The retraction of Section 8.3 effectively removed the previously State adopted NNC for chlorophyll-a and TP.

The designated uses of West Virginia waterbodies are listed below in Table 194. Previously the state adopted NNC were described as follows in the text below from the state water quality standards.
8.3.a. This subsection establishes nutrient criteria designed to protect Water Use Categories B and C.

The following cool water nutrient criteria shall apply to cool water lakes. (See Appendix F for a representative list.) The following warm water nutrient criteria shall apply to all other lakes with a summer residence time greater than 14 days.

Table 194. Designated uses of West Virginia waterbodies Source: http://www.dep.wv.gov/WWE/Programs/wqs/Pages/default.aspx.

Category	Use Subcategory	Use Category	Description
A	Public water	Human health	Waters, which, after conventional treatment, are used for human consumption.
B1	Warm water fishery	Aquatic life	Propagation and maintenance of fish and other aquatic life in streams or stream segments that contain populations composed of all warm aquatic life.
B2	Trout waters		Propagation and maintenance of fish and other aquatic life in streams or stream segments that sustain year-round trout populations. Excluded are those streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.
B4	Wetlands		Propagation and maintenance of fish and other aquatic life in wetlands. Wetlands generally include swamps, marshes, bogs and similar areas.
C	Water contact recreation	Human health	Swimming, fishing, water skiing and certain types of pleasure boating such as sailing in very small craft and outboard motor boats.
D1	Irrigation	All other	All stream segments used for irrigation.
D2	Livestock watering		All stream segments used for livestock.
D3	Wildlife		All stream segments and wetlands used for wildlife.
E1	Water transport		All stream segments modified for water transport and having permanently maintained navigation aides.
E2	Cooling water		All stream segments having one or more users for industrial cooling.
E3	Power production		All stream segments extending from a point 500 feet upstream from the intake to a point one-half mile below the wastewater discharge point.
E4	Industrial		All stream segments with one or more industrial users. It does not include water for cooling.

8.3. Criteria for Nutrients in Lakes
8.3.b.

Total phosphorus shall not exceed 50 μg/l for warm water lakes and 30 μg/l for cool water lakes based on an average of four or more samples collected during the period May 1–October 31. In lieu of such sampling, impairment may be evidenced at any time by noncompliance with section 3.2, as determined by the Secretary. Chlorophyll-*a* shall not exceed 30 μg/l for warm water lakes and 15 μg/l for cool water lakes based on an average of four or more samples collected during the period May 1–October 31. In lieu of such sampling, impairment may be evidenced at any time by noncompliance with section 3.2, as determined by the Secretary.

According to (Laidlaw 2010a) West Virginia will likely propose NNC for the Greenbrier River which is based on a 30 day average total concentration which shall no exceed 10 ug/L in the mainstem of the river. It would be based on 4 or more samples collected at base flow conditions, during the period of May 1 to October 31 (West Virginia Department of Environmental Protection 2010). In a recent meeting note regarding nutrient criteria WVDEP also substantiates this, although no specific information is provided(West Virginia Department of Environmental Protection 2010).WV DEP also plans to continue a waterbody by waterbody approach where problems are evident. No information was provided on how this would be done.

Again, the State Adopted NNC was rescinded by West Virginia upon finding out that EPA had not acted on their adopted standards. The State of West Virginia currently has a mutually agreed to Nutrient Criteria Development Plan (West Virginia Nutrient Criteria Committee to the Environmental Quality Board 2004). In addition, several proposals and technical guidance manuals have been published industry groups and natural resource agencies (Christ et al. 2007; Hansen et al. 2006; Rowe 2006). The only "official" agency technical guidance manual applies to lakes and reservoirs (Hansen et al. 2006). The status of the other documents is unclear. Several were produced by members of the their Nutrient Criteria Committee (WVNCC). The "Lake" document appeared to be a consensus document produced at the request of WVDEP, while the others appear to be published by members of the WVNCC but do not appear to be "official" reports sanctioned by WVDEP but rather as differing opinions by individual members or member groups (Christ et al. 2007; Rowe 2006; West Virginia Coal Association et al. 2006). The 2004 Plan is very basic and provides minimal detail. The outline proposed and graphic depiction of the overall process is presented below and in Figure 33.

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Figure 33. Criteria Development Process for West Virginia EQB – Environmental Quality Board. Source:(West Virginia Nutrient Criteria Committee to the Environmental Quality Board 2004).

1) Selection of Parameters

West Virginia will consider where appropriate for rivers and streams, lakes and reservoirs, and wetlands setting criteria for P, N, turbidity, chlorophyll a, and secchi

Depth. The State also will consider setting criteria for other response parameters where appropriate (e.g. biological community measures, aesthetic/qualitative/narrative standards, and standing stocks of nutrients.) West Virginia will evaluate parameters from other inter-state and partnership agreements and incorporate them into nutrient criteria, as appropriate.

2) Regionalization

a) Waters draining to the Potomac River
b) Waters draining to the Ohio River
c) West Virginia Level IV Ecoregions

Different criteria may be developed for different groups of waters, to the extent that data are available to support the distinctions. In some instances, geology and terrain may be used to refine regionalization.

3) Classifications

Classes of waters for which criteria will be developed include:

a) Shared Waters
i) Mainstem Ohio River
ii) Mainstem Potomac River
iii) Mainstem North Branch Potomac River
iv) Mainstem Tug Fork River
v) Mainstem Big Sandy River

b) All Other Waters
i) Lakes & Reservoirs
ii) Wetlands
iii) Streams & Rivers (considering size, order, and gradient)

Criteria may be extrapolated from a data rich watershed to similar watersheds that are not data rich, but that share similar geology, topography, and waterbody characteristics.

4) Prioritization

a) Lakes & Reservoirs
b) Streams & Rivers
c) Wetlands

Note that this “consecutive” approach has been chosen based on limitations in data, funding and technical resources. We intend to develop criteria as data becomes available.

5) Inventory of Existing Data

Accumulate and evaluate data from the following sources:
a) DEP large river and wadeable stream data
b) WV Department of Agriculture data
c) ORSANCO data
d) Cacapon Institute information
e) USGS data
f) WV Bureau of Public Health information
g) US Army Corps of Engineers data
h) NPDES data
i) Volunteered monitoring data
j) WV DNR data
k) Lake Study data
l) USEPA data (e.g. EMAP)
• USEPA National Database
• USEPA Regional Database (Region 3)
m) US Forest Service data (e.g. Fernow Experimental Forest)
n) NRCS data (e.g. National Resource Inventory)
o) University data
p) Other States' shared water data
q) US Fish & Wildlife Service

WVDEQ stated that data will first be analyzed to determine where data gaps exist in order to define subsequent sampling and analysis needs. Data will then be used according to the approach outlined in Section II.

II Approach (WVDEP steps).

1) Define impairment.
2) Depending on the availability of data of sufficient quantity and quality, and funds for research and model development, the state will consider the following methods, in the following order of preference:
• Empirical and/or cause and effect analyses based on West Virginia data.
• Empirical and/or cause and effect analyses based on other data.
• Alternatives to the first two approaches are to define when and under what circumstances reference-based or other methods might be appropriate.

This process was supposed to be complete by 2009. To our knowledge NNC have not been successfully adopted in West Virginia as of August 2011.

As previously stated WVDEQ and other organizations affiliated with the WVNNC have conducted several studies and published guidance documents and recommended NNC for both flowing waters and lakes and reservoirs (Christ et al. 2007; Hansen et al. 2006; Rowe 2006). The only official recommendation is from the analysis conducted by the (Hansen et al. 2006). In that report they recommended NNC for flowing waters, lakes and reservoirs. The NCC decided to focus first on developing nutrient criteria for lakes and reservoirs, and to focus later on rivers and streams. The lake and criteria document was submitted by the West Virginia Rivers Coalition, the Cacapon Institute, the Conservation Fund's Freshwater Institute, and the Appalachian Center for the Economy and the Environment upon request to WVDEP for its consideration in proposing defensible criteria to the legislature and to USEPA. The organizations recommended that WVDEP reject the criteria proposed by USEPA as too stringent. Instead, the weight of evidence indicates that standards considerably higher than those proposed by USEPA will be adequately protective of our water bodies. Based on analyses of West Virginia data, phosphorus criteria should be between 23 and 53 ug/L, but because of data gaps it is not possible to derive one single number in this range **Error! Reference source not found.**. he group stated that the number that is ultimately chosen depends on how much risk of harm is to be tolerated. A TP criterion near the low end of the range, i.e. 30 ug/L mean, should protect cold and cool water lakes from most if not all harms due to nutrients. A TP criterion at the top of the range, i.e. 50 ug/L mean, may well protect warm water lakes from harm, but is unlikely to protect cool or cold water lakes.

Table 195. Recommended NNC for West Virginia Lakes and Reservoirs. Source:(Hansen et al. 2006).

Recommended by	Designated use	TP (not to exceed)	Chlorophyll a (not to exceed)	Secchi depth (not less than)	TN (not to exceed)
USEPA	Not specified	8 µg/L	2.8 µg/L	9.4 feet	0.46 mg/L
This report	B and C, Cool water	30 µg/L	10 µg/L	None	None
This report	B and C, Warm water	50 µg/L	25 µg/L	None	None

Note: USEPA recommendations from USEPA (2000a). The USEPA recommendation for Secchi depth of 2.86 meters is converted to 9.4 feet. USEPA's chlorophyll a recommendation is rounded.

Several factors were evaluated for derivation of these recommended NNC. These included lake residence time, TP relationships with dissolved oxygen and hypoxia risks, and with chlorophyll-*a*. The results of the regression revealed significant relationships between minimum epilimnetic DO values of less than 6 mg/L for lakes with average TP greater than 33 µg/L. This relationship implies that lakes with TP levels as high as 33 µg/L are not likely to experience hypoxia in the epilimnion, even in hot summers with little rainfall. Higher acceptable TP values were predicted when Virginia lakes were included. They also evaluated TSI, recreational user surveys and also evaluated TN relationships with chlorophyll-*a*. The recommended NNC above were largely adopted by West Virginia, but never endorsed by EPA. West Virginia as stated earlier ultimately rescinded these NNC.

Wisconsin

The State of Wisconsin has state adopted and federally approved NNC for TP in flowing waters and lakes and reservoirs (Table 196).

Table 196. Existing numeric nutrient criteria for Wisconsin.[1]

Waterbody Type	N	P	Chl-*a*	Clarity[2]
Lakes and Reservoirs		S		
Rivers and Streams		S		
Estuaries	N/A	N/A	N/A	N/A
Wetlands				

S = Statewide W = for selected waterbody N/A=Not Applicable

[1] From Wisconsin's 2010 water quality standards posted to the Wisconsin State Legislature website (accessed February 7, 2011). This table indicates whether a state/territory has numeric nutrient criteria for Clean Water Act purposes. If a state/territory has criteria for the protection of drinking water or human health, those criteria may be found on the tabs for either statewide or site-specific criteria.

[2] Source: EPA's (United States Environmental Protection Agency 2008b; Wisconsin Department of Natural Resources 2010) http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_wi.cfm (http://www.dnr.state.wi.us/org/water/wm/WQS/)(http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_wi.cfm)

The following information reflects Wisconsin's 2010 water quality standards posted to the Wisconsin State Legislature website (accessed February 7, 2011)(Wisconsin Department of Natural Resources 2010).

Chapter NR 102
Water Quality Standards for Wisconsin Surface Waters
NR 102.04 Categories of surface water uses and criteria.

(1) General. To preserve and enhance the quality of waters, surface water uses and criteria are established to govern water management decisions. Practices attributable to municipal, industrial, commercial, domestic, agricultural, land development or other activities shall be controlled so that all surface waters including the mixing zone meet the following conditions at all times and under all flow and water level conditions:
(c) Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.

NR 102.06 Phosphorus.

(1) General. This section identifies the water quality criteria for total phosphorus that shall be met in surface waters.

(3) Streams and Rivers. To protect the fish and aquatic life uses established in s. NR 102.04 (3) on rivers and streams that generally exhibit unidirectional flow, total phosphorus criteria are established as follows:
a) **A total phosphorus criterion of 100 ug/L is established for the following rivers or other unidirectional flowing waters:**
(Note List of 46 Rivers not listed here but contained in regulation).

(b) Except as provided in subs. (6) and (7), all other surface waters generally exhibiting unidirectional flow that are not listed in par. (a) are considered streams and shall meet a total phosphorus criterion of 75 μg/L.

(4) Reservoirs and Lakes. Except as provided in sub. (1), to protect fish and aquatic life uses established in s. NR 102.04 (3) and recreational uses established in s. NR 102.04 (5), total phosphorus criteria are established for reservoirs and lakes, as follows:

(a) For stratified reservoirs, total phosphorus criterion is 30 μg/L. For reservoirs that are not stratified, total phosphorus criterion is 40 μg/L.

(b) For the following lakes that do not exhibit unidirectional flow, the following total phosphorus criteria are established:

1. For stratified, two−story fishery lakes, **15 μg/L**.
2. For lakes that are both drainage and stratified lakes, **30 μg/L**.
3. For lakes that are drainage lakes, but are not stratified lakes, **40 μg/L.**
4. For lakes that are both seepage and stratified lakes, **20 μg/L**.
5. For lakes that are seepage lakes, but are not stratified lakes, **40 μg/L**.

(c) Waters impounded on rivers or streams that don't meet the definition of reservoir in this section shall meet the river and stream criterion in sub. (3) that applies to the primary stream or river entering the impounded water.

(5) Great Lakes. To protect fish and aquatic life uses established in s. NR 102.04 (3) and recreational uses established in s. NR 102.04 (5) on the Great Lakes, total phosphorus criteria are established as follows:

(a) For both open and nearshore waters of Lake Superior, **5 ug/L.**
(b) For both open and nearshore waters of Lake Michigan, excluding waters identified in par. (c), **7 ug/L.**
(c) For the portion of Green Bay from the mouth of the Fox River to a line from Long Tail Point to Point au Sable, the water clarity and other phosphorus-related conditions that are suitable for support of a diverse biological community, including a robust and sustainable area of submersed aquatic vegetation in shallow water areas.

(6) Exclusions. The following waters are excluded from subs. (3) (b), (4) and (5):
(a) Ephemeral streams.
(b) Lakes and reservoirs of less than 5 acres in surface area.
(c) Wetlands, including bogs.
(d) Waters identified as limited aquatic life waters in ch. NR 104. Limited aquatic life waters are those subject to the criteria in s. NR 104.02 (3) (b) (2).

Wisconsin also has an active Nutrient Criteria Development Plan (Wisconsin Department of Natural Resources 2007). Many of the proposed actions in this plan (ecoregion regionalization studies, stressor response studies, user surveys) were used in the final adoption of lake, reservoir and flow water TP NNC. Several important studies were used to derive relationships between TP and chlorophyll-*a* etc ((Robertson et al. 2006; Robertson et al. 2008; Wang et al. 2007).

Wyoming

Wyoming currently lacks NNC for any of its waterbodies (Paul 2009; Wyoming Department of Environmental Quality 2000; Wyoming Department of Environmental Quality 2001; Wyoming Department of Environmental Quality 2007a; Wyoming Department of Environmental Quality 2007c; Wyoming Department of Environmental Quality 2008) (http://deq.state.wy.us/wqd/watershed/surfacestandards/index.asp , http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/states_wy.cfm).

Wyoming organizes its waters into four classes (Wyoming Department of Environmental Quality 2007b). These waters are classified according to existing and designated uses. Class 1 are those surface waters in which no further water quality degradation by point source discharges other than from dams will be allowed. Nonpoint sources of pollution must be controlled through implementation of appropriate best management practices. These waters include all surface waters in the boundaries of national parks and congressionally designated wilderness areas, selected mainstem rivers, Fremont Lake and the wetlands adjacent to those waters.

Class 2 are waters, other than those designated as Class 1, that are known to support fish and/or drinking water supplies or where those uses are attainable. Class 3 are waters, other than those designated as Class 1, that are intermittent, ephemeral or isolated waters and because of natural habitat conditions, do not support nor have the potential to support fish populations or spawning, or certain perennial waters that lack the natural water quality to support fish. Waters not specifically designated as Class 1, 2, or 4, are designated Class 3 by default. Class 4 are waters, other than those designated as Class 1, where it has been determined that aquatic life uses are not attainable pursuant to the provisions of Section 33 of the Wyoming Surface Water Quality Standards. Class 4 waters include waters that have an approved use attainability analysis (UAA) containing defensible reasons for not protecting aquatic life uses.

The state does have a mutually accepted Nutrient Criteria Development Plan (Wyoming Department of Environmental Quality 2008). Like many other plans, the Wyoming Department of Environmental Quality (WYDEQ) with support a consultant, Tetra Tech Inc., summarized the available data and/or how they would collect it, described available EPA approved approaches (ecoregion reference based, stressor response and literature derived, then proceeded to indicate which approaches would best apply to each waterbody and how this could be tied to designated uses. Wyoming planned to apply a weight-of-evidence approach that incorporates a combination of all three of the conceptual approaches described in the previous section. In addition, WYDEQ planned on using external peer review for evaluating the development of nutrient criteria.

Wyoming planned to develop nutrient criteria for different waterbody types in the following order:

1. Lakes and reservoirs
2. Streams and rivers

3. Wetlands

There are fewer lakes and reservoirs in the state than streams and rivers. In addition, there is substantially more scientific literature support for development of appropriate lake and reservoir nutrient criteria relative to streams and rivers. Therefore, nutrient criteria development for lakes and reservoirs will be the first priority and is anticipated to be more straightforward than developing criteria for streams.

Non-State and Territorial Government Organizations

There are several non-state and territorial government organizations focused on specific watersheds that have authority to develop water quality standards and therefore develop NNC (Delaware River Basin Commission 1996a; Delaware River Basin Commission 1996b)(http://www.orsanco.org/images/stories/files/pollutionControlStandards/2011%20standards.pdf.)(Ohio River Valley Water Sanitation Commission 2011; Santoro and Limbeck 2008; United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2007; United States Environmental Protection Agency 2008b). The Chesapeake Bay regional water quality standard and associated NNC were derived in response to a TMDL to improve dissolved oxygen and protect submerged aquatic vegetation(United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2007). This TMDL NNC applies to all coastal states surrounding the Chesapeake Bay. We have described this NNC in the section dealing with the State of Virginia and other bordering states so we will not discuss this further. This TMDL NNC is updated every few years as new model runs are implemented (United States Environmental Protection Agency 2003b; United States Environmental Protection Agency 2007).

Ohio River Valley Water Sanitation Commission

The EPA has stated that the Ohio River Valley Water Sanitation Commission (ORSANCO) has adopted NNC for ammonia, nitrite and nitrates (United States Environmental Protection Agency 2008b). However, after careful examination of ORSANCO's water quality standards these NNC were developed for prevention of toxicity and to protection human consumption of water from reservoirs. There does not appear to be any NNC for protection of aquatic life uses. Their Nutrient Criteria Development Plan does mention protection of aquatic life uses as a goal for the plan and includes a description of the types of parameters (e.g. N, P, and chlorophyll-*a*)(Ohio River Valley Water Sanitation Commission 2002). This Plan is very basic and contains little detail on how this will be accomplished.

Delaware River Basin Commission

The Delaware River Basin Commission has adopted and EPA has approved NNC for clarity for all water body types (Delaware River Basin Commission 1996a; Delaware River Basin Commission 1996b). The values range from not to exceed background levels by 10 NTU to not to exceed 40 NTU, based on a 30 day average values in addition of a absolute maximum value based NNC, that is measurements shall not exceed 20 to 150 NTU depending on waterbody type (Delaware River Basin Commission 1996b). The Delware River Basin Commision does have a Nutrient Criteria Development Plan(Santoro and Limbeck 2008). The strategy is focused on developing NNC to protect the lower tidal portions of the river. The Commission did note that it would not use the EPA ecoregion values provided in their ecoregion guidance documents because many of the values were derived from rivers other than the Delaware River Basin, and varied tremendously due to the many ecoregions that intersect the drainage. Therefore they, like many other member states, would likely utilize more refined values based on their own monitoring data. Also, although nutrient levels appear elevated, it appears that there have been no adverse phytoplankton blooms that affect dissolved oxygen dynamics or human health in recent years. The DRBC proposed in their Plan to maintain existing water quality as a basis for nutrient criteria in the bay. They also suggested the development of eutrophication models for each major river zone (upper, middle and lower Delaware River) to assist in evaluating the effects of the discharge of nutrients from upstream segments on lower, downstream segments. They acknowledged also the upper reaches of the river appear to be oligotrophic and do not currently have any problems. In general for many portions of the watershed, the maintenance of existing water quality (EWQ), through point source controls and best management practices should prevent eutrophic conditions from arising.

Indian Tribes

Finally, we have not mentioned any of the major Native American Tribes which in some cases have their own water quality standards program and have adopted NNC. These documents and plans are however accessible through the EPA web site (http://water.epa.gov/scitech/swguidance/standards/wqslibrary/tribes.cfm). There are approximately 37 recognized tribes that have water quality standards. It is unclear how many may have NNC as well or are in the process of developing them.

Other Nations

We did not conduct an extensive review of other European, Canadian or Central and South American government programs to control eutrophication through implementation of NNC. However, we did find that the Canadian federal and/or provincial governments had adopted NNC for their waters. For example, in British Columbia the aquatic life use protection value was 5 to 15 *u*g/L in lakes, and 100 mg/m^2 for periphyton chlorophyll in streams (http://www.gov.bc.ca/wat/wq/BCguidelines/nutrients/nutrients.html). Further examination of international regulations and approaches may be useful if time and resources permit.

Conclusions and Recommendations

A comprehensive compilation and review of past and recent water quality data and literature was conducted using existing federal and state water quality databases and a review of online literature. The candidate water quality data was compiled for potential future analyses from multiple online electronic data available from various data sources including the Texas Water Development Board (TWDB), TCEQ, United States Geological Service (USGS), EPA STORET, National Coastal Condition Assessment, National Lakes Assessment and National Rivers and Streams Assessment. The TCEQ database is by far the most comprehensive data set within the state. Other complimentary sets include data collected by the intense monitoring conducted by the TWDB during the 1960's through 1980's which was focused on the bays and estuaries and associated with freshwater flow studies. There are however numerous limitations in the current monitoring programs and include 1) lack of extensive periphyton monitoring in streams, 2) limited number of total nitrogen measurements and 3) a reduced number of paired nutrient (TN and/or TP) and chlorophyll-*a* samples. In addition, in many cases total phosphorus levels and/or other variables are reported at less than detection limits.

In addition to environmental data compiled for this project we also compiled recent statistics and current data on state numeric nutrient criteria including nutrient criteria development plans and recent approaches used by various states in the process of promulgating numeric based standards. For each state and territory we also compiled and summarized recent numeric nutrient criteria planning support documents, water quality standards, and technical reports and peer reviewed journal articles describing methods to develop NNC. Standards containing numeric nutrient criteria were summarized and important sections transcribed verbatim and placed in this report with associated commentary as needed. In addition to these regulatory standards and Nutrient Criteria Development Plans and associated research articles we also compiled recent published literature on NNC development and research. These studies illustrate the various methods used by states to derive numeric nutrient criteria. In addition, federal planning documents and technical support documents and associated review reports and/or derived studies are included as resource documents in the electronic resource directories created for this project.

After a careful review of each states ongoing NNC development program and existing adopted and/or EPA approved or promulgated we can conclude the following. Most states had similar although widely varying in content Nutrient Criteria Development Plan strategies. That is common steps included 1) compilation and review of data, 2) preliminary review of EPA provided ecoregion derived draft NNC for freshwater systems, 3) establishing a priority that focused on development of NNC for lakes/reservoirs first and then streams or rivers next followed by estuaries if applicable or wetlands if land-locked. This was often based on the assumption that lakes and reservoirs were often used by the public more and often served as sources for drinking water. It should be noted, that some states did have NNC for reservoirs or rivers that focused on protection of drinking water, which we mention but did not include in our grouping of states with NNC to protect aquatic life from eutrophication, NOT toxic, effects.

Based on our review of state water quality programs, many states have prioritized their numeric nutrient criteria (NNC) development tasks based on waterbody type. In most cases states chose to first develop NNC for lakes or reservoirs, followed next by streams and rivers and finally estuaries and wetlands. However, this was not the pattern followed by all states. The majority of states first attempted to utilize an ecoregion reference condition approach. However, most states recognized the limitation of this method and the need to use more quantitative stressor-response modeling approaches. Very few states or territories used "off the shelf" values provided by EPA in their Ecoregion Nutrient guidance documents and chose to regionalize their approach based on more specific data collected by the state or other agencies (e.g. USGS). They made this decision in most cases because they felt the EPA ecoregion were too spatially coarse and they found that their monitoring data provided better more representative spatial coverage to build their database upon. They also found if they used the EPA ecoregion values they would often classify waterbodies containing little or no anthropogenic sources of stress as being impaired due to "high" values of TP or TN, even though the biological community or "response" variable like chlorophyll-*a* seems to be supporting aquatic life uses.

When possible most states preferred the use of stressor response or causal and effect models based on their own ambient data because they felt that a clear demonstration of cause and effect is much more effective in convincing the regulated community that the NNC are reasonable, and also use of such representative values could be used to successfully manage and control sources of eutrophication. This also allows investigators and managers to more easily describe the problem causing a reduction in the designated uses of an area or loss of fishing and/or associated human recreational uses. Unfortunately many states lacked sufficient numbers of observations containing paired variables (e.g. chlorophyll-*a* versus nutrients). This limits the ability of these states to use this approach.

Based on our review many states utilized a "weight of evidence approach", utilizing reference condition/ecoregion based approach using state specific data from finer resolution ecoregion level 3 and 4. The "weight of evidence" approach which was often used included a combination of methods which included ecoregion based statistically derived values, stressor-response modeling using paired nutrient values and response variables, usually chlorophyll-*a* (open water or periphyton based) and subsequent development of thresholds using linear regression, quantile regression, breakpoint analysis and in some cases shifts in community composition. In the case of Florida, new consideration for downstream standards was also emphasized in the case of new stream standards that impact streams that eventually flow into lakes or estuaries. Consequently new stream standards may have to be protective of downstream streams that flow into lakes or estuaries.

Texas will be challenged in developing standards for freshwater streams and estuaries due to the complex biogeography of our state, which is influenced by natural gradients in climate, rainfall and streamflow. This complexity is illustrated by the range of conditions extending from the hypersaline Laguna Madre containing marine seagrasses to small first order acidic streams in east Texas. For example, development of NNC for estuaries might focus on protection of seagrasses and other designated uses from excessive periphyton growth or phytoplankton shading. In contrast stream systems might require NNC that provide meaningful targets to prevent excessive nuisance periphyton growth. Larger rivers in contrast may require NNC that protect against excessive phytoplankton growth. Each of the unique designated uses of these waterbodies will need to be addressed individually. Therefore a combination of data and analytical tools will likely be needed to develop numeric nutrient criteria. The data contained in the databases that were produced and the associated technical and regulatory literature should provide TCEQ with important additional tools and information to complete this task.

Although extensive subsequent analyses will be needed several suggestions and observations can be made at this time.

1. Texas like many states lacks a long-term comprehensive database of paired measurements of periphyton biomass and chlorophyll-*a* along with TN and TP, for streams and smaller rivers. This will make it difficult to develop stressor response based NNC for these systems. Additional supplement monitoring and/or special studies such as the research conducted by (King 2009) on small streams. However, very little data or research has been conducted on larger rivers.
2. EPA in their guidance documents has indicated that the preferred nutrient forms for analysis are TN and TP. Texas has historically not measured TN directly. In addition, the lack of large scale measurements of this parameter or at least TKN and combined NO_x will limit the ability to use TN as a causative variable in statistical ecoregion based NNC methods. It may be possible however to relationships between NO_x and/or TIN (NO_x + NH_3-N) and chlorophyll-*a* for larger rivers and/or estuaries and tidal streams. Also, there is some historical data collected by the TWDB that does contain TN values which might be useful in constructing historical baseline conditions
3. For coastal systems, many states utilized an approach that attempted to relate designated uses (e.g. support of fisheries) with existing or past water quality. Texas which does contain a long-term fisheries database collected by Texas Parks and Wildlife Department may want to explore this option as well.
4. Texas should carefully evaluate the studies and methods developed in Florida and the Chesapeake Bay for the protection of SAV as they develop NNC for seagrasses in their coastal estuarine systems. Even so, this will be difficult due to the range of seagrass communities encountered from high salinity tolerant turtle grass to freshwater/oligohaline species such as widgeon grass (*Ruppia maritima*)

Currently there are few major efforts to develop NNC for estuaries and negligible activity for wetlands, other than including them with adjacent waterbody types during the derivation and application of NNC. Due to the fundamental difference in the functioning of wetlands and the density of emergent and submerged plants and algae and periodic exposure to atmospheric conditions and different hydrology it will very difficult to develop NNC for wetlands in the near future. Wetlands will likely need to be handled separately from other waterbody types.

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Appendix 1. TCEQ Nutrient Project Directory Key

TCEQ Nutrient Project Directory Key

Contract # 582-10-90477

Title: Texas Nutrient Criteria Development Support Project

FTP Site: ftp://eih-ftp.uhcl.edu

Login credentials:

Account: uhcl\eihftprw

Password: &Eih%fTp9

Main Directory: TCEQ Nutrients Project

Sub Directory: Environmental Data

SubLevel2: Access Database

SubLevel3: AccessNutrientDatabase_FINAL.accdb

1) Contains raw data compiled from TCEQ, USGS, EPA, NOAA, CRP, HARC, TWDB, GLO, TPWD, USDA, NPS, and other sources in Microsoft Access database format.
2) Data are from published agency reports and scientific journal articles and are joined in multiple tables linked for querying.
3) Contains data collected from 1 January 1930 to 15 November 2010.
4) NOTE: not all papers or reports provided in the EndNote database and PDF folder are included in this database (i.e. those papers not including raw data).
5) Detailed parameter descriptions available in table design view.

SubLevel2: Electronic Datasets

NOTE: All electronic database files contain two worksheet tabs. Tab one (labeled as "Source_Database") contains the full dataset with all raw data. The second tab (labeled as "Parameter_Descriptions") contains information including: column number, column header, EPA STORET parameter code (if available), parameter description, and units for each parameter.

SubLevel3: 1398_EPA_NCCA_Database_FINAL.xlsx

1) The National Coastal Condition Assessment (NCCA) is part of a series of assessments conducted by states, tribes, the US EPA, and other partners. Data presented in this file is only for the state of Texas. Contains data collected from 9 July 1991 to 9 September 2004.
2) Raw data were downloaded from the EPA website: http://water.epa.gov/type/watersheds/monitoring/nationalsurveys.cfm

3) Data were pivoted in ArcGIS (corresponding values determined by exact matches in site/date/depth data)
4) Compiled data was exported from ArcGIS and saved as EPA_NCA_Database_FINAL.xlsx.

SubLevel3: 1398_EPA_NCCA_QAPP.PDF

1) The National Coastal Condition Assessment (NCCA) QAPP provided by the EPA website.

SubLevel3: 1397_EPA_STORET_Legacy_Database_FINAL.xlsx

1) The EPA STORET Legacy database is a repository of ambient water quality data collected prior to 1999. Agencies reporting data from Texas to this database include: US EPA, US Corps of Engineers, Vicksburg District CoE, National Park Service, Oklahoma Conservation Committee, Texas Department of Health, Texas Department of Water Resources, Texas Water Commission, and US Forest Service. Contains data collected from 1 May 1941 to 30 December 1998.
2) Raw data for the state of Texas was downloaded from the EPA STORET Legacy FTP website: ftp://ftp.epa.gov/storet/exports/
3) Data was filtered for parameters pertinent to this study and county data were compiled into one database. Data were then pivoted in ArcGIS (corresponding values determined by exact matches in site/date/depth data).
4) Compiled data were exported from ArcGIS and saved as EPA_STORET_Legacy_Database_FINAL.xlsx.
5) File also contains third spreadsheet tab titled "Comment_Codes". This tab includes descriptions of the comment codes found for each parameter comment column.
6) NOTE: Data may be duplicated in TCEQ_Database_FINAL.xlsx. To maximize efficiency and reduce the potential for data loss, these two databases were not cross referenced for duplicated data. Care should be taken if these two databases are to be compared in the future.

SubLevel3: 1256_Montagna_Citations.docx

1) This file contains full citations for the scientific journal articles and book chapters that the summarized data from Dr. Paul Montagna's raw database are presented in.

SubLevel3: 1256_Montagna_Database_FINAL.xlsx

1) This database contains raw data compiled by Dr. Paul Montagna (now at TAMUCC) from studies performed at UTMSI. Summarized data from these studies have been presented in scientific journals and book chapters. See file Montagna_Citations.docx (in SubLevel2: Electronic Datasets) for full citations of articles and chapters. Contains data collected from 28 January 1987 to 27 October 2010.
2) Raw data were provided in Excel files by data type (hydrography and nutrients).
3) Data were merged by joining corresponding hydrography data to the nutrient data in ArcGIS using matching site/data/depth data.
4) Merged data were exported from ArcGIS and saved as Montagna_Database_FINAL.xlsx.
5) NOTE: EPA STORET parameter codes not available, but methodology described in supporting documents.

SubLevel3: 1258_NAWQA_Database_FINAL.xlsx

1) The National Water Quality Assessment (NAWQA) program was implemented to assess water quality conditions throughout the continental US. This project is currently in its second decade of monitoring. Data presented in this file is only for the state of Texas. Contains data collected from 1 October 1991 to 23 February 2011.
2) Raw data were extracted by parameter as tab-delimited text files from the NAWQA website: http://infotrek.er.usgs.gov/nawqa_queries/swmaster/index.jsp
3) Text files were merged and data were pivoted in ArcGIS (corresponding values determined by exact matches in site/date/depth data).
4) Compiled data were exported from ArcGIS and saved as NAWQA_Database_FINAL.xlsx.
5) NOTE: The NAWQA program was performed outside of the normal scope of USGS data collection. The data presented here does not include routine USGS data or data collected outside the realm of this study.

SubLevel3: 1255_Quigg_Database_FINAL.xlsx

1) This database contains raw data collected by Tyra Boone from Dr. Antoinetta Quigg's lab at TAMUG for her Master's

thesis. Contains data collected from 19 February 2008 to 14 June 2010.

2) Raw data was provided in multiple Excel files separated by data year (2008, 2009, and 2010). Nutrient data represented in [uMol/L] were converted to [mg/L].
3) Data for all data years were combined into a single .xlsx file and the completed spreadsheet was saved as Quigg_Database_FINAL.xlsx.
4) NOTE: EPA STORET parameter codes not available, but methodology described in supporting documents.

SubLevel3: 1255_Quigg_QAPP.docx

1) This file contains the QAPP documents provided by Dr. Antoinetta Quigg for her raw database.

SubLevel3: TCEQ_Database_FINAL.xlsx

1) This database contains data compiled by the TCEQ from the Surface Water Quality Monitoring (SWQM) network. These data were collected under multiple EPA approved QAPPs. Contains data collected from 4 February 1968 to 25 August 2010.
2) A formal request was sent to Laurie Eng at TCEQ for pertinent parameter data collected for the SWQM network database. Raw data was provided by TCEQ in tab-delimited text files divided by Texas basin number (1-25).
3) Pivot tables were made for each of the basin raw datasets in ArcGIS (corresponding values determined by exact matches in site/date/depth data).
4) Compiled data were exported from ArcGIS and data for each basin was merged into one Excel file and saved as TCEQ_Database_FINAL.xlsx.
5) TKN was not originally included in the TCEQ data set query; this data was extracted from the TCEQ website: http://www.tceq.texas.gov/waterquality/monitoring/txwaterdata.html
6) NOTE: Data may be duplicated in EPA_STORET_Legacy_Database_FINAL.xlsx. To maximize efficiency and reduce the potential for data loss, these two databases were not cross checked for duplicated data. Care should be taken if these two databases are to be compared in the future.

SubLevel3: TWDB_CDS_Database_FINAL.xlsx

1) The TWDB Coastal Data System (CDS) was performed in cooperation with the USGS to investigate water quality in the principal estuaries along the Texas coast. Numeric parameter codes were not provided, however, APHA/AWWA/WEF standard methods from 1971 and earlier are cited. Contains data collected from 30 November 1960 to 29 July 1989.
2) Raw data was obtained from Dharhas Pothina (TWDB) as a .zip file through email. This .zip file contained multiple tab-delimited text files divided by Texas estuary and the agency responsible for data collection.
3) Estuary text files were converted to Excel documents and parameter codes were filtered for parameters pertinent to this study. Pivot tables were then made for each estuary dataset using ArcGIS (corresponding values determined by exact matches in site/date/depth data).
4) Compiled data were exported from ArcGIS and data for each estuary was merged into one Excel file and saved as TWDB_CDS_Database_FINAL.xlsx.
5) NOTE: This data set is more extensive than that reported in the TWDB published reports (prepared by the USGS). These TWDB published reports have been digitized and are included in the EndNote database but raw data from these reports has not been added to the Access database to eliminate the potential for data duplication.
6) NOTE: Data may be partially duplicated in Ward_Database_FINAL.xlsx. To maximize efficiency and reduce the potential for data loss, these two databases were not cross referenced for duplicated data. Care should be taken if these two databases are to be compared in the future.

SubLevel3: USGS_Database_FINAL.xlsx

1) This data base contains raw data provided by Jeff East of USGS through an FTP site. Data included in this report originate from any USGS gage sites where nutrient data were collected simultaneously. Contains data collected from 18 June 1959 to 2 March 2011.
2) Raw data was provided as a tab-delimited text file and converted to an Excel spreadsheet.
3) The completed spreadsheet was saved as USGS_Database_FINAL.xlsx.

SubLevel3: Ward_Database_FINAL.xlsx

1) This database was compiled for the CCBNEP and GBNEP to identify problems facing the bays and estuaries in Corpus Christi and Galveston Bay. Contains data collected from 11 January 1950 to 29 January 1996.
2) Raw data were provided by George Ward through an FTP site. Data from each bay system were divided by parameter and opened as tab-delimited files in Excel.
3) For each bay system, pertinent parameters were compiled into an Excel document and pivot tables were made for each of the raw datasets using ArcGIS (corresponding values determined by exact matches in site/date/depth data).
4) The compiled data sets from each bay system were combined into a single file and saved as Ward_Database_FINAL.xlsx.
5) Summary reports for CCBNEP and GBNEP were provided as PDF documents. These documents were entered into the EndNote database and are stored as PDFs.
6) NOTE: Data may be partially duplicated in TWDB_CDS_Database_FINAL.xlsx. To maximize efficiency and reduce the potential for data loss, these two databases were not cross referenced for duplicated data. Care should be taken if these two databases are to be compared in the future.
7) NOTE: EPA STORET parameter codes not available, but methodology described in supporting documents.

SubLevel2: Maps of Environmental Data Used

NOTE: All of the following folders contain JPEG files of maps created in ArcGIS from data provided in each of the raw databases. Maps show station locations by basin, waterbody type, and/or collecting agency.

SubLevel3: Access_Nutrient_Database_Maps
SubLevel3: EPA_NCCA_Database_Maps
SubLevel3: EPA_STORET_Legacy_Database_Maps
SubLevel3: Montagna_Database_Maps
SubLevel3: NAWQA_Database_Maps
SubLevel3: Quigg_Database_Maps
SubLevel3: TCEQ_Database_Maps
SubLevel3:TWDB_CDS_Database_Maps
SubLevel3: USGS_Database_Maps
SubLevel3: USGS_Gage_Site_Maps

SubLevel4: Active_Gages
SubLevel4: Annual_Archived_Data
SubLevel4: Daily_Archived_Data

SubLevel3: Ward_Database_Maps

Sub Directory: Literature

<u>SubLevel2: EndNote Bibliography</u>

SubLevel3: Nutrient Criteria.Data: contains files necessary for library sharing

SubLevel3: Nutrient Criteria.enl

<u>SubLevel2: PDF</u>

1) Contains complete PDFs of each Literature document in the EndNote Bibliography. Files are labeled by: EndNote Call Number_Author_Year.

Sub Directory: Report

<u>SubLevel2:</u> *TexasNutrientCriteriaDevelopmentSupportProjectReport_FINAL.docx*

Sub Directory: State Criteria Resources

<u>SubLevel2: Federal Criteria Guidance</u>

SubLevel3: CALM

1) The Consolidated Assessment and Listing Methodology were created to provide a standard set of methods for collection and use of water quality data and information.
2) Contains MHTML files with links to the CALM home page and report guidelines and a PDF document with the first edition of CALM.

SubLevel3: Chesapeake Bay Guidance

1) Contains PDFs of documents produced by the EPA and State Partnerships on water quality criteria and nutrient trading in the Chesapeake Bay System.

SubLevel3: Ecoregion

1) EPA Ecoregion nutrient technical guidance documents and associated peer reviews.

SubLevel4: Lakes & Reservoirs

SubLevel4: Rivers & Streams

SubLevel4: TX Ecoregion Nutrient Data

SubLevel3: EmipricalApproach

1) EPA Empirical Approaches to Criteria Development Documents

SubLevel3: EPACriteriaLists

1) National Recommended Water Quality Criteria document and website link.

SubLevel3: Estuarine

1) EPA EstuarineTechnical Support Documents for development of numeric nutrient criteria.

SubLevel3: General

1) EPA generalTechnical Support Documents for development of numeric nutrient criteria.

SubLevel3: Lakes

1) EPA Lakes Technical Support Documents for development of numeric nutrient criteria.

SubLevel3: Rivers

1) EPA Rivers and streams Technical Support Documents for development of numeric nutrient criteria.

SubLevel3: StressorResponse

1) EPA Guidance on use of stressor response relationships to develop numeric nutrient criteria technical guidance.

SubLevel3: USGS

1) USGS Technical reports on development of regional approaches to deriving numeric nutrient criteria. Includes database.

SubLevel3: Wetlands

1) EPA wetlands Technical Support Documents for development of numeric nutrient criteria.

<u>SubLevel2: NSTEPS</u> *(Nutrient Scientific Technical Exchange Partnership and Support)*

SubLevel3: Guidance

1) NSTEPS online guidance documents and reports

SubLevel3: StatisticalTools

1) NSTEPS statistical tools for evaluation of water quality criteria.

SubLevel3: TechnicalArticles

1) NSTEP various technical articles on topics ranging from eutrophication to nutrient criteria development.

<u>SubLevel2: State Criteria & Plans Information</u>

SubLevel3: All States

1) Each state folder contains the latest available information on water quality standards for the state, as well as various technical support documents and numeric nutrient criteria development plans. This includes both state and federally approved standards and draft or proposed standards.

SubLevel3: State Summary Data

1) Folder contains PDF documents as well as internet site links with summary information generated by various authors on the status of state nutrient criteria development.

Appendix 2. Maps of Historical TCEQ Monitoring Sites

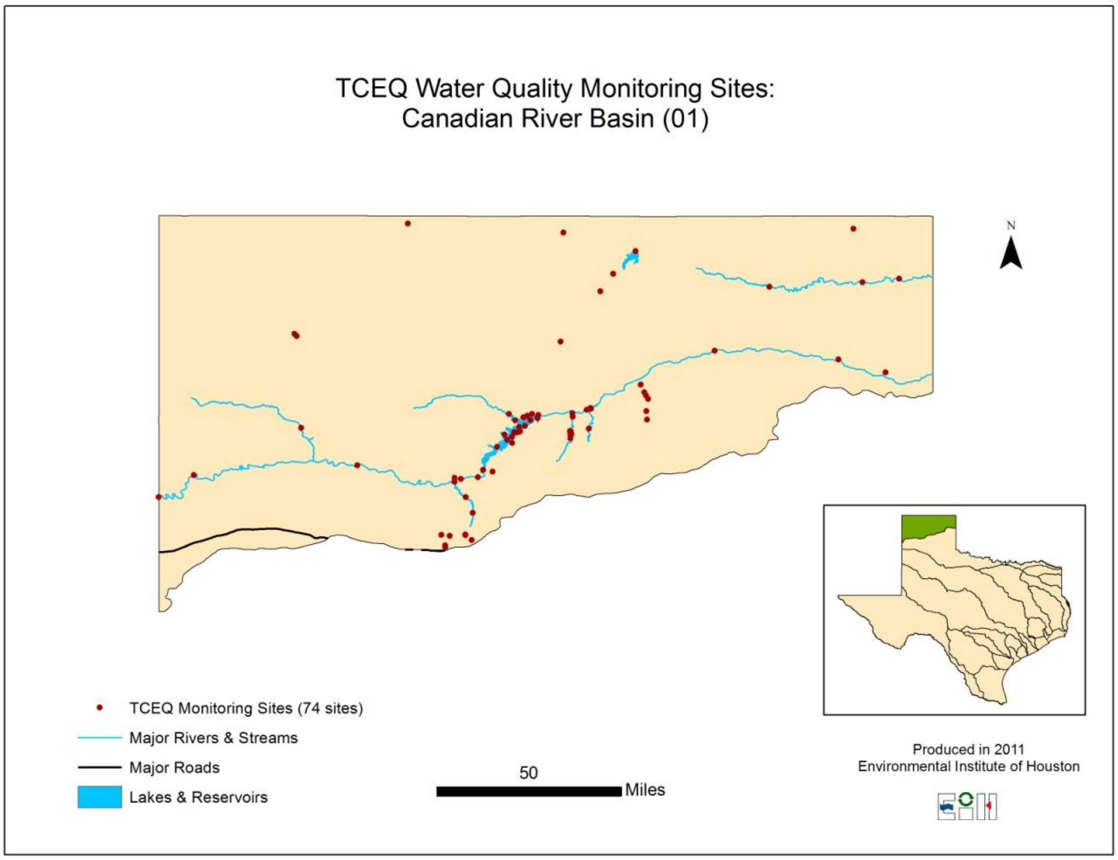

Figure A2. 1. Location of all TCEQ stream monitoring sites where historical data exists within the Canadian River Basin.

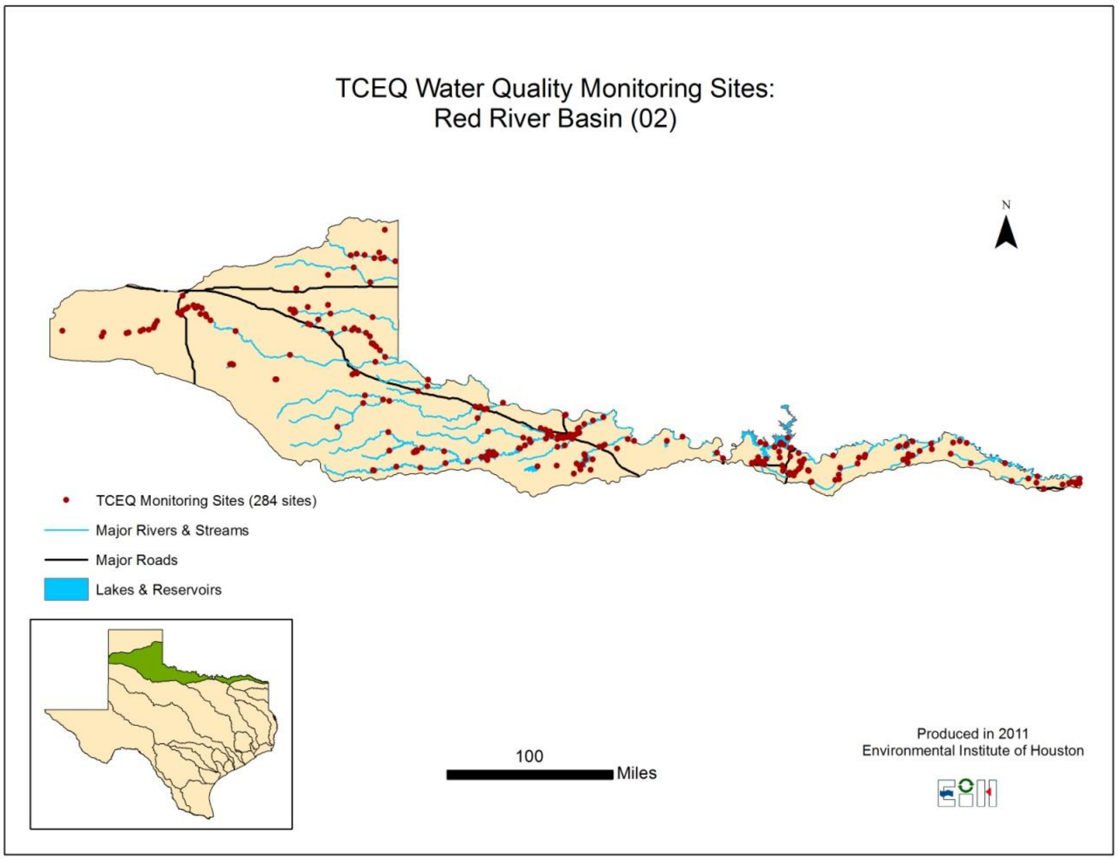

Figure A2. 2. Location of all TCEQ stream monitoring sites where historical data exists within the Red River Basin.

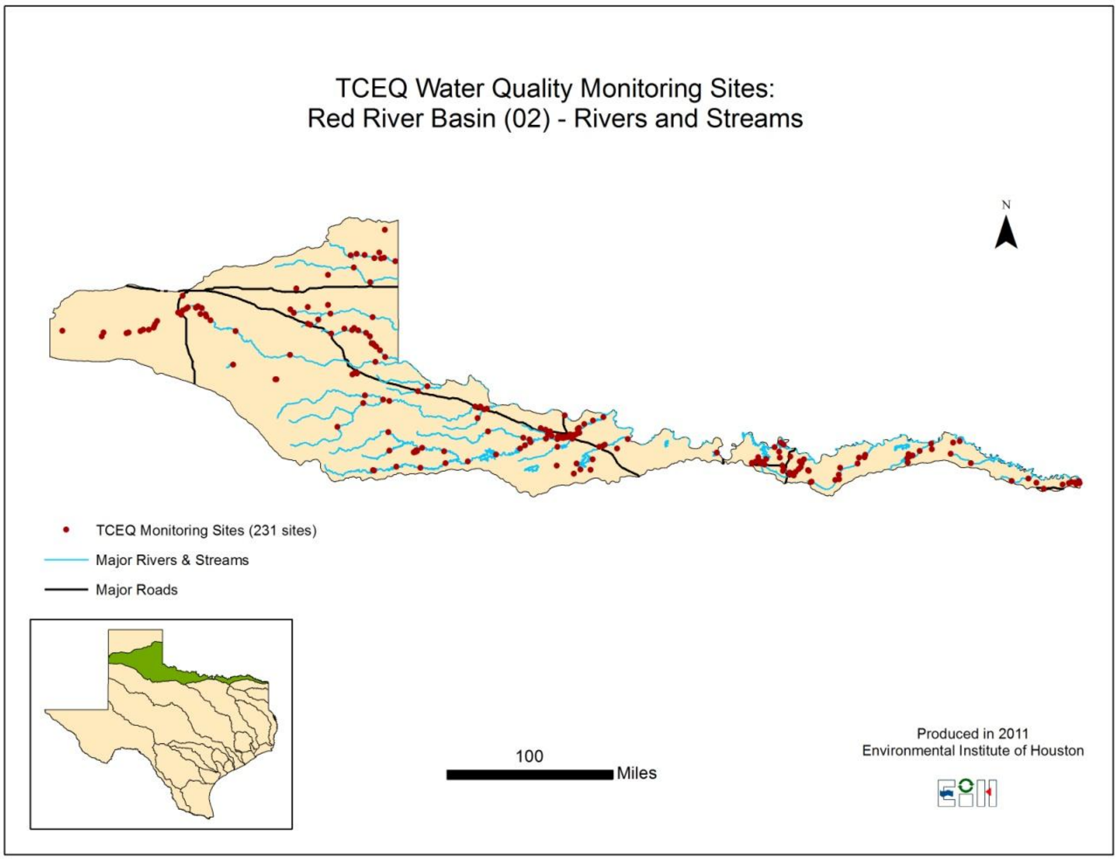

Figure A2. 3. Location of stream and river TCEQ stream monitoring sites where historical data exists within the Red River Basin

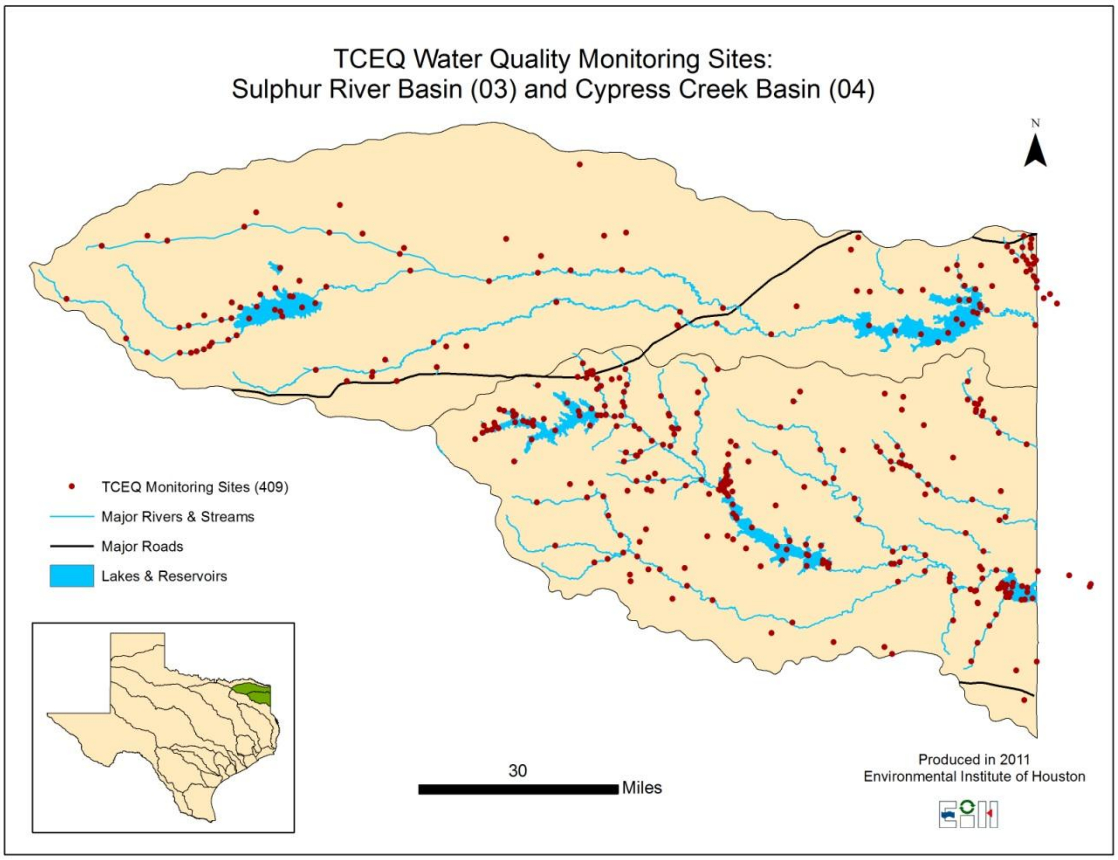

Figure A2. 4. Location of all TCEQ stream monitoring sites where historical data exists within the Sulfur and Cypress Creek River Basins.

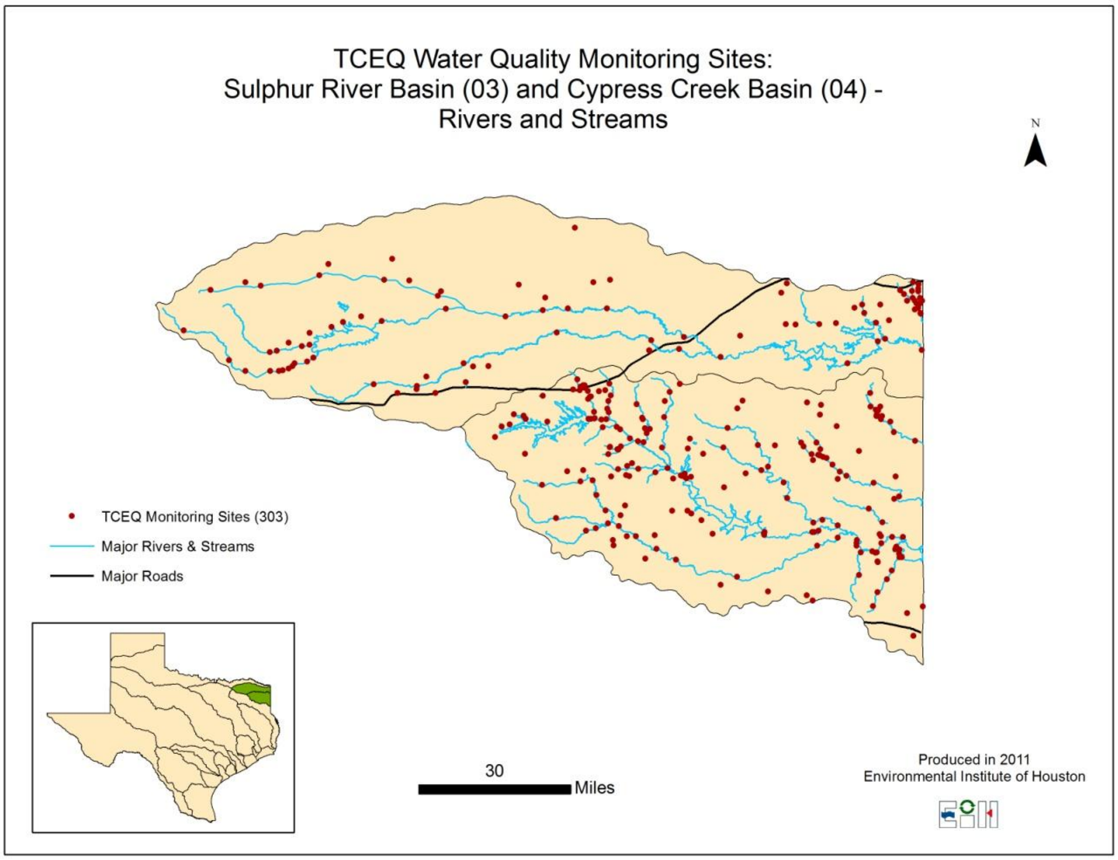

Figure A2. 5. Location of stream and river TCEQ stream monitoring sites where historical data exists within the Sulfur and Cypress Creek River Basins.

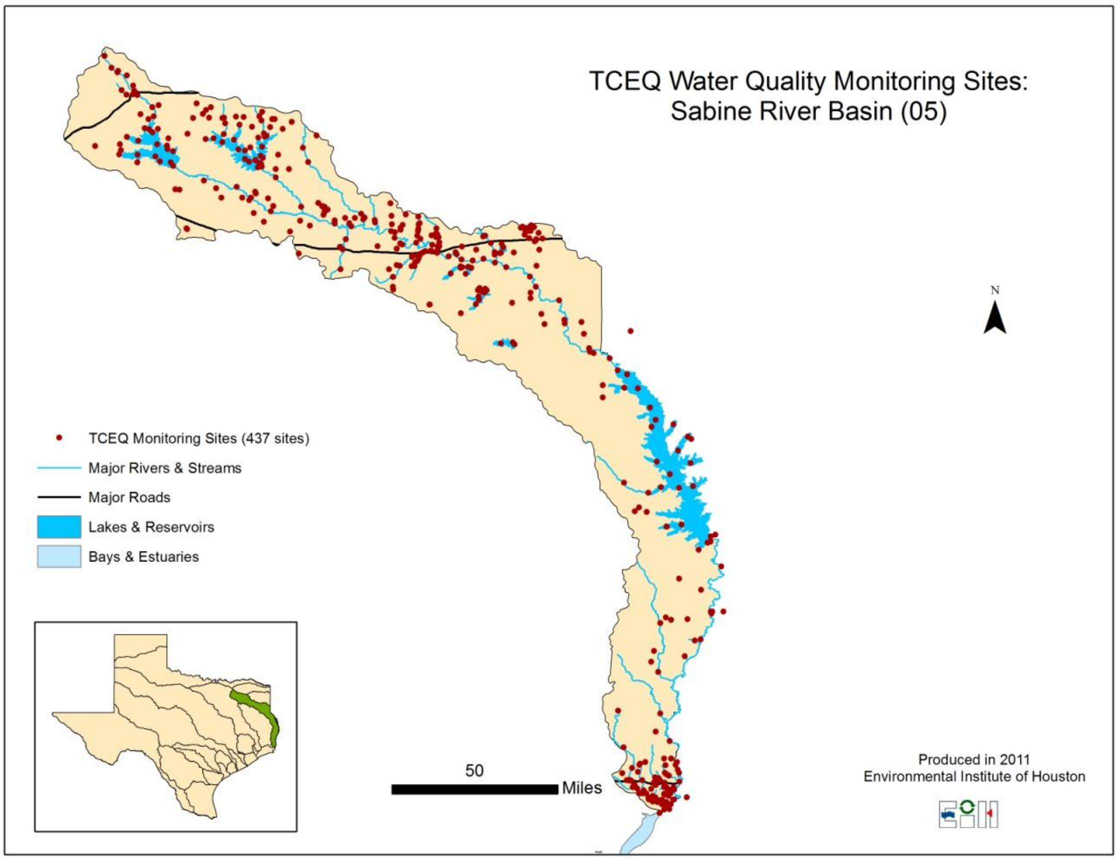

Figure A2. 6. Location of all TCEQ stream monitoring sites where historical data exists within the Sabine River Basin.

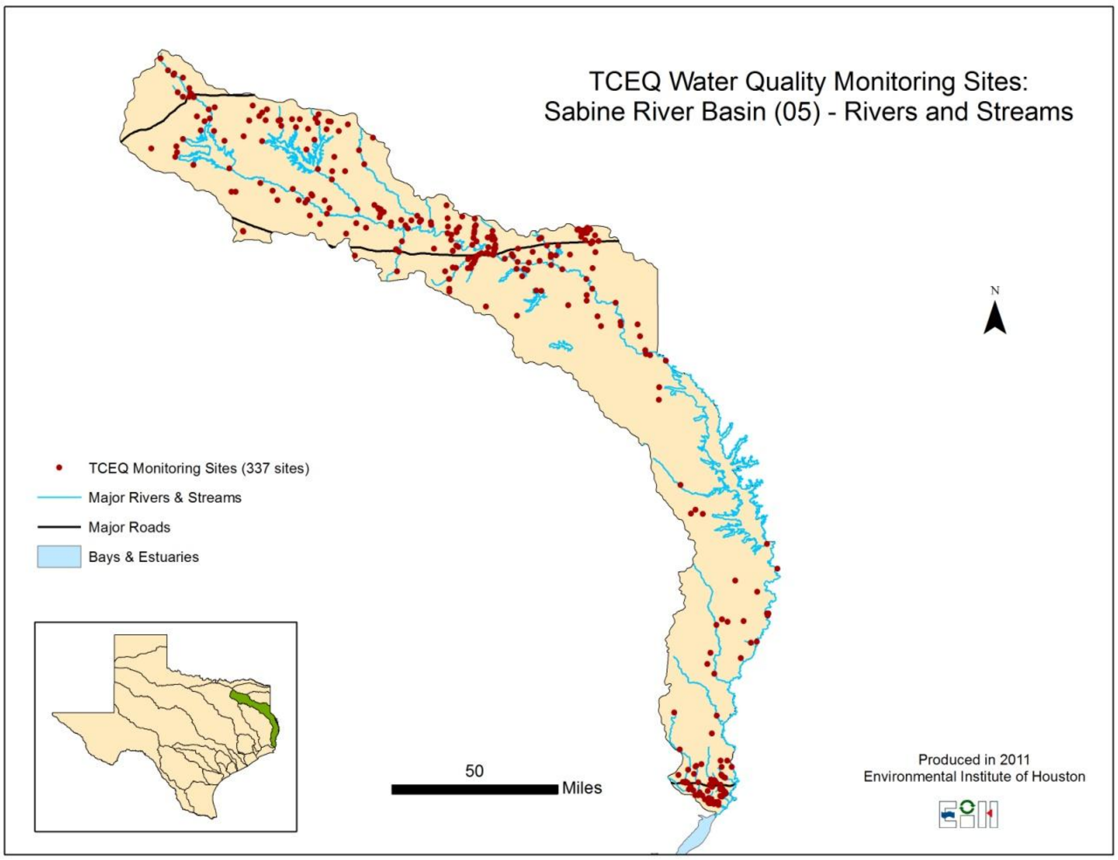

Figure A2. 7. Location of all river and stream TCEQ stream monitoring sites where historical data exists within the Sabine River Basin.

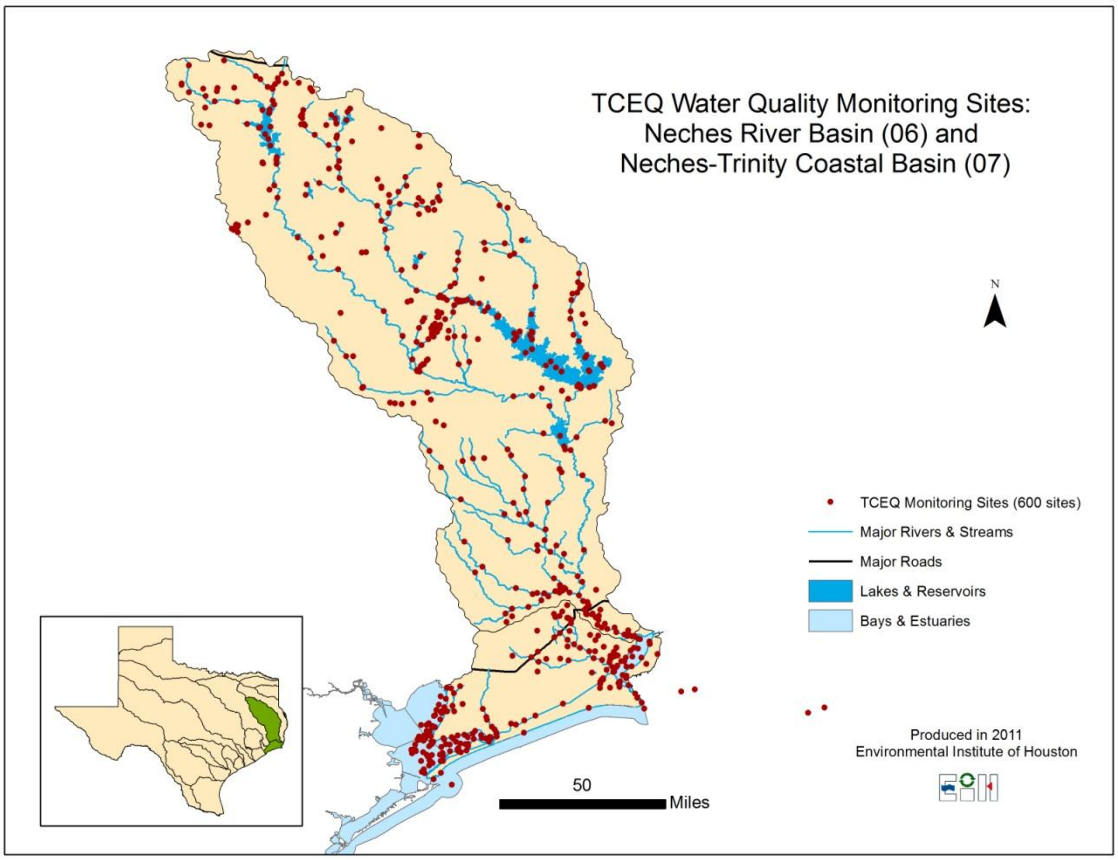

Figure A2. 8. Location of all TCEQ monitoring sites where historical data exists within the Neches River and Neches-Trinity Coastal Basins.

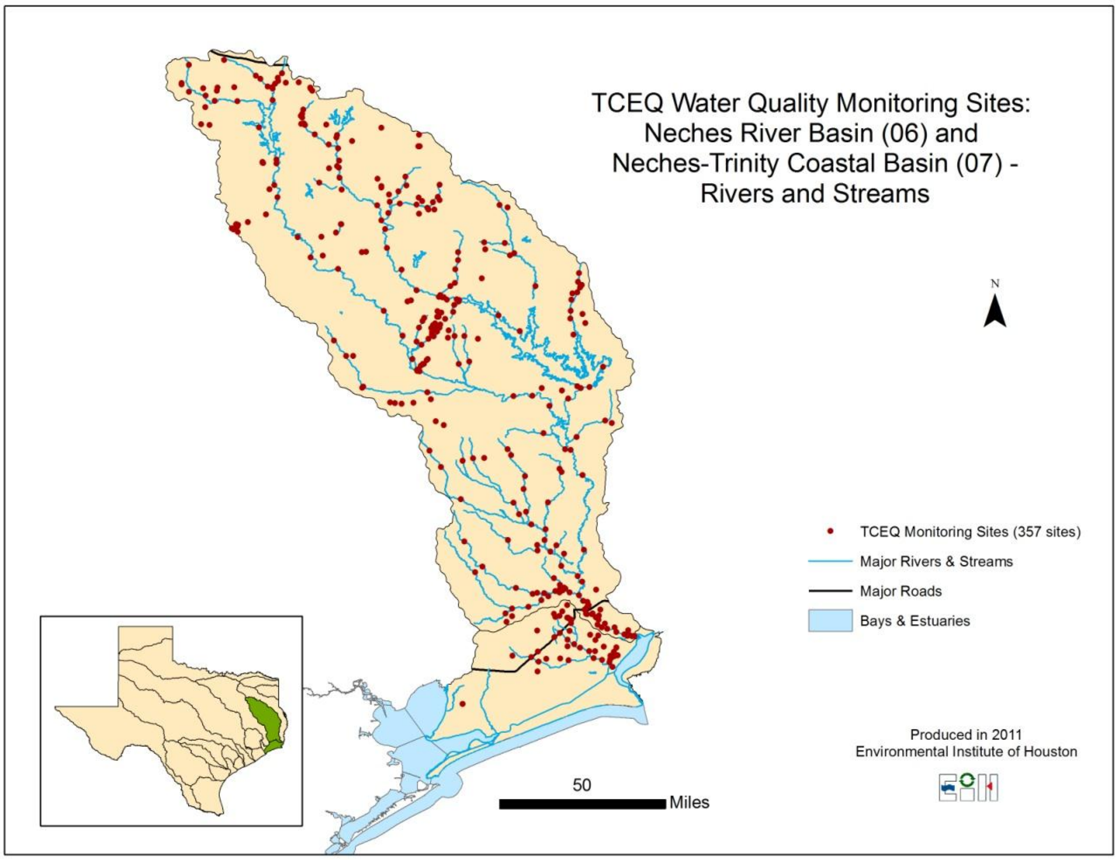

Figure A2. 9. Location of all stream and river TCEQ monitoring sites where historical data exists within the Neches River and Neches-Trinity Coastal Basins.

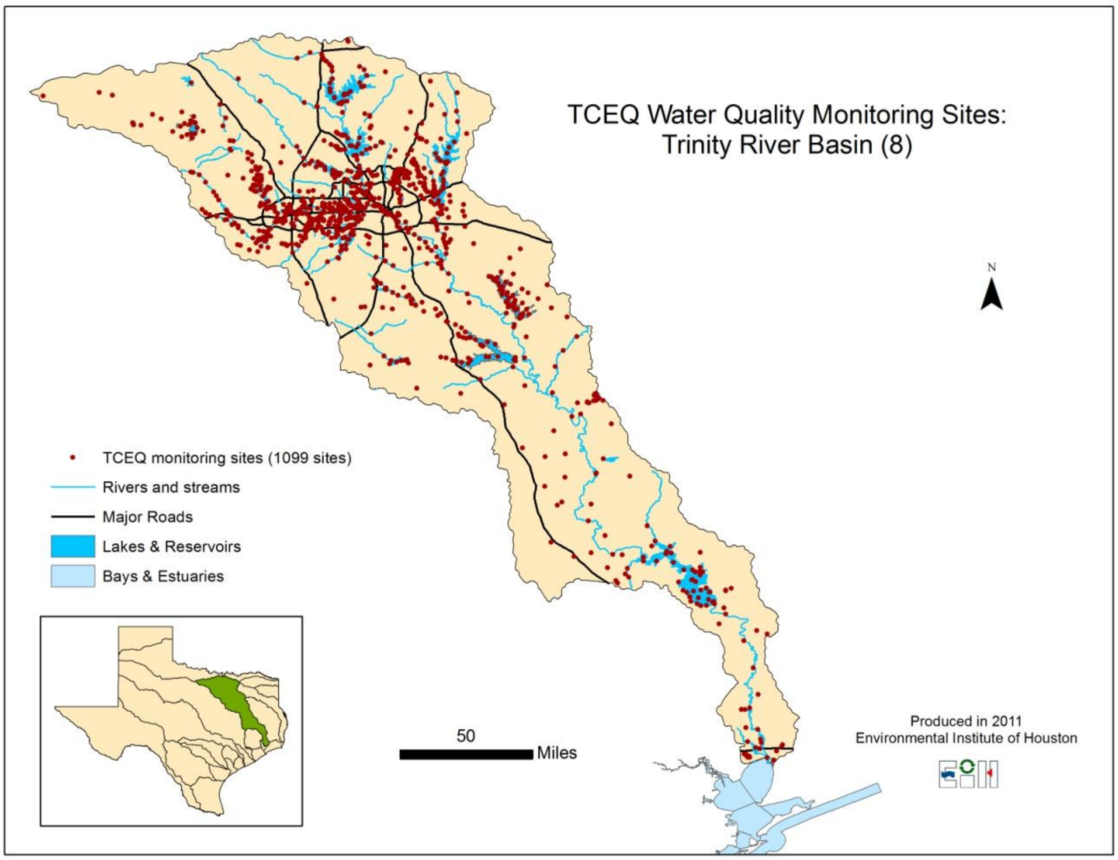

Figure A2. 10. Location of all TCEQ monitoring sites where historical data exists within the Trinity River Basin.

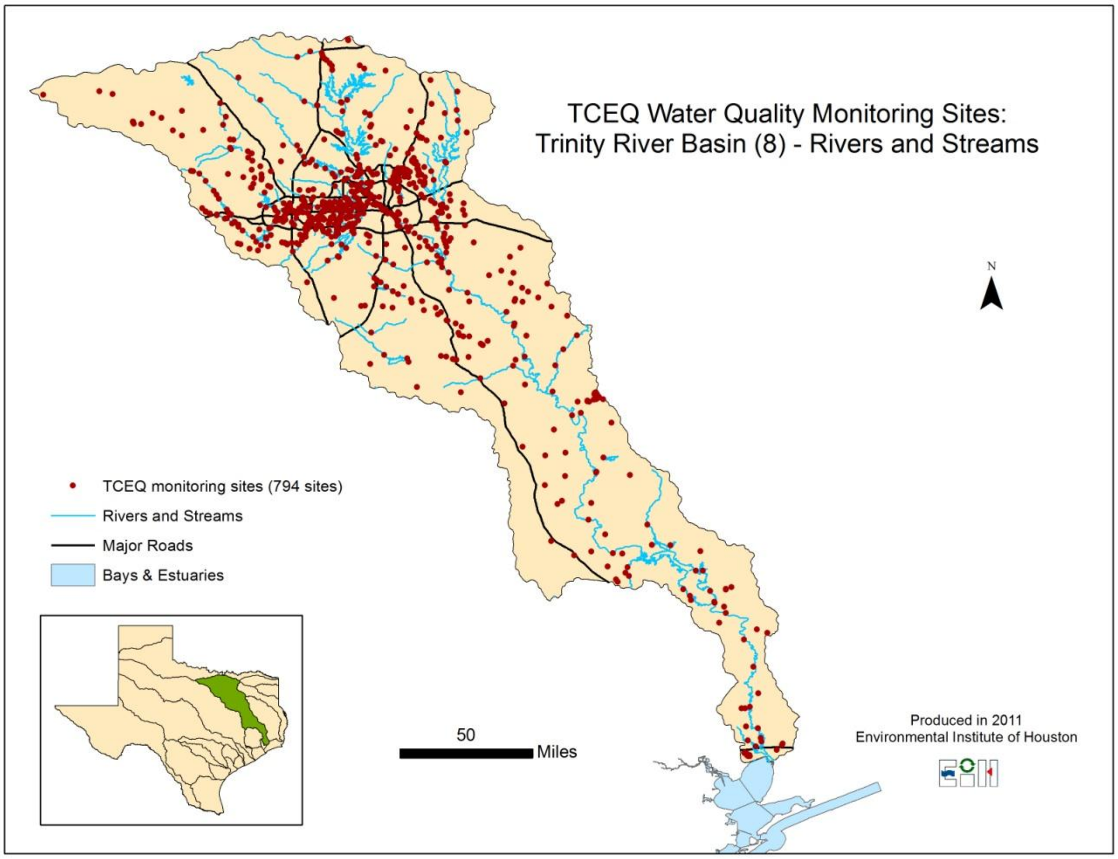

Figure A2. 11. Location of all river and stream TCEQ monitoring sites where historical data exists within the Trinity River Basin.

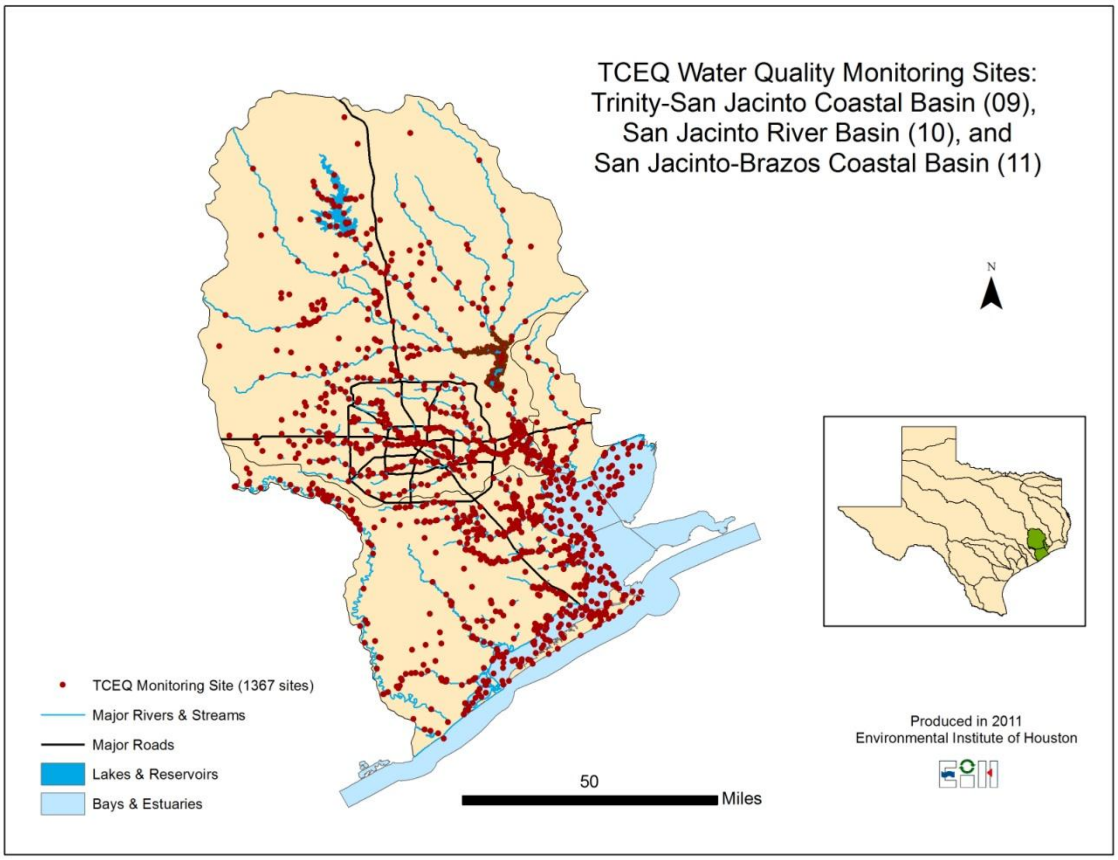

Figure A2. 12. Location of all TCEQ monitoring sites where historical data exists within the Trinity San Jacinto Coastal, San Jacinto River and San Jacinto-Brazos Coastal Basins.

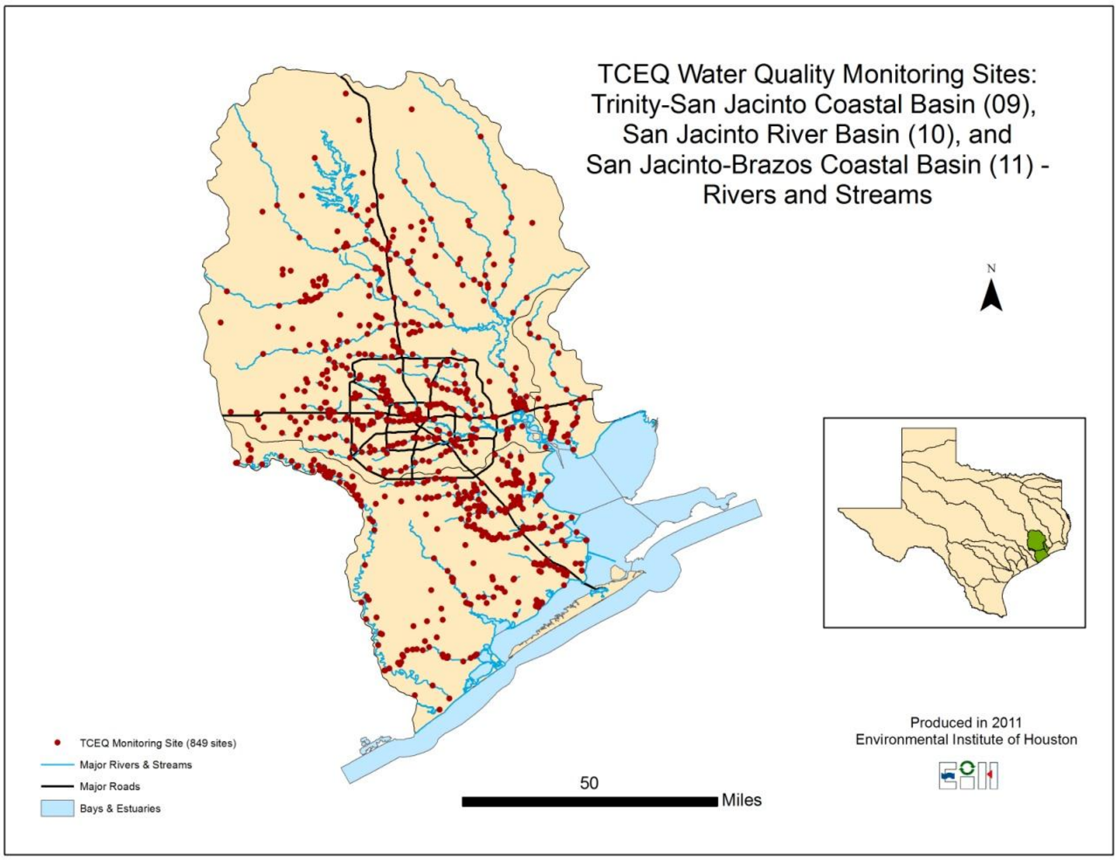

Figure A2. 13. Location of all TCEQ river and stream monitoring sites where historical data exists within the Trinity San Jacinto Coastal, San Jacinto River and San Jacinto-Brazos Coastal Basins.

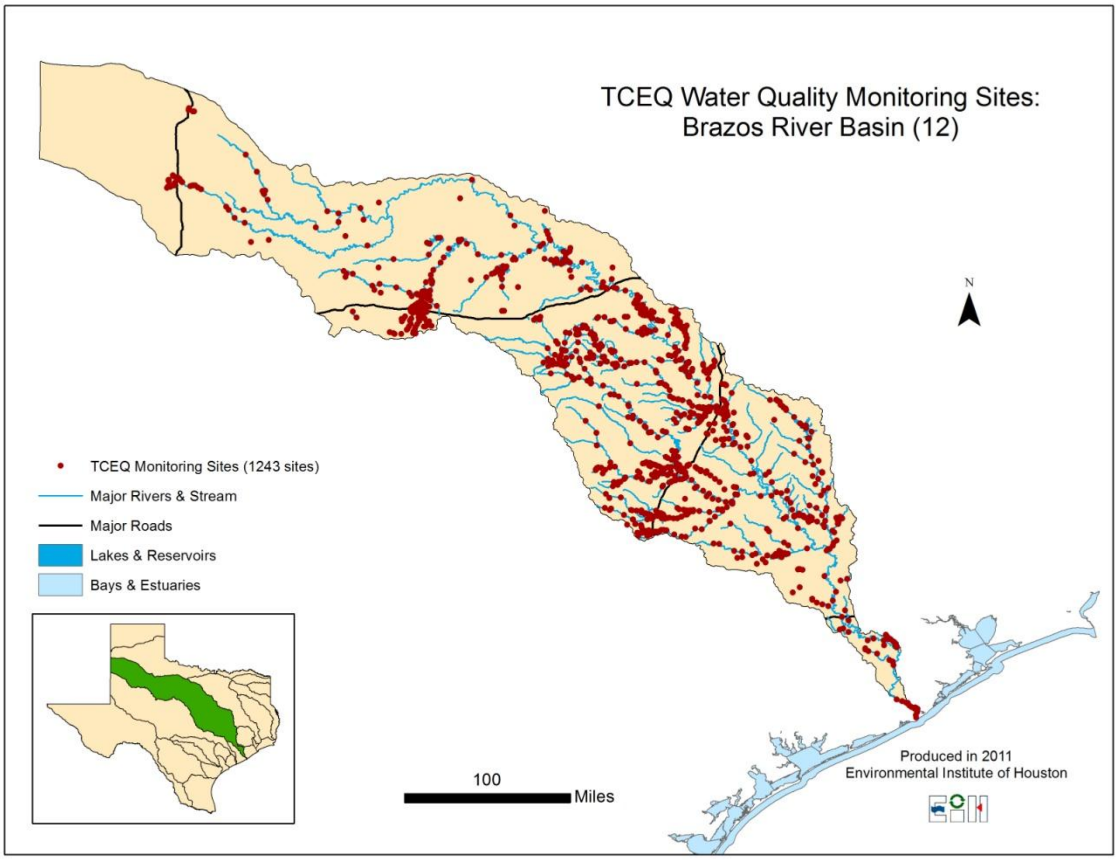

Figure A2. 14. Location of all TCEQ monitoring sites where historical data exists within the Brazos River Basin.

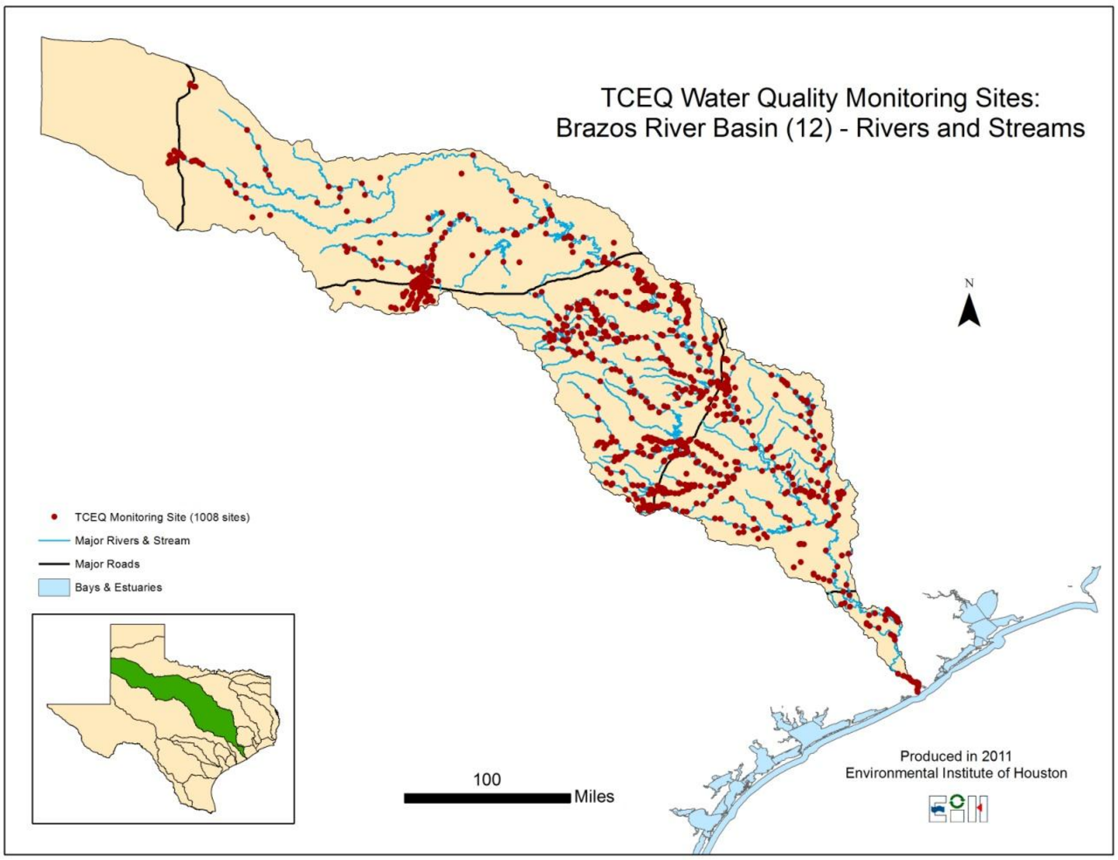

Figure A2. 15. Location of all river and stream TCEQ monitoring sites where historical data exists within the Brazos River Basin.

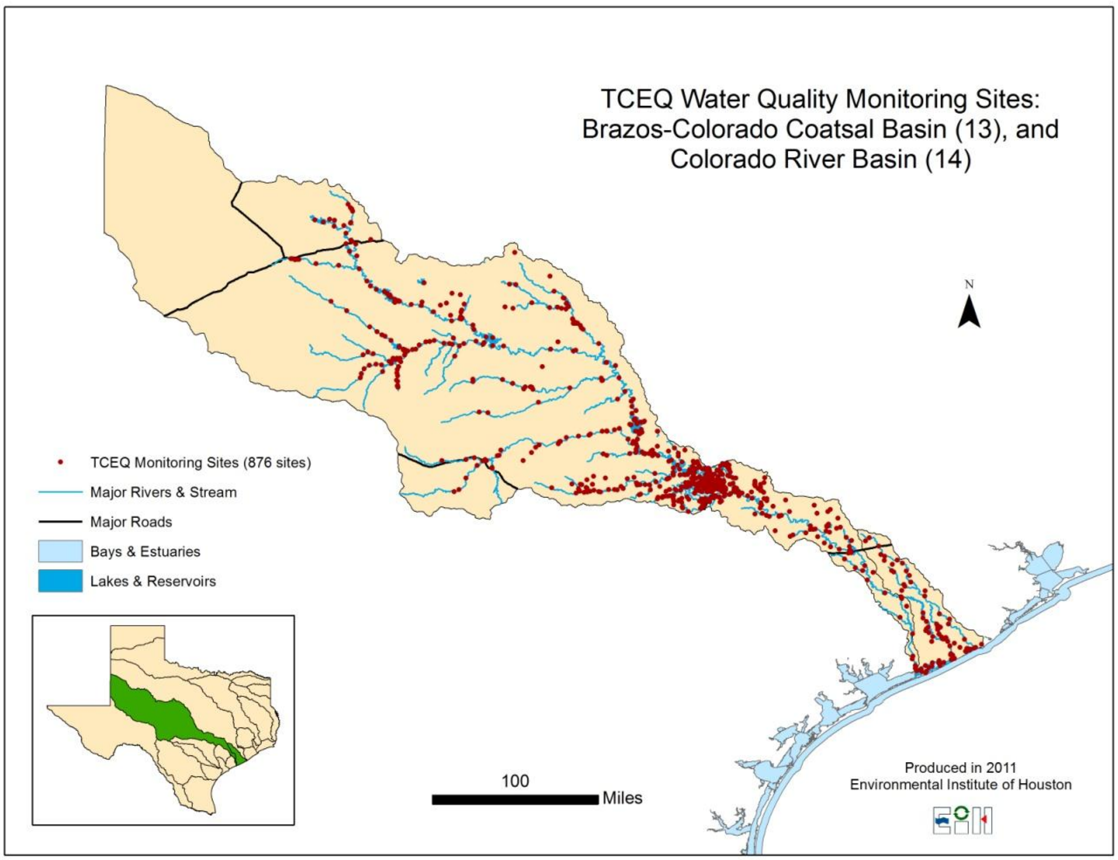

Figure A2. 16. Location of all TCEQ monitoring sites where historical data exists within the Brazos-Colorado Coastal Basin.

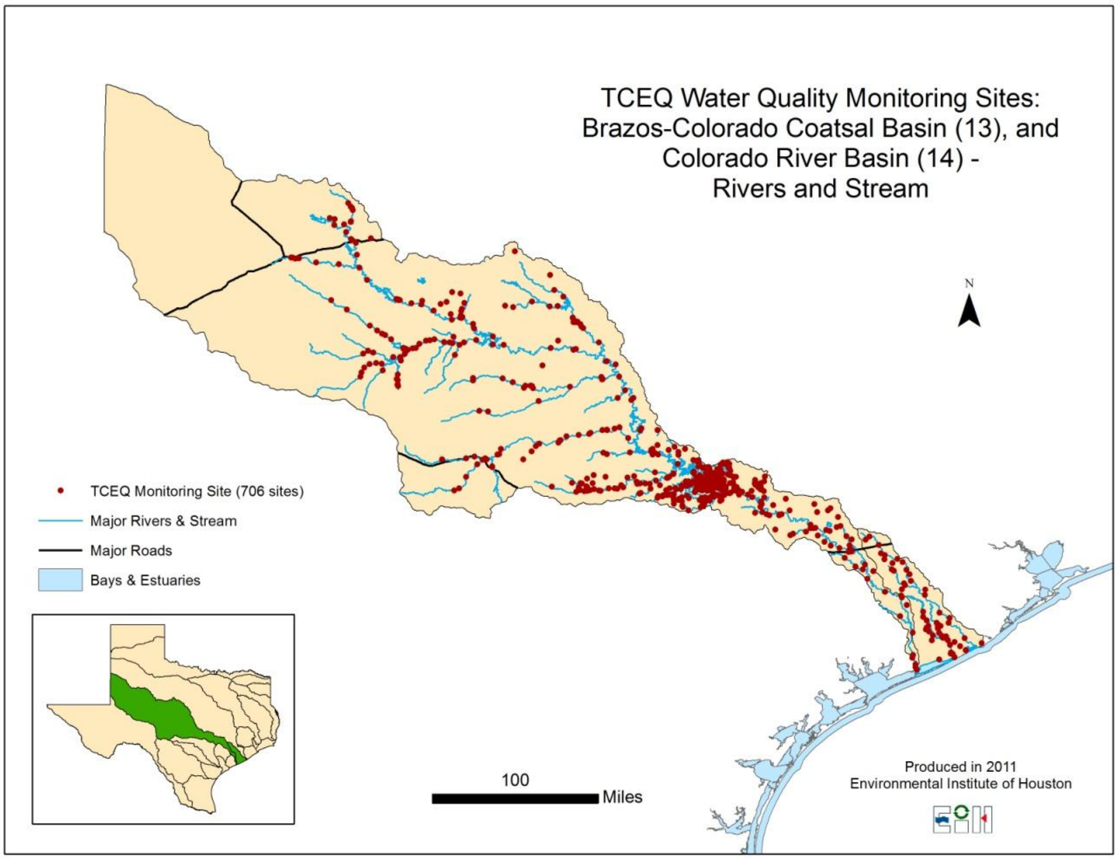

Figure A2. 17. Location of all river and stream TCEQ monitoring sites where historical data exists within the Brazos-Colorado Coastal Basin.

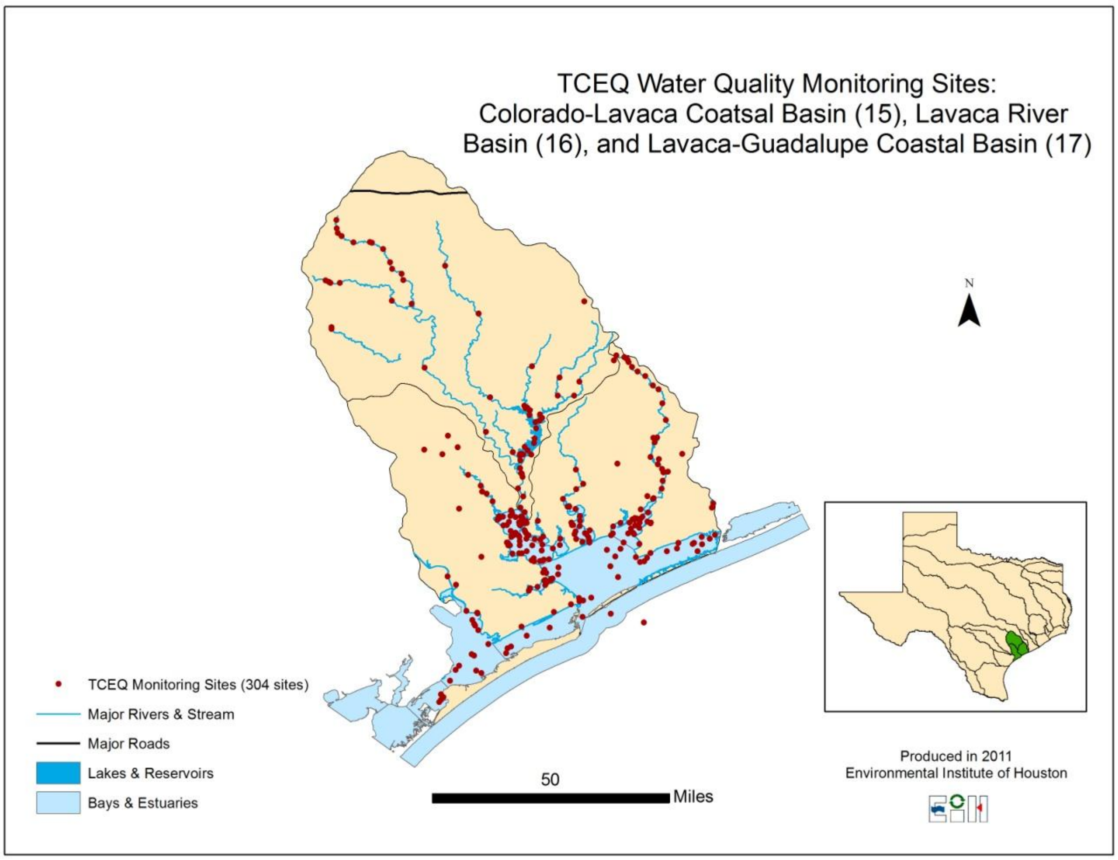

Figure A2. 18. Location of all TCEQ monitoring sites where historical data exists, within the Colorado-Lavaca Coastal, Lavaca River, and Lavaca-Guadalupe Coastal Basins.

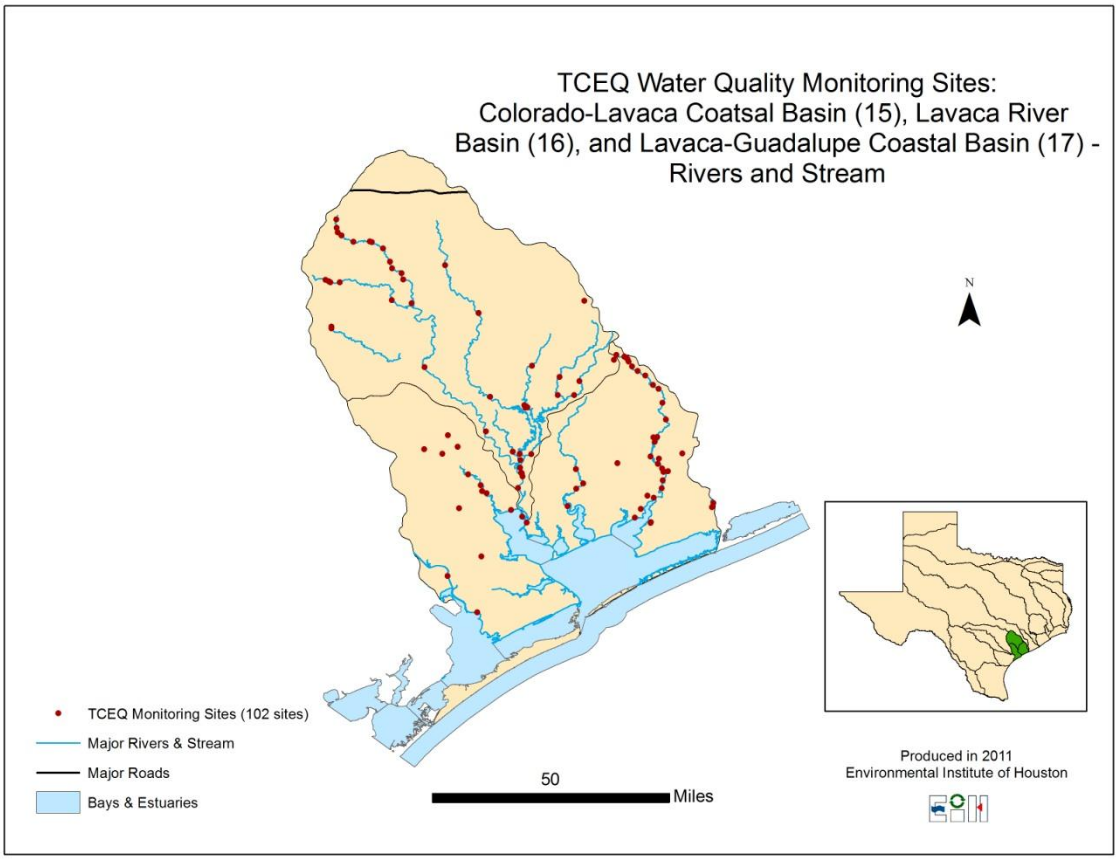

Figure A2. 19. Location of all river and stream TCEQ monitoring sites where historical data exists, within the Colorado-Lavaca Coastal, Lavaca River, and Lavaca-Guadalupe Coastal Basins.

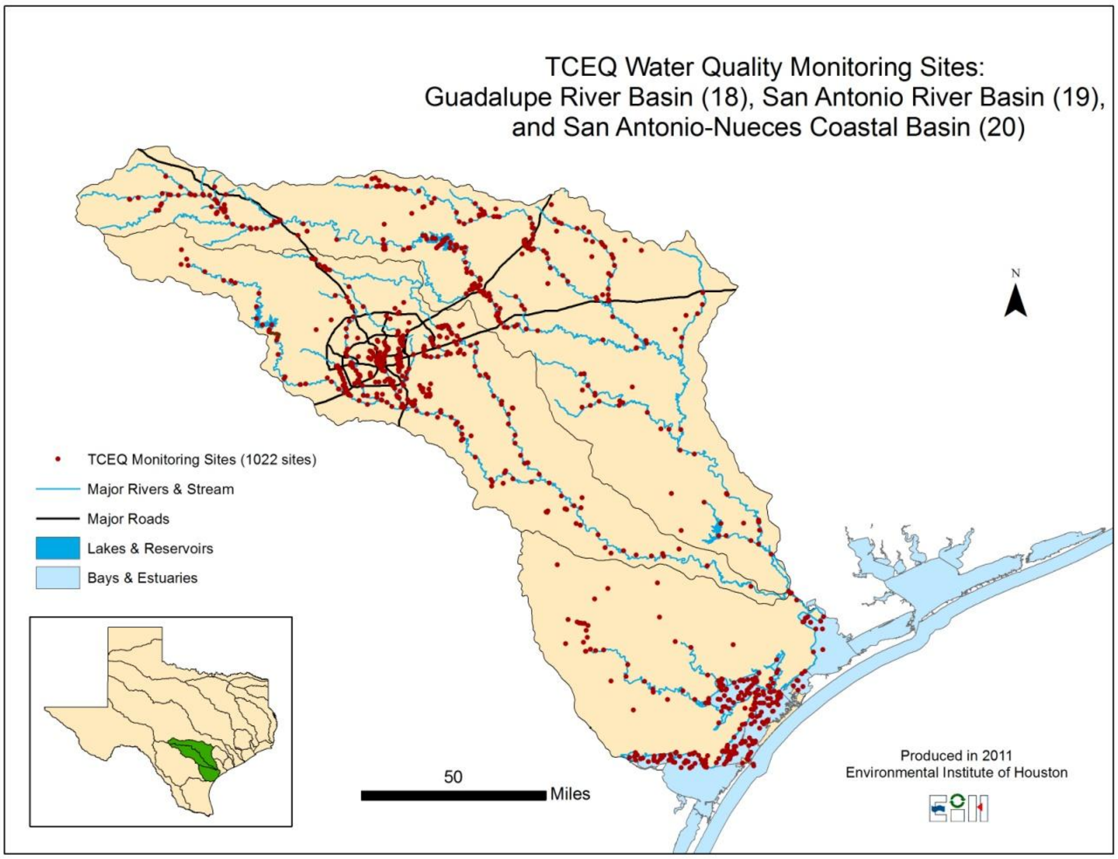

Figure A2. 20. Location of all TCEQ monitoring sites where historical data exists, within the Guadalupe River, San Antonio River, and San Antonio-Nueces Coastal Basins.

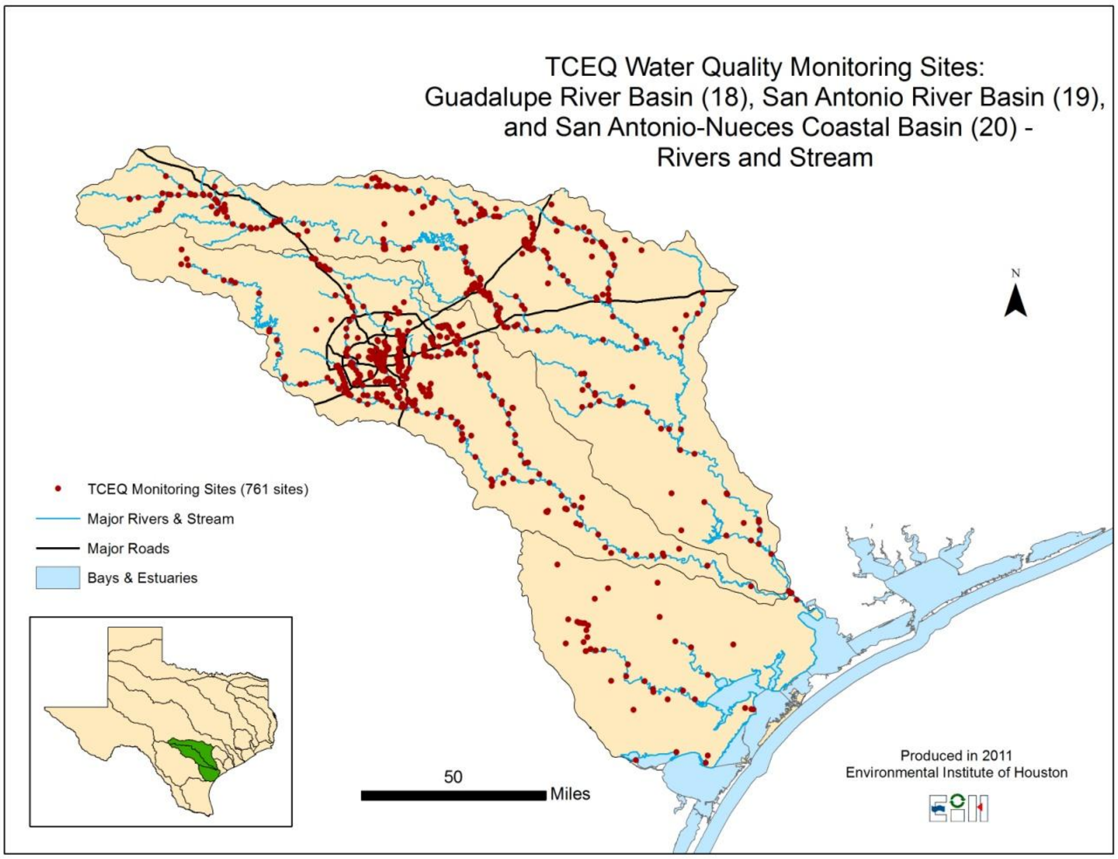

Figure A2. 21. Location of all river and stream TCEQ monitoring sites where historical data exists, within the Guadalupe River, San Antonio River, and San Antonio-Nueces Coastal Basins.

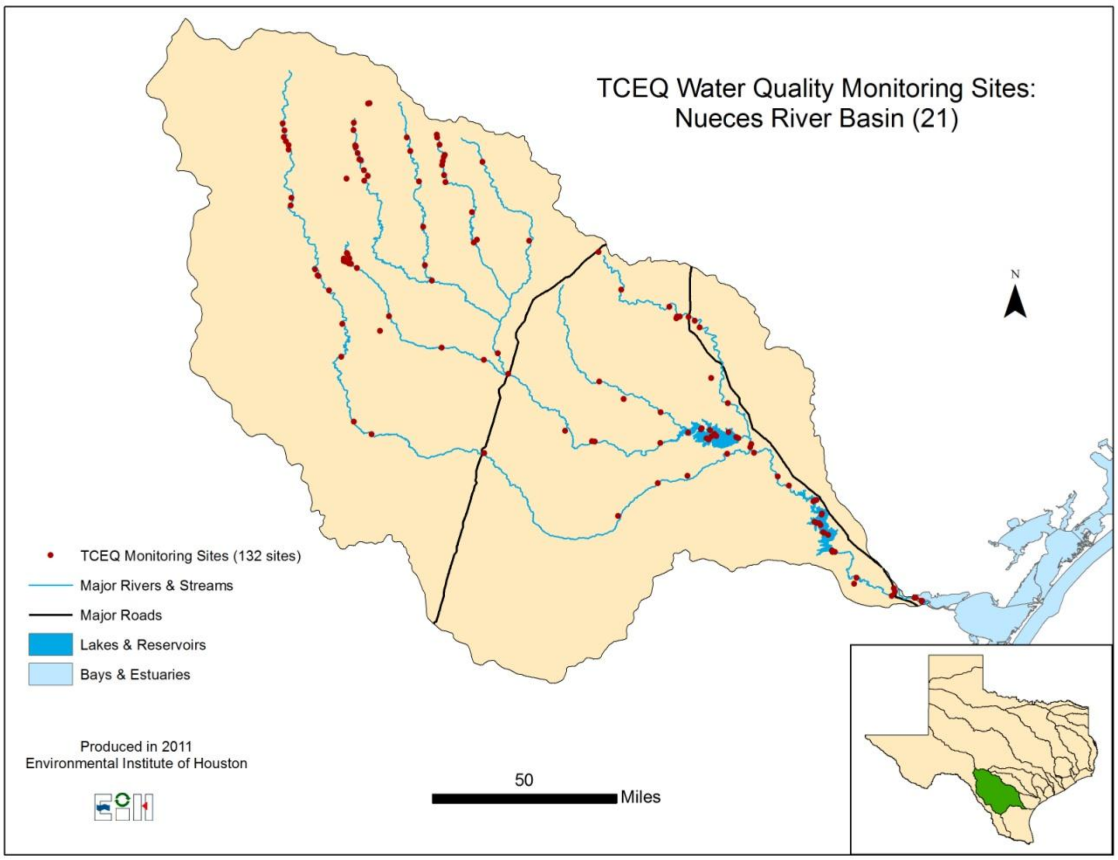

Figure A2. 22. Location of all TCEQ monitoring sites where historical data exists, within the Nueces River Basin.

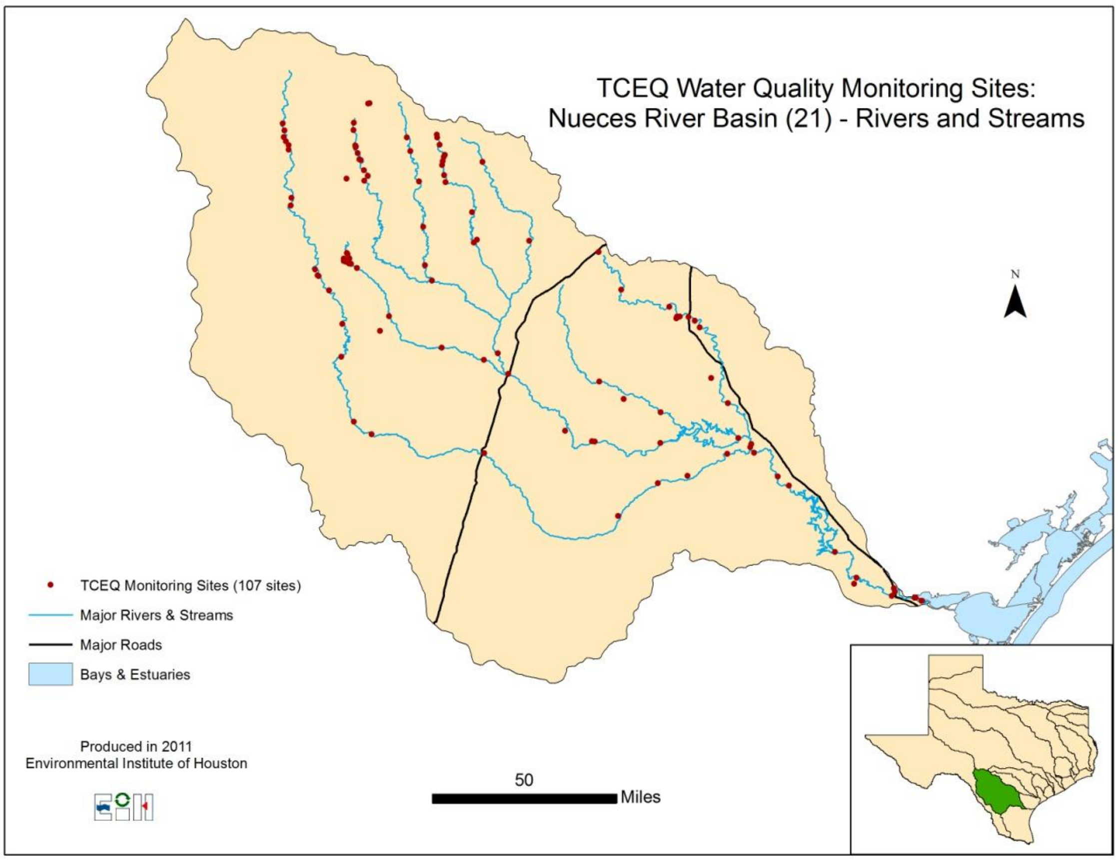

Figure A2. 23. Location of all river and stream TCEQ monitoring sites where historical data exists, within the Nueces River Basin.

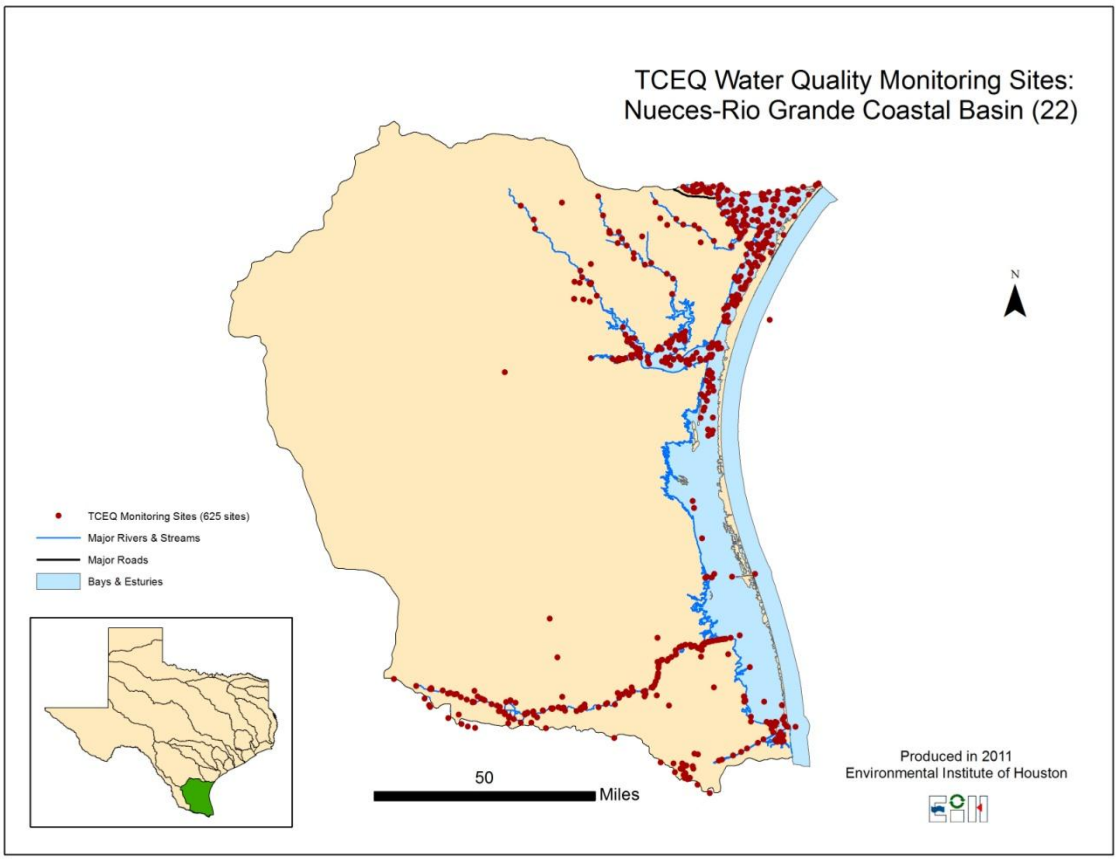

Figure A2. 24. Location of all TCEQ monitoring sites where historical data exists, within the Nueces-Rio Grande Coastal Basin.

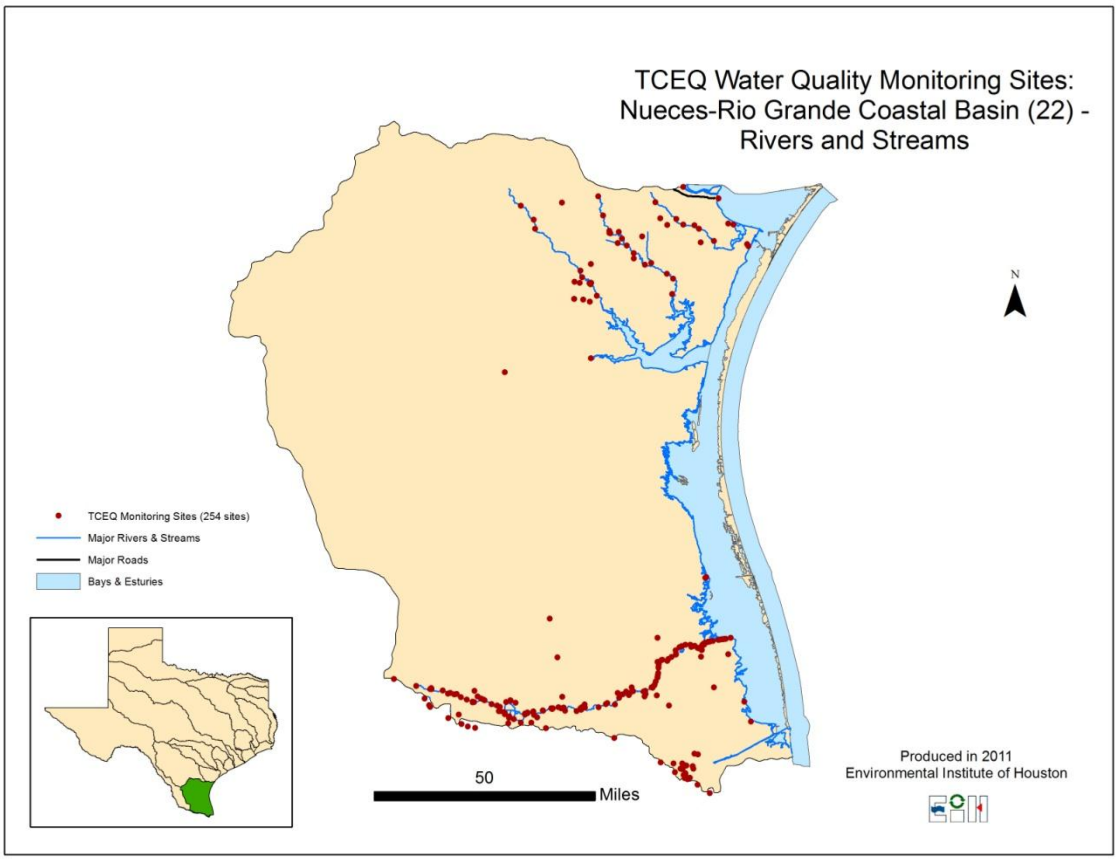

Figure A2. 25. Location of all river and stream TCEQ monitoring sites where historical data exists, within the Nueces-Rio Grande Coastal Basin.

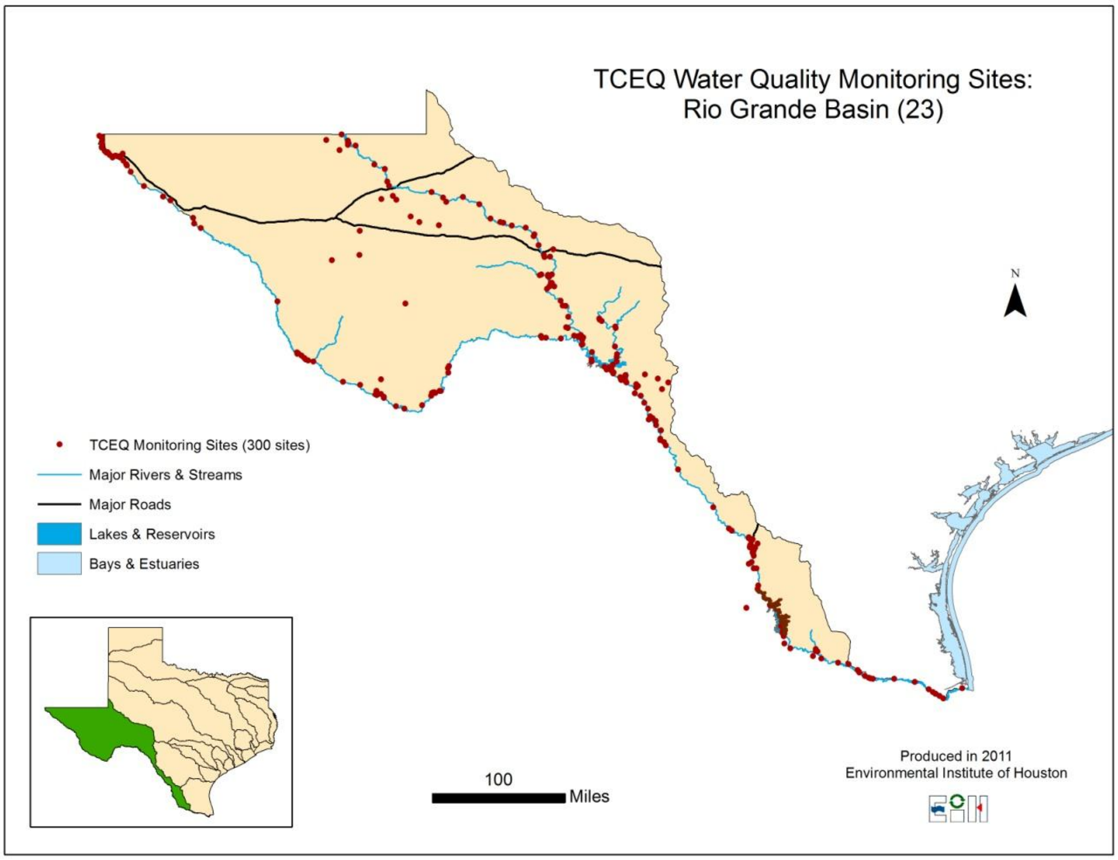

Figure A2. 26. Location of all TCEQ monitoring sites where historical data exists within the Rio Grande River Basin.

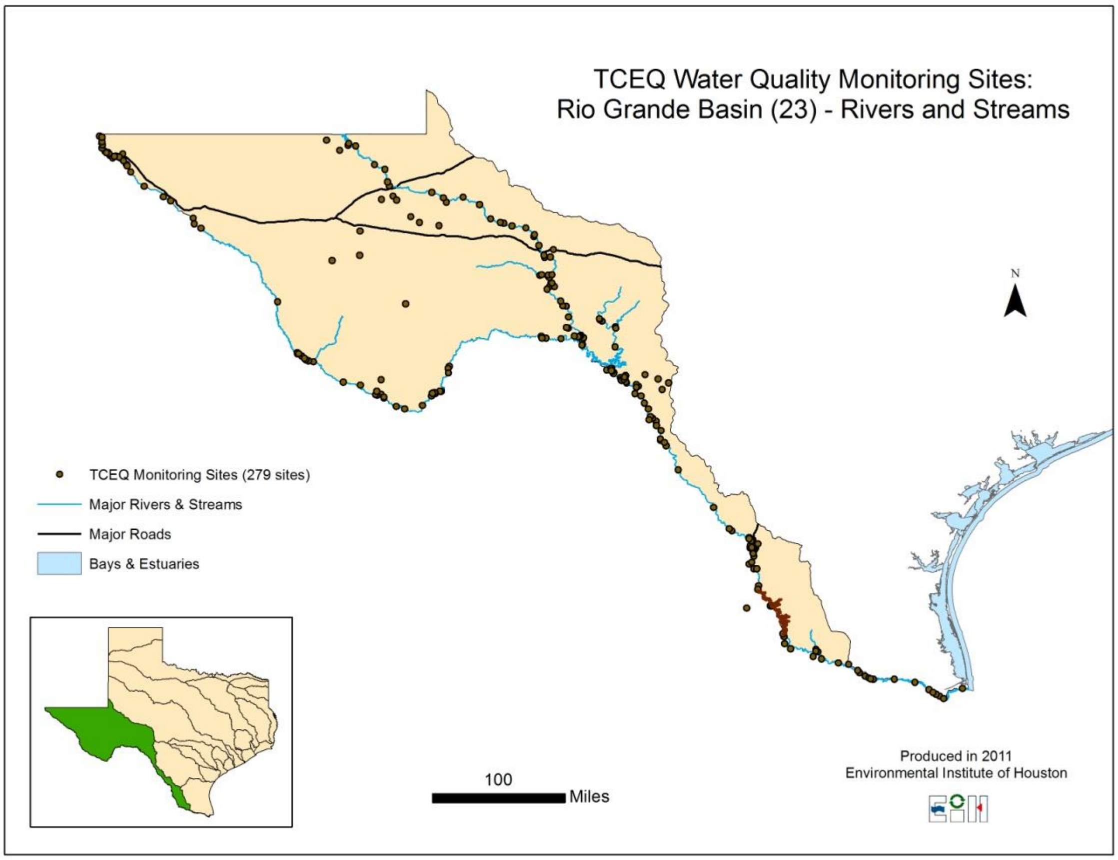

Figure A2. 27. Location of all river and stream TCEQ monitoring sites where historical data exists within the Rio Grande River Basin.

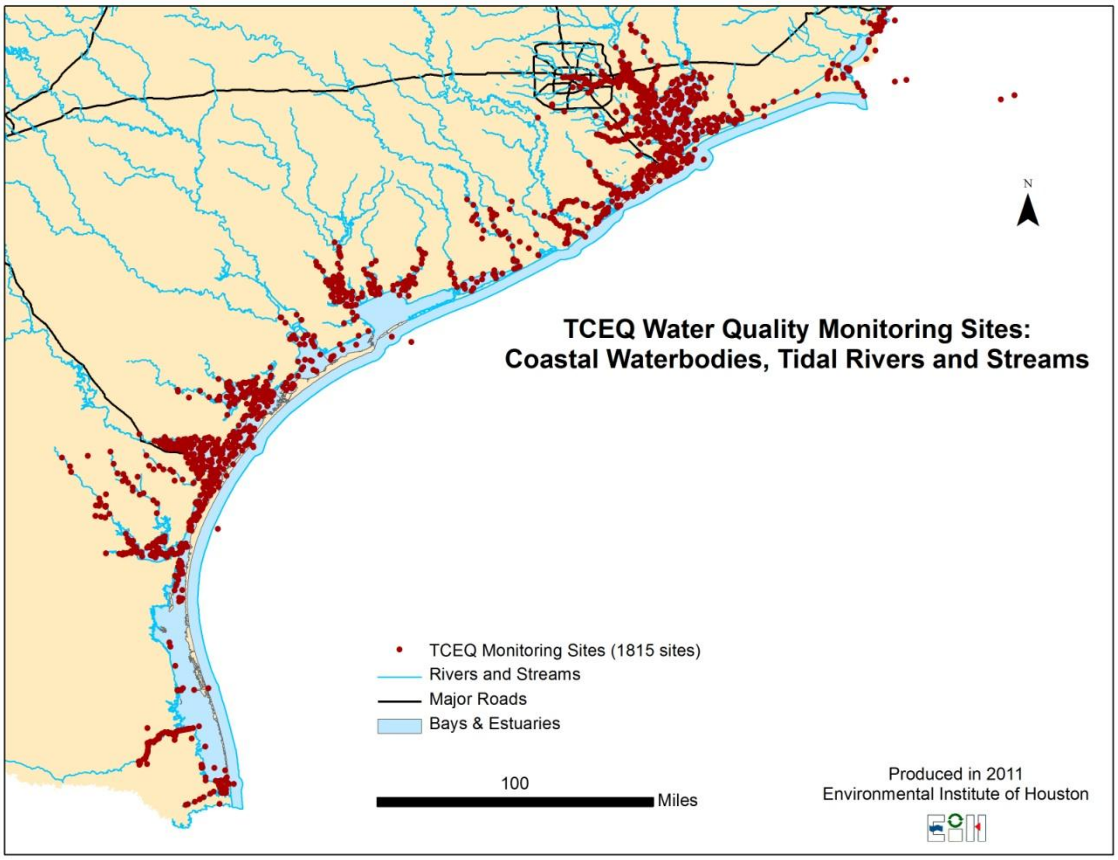

Figure A2. 28. Location of all TCEQ monitoring sites where historical data exists within coastal waterbodies including TCEQ designated estuaries and tidal streams.

Appendix 3. Tables and Maps of Historical USGS Stream Gages, Water Quality Monitoring and NAWQA Sites

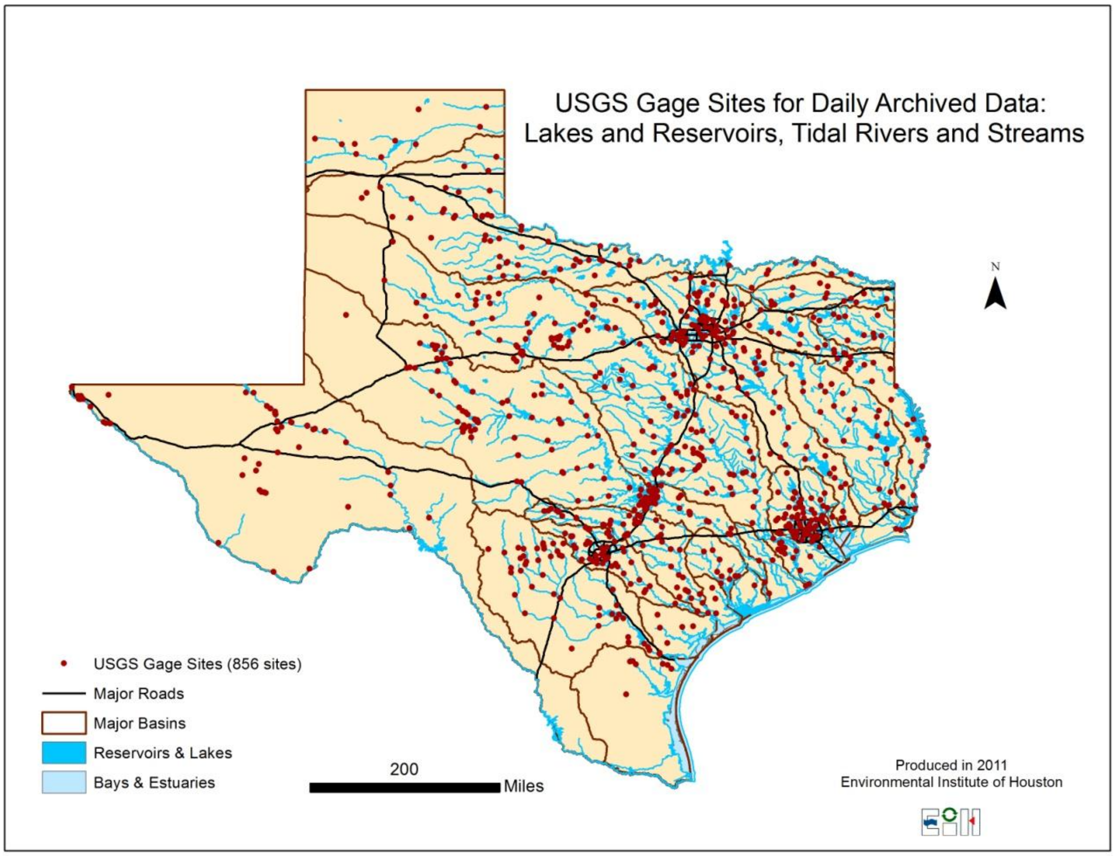

Figure A3. 1. Location of USGS gages containing archived daily streamflow and/or gage height data within Texas. A total 820 sites were identified (3 lakes, 1 estuarine, 817 streams, rivers, canals) that contained at least one observation of either variable.

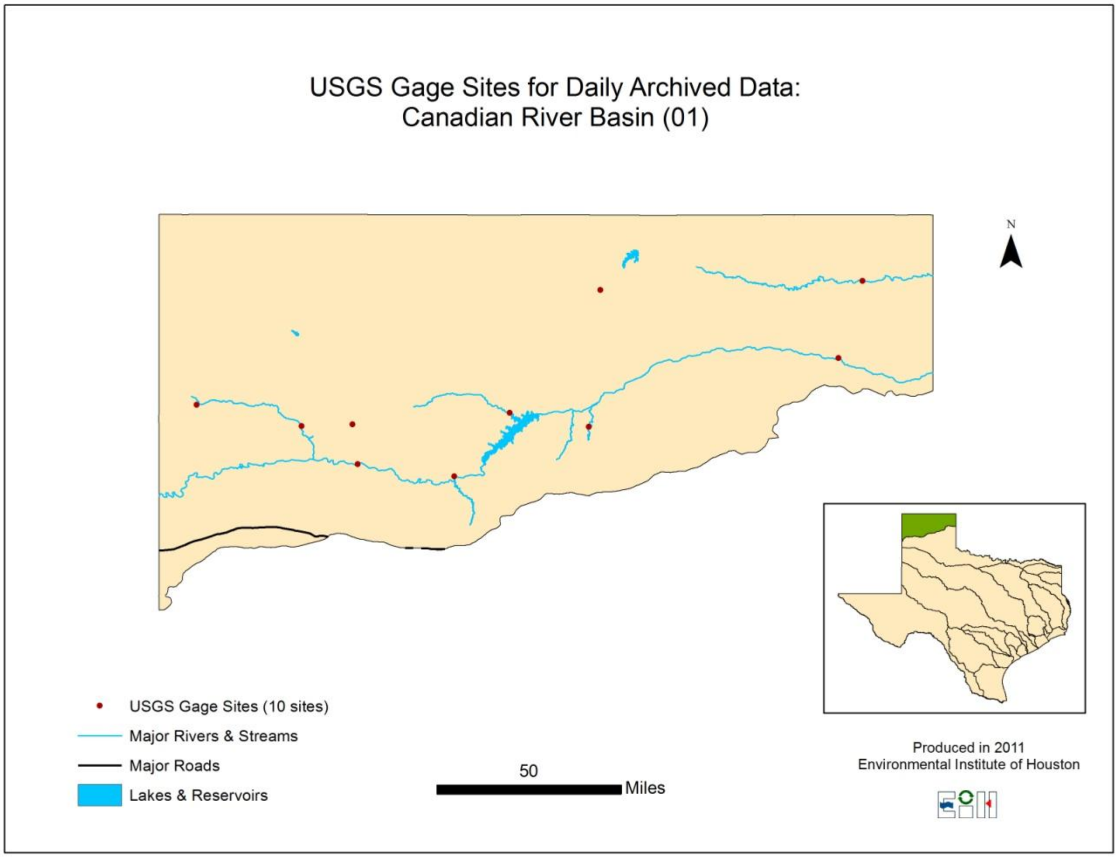

Figure A3. 2. Location of USGS gages containing archived daily data in the Canadian River Basin.

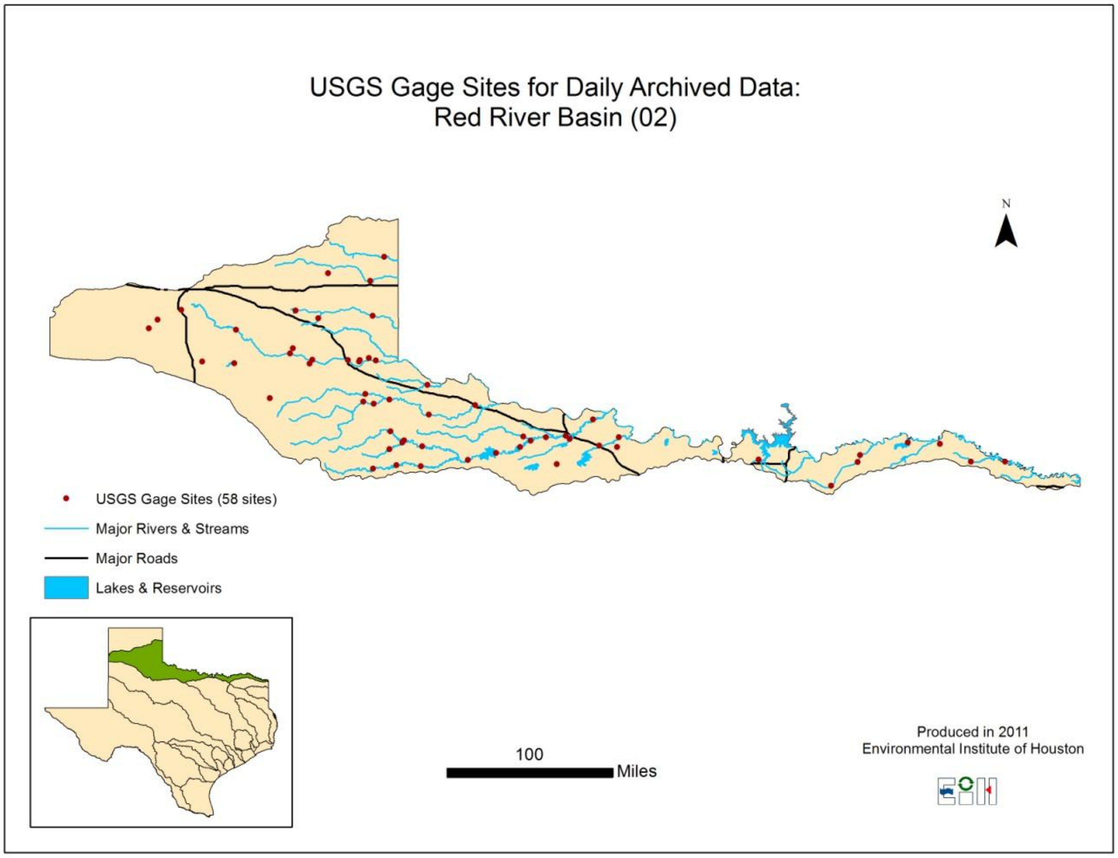

Figure A3. 3. Location of USGS gages containing archived daily data in the Red River Basin.

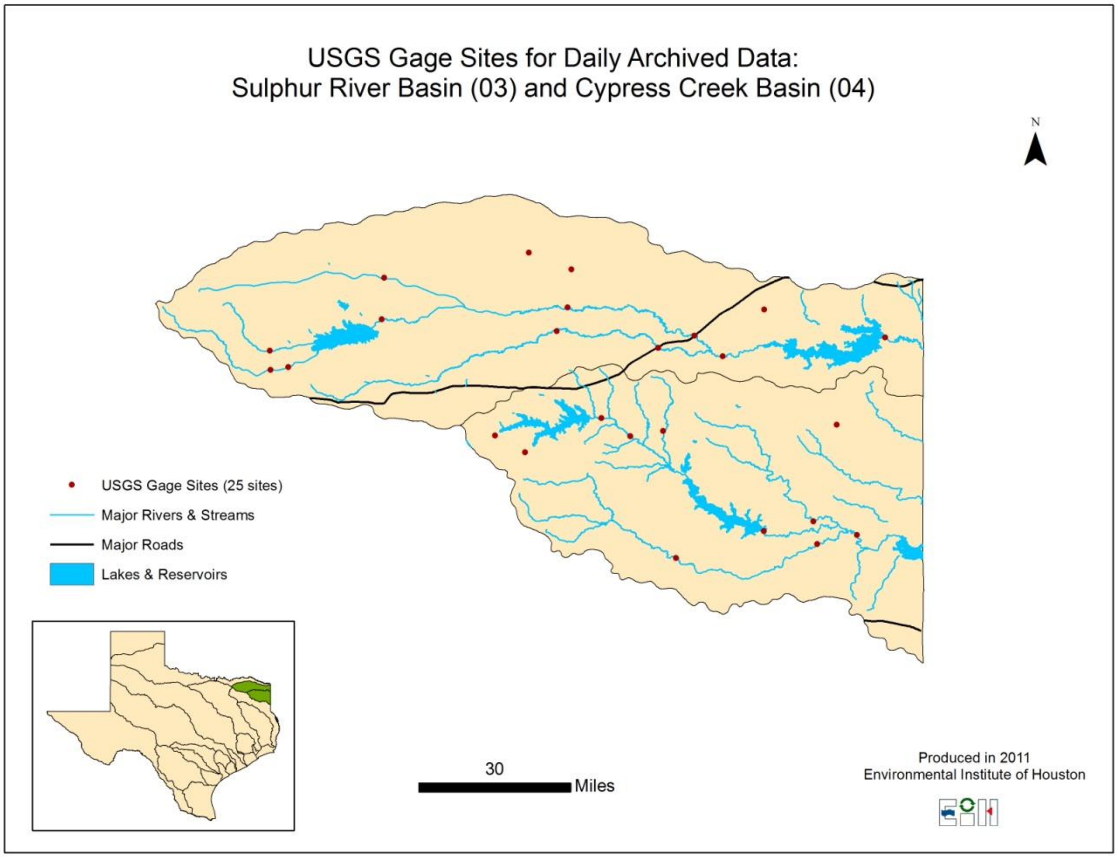

Figure A3. 4. Location of USGS gages containing archived daily data in the Sulfur River and Cypress Creek Basins.

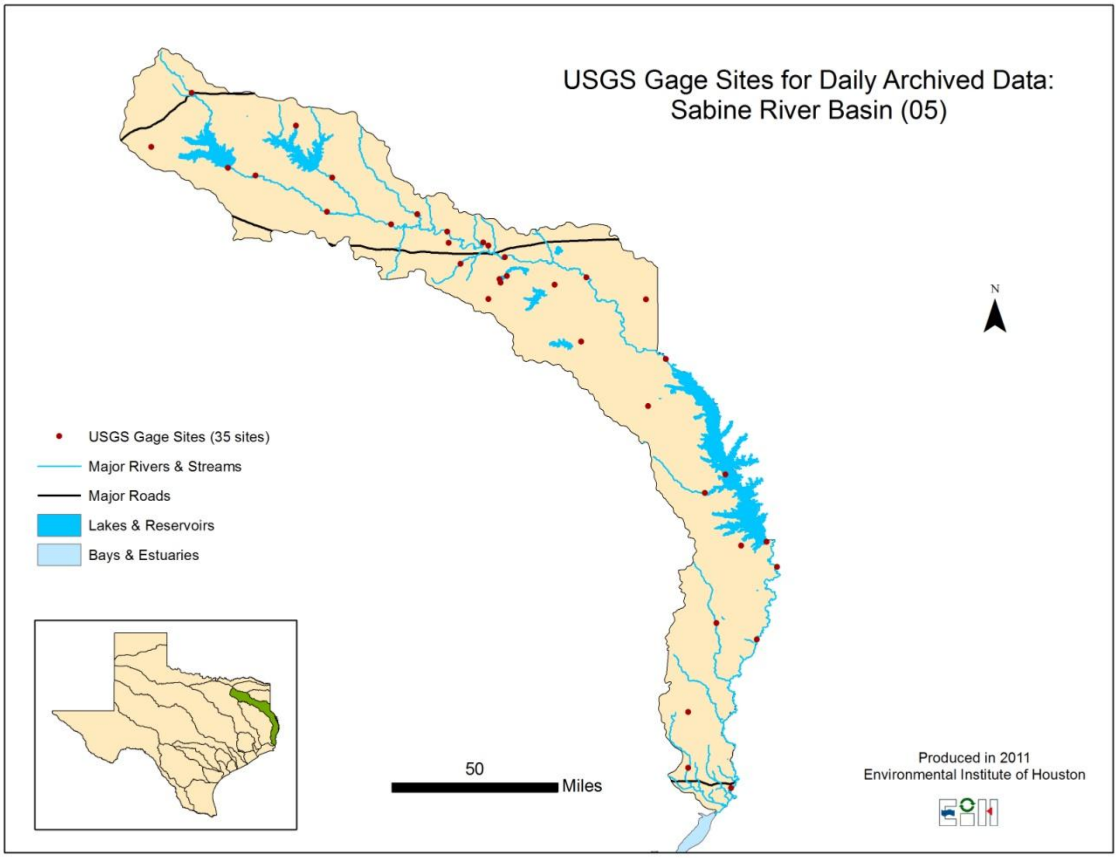

Figure A3. 5. Location of USGS gages containing archived daily data in the Sabine River Basin.

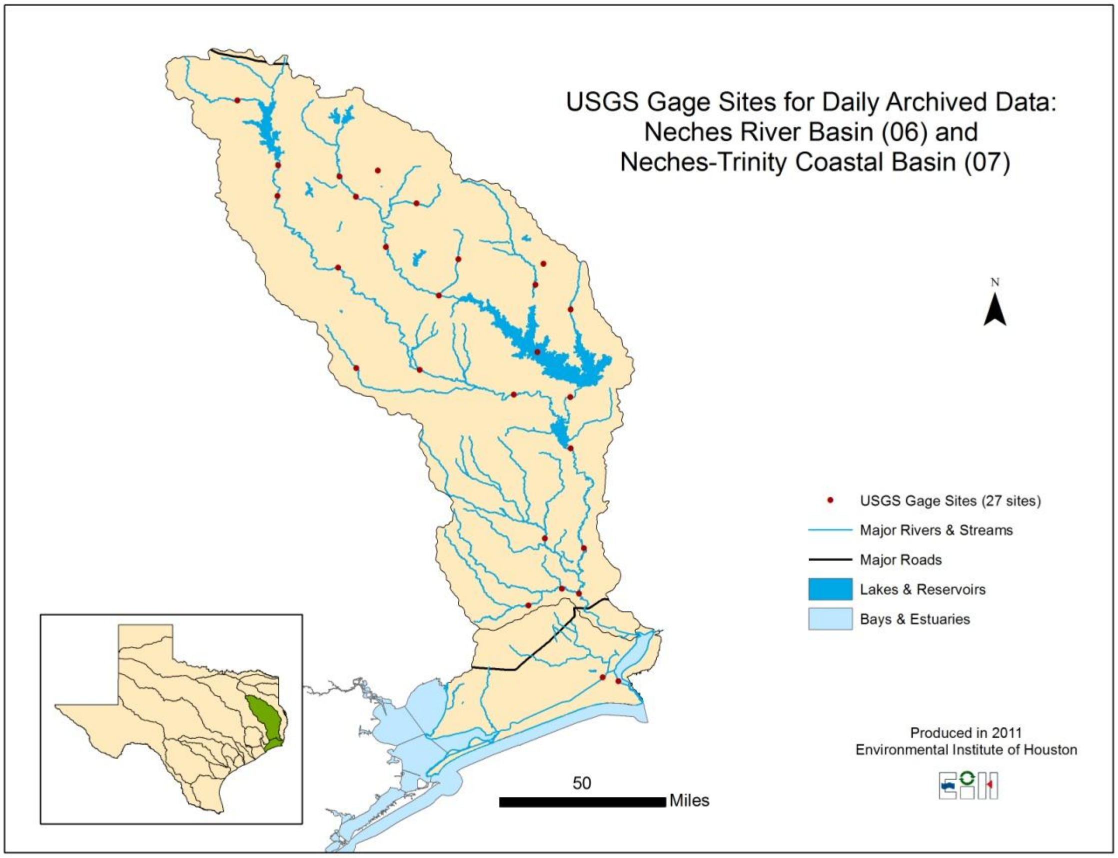

Figure A3. 6. Location of USGS gages containing archived daily data in the Neches River and Neches-Trinity Coastal Basins.

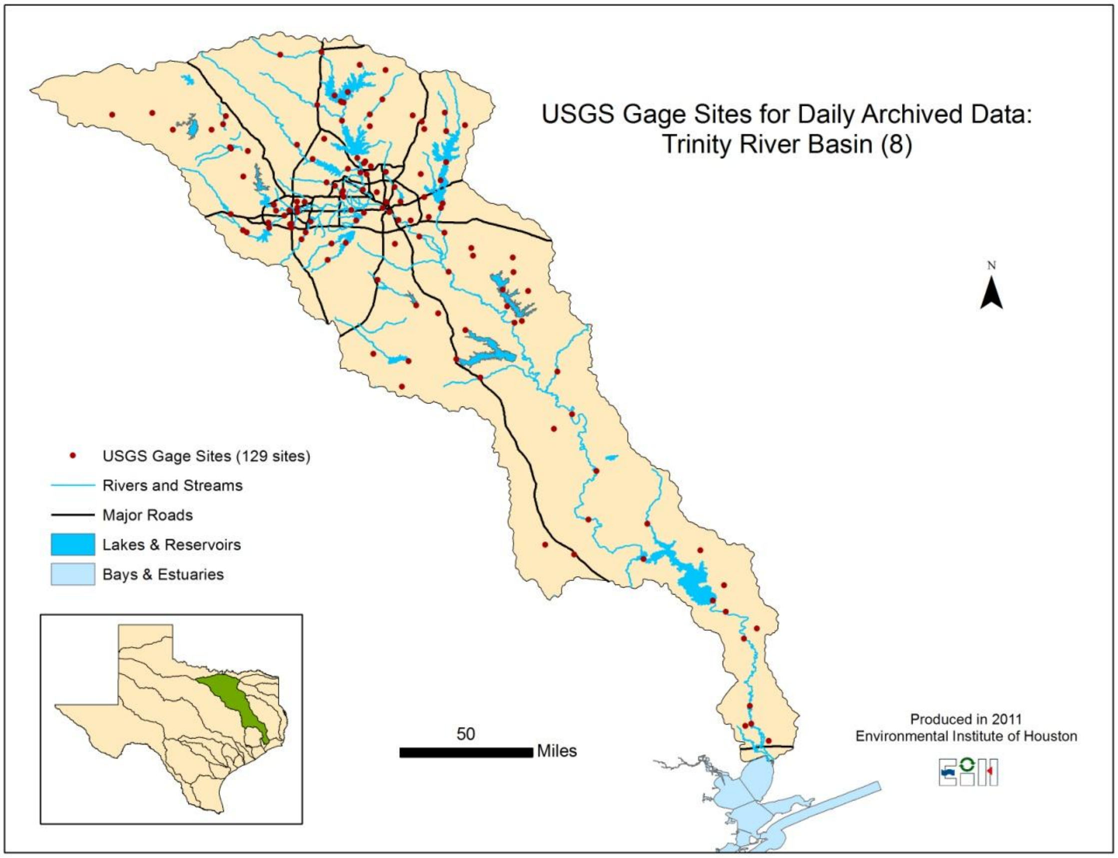

Figure A3. 7. Location of USGS gages containing archived daily data in the Trinity River Basin.

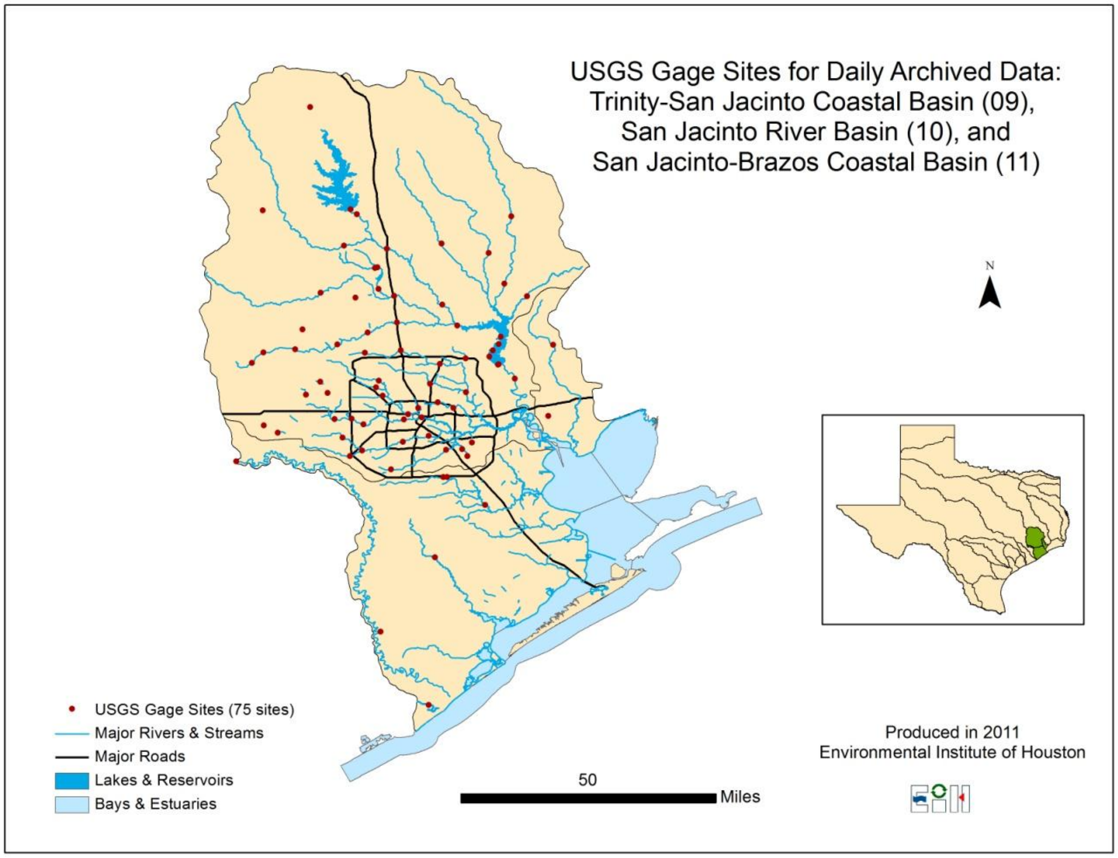

Figure A3. 8. Location of USGS gages containing archived daily data in the Trinity-San Jacinto Coastal, San Jacinto, and the San Jacinto-Brazos River Basins.

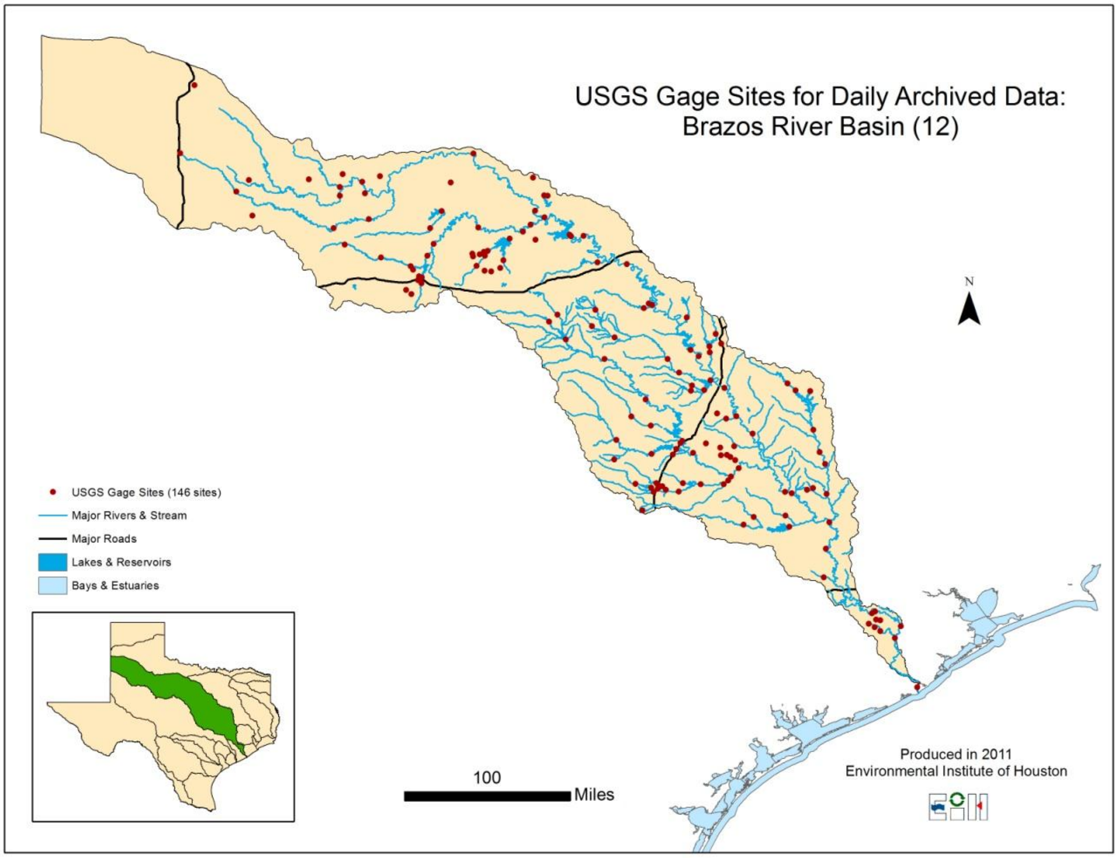

Figure A3. 9. Location of USGS gages containing archived daily data in the Brazos River Basin.

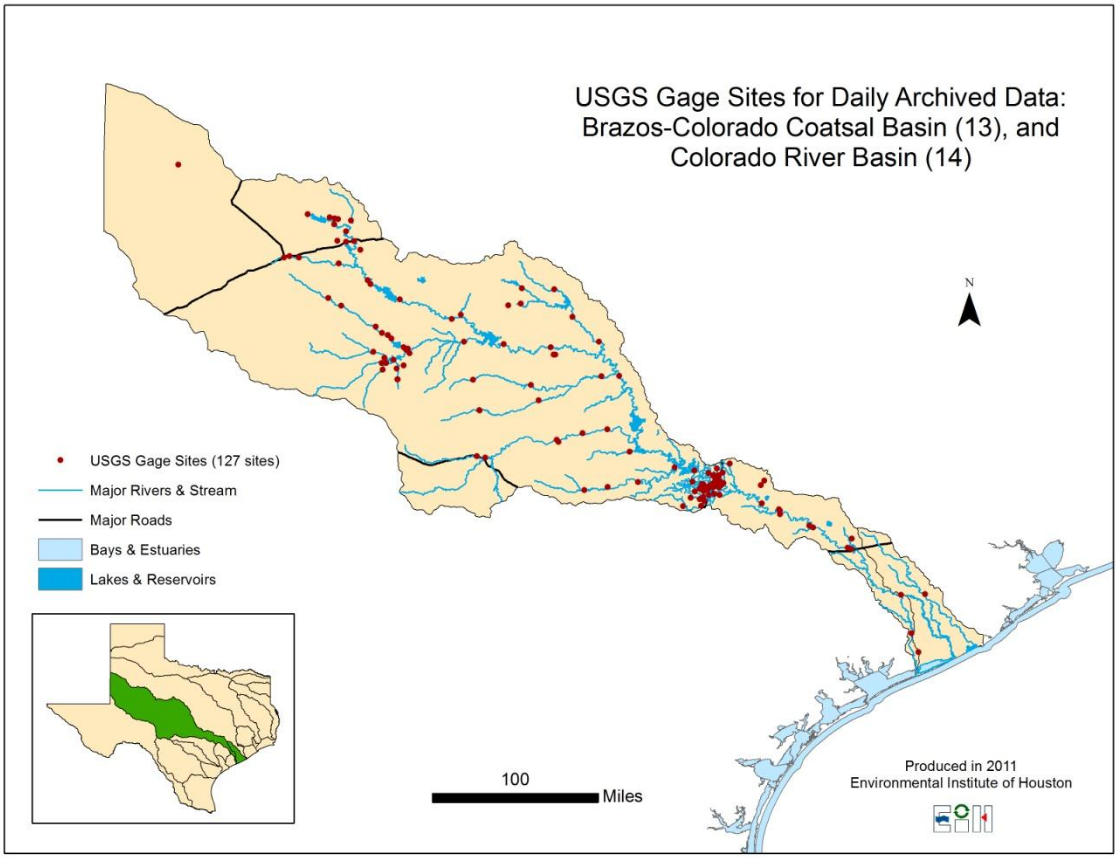

Figure A3. 10. Location of USGS gages containing archived daily data in the Brazos-Colorado Coastal and Colorado River Basins.

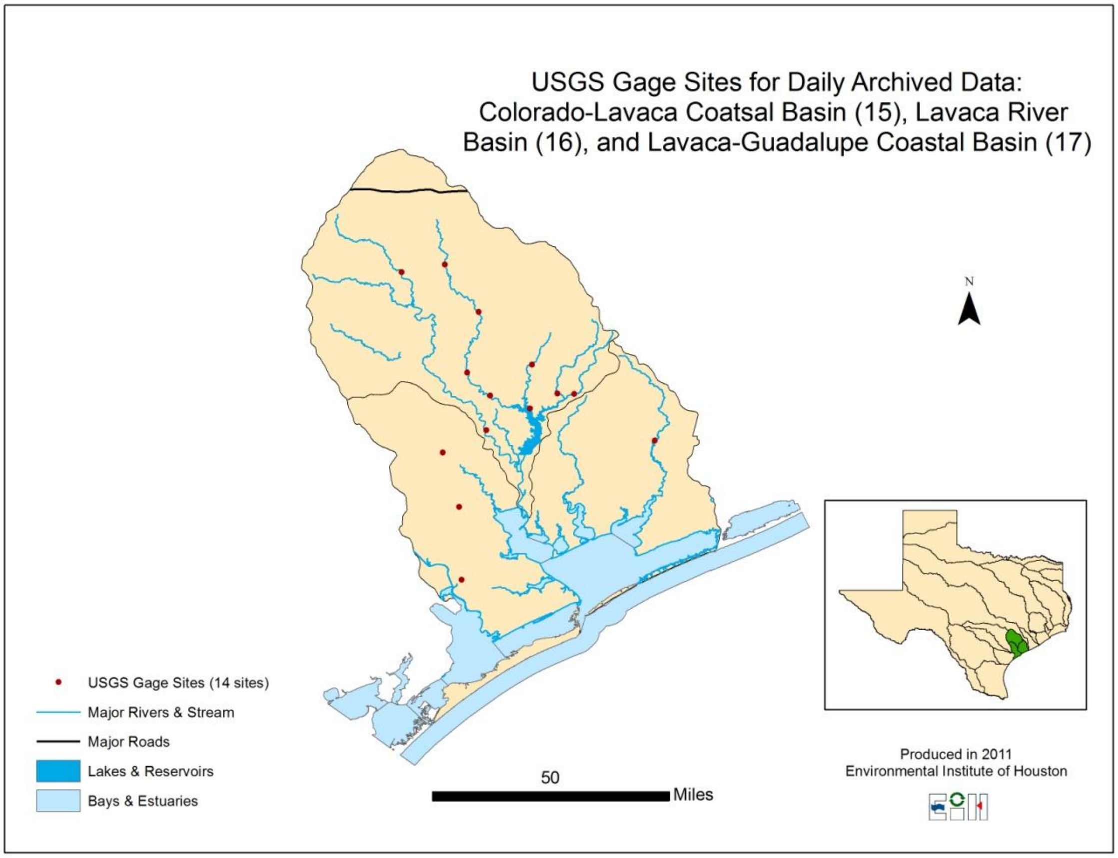

Figure A3. 11. Location of USGS gages containing archived daily data in the Colorado-Lavaca Coastal, Lavaca River and Lavaca-Guadalupe Coastal River Basins.

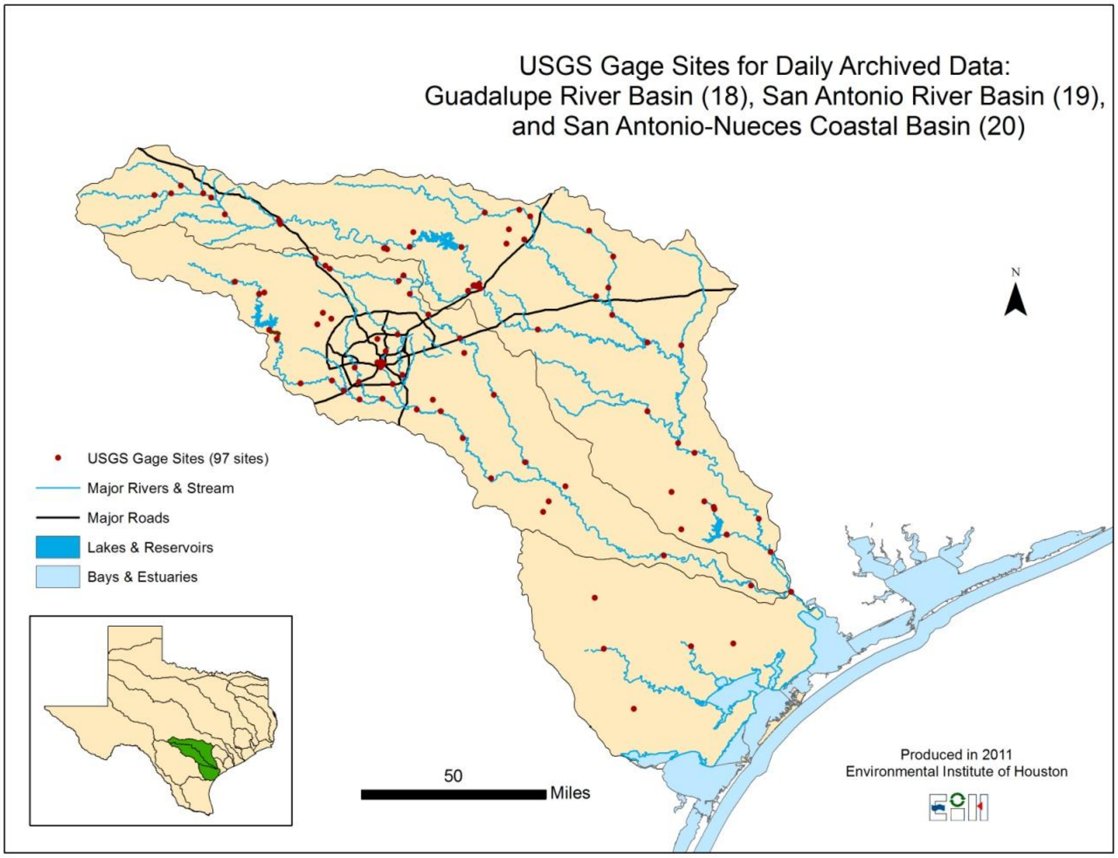

Figure A3. 12. Location of USGS gages containing archived daily data in the Guadalupe River, San Antonio River, and San Antonio-Nueces Coastal River Basins.

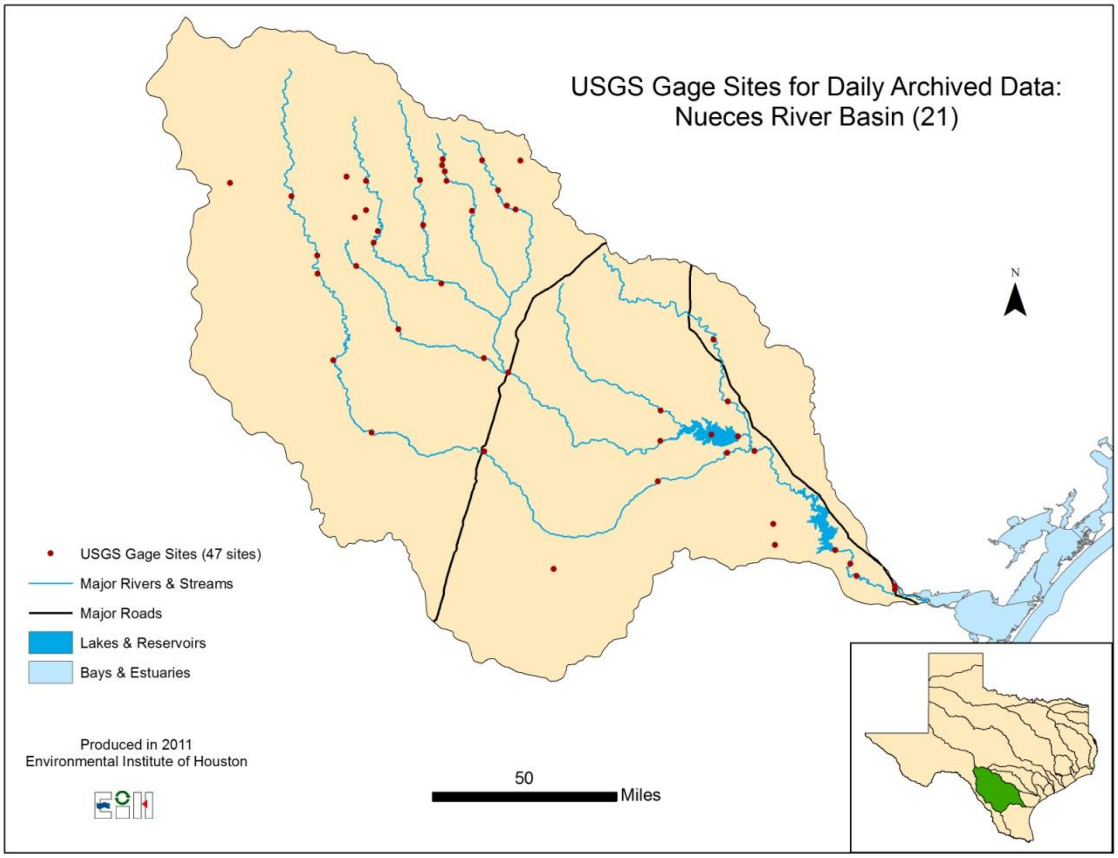

Figure A3. 13. Location of USGS gages containing archived daily data in the Nueces River Basin.

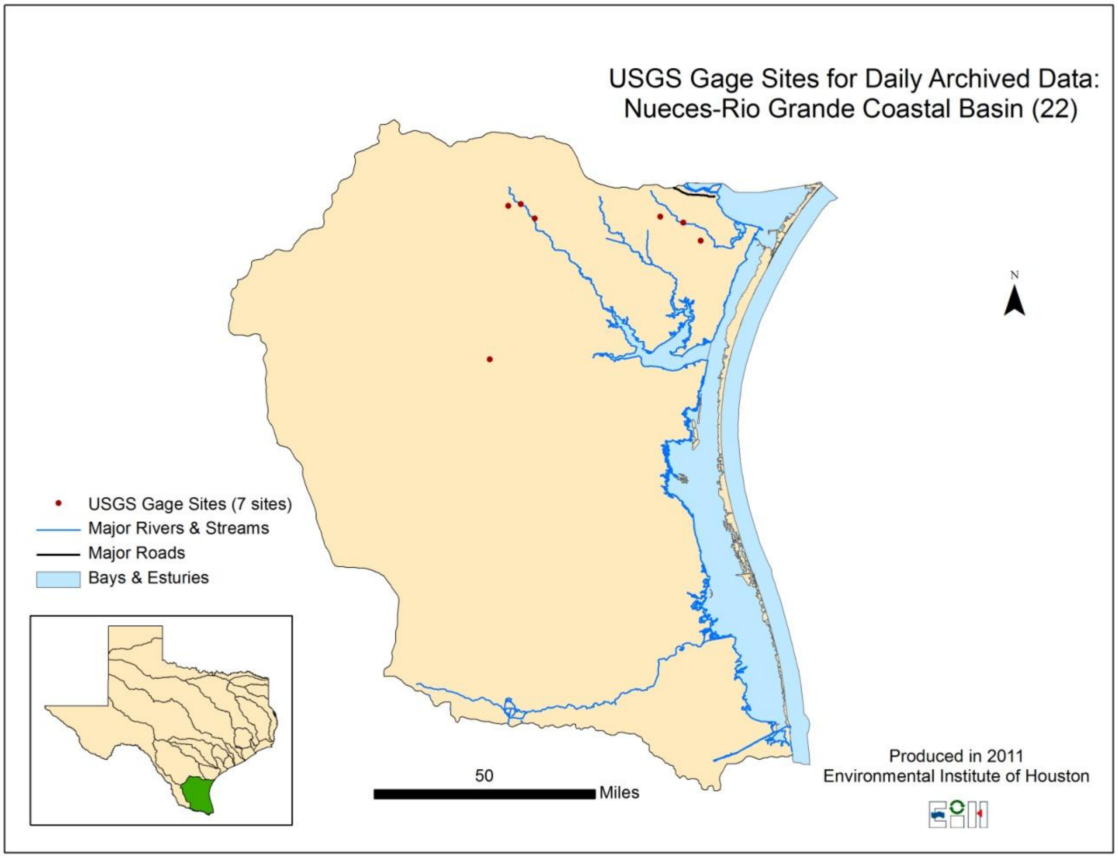

Figure A3. 14. Location of USGS gages containing archived daily data in the Nueces-Rio Grande Coastal Basins.

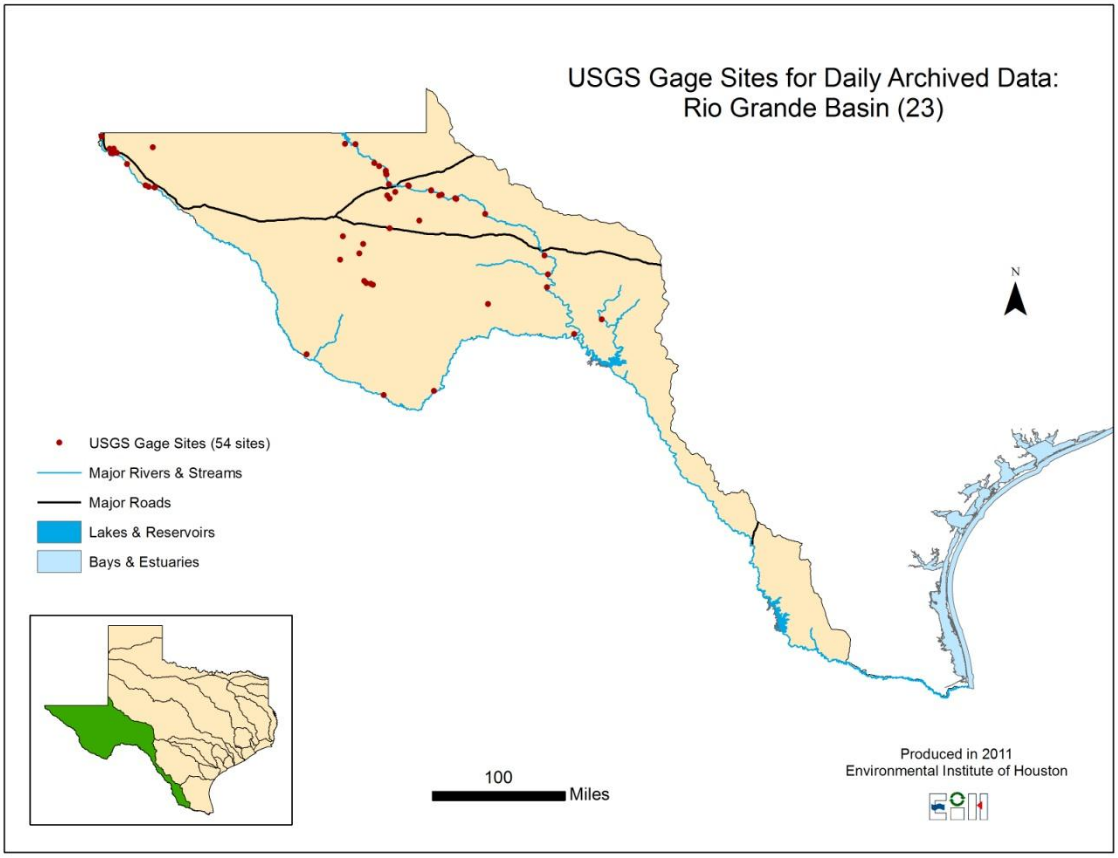

Figure A3. 15. Location of USGS gages containing archived daily data in the Rio Grande River Basin.

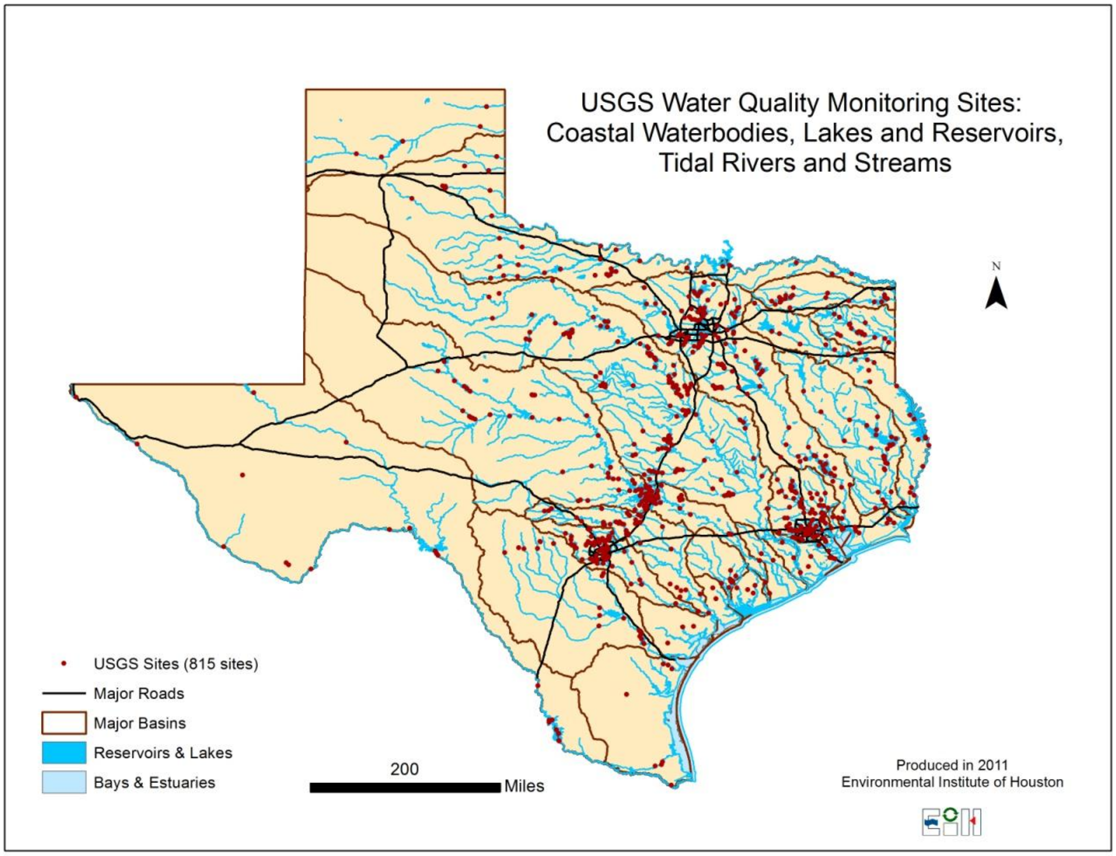

Figure A3. 16. Location of the 815 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in lakes, rivers, streams and estuaries within Texas.

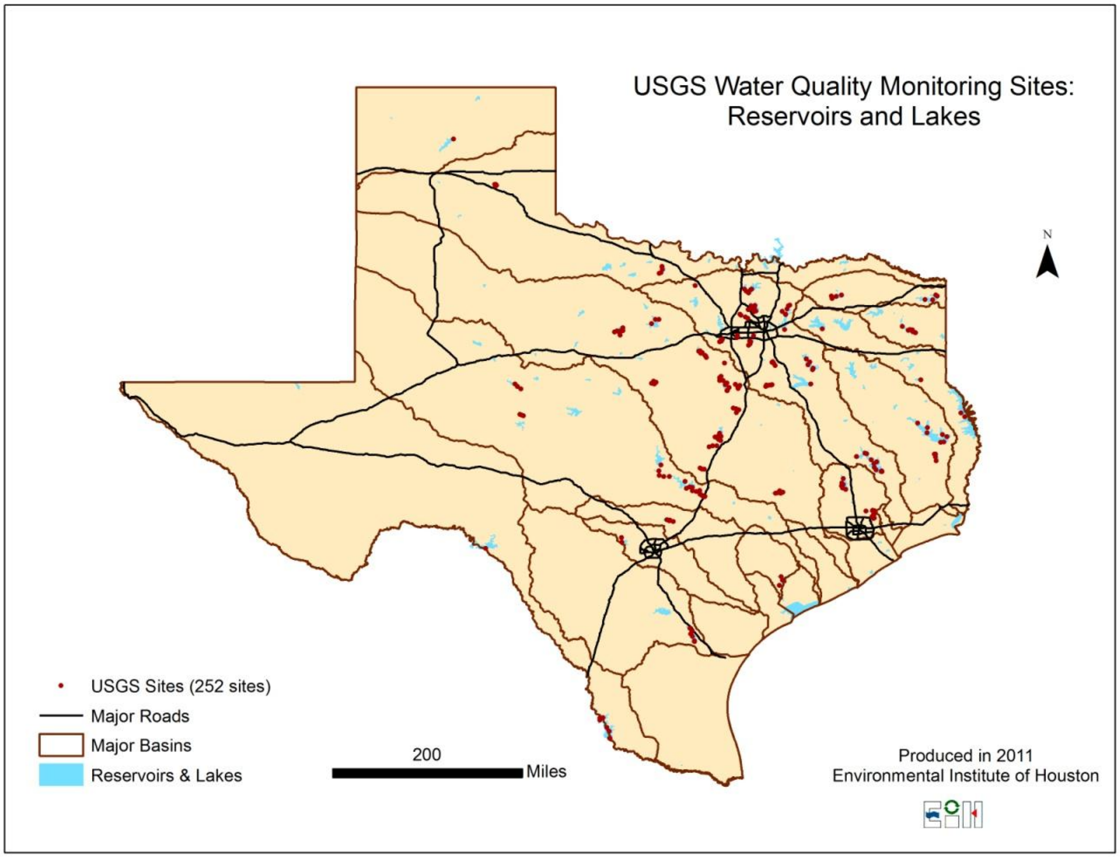

Figure A3. 17. Location of the 252 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in lakes within Texas.

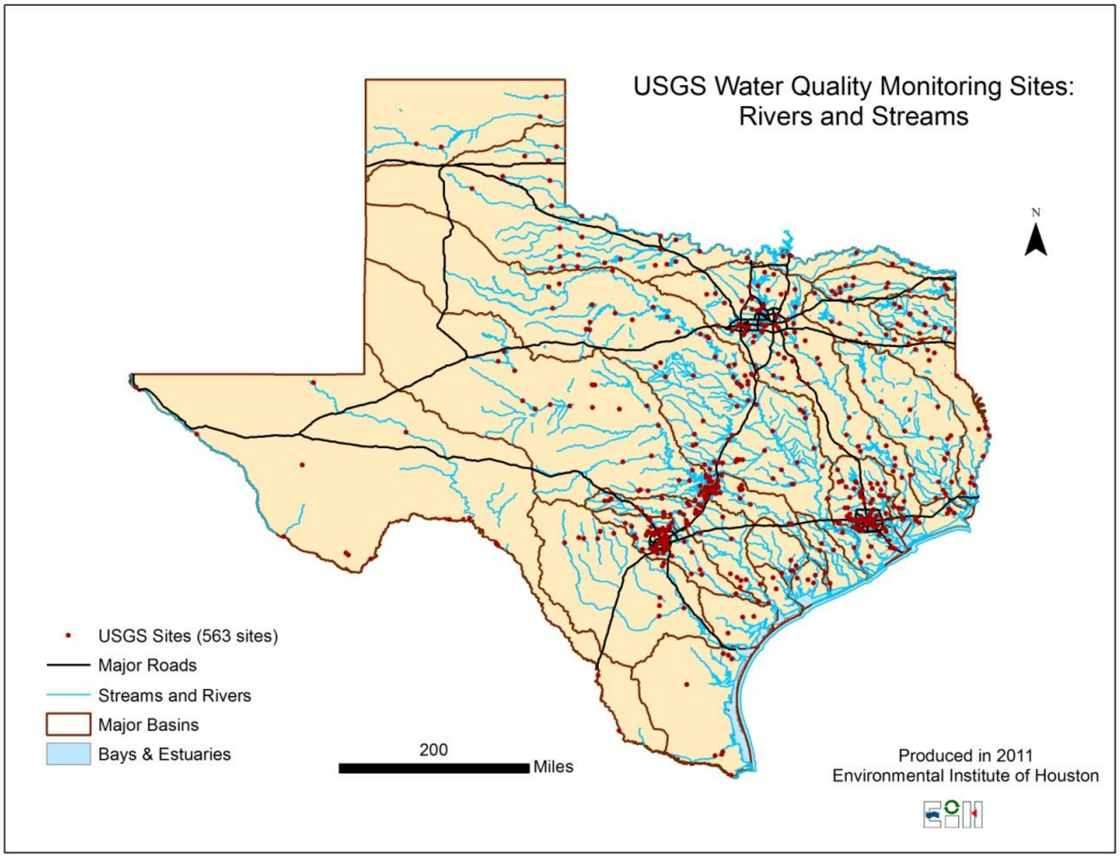

Figure A3. 18. Location of the 563 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within Texas.

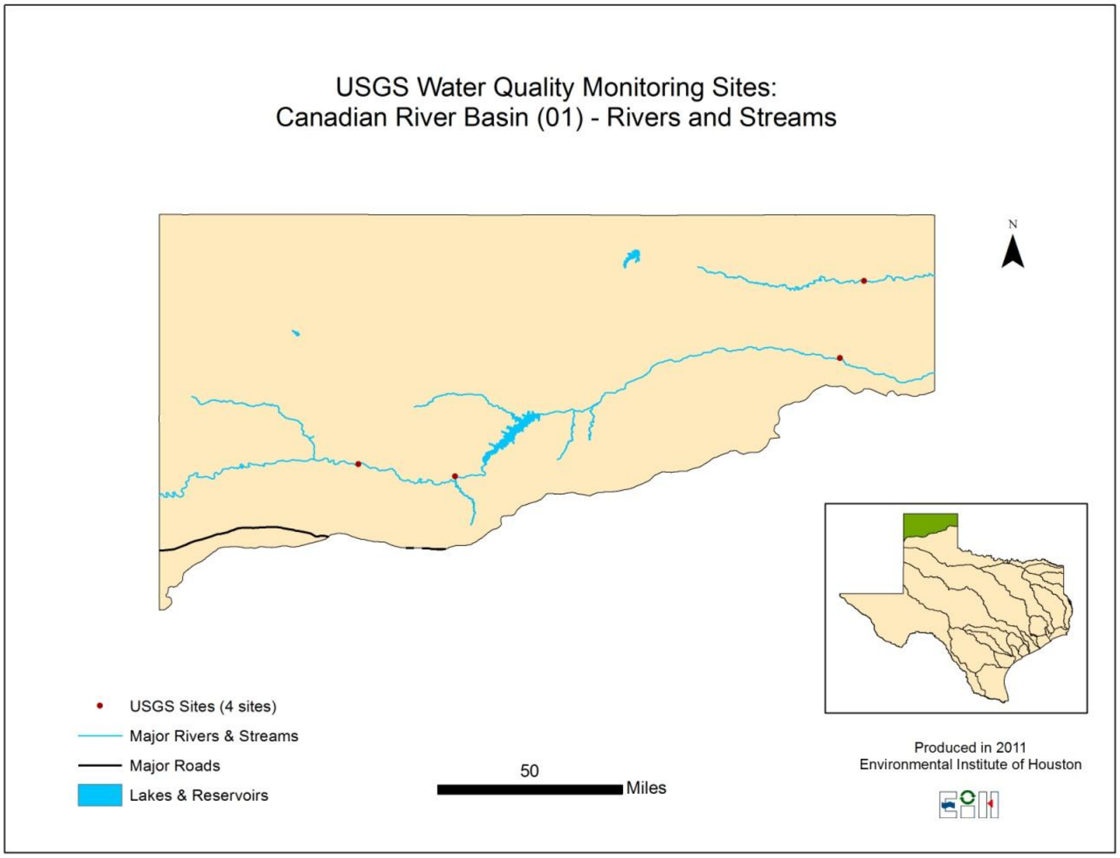

Figure A3. 19. Location of the four sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Canadian River Basin, Texas.

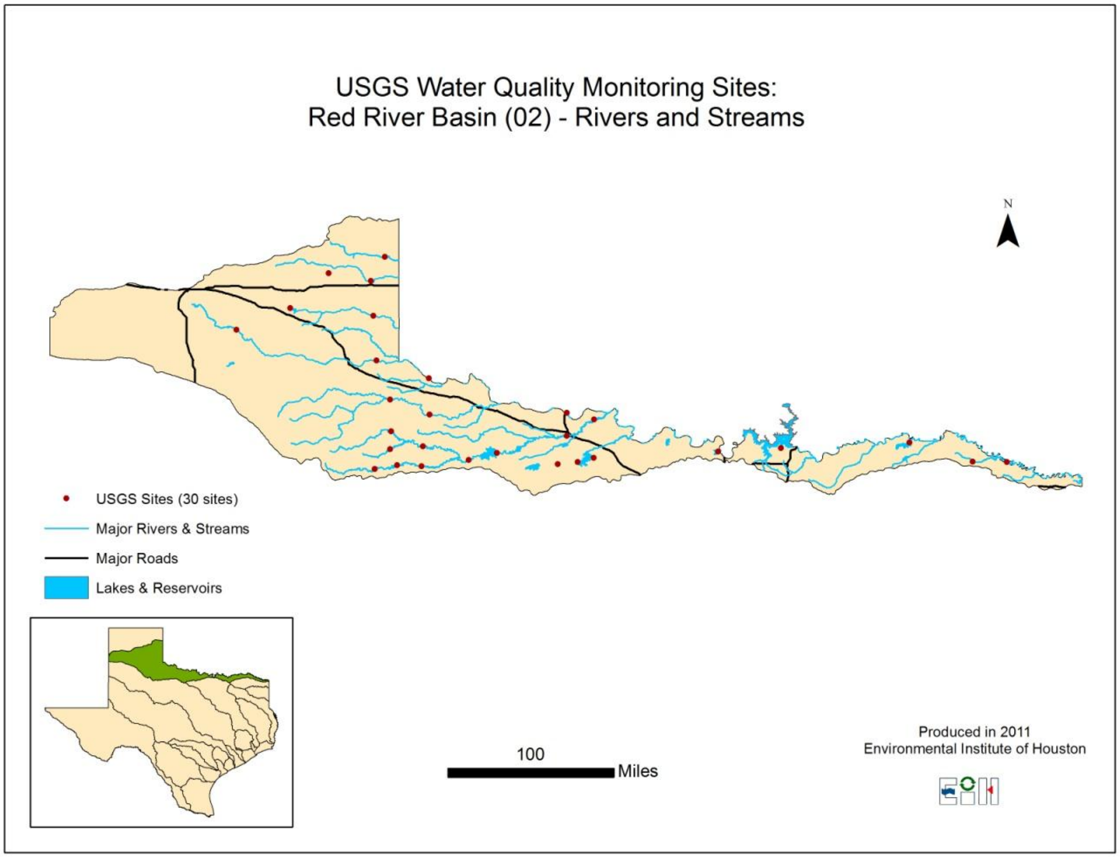

Figure A3. 20. Location of the 30 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Red River Basin, Texas.

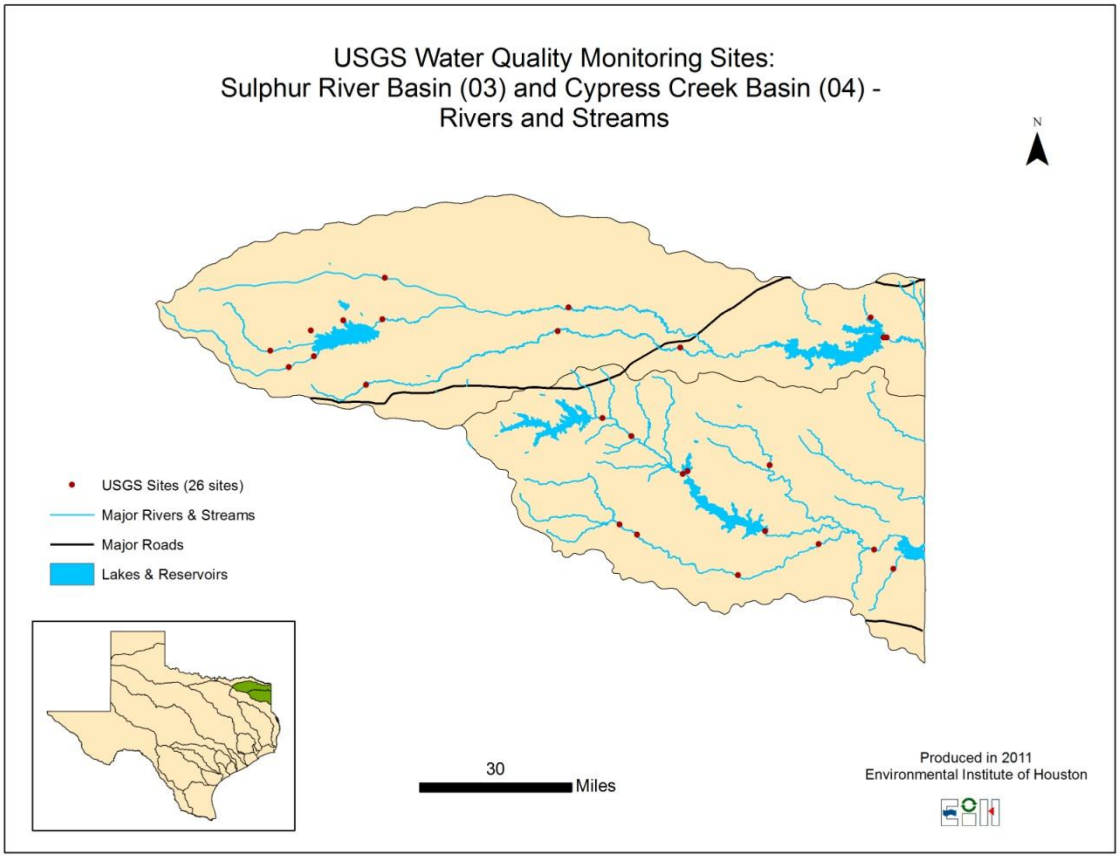

Figure A3. 21. Location of the 26 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Sulphur River and Cypress Creek Basins, Texas.

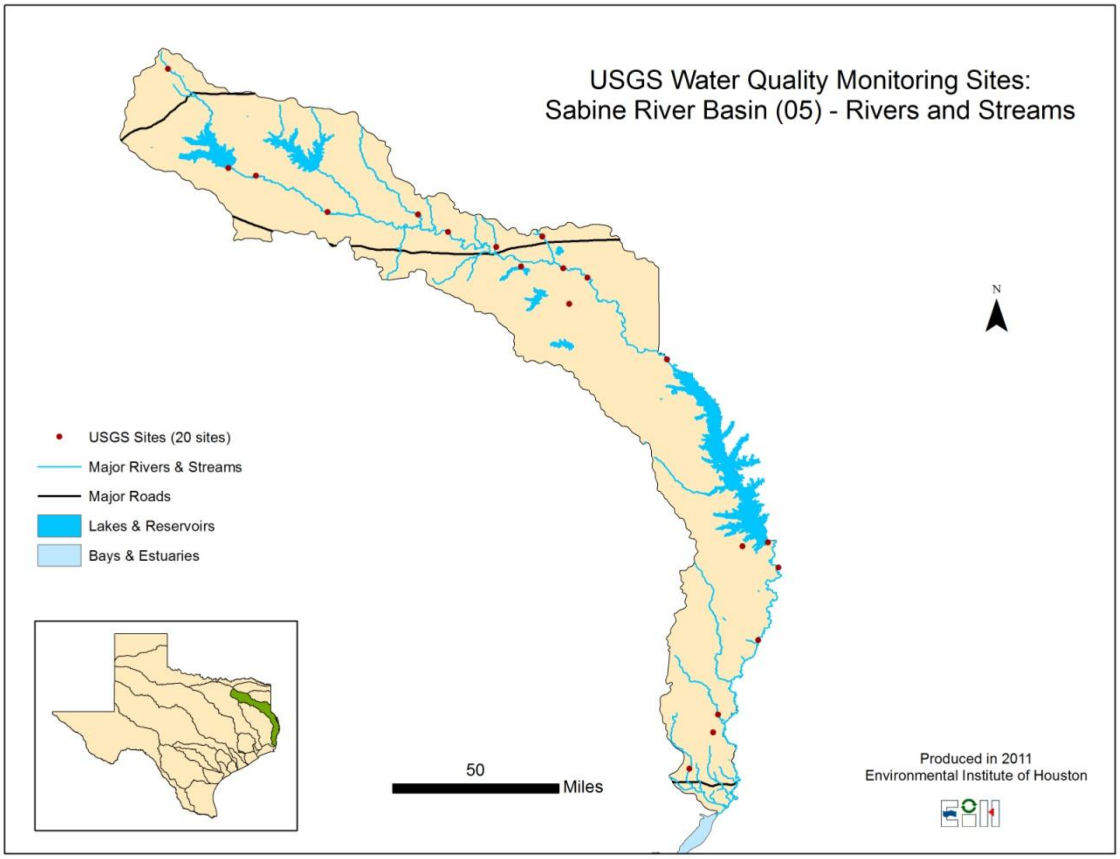

Figure A3. 22. Location of the 20 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Sabine River Basin, Texas.

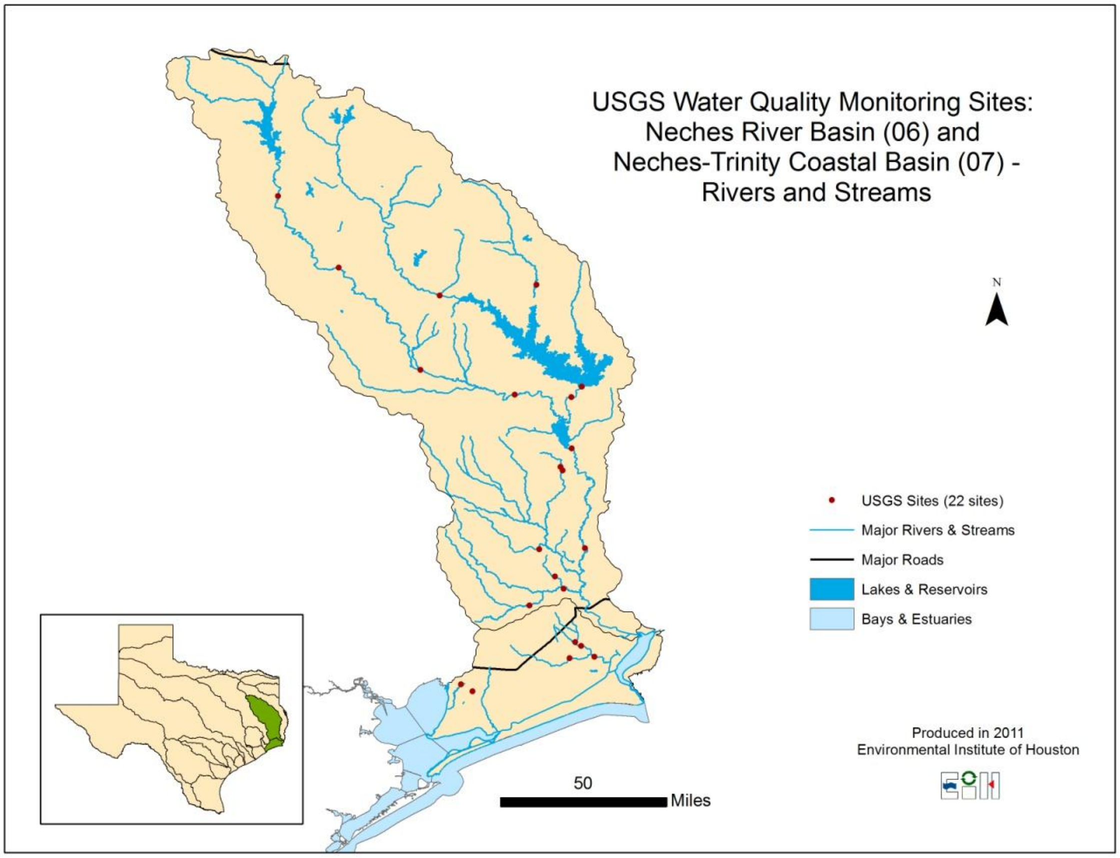

Figure A3. 23 Location of the four sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Neches River and Neches-Trinity Coastal Basins, Texas.

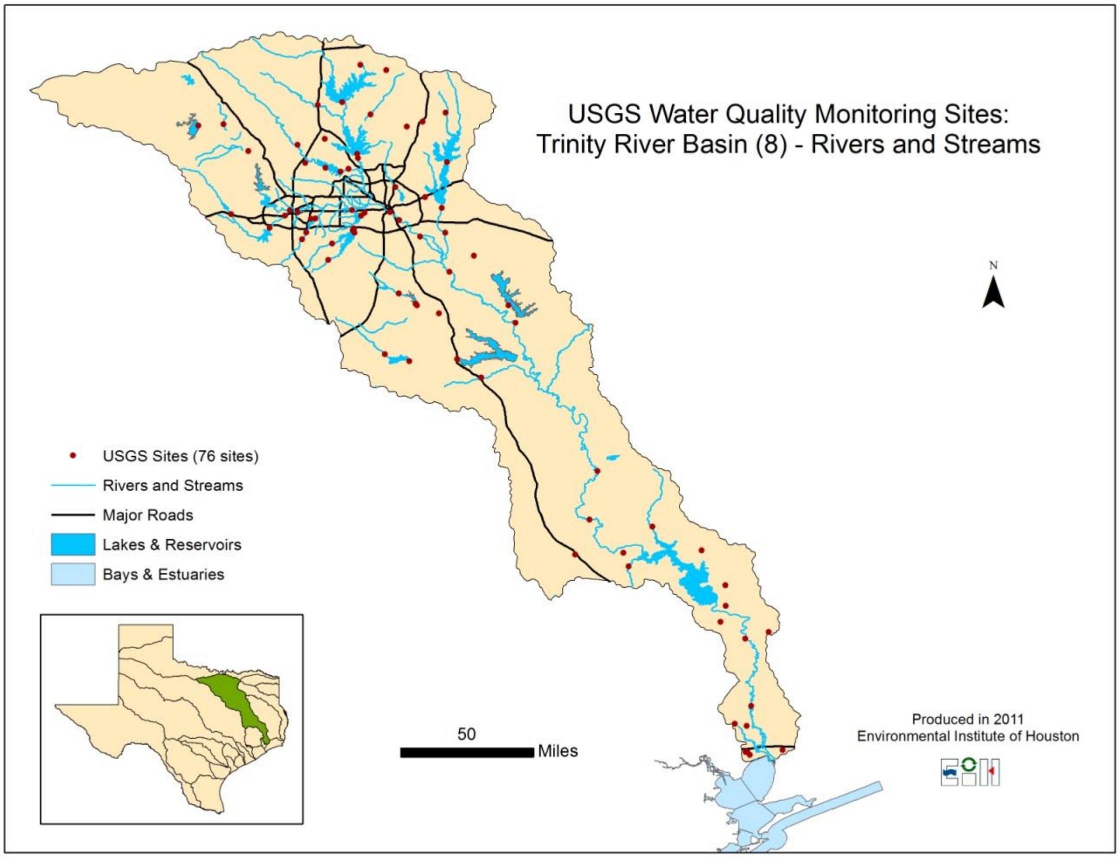

Figure A3. 24. Location of the four sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Trinity River Basin, Texas.

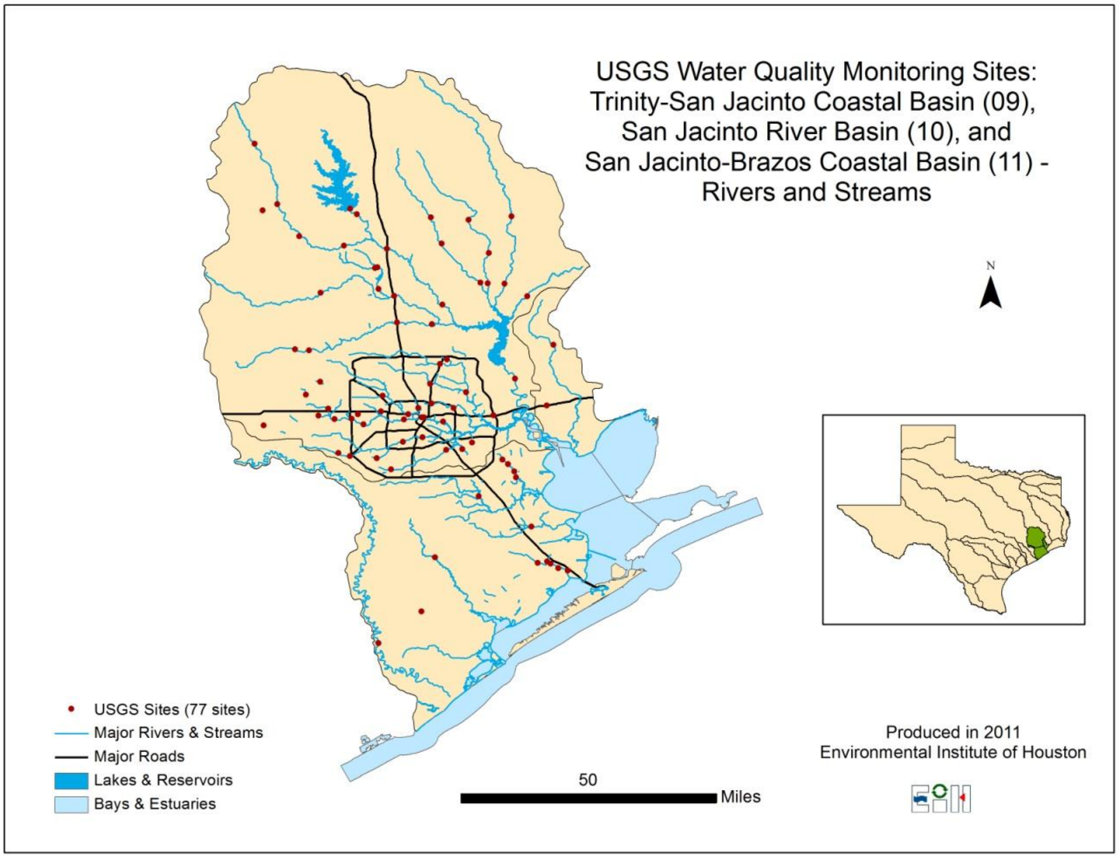

Figure A3. 25. Location of the 77 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Trinity-San Jacinto Coastal, San Jacinto River, and San Jacinto-Brazos Coastal Basins, Texas.

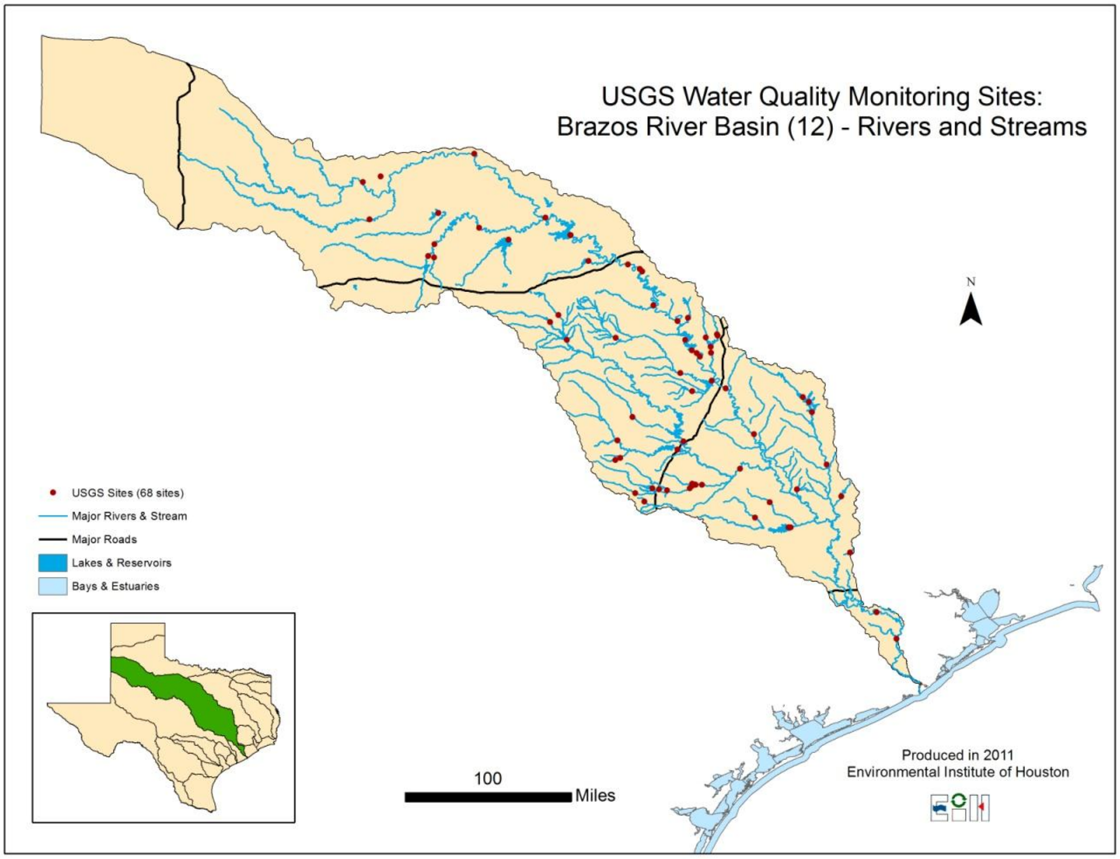

Figure A3. 26. Location of the 68 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Brazos River Basin, Texas.

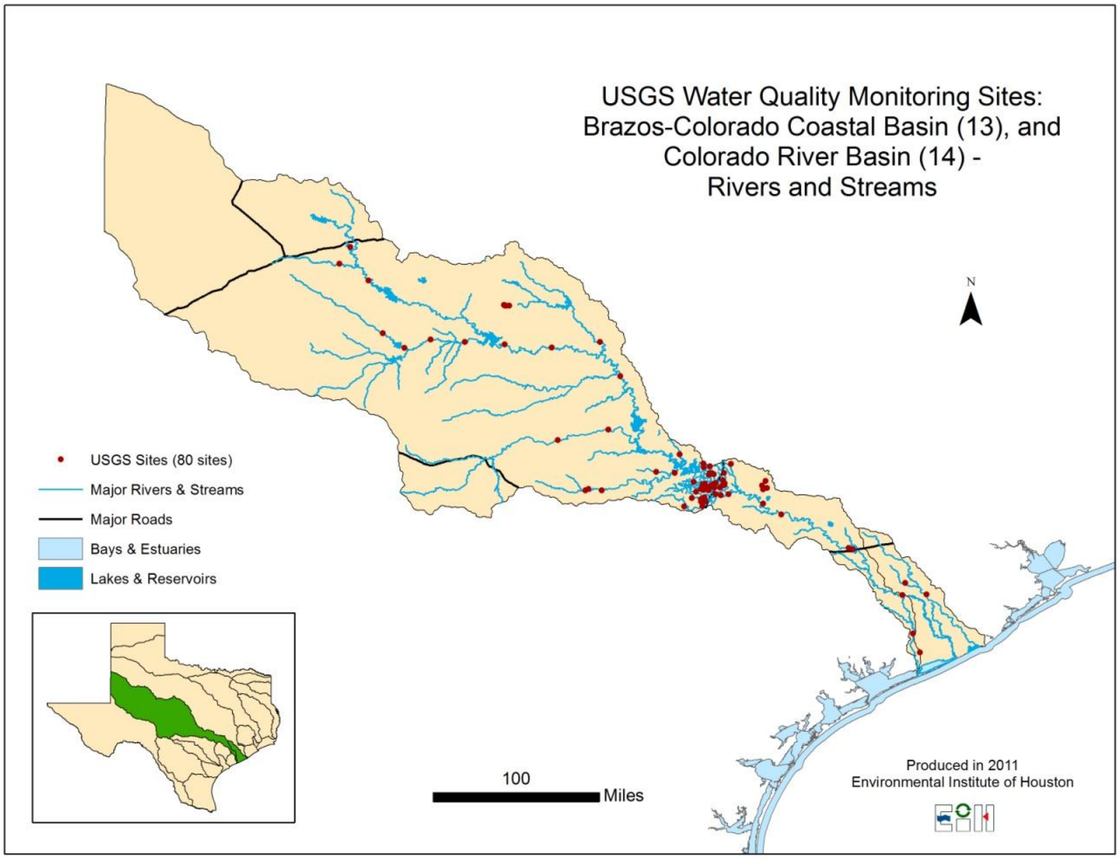

Figure A3. 27. Location of the 80 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Brazos-Colorado Coastal and Colorado River Basins, Texas.

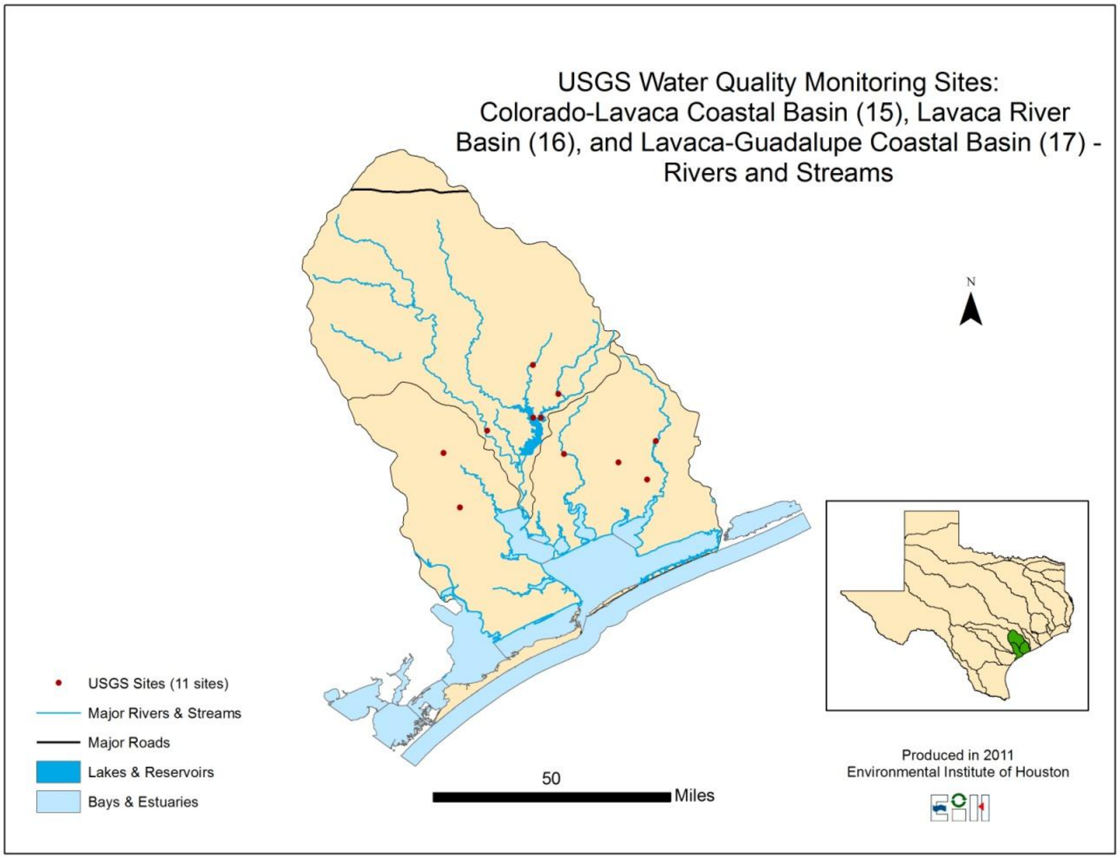

Figure A3. 28. Location of the 11 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Colorado-Lavaca Coastal, Lavaca River, and Lavaca-Guadalupe Coastal Basins, Texas.

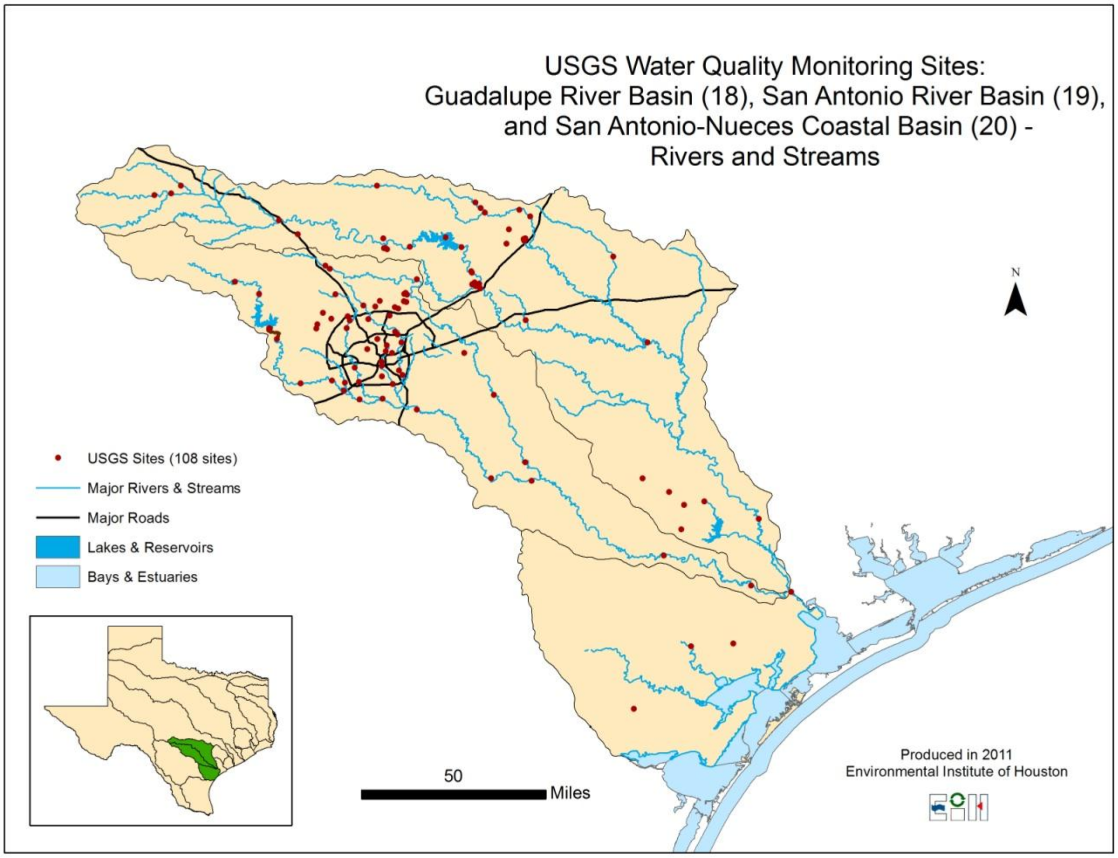

Figure A3. 29. Location of the 108 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Guadalupe River, San Antonio River, and San Antonio-Nueces Coastal River Basins, Texas.

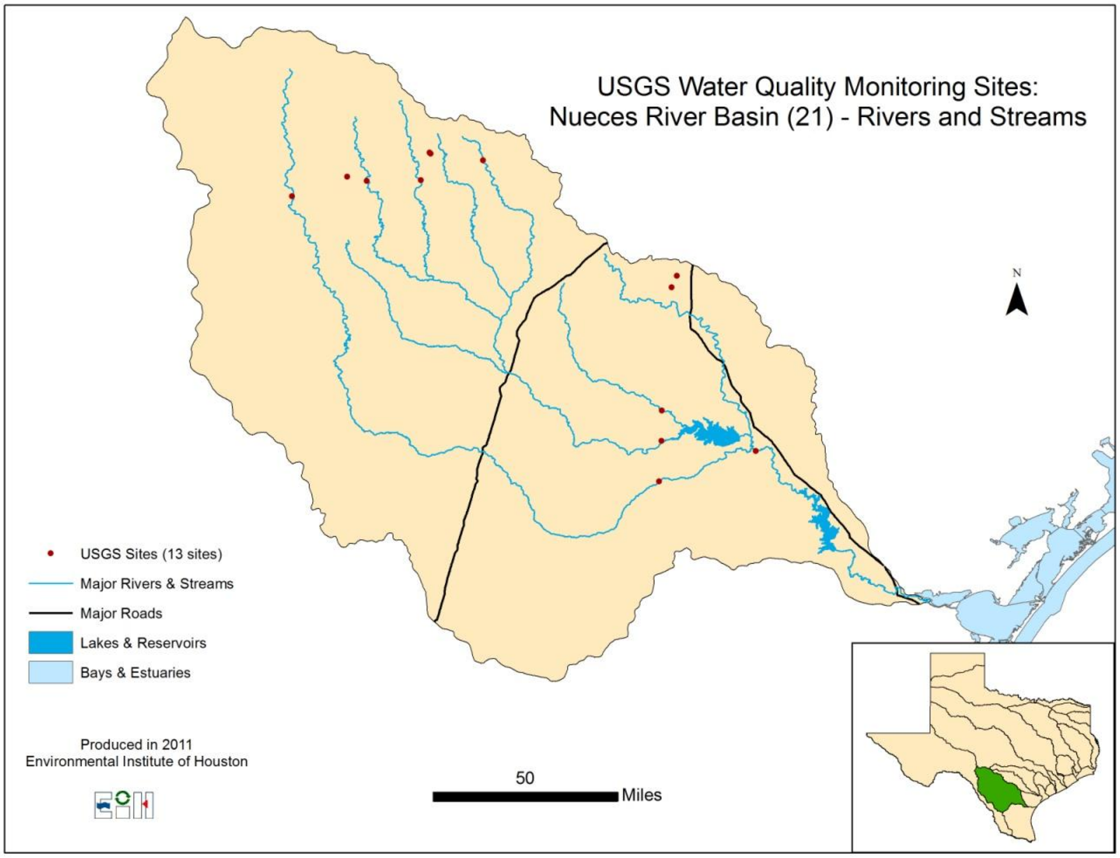

Figure A3. 30. Location of the 13 sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Nueces River Basin, Texas.

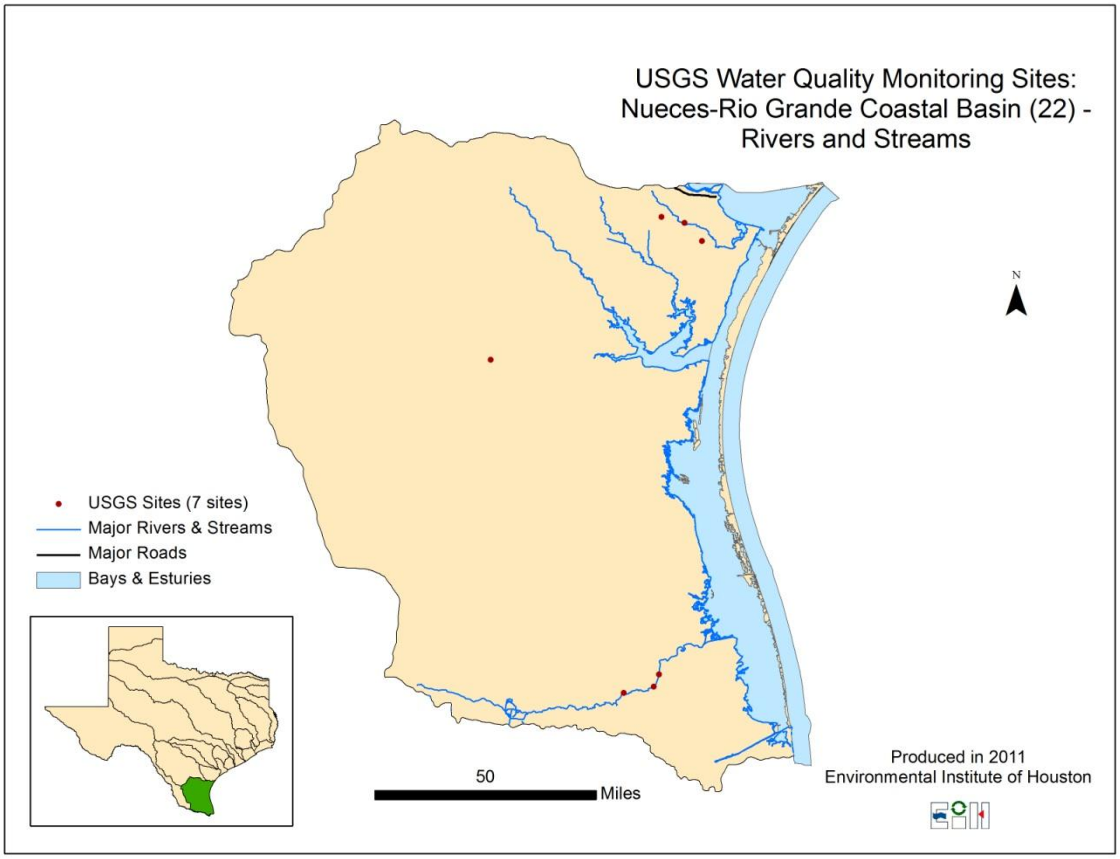

Figure A3. 31. Location of the seven sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Nueces-Rio Grande Coastal Basin, Texas.

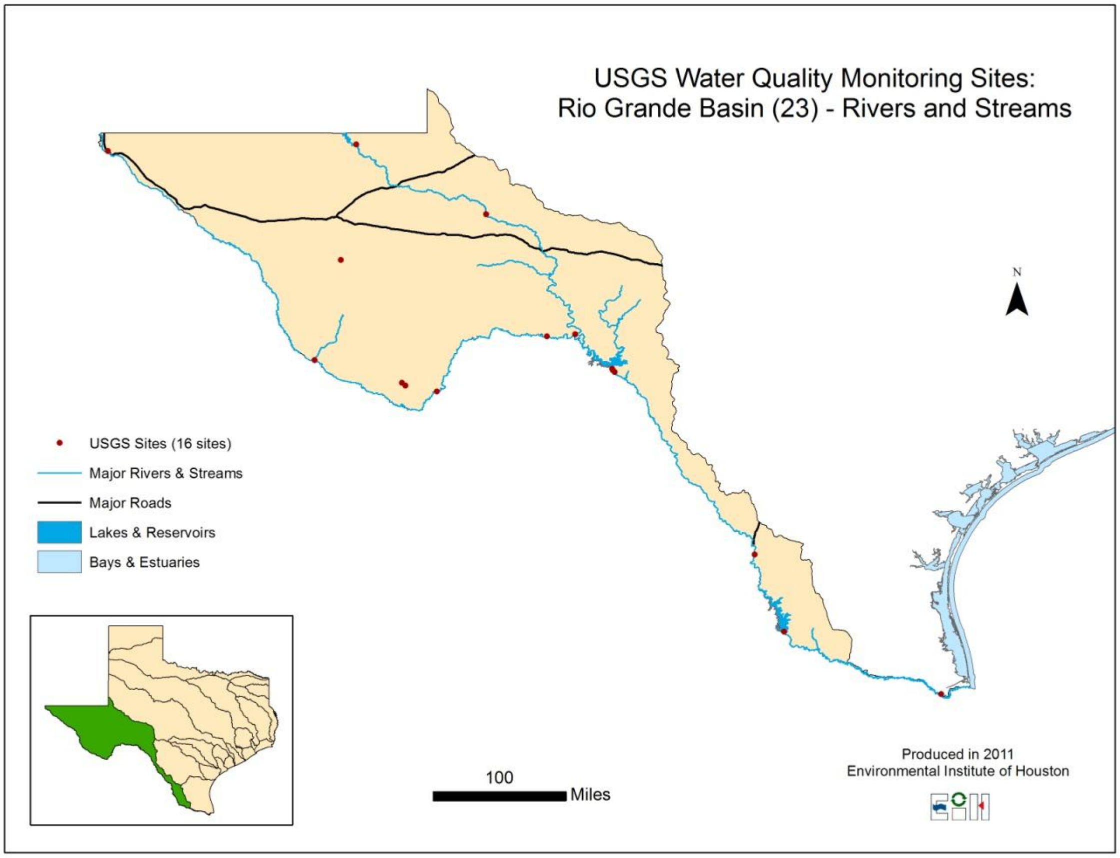

Figure A3. 32. Location of the four sites monitored by USGS containing nutrient and/or chlorophyll-*a* data in streams and rivers within the Rio Grande River Basin, Texas.

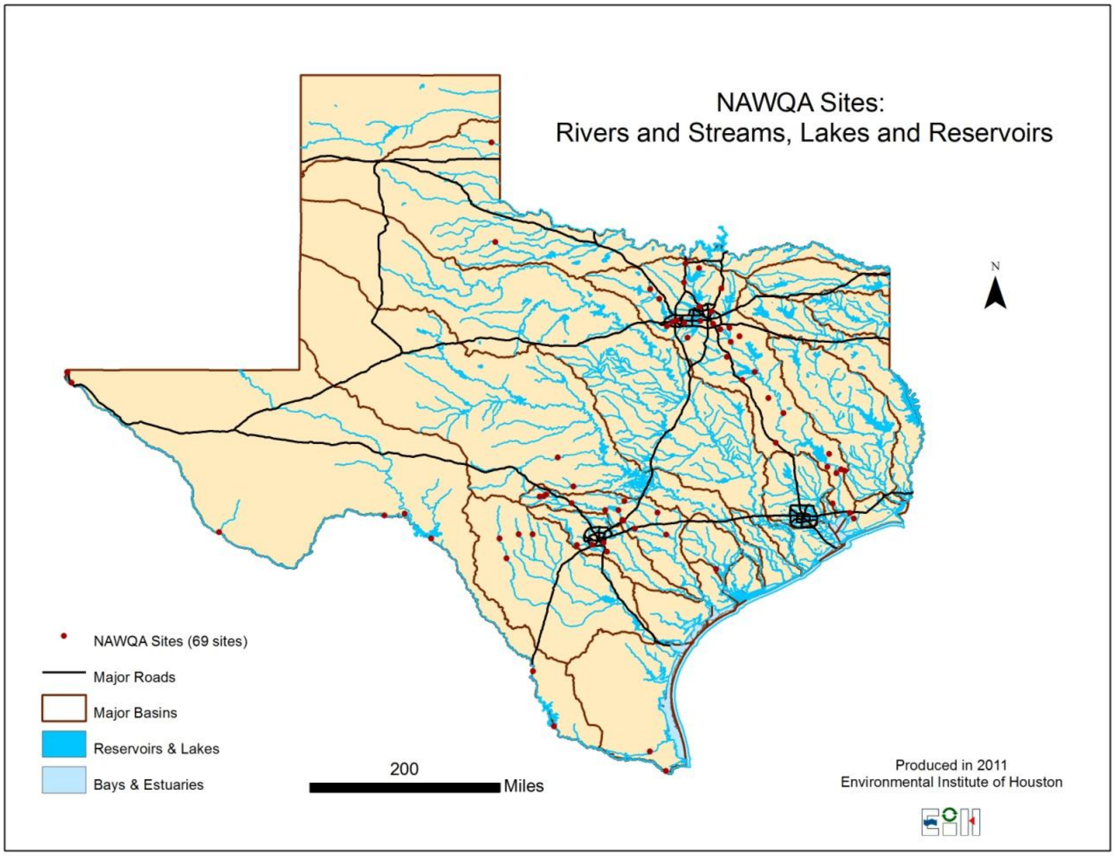

Figure A3. 33. Distribution of the 69 USGS NAWQA sites within the state of Texas containing nutrient and/or chlorophyll-*a* data.

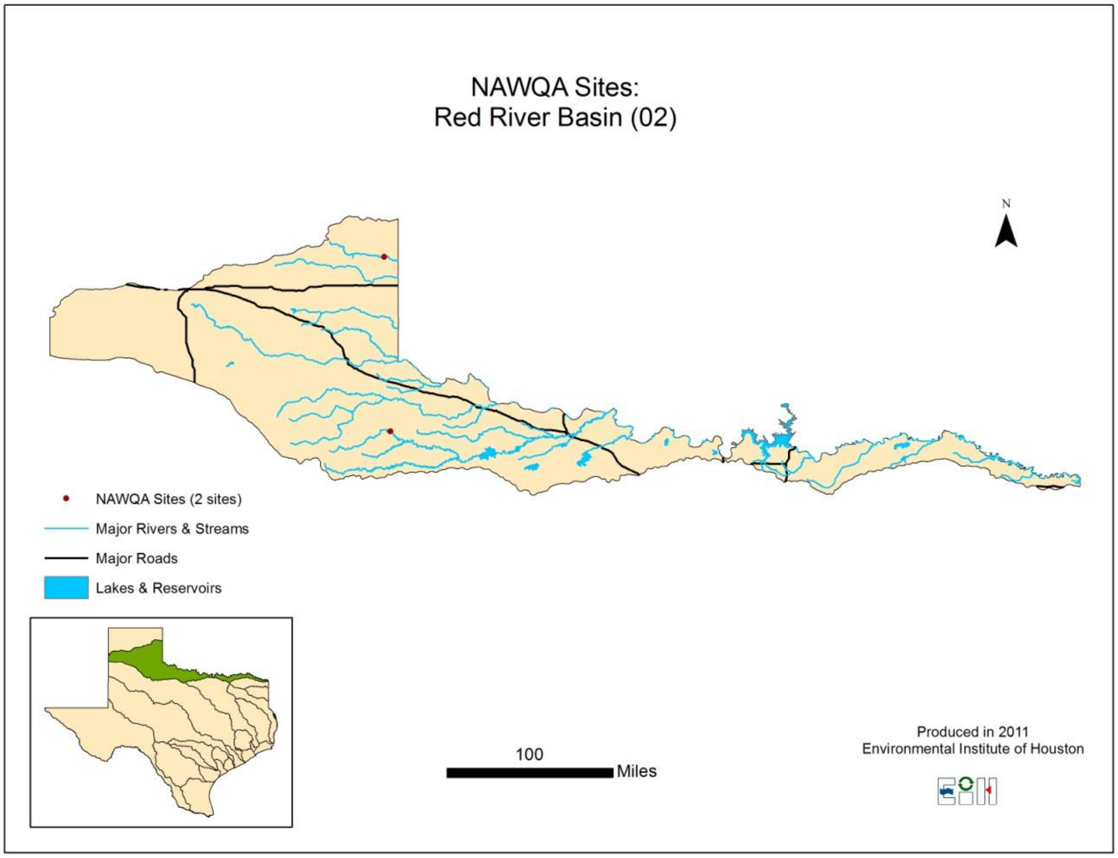

Figure A3. 34. Distribution of the two USGS NAWQA sites in the Red River basin, Texas containing nutrient and/or chlorophyll-*a* data.

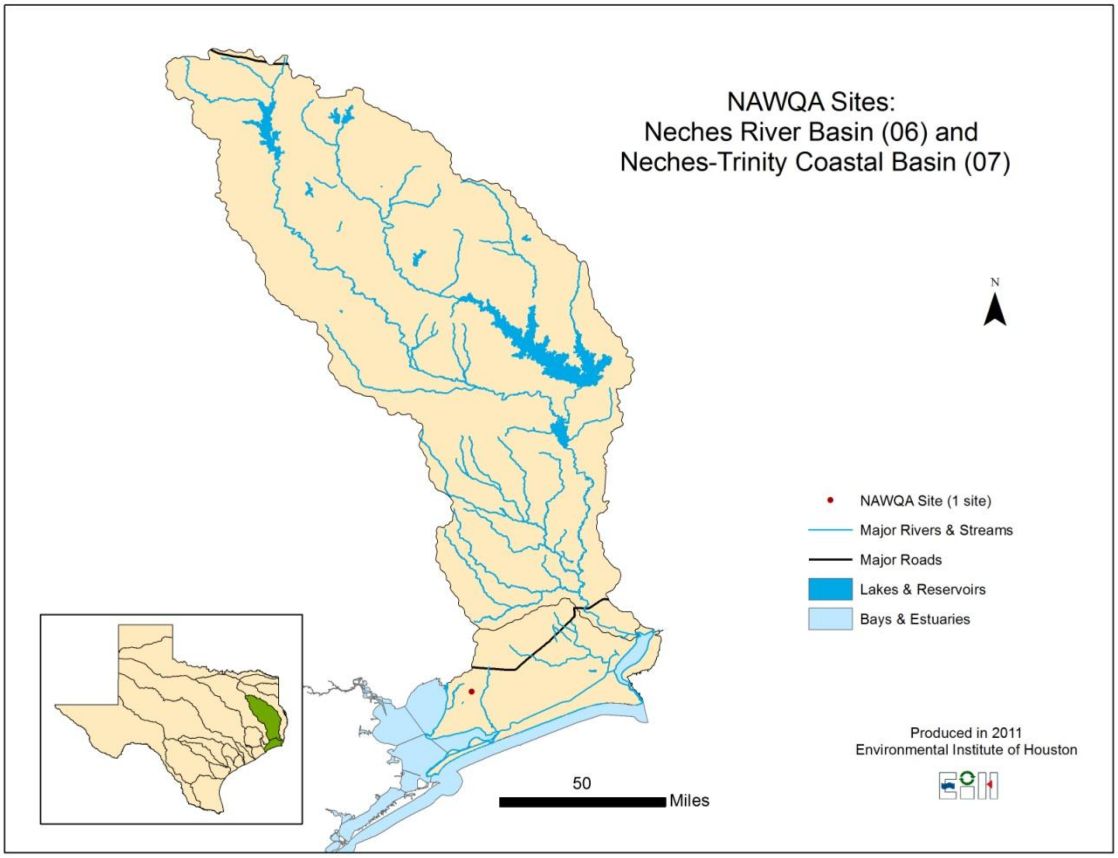

Figure A3. 35. Location of the sole USGS NAWQA site in the Neches River and the Neches-Trinity Coastal basins, Texas containing nutrient and/or chlorophyll-*a* data.

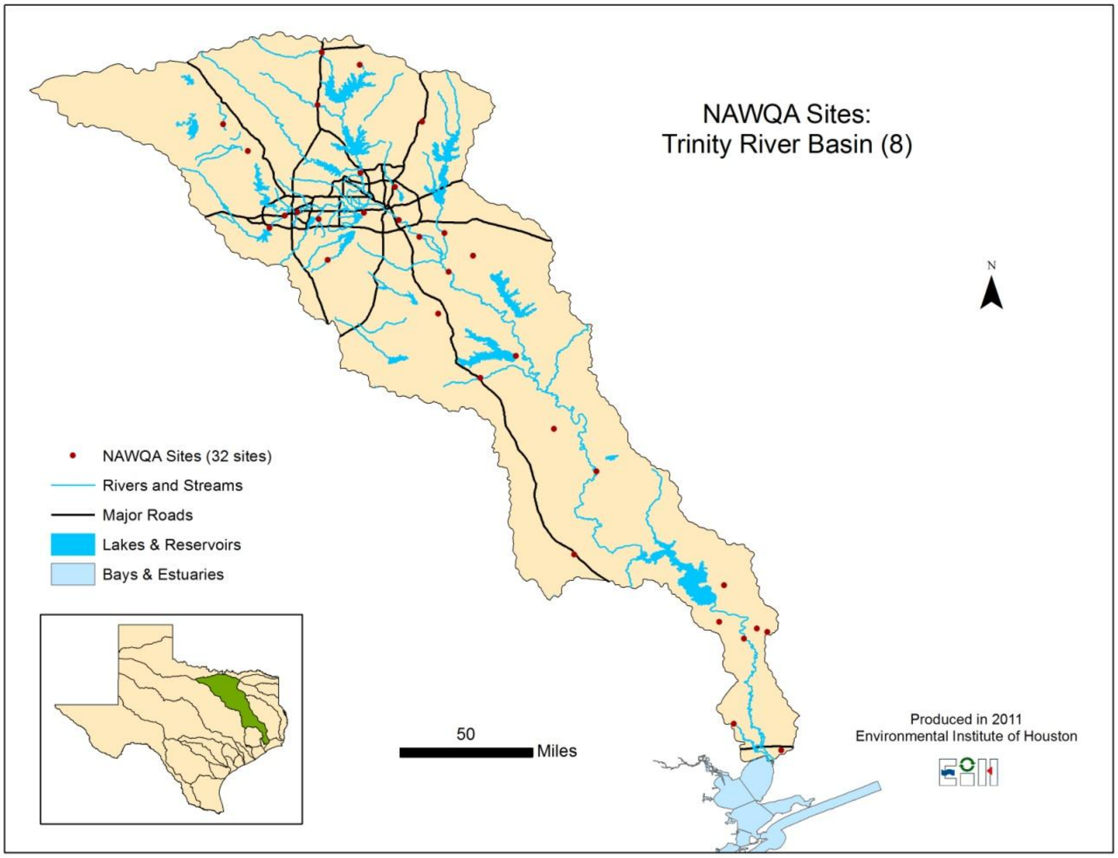

Figure A3. 36. Distribution of the 32 USGS NAWQA sites in the Trinity River basin, Texas containing nutrient and/or chlorophyll-*a* data.

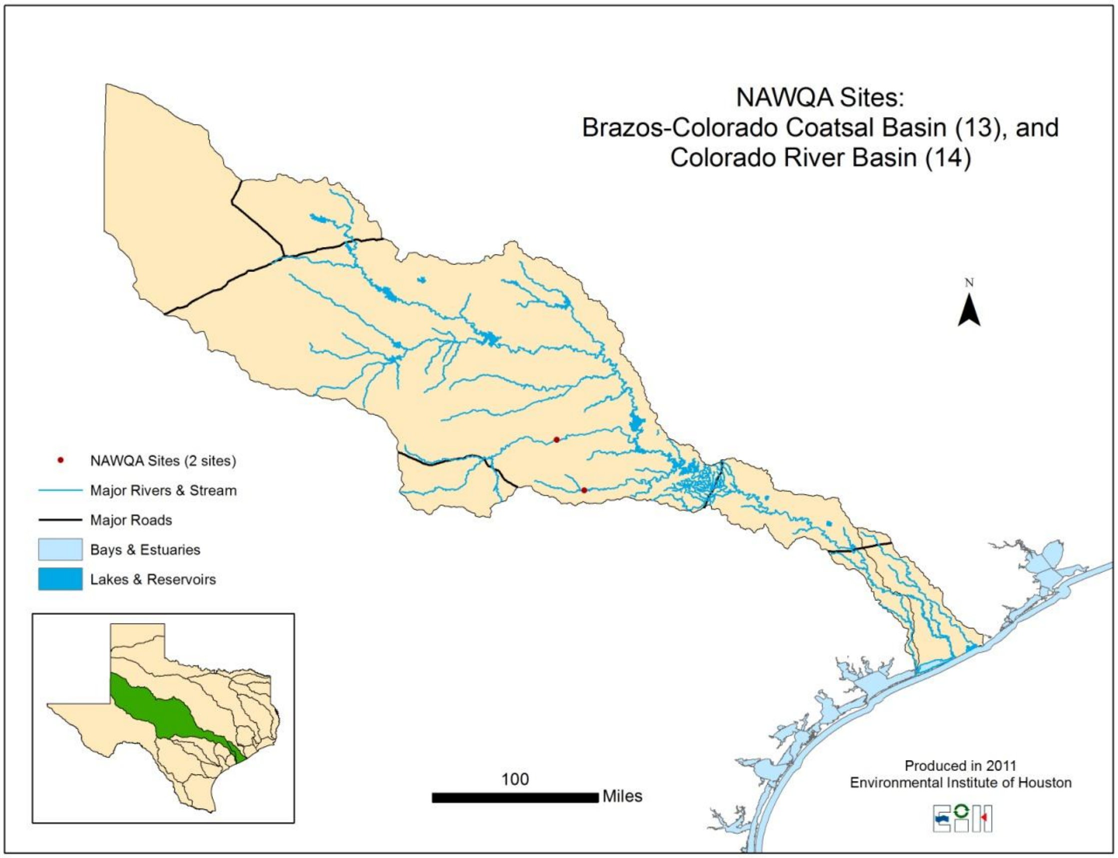

Figure A3. 37. Distribution of the two USGS NAWQA sites in the Colorado River and the Brazos-Colorado Coastal basins, Texas containing nutrient and/or chlorophyll-*a* data.

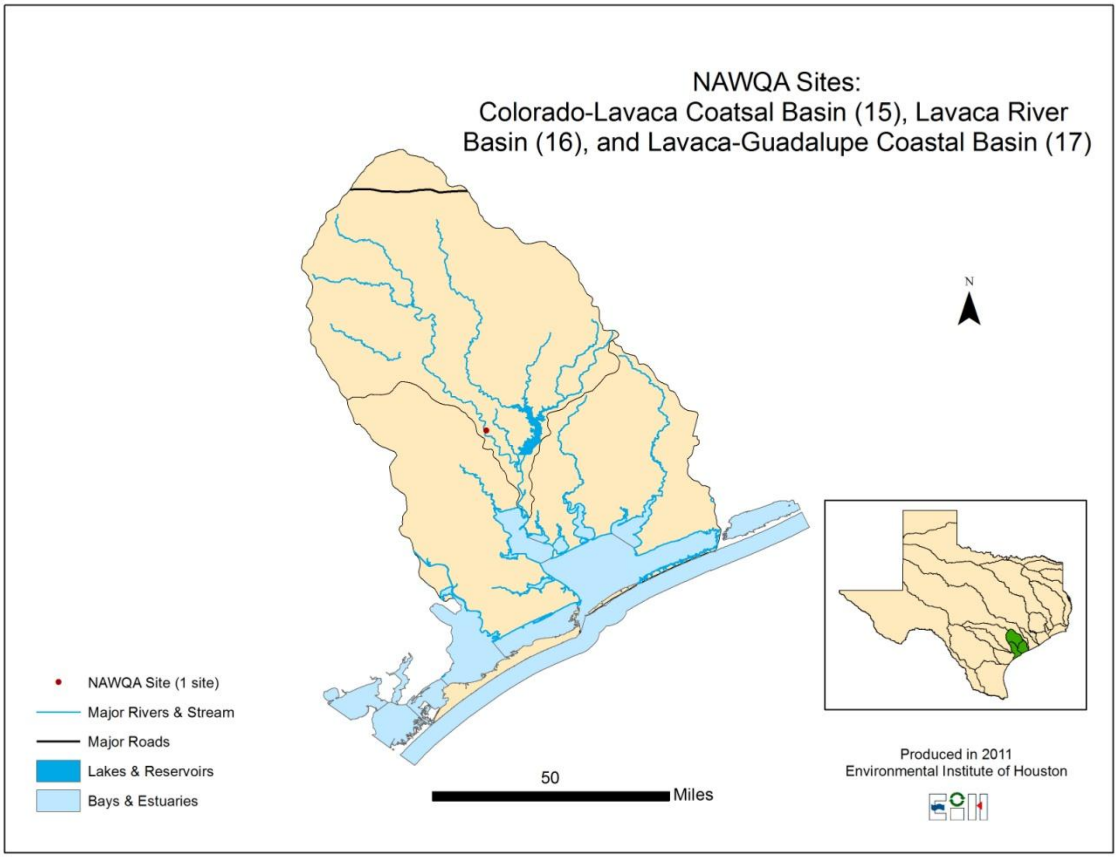

Figure A3. 38. Location of the sole USGS NAWQA site in the Colorado-Lavaca Coastal Basin, Lavaca River Basin, and the Lavaca-Guadalupe Coastal basins, Texas containing nutrient and/or chlorophyll-*a* data.

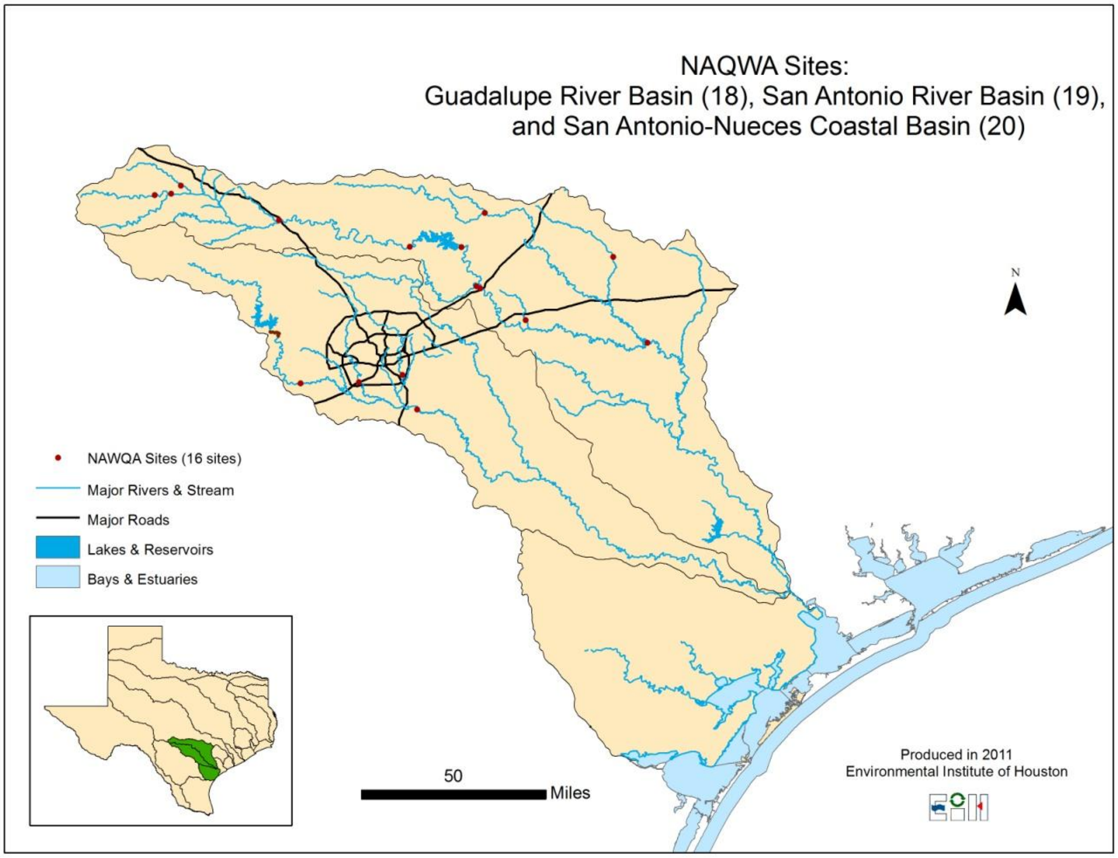

Figure A3. 39. Distribution of the 16 USGS NAWQA sites in the Guadalupe River, San Antonio River and San Antonio-Nueces Coastal basins, Texas containing nutrient and/or chlorophyll-*a* data.

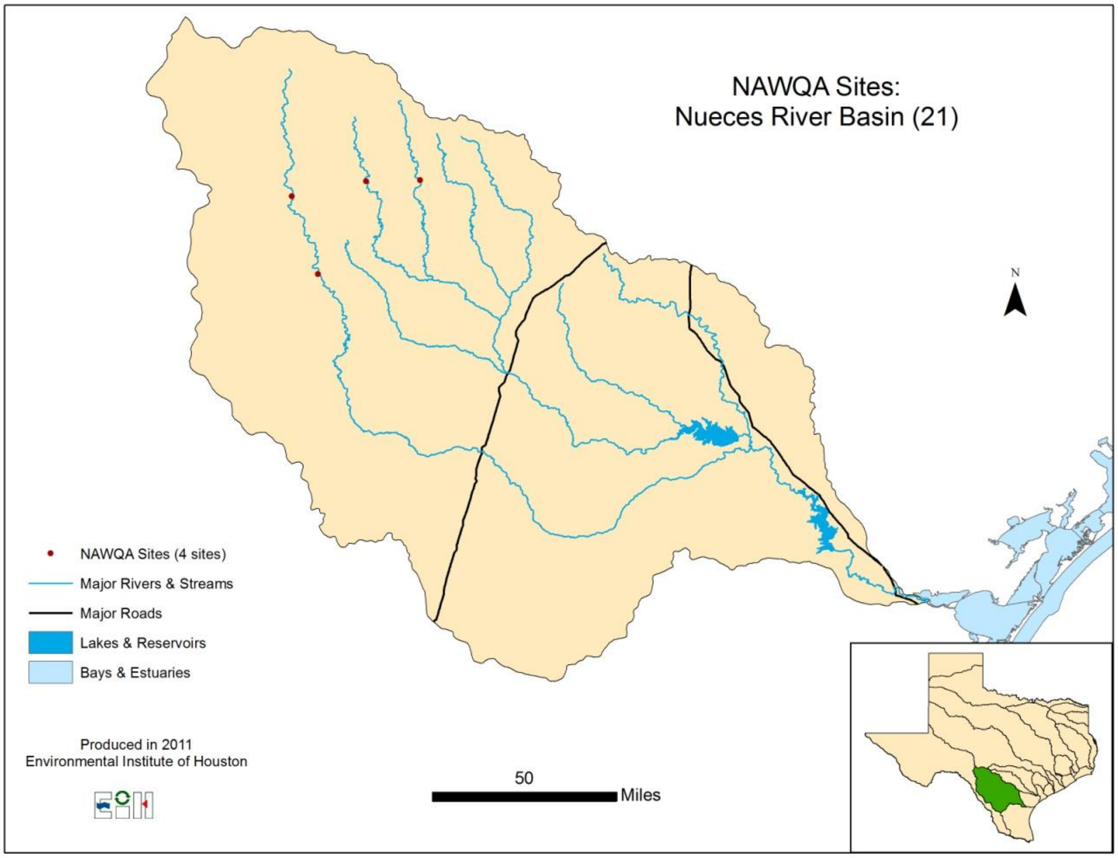

Figure A3. 40. Distribution of the four USGS NAWQA sites in the Nueces River basin, Texas containing nutrient and/or chlorophyll-*a* data.

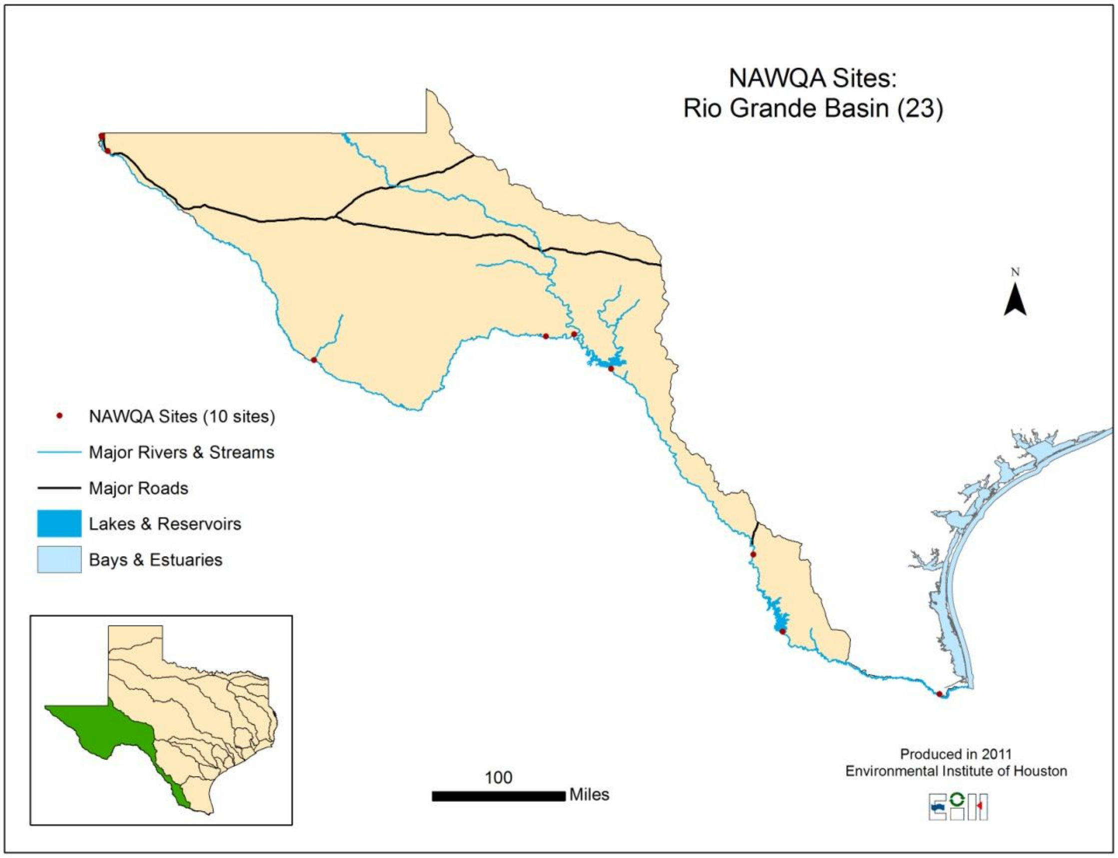

Figure A3. 41. Distribution of the 10 USGS NAWQA sites in the Rio Grande River basin, Texas containing nutrient and/or chlorophyll-*a* data.

Table A3. 1. List of USGS gage sites in Texas containing water level or stream flow data. Those sites with water quality data area also noted[1].

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
7227420	Cramer Ck at US Hwy 54 nr Dalhart, TX	Stream	35.75125	-102.8931667	205	11090102	10/4/2007	5/5/2011	25
7227500	Canadian Rv nr Amarillo, TX	Stream	35.4703261	-101.879628	375	11090105	1/16/1924	6/14/2011	1626
7227890	Big Blue Ck nr Fritch, TX	Stream	35.72077778	-101.6625278	341	11090105	2/17/2010	5/5/2011	12
7228000	Canadian Rv nr Canadian, TX	Stream	35.935042	-100.3706884	211	11090106	6/2/1924	5/9/2011	1468
7227920	Dixon Ck nr Borger, TX	Stream	35.6647649	-101.3509971	233	11090106	3/11/1974	8/15/1989	143
7233500	Palo Duro Ck nr Spearman, TX	Stream	36.20225497	-101.305993	195	11100104	6/4/1936	5/6/2011	437
7235000	Wolf Ck at Lipscomb, TX	Stream	36.23864885	-100.2756889	295	11100202	11/18/1961	5/9/2011	266
7295500	Tierra Blanca Ck abv Buffalo Lk nr Umbarger, TX	Stream	34.84867146	-102.1760295	117	11120101	2/25/1942	5/25/2011	125
7298500	Pr Dog Twn Fk Red Rv nr Brice, TX	Stream	34.62783574	-100.9406994	191	11120103	8/11/1939	6/3/2011	440
7297910	Pr Dog Twn Fk Red Rv nr Wayside, TX	Stream	34.83755505	-101.4140578	11	11120103	10/7/1967	6/21/2011	430
7299540	Pr Dog Twn Fk Red Rv nr Childress, TX	Stream	34.56922728	-100.1940023	75	11120105	4/5/1965	6/14/2011	552
7299495	Prairie Dog Town Fork Red River near Lakeview, TX	Stream	34.5717243	-100.7470787	191	11120105	8/26/1987	2/18/1988	2
7299511	Jonah Creek near Newlin, TX	Stream	34.64005685	-100.3998427	75	11120105	8/26/1987	2/18/1988	2
7299541	Dry Salt Creek near Memphis, TX	Stream	34.7253325	-100.4140104	75	11120105	8/26/1987	2/18/1988	2
7299542	Salt Creek near Childress, TX	Stream	34.61422547	-100.2795616	75	11120105	8/26/1987	2/18/1988	2
7299543	East Salt Creek near Childress, TX	Stream	34.6170035	-100.2528942	75	11120105	8/26/1987	2/18/1988	2
7299545	Buck Creek at Loco, TX	Stream	34.70283589	-100.1881691	75	11120105	8/25/1987	2/17/1988	2
7299547	Twin Mill Branch near Loco, TX	Stream	34.68116965	-100.1870579	75	11120105	8/25/1987	2/17/1988	2
7299548	Buck Creek near Loco, TX	Stream	34.6692257	-100.1570563	75	11120105	8/25/1987	2/17/1988	2
7299550	Buck Creek near Childress, TX	Stream	34.61172738	-100.1109427	75	11120105	8/25/1987	2/17/1988	2
7299553	Settlers Creek near Hollis, OK	Stream	34.6450603	-100.0789967	75	11120105	8/25/1987	2/17/1988	2
72995415	Wet Salt Creek near Memphis, TX	Stream	34.72561107	-100.3617867	75	11120105	8/26/1987	2/18/1988	2
72995425	East Salt Creek near Memphis, TX	Stream	34.71755677	-100.2884513	75	11120105	8/26/1987	2/18/1988	2
72995435	Buck Creek near Quail, TX	Stream	34.8431094	-100.346787	87	11120105	8/25/1987	2/17/1988	2
72995440	Buck Creek near Rolla, TX	Stream	34.81949955	-100.2765068	87	11120105	8/25/1987	2/17/1988	2
72995445	House Log Creek near Wellington, TX	Stream	34.7906116	-100.2392832	87	11120105	8/25/1987	2/17/1988	2
729951190	Jonah Creek near Estelline, TX	Stream	34.60116908	-100.3765085	75	11120105	8/26/1987	2/18/1988	2
7299890	Lelia Lk Ck bl Bell Ck nr Hedley, TX	Stream	34.93560669	-100.6965246	129	11120201	11/19/1968	6/20/2011	149
7300000	Salt Fk Red Rv nr Wellington, TX	Stream	34.95755294	-100.220949	87	11120202	4/20/1920	5/10/2011	570
7299985	Salt Fork Red River near Quail, TX	Stream	35.03282888	-100.3954013	87	11120202	8/26/1987	2/18/1988	2
7299990	Dozier Creek near Dozier, TX	Stream	35.02310697	-100.3390099	87	11120202	8/26/1987	2/18/1988	2
7299995	Lake Creek near Samnorwood, TX	Stream	35.00116285	-100.308175	87	11120202	8/26/1987	2/18/1988	2
7299997	Tributary to Salt Fork Red River near Lutie, TX	Stream	34.97977457	-100.2603952	87	11120202	8/26/1987	2/18/1988	2
7299999	Cottonwood Creek near Wellington, TX	Stream	34.9506086	-100.2248381	87	11120202	8/26/1987	2/18/1988	2
7300001	Indian Creek near Wellington, TX	Stream	34.97255266	-100.2159488	87	11120202	8/26/1987	2/18/1988	2
7300002	Tributary to Salt Fork Red River nr Wellington, TX	Stream	34.9797748	-100.1987259	87	11120202	8/26/1987	2/18/1988	2
7300005	Panther Creek near Wellington, TX	Stream	34.97588609	-100.1695579	87	11120202	8/26/1987	2/18/1988	2
7300120	Salt Fork Red River near Dodson, TX	Stream	34.8875551	-100.0512187	87	11120202	8/26/1987	2/18/1988	2
7300130	Sand Creek near Dodson, TX	Stream	34.84838926	-100.0634412	87	11120202	8/26/1987	2/18/1988	2
7301200	McClellan Ck nr McLean, TX	Stream	35.3292151	-100.609301	179	11120301	3/27/1987	3/5/2003	30
7301410	Sweetwater Ck nr Kelton, TX	Stream	35.47310419	-100.1209501	483	11120302	11/16/1961	5/10/2011	514
7301300	N Fk Red Rv nr Shamrock, TX	Stream	35.2642163	-100.2417855	483	11120302	2/19/1964	5/10/2011	365
7299670	Groesbeck Ck at SH 6 nr Quanah, TX	Stream	34.35451979	-99.7403719	197	11130101	11/30/1961	5/11/2011	462
7299580	Groesbeck Creek near Quanah, TX	Stream	34.3431327	-99.6456478	197	11130101	3/25/1986	2/17/1988	3
7299730	Tributary to Wanderers Creek near Odell, TX	Stream	34.3109143	-99.4409209	487	11130101	8/25/1987	2/17/1988	2
7299570	Red Rv nr Quanah, TX	Stream	34.4131291	-99.7345385	197	11130101	3/9/1988	3/9/1988	1
7299732	Wanderers Creek near Odell, TX	Stream	34.31091429	-99.4423098	487	11130101	3/25/1996	3/25/1996	1
7308500	Red Rv nr Burkburnett, TX	Stream	34.11009327	-98.5317234	485	11130102	7/11/1924	5/23/2011	758
7307750	Middle Pease Rv at Hwy 62 & 83 nr Paducah, TX	Stream	34.2086816	-100.3012257	101	11130104	1/14/1992	7/23/1997	16
7308200	Pease Rv nr Vernon, TX	Stream	34.1795833	-99.3233333	487	11130105	10/6/1959	5/12/2011	445
7307800	Pease Rv nr Childress, TX	Stream	34.2275718	-100.0737179	101	11130105	10/15/1984	5/11/2011	216
7311700	N Wichita Rv nr Truscott, TX	Stream	33.82064216	-99.7864822	275	11130204	10/6/1959	5/9/2011	610
7311600	N Wichita Rv nr Paducah, TX	Stream	33.9506365	-100.0648269	101	11130204	7/12/1961	5/17/2011	185
7311630	Middle Wichita Rv nr Guthrie, TX	Stream	33.7959174	-100.0751027	269	11130204	10/26/1993	5/18/2011	133
7311800	S Wichita Rv nr Benjamin, TX	Stream	33.644257	-99.8009252	275	11130205	10/6/1959	5/18/2011	343
7311783	S Wichita Rv bl Low Flow Dam nr Guthrie, TX	Stream	33.62203029	-100.2089951	269	11130205	9/27/1984	5/19/2011	232
7311790	S Wichita Rv at Ross Rh nr Benjamin, TX	Stream	33.6550874	-100.0139878	269	11130205	3/8/1988	1/30/1997	51
7311782	S Wichita Rv at Low Flow Dam nr Guthrie, TX	Stream	33.62203029	-100.2089951	269	11130205	10/18/1985	12/21/2010	5
7312110	S Side Canal nr Dundee, TX	Canal	33.81398475	-98.932844	9	11130206	9/30/1971	6/20/2011	306
7312500	Wichita Rv at Wichita Falls, TX	Stream	33.90954178	-98.5336663	485	11130206	3/30/1938	5/10/2011	531
7312100	Wichita Rv nr Mabelle, TX	Stream	33.7600934	-99.1428495	23	11130206	1/7/1952	5/18/2011	505
7312700	Wichita Rv nr Charlie, TX	Stream	34.0531504	-98.2967139	77	11130206	1/22/1968	5/5/2011	315
7311900	Wichita Rv nr Seymour, TX	Stream	33.70036966	-99.3886905	23	11130206	10/5/1959	5/6/2011	280
7312130	Wichita Rv at SH 25 nr Kamay, TX	Stream	33.86926267	-98.839231	485	11130206	6/24/1996	8/19/2008	46
7312610	Holliday Ck at Wichita Falls, TX	Stream	33.88444444	-98.4988889	485	11130206	2/20/2009	5/20/2011	21
7312497	Wichita Rv bl FM 1634 at Wichita Falls, TX	Stream	33.91419444	-98.5690278	485	11130206	2/17/2008	9/7/2010	20
7312330	Wichita Rv at FM 368 nr Iowa Park, TX	Stream	33.89694444	-98.7072222	485	11130206	4/30/2009	3/23/2011	9
7312605	Holliday Ck at SW Pkwy, Wichita Falls, TX	Stream	33.85666667	-98.5194444	485	11130206	8/19/2008	8/19/2008	1
7312200	Beaver Ck nr Electra, TX	Stream	33.90592785	-98.9050666	485	11130207	5/5/1960	5/9/2011	371

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
7315200	E Fk Little Wichita Rv nr Henrietta, TX	Stream	33.81287833	-98.0850406	77	11130209	11/26/1963	5/12/2011	281
7314500	Little Wichita Rv nr Archer City, TX	Stream	33.66260225	-98.6131124	9	11130209	10/2/1985	5/11/2011	228
7314900	Little Wichita Rv abv Henrietta, TX	Stream	33.8267666	-98.2400458	77	11130209	12/31/1952	5/12/2011	158
7314810	Little Wichita Rv at Halsell Rh nr Lk Arrowhead,TX	Stream	33.7773229	-98.3553273	77	11130209	9/6/2001	9/24/2001	10
7314850	Little Wichita Rv at Priddy Rh nr Henrietta, TX	Stream	33.80593367	-98.2622688	77	11130209	7/17/2001	9/24/2001	8
7314801	Little Wichita Rv blw Dam nr Lk Arrowhead, TX	Stream	33.7659342	-98.3703278	77	11130209	9/10/2001	9/14/2001	3
7331600	Red River at Denison Dam nr Denison, TX	Stream	33.81899124	-96.5633264	181	11140101	9/20/1982	6/2/2011	133
7332620	Bois D'Arc Ck at FM 1396 nr Honey Grove, TX	Stream	33.6822222	-95.9844444	147	11140101	6/22/2006	6/7/2011	41
7332622	Bois D'Arc Ck at FM 409 nr Honey Grove, TX	Stream	33.74416667	-95.9611111	147	11140101	6/24/2009	5/2/2011	21
7335390	Pat Mayse Lk nr Chicota, TX	Lake	33.8526043	-95.5446813	277	11140101	5/2/1991	5/2/1991	1
7336820	Red River near De Kalb, TX	Stream	33.68400005	-94.6943774	37	11140106	5/5/1990	6/1/2011	52
7343000	N Sulphur Rv nr Cooper, TX	Stream	33.47483009	-95.5877347	277	11140301	11/8/1949	5/2/2011	615
7342470	S Sulphur Rv nr Commerce, TX	Stream	33.21983497	-95.8627421	231	11140301	5/1/1956	8/7/2001	221
7342500	S Sulphur Rv nr Cooper, TX	Stream	33.356499	-95.5949562	119	11140301	12/23/1937	4/26/2011	198
7342480	Middle Sulphur Rv at Commerce, TX	Stream	33.26650079	-95.9155217	231	11140301	10/27/1987	5/3/2011	154
7342465	S Sulphur Rv at Commerce, TX	Stream	33.21177979	-95.9141328	231	11140301	10/29/1991	4/26/2011	134
7343200	Sulphur Rv nr Talco, TX	Stream	33.39066814	-95.0624408	387	11140302	12/12/1956	4/27/2011	492
7344210	Sulphur Rv nr Texarkana, TX	Stream	33.30416667	-94.1513889	37	11140302	12/6/1979	5/10/2011	85
7343450	Sulphur Rv at IH 30 nr Dalby Springs, TX	Stream	33.30944444	-94.6980556	37	11140302	9/17/2008	4/29/2011	28
7343356	Cuthand Ck at FM 910 nr Cuthand, TX	Stream	33.49888889	-95.0513889	387	11140302	8/26/2010	4/27/2011	12
7344100	Anderson Ck at Hwy 98 nr Simms, TX	Stream	33.38444444	-94.4980556	37	11140302	8/25/2010	4/28/2011	8
7344285	Swampoodle Creek @ Broad street @ Texarkana, TX	Stream	33.4184585	-94.0493548	37	11140302	10/19/1993	12/30/2002	6
7343500	White Oak Ck nr Talco, TX	Stream	33.32233617	-95.0927184	449	11140303	11/25/1949	4/27/2011	548
7343850	White Oak Ck nr Omaha, TX	Stream	33.2751187	-94.7418746	343	11140303	8/27/1992	9/12/2007	31
7343840	White Oak Ck at IH 30 nr Omaha, TX	Stream	33.2747222	-94.8025	343	11140303	8/25/2010	6/7/2011	11
7344500	Big Cypress Ck nr Pittsburg, TX	Stream	33.02095787	-94.8821554	449	11140305	3/9/1943	4/19/2011	471
7344486	Brushy Ck at Scroggins, TX	Stream	32.9756785	-95.1843857	159	11140305	12/21/1977	10/22/2004	195
7344482	Big Cypress Ck nr Winnsboro, TX	Stream	33.0234537	-95.2702213	159	11140305	2/3/1974	11/12/1991	152
7344493	Big Cypress Ck at US Hwy 271 nr Pittsburg, TX	Stream	33.07293056	-94.9652278	63	11140305	12/16/2004	4/19/2011	46
7346000	Big Cypress Ck nr Jefferson, TX	Stream	32.74958345	-94.4988102	315	11140306	7/19/1924	5/11/2011	494
7346045	Black Cypress Bayou at Jefferson, TX	Stream	32.7779173	-94.3574153	315	11140306	9/13/1964	5/10/2011	332
7346140	Frazier Ck nr Linden, TX	Stream	33.05402005	-94.2901904	67	11140306	8/20/1958	1/15/1992	239
7346080	Big Cypress Ck abv SH 43 nr Karnack, TX	Stream	32.7386111	-94.2325	315	11140306	5/5/2006	4/25/2011	58
7346070	Little Cypress Ck nr Jefferson, TX	Stream	32.71291998	-94.3460265	203	11140307	1/28/1938	5/10/2011	754
7346050	Little Cypress Ck nr Ore City, TX	Stream	32.6726406	-94.7510435	459	11140307	12/17/1962	6/11/2010	324
8018500	Sabine Rv nr Mineola, TX	Stream	32.61374667	-95.4857901	499	12010001	6/24/1939	5/12/2011	624
8017200	Cowleech Fk Sabine Rv at Greenville, TX	Stream	33.1328933	-96.0769164	231	12010001	2/14/1959	4/27/2011	452
8017300	S Fk Sabine Rv nr Quinlan, TX	Stream	32.89790085	-96.2533118	231	12010001	2/14/1959	4/19/2011	391
8017410	Sabine Rv nr Wills Point, TX	Stream	32.8062358	-95.9194109	467	12010001	9/11/1960	4/20/2011	355
8020000	Sabine Rv nr Gladewater, TX	Stream	32.52708909	-94.9602175	183	12010002	9/29/1932	5/11/2011	789
8019500	Big Sandy Ck nr Big Sandy, TX	Stream	32.6040291	-95.0916099	459	12010002	2/16/1939	5/11/2011	674
8022000	Sabine Rv nr Tatum, TX	Stream	32.36987696	-94.457978	365	12010002	2/9/1939	10/4/1978	400
8022040	Sabine Rv nr Beckville, TX	Stream	32.32737887	-94.3535302	365	12010002	10/4/1978	5/10/2011	238
8022300	Murvaul Bayou nr Gary, TX	Stream	32.0484985	-94.3754778	365	12010002	12/13/1957	7/13/1983	231
8022070	Martin Ck nr Tatum, TX	Stream	32.2957125	-94.4915904	365	12010002	4/12/1974	10/1/1996	188
8020900	Sabine Rv bl Longview, TX	Stream	32.41681793	-94.7099324	183	12010002	10/3/1995	5/10/2011	110
8019200	Sabine Rv nr Hawkins, TX	Stream	32.55986369	-95.206614	499	12010002	10/7/1997	5/11/2011	94
8020450	Sabine Rv abv Longview, TX	Stream	32.47987044	-94.80438	183	12010002	8/23/1983	2/23/2011	53
8020820	Grace Ck nr Longview, TX	Stream	32.46194444	-94.75	183	12010002	6/20/1996	12/6/1996	5
8019000	Lake Fk Ck nr Quitman, TX	Stream	32.76318386	-95.4630094	499	12010003	6/27/1924	5/12/2011	695
8018730	Burke Ck nr Yantis, TX	Stream	32.99067368	-95.6219013	223	12010003	12/11/1978	10/2/1989	72
8022500	Sabine Rv at Logansport, LA	Stream	31.97238949	-94.0063014	419	12010004	3/20/1906	4/7/1970	457
8028500	Sabine Rv nr Bon Wier, TX	Stream	30.74714557	-93.608508	351	12010005	7/6/1923	6/8/2011	719
8030500	Sabine Rv nr Ruliff, TX	Stream	30.30381684	-93.7437784	351	12010005	12/12/1924	6/9/2011	704
8029500	Big Cow Ck nr Newton, TX	Stream	30.81888889	-93.7855556	351	12010005	3/9/1952	6/7/2011	522
8026000	Sabine Rv nr Burkeville, TX	Stream	31.06408004	-93.5196165	351	12010005	9/21/1955	6/7/2011	445
8031000	Cow Bayou nr Mauriceville, TX	Stream	30.18632045	-93.9085058	361	12010005	2/3/1952	6/8/2011	441
8025360	Sabine Rv at Toledo Bd Res nr Burkeville, TX	Stream	31.1737991	-93.5660077	351	12010005	7/15/1969	4/7/2011	55
8032000	Neches Rv nr Neches, TX	Stream	31.89239037	-95.430786	73	12020001	2/9/1939	6/8/2011	661
8031200	Kickapoo Ck nr Brownsboro, TX	Stream	32.3095926	-95.6055158	213	12020001	4/25/1962	1/4/1989	233
8031500	Neches Rv nr Reese, TX	Stream	32.02516337	-95.4280097	73	12020001	4/10/1924	8/8/1929	37
8031400	Lk Palestine nr Frankston, TX	Lake	32.05349518	-95.436899	1	12020001	11/1/1989	5/22/1990	8
8033000	Neches Rv nr Diboll, TX	Stream	31.13296574	-94.8099306	5	12020002	11/5/1923	10/31/2009	522
8033300	Piney Ck nr Groveton, TX	Stream	31.14046214	-95.0866021	455	12020002	10/1/1948	5/3/1988	220
8041000	Neches Rv at Evadale, TX	Stream	30.35576378	-94.0932373	241	12020003	7/16/1904	3/23/2011	754
8033500	Neches Rv nr Rockland, TX	Stream	31.025	-94.3994444	457	12020003	10/4/1923	6/8/2011	616
8040600	Neches Rv nr Town Bluff, TX	Stream	30.79103579	-94.1510237	241	12020003	10/3/1989	4/26/2011	152
8041780	Neches Rv Saltwater Barrier at Beaumont, TX	Stream	30.156878	-94.1143469	361	12020003	6/4/2003	5/25/2011	75
8041749	Pine Island Bayou abv Bl Pump Plant, Beaumont, TX	Stream	30.17882253	-94.1887943	245	12020003	10/14/2003	2/2/2011	53
8036500	Angelina Rv nr Alto, TX	Stream	31.66962144	-94.9568819	73	12020004	5/9/1940	6/7/2011	509

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8033900	E Fk Angelina Rv nr Cushing, TX	Stream	31.86017169	-94.8232697	401	12020004	1/8/1964	12/14/1988	246
8034500	Mud Ck nr Jacksonville, TX	Stream	31.97655578	-95.1607787	73	12020004	7/17/2001	5/18/2011	71
8038000	Attoyac Bayou nr Chireno, TX	Stream	31.50434957	-94.3043677	405	12020005	12/17/1923	10/31/2009	505
8039100	Ayish Bayou nr San Augustine, TX	Stream	31.39629597	-94.1510289	405	12020005	2/17/1959	7/28/2010	329
8037050	Bayou Lanana at Nacogdoches, TX	Stream	31.61629047	-94.6413205	347	12020005	12/15/1964	1/6/1994	258
8041500	Village Ck nr Kountze, TX	Stream	30.3979862	-94.2635215	199	12020006	5/16/1924	6/16/2011	704
8041550	Village Ck at SH 327 nr Silsbee, TX	Stream	30.34687575	-94.2390755	199	12020006	10/3/1978	6/9/2011	48
8041700	Pine Island Bayou nr Sour Lake, TX	Stream	30.1060464	-94.3346324	245	12020007	10/29/1967	5/24/2011	353
8041720	Pine Island Bayou at SH 105 nr Sour Lake, TX	Stream	30.13576813	-94.2790752	199	12020007	10/29/1967	10/5/2010	51
8044000	Big Sandy Ck nr Bridgeport, TX	Stream	33.23178218	-97.6947538	497	12030101	10/9/1936	5/3/2011	707
8044500	W Fk Trinity Rv nr Boyd, TX	Stream	33.08539917	-97.558636	497	12030101	1/20/1947	4/19/2011	641
8042800	W Fk Trinity Rv nr Jacksboro, TX	Stream	33.29177926	-98.0805979	237	12030101	3/1/1956	4/18/2011	519
8044800	Walnut Ck at Reno, TX	Stream	32.94568035	-97.5830798	367	12030101	4/14/1992	4/20/2011	112
8043950	Big Sandy Ck nr Chico, TX	Stream	33.27428117	-97.6786424	497	12030101	10/1/1997	8/17/2004	44
8044140	Salt Ck nr Paradise, TX	Stream	33.09845327	-97.6500279	497	12030101	12/14/1992	8/9/1995	17
8044135	Garrett Ck nr Paradise, TX	Stream	33.10511968	-97.6550282	497	12030101	12/14/1992	5/9/1995	9
8042900	Beans Ck at Wizard Wells, TX	Stream	33.1998374	-97.9672615	237	12030101	4/6/1993	5/8/1995	6
8047500	Clear Fk Trinity Rv at Ft Worth, TX	Stream	32.732353	-97.3589063	439	12030102	3/17/1924	6/13/2011	934
8049500	W Fk Trinity Rv at Grand Prairie, TX	Stream	32.7625	-96.9944444	113	12030102	3/20/1925	6/15/2011	928
8048000	W Fk Trinity Rv at Ft Worth, TX	Stream	32.76096337	-97.3325167	439	12030102	8/21/1920	3/28/2011	789
8047000	Clear Fk Trinity Rv nr Benbrook, TX	Stream	32.66513275	-97.4419642	439	12030102	7/9/1947	4/20/2011	652
8049700	Walnut Ck nr Mansfield, TX	Stream	32.5809695	-97.1019533	439	12030102	9/30/1960	6/6/2011	385
8048800	Big Fossil Ck at Haltom City, TX	Stream	32.80735146	-97.2486256	439	12030102	5/25/1957	10/18/1991	260
8050100	Mountain Ck at Grand Prairie, TX	Stream	32.74763085	-96.9258382	113	12030102	10/10/1960	5/24/2011	189
8048543	W Fk Trinity Rv at Beach St, Ft Worth, TX	Stream	32.7517972	-97.2894598	439	12030102	10/7/1976	6/6/2011	176
8048970	Village Ck at Everman, TX	Stream	32.60346909	-97.2650142	439	12030102	10/23/1989	4/19/2011	153
8049580	Mountain Ck nr Venus, TX	Stream	32.49097237	-97.1230646	251	12030102	10/22/1985	4/18/2011	118
8047050	Marys Ck at Benbrook, TX	Stream	32.6951316	-97.4472422	439	12030102	5/14/1998	4/21/2011	85
8045850	Clear Fk Trinity Rv nr Weatherford, TX	Stream	32.74040699	-97.6519711	367	12030102	5/22/1980	4/18/2010	69
8049565	Trigg Br at DFW Airport nr Euless, TX	Stream	32.86734948	-97.039175	439	12030102	10/26/1984	5/17/2004	43
8048980	Village Ck at Kennedale, TX	Stream	32.64124563	-97.2422358	439	12030102	7/21/1986	8/22/1991	35
8049240	Rush Ck at Woodland Pk Blvd, Arlington, TX	Stream	32.71402097	-97.172234	439	12030102	2/12/1993	12/6/1994	23
8049553	Big Bear Ck at Euless/Grapevine Rd nr Grapevine,TX	Stream	32.8947222	-97.0822222	439	12030102	8/27/2002	6/8/2004	20
8049569	Bear Ck at SH 183 nr Euless, TX	Stream	32.83555556	-97.0358333	439	12030102	9/19/2002	5/17/2004	18
8045550	WFk TrinityRv at White Settlement Rd,Fort Worth,TX	Stream	32.7597222	-97.4038889	439	12030102	4/17/2009	4/20/2011	16
8045995	Clear Fork Trinity Rv at Kelly Rd nr Aledo, TX	Stream	32.65305556	-97.5863889	367	12030102	7/28/2010	4/19/2011	11
8049900	Mountain Ck nr Duncanville, TX	Stream	32.66207799	-96.9825057	113	12030102	4/9/1992	8/3/1993	4
8049850	Mountain Ck abv Duncanville, TX	Stream	32.6520783	-96.9902836	113	12030102	5/26/1993	5/26/1993	1
8049566	Trigg Lk at DFW Airport nr Ft Worth, TX	Lake	32.85333333	-97.0441667	439	12030102	12/3/2002	6/8/2004	12
8055500	Elm Fk Trinity Rv nr Carrollton, TX	Stream	32.965957	-96.94445	113	12030103	12/15/1923	5/26/2011	280
8050400	Elm Fk Trinity Rv at Gainesville, TX	Stream	33.62427479	-97.1564016	97	12030103	8/29/1985	5/3/2011	199
8051500	Clear Ck nr Sanger, TX	Stream	33.3362269	-97.1794587	121	12030103	3/9/1949	4/27/2011	189
8052700	Little Elm Ck nr Aubrey, TX	Stream	33.28344977	-96.8927805	121	12030103	6/8/1956	4/28/2011	186
8053000	Elm Fk Trinity Rv nr Lewisville, TX	Stream	33.0456773	-96.9611173	121	12030103	3/7/1949	5/26/2011	174
8050800	Timber Ck nr Collinsville, TX	Stream	33.55455428	-96.9472267	97	12030103	10/21/1985	5/25/2011	166
8050840	Range Ck nr Collinsville, TX	Stream	33.52622016	-96.8072191	181	12030103	12/14/1992	5/25/2011	115
8052745	Doe Br at US Hwy 380 nr Prosper, TX	Stream	33.2192846	-96.8919475	121	12030103	10/12/2004	4/11/2011	51
8052780	Hickory Ck at Denton, TX	Stream	33.15178696	-97.1419573	121	12030103	4/23/1985	6/21/2011	49
8051130	Elm Fk Trinity Rv nr Pilot Point, TX	Stream	33.3503934	-97.0472314	121	12030103	10/23/1986	11/5/1992	45
8051135	Elm Fk Trinity Rv at Greenbelt nr Pilot Point, TX	Stream	33.3497222	-97.0355556	121	12030103	5/27/2004	6/22/2011	31
8053009	Indian Ck at FM 2281, Carrollton, TX	Stream	33.02694444	-96.9172222	121	12030103	3/8/2007	4/4/2011	30
8055560	Elm Fk Trinity Rv at Spur 348, Irving, TX	Stream	32.87333333	-96.9305556	113	12030103	5/24/2007	6/13/2011	30
8053010	Indian Ck at Hebron Pkwy, Carrollton, TX	Stream	33.0184554	-96.9244494	121	12030103	8/26/1986	1/11/1990	13
8053030	Furneaux Ck at Josey Lane, Carrollton, TX	Stream	33.00151114	-96.8863926	121	12030103	9/5/1986	1/11/1990	12
8053090	Hutton Br at Broadway, Carrollton, TX	Stream	32.9567905	-96.91056	113	12030103	9/6/1986	1/11/1990	12
8053500	Denton Ck nr Justin, TX	Stream	33.11901003	-97.2905732	121	12030104	9/30/1949	6/22/2011	193
8055000	Denton Ck nr Grapevine, TX	Stream	32.9870677	-97.0127857	121	12030104	9/30/1946	5/26/2011	136
8053800	Elizabeth Ck at SH 114 nr Roanoke, TX	Stream	33.0201234	-97.2480713	121	12030104	12/9/1997	4/22/2003	11
8057410	Trinity Rv bl Dallas, TX	Stream	32.70763139	-96.7358319	113	12030105	11/16/1956	4/18/2011	447
8057200	White Rk Ck at Greenville Ave, Dallas, TX	Stream	32.88929207	-96.7566664	113	12030105	7/18/1961	4/25/2011	297
8057445	Prairie Ck at US Hwy 175, Dallas, TX	Stream	32.70485346	-96.6699955	113	12030105	11/4/1975	5/2/2011	256
8057000	Trinity Rv at Dallas, TX	Stream	32.7748517	-96.8219464	113	12030105	4/26/1922	6/21/2011	228
8062700	Trinity Rv at Trinidad, TX	Stream	32.14765255	-96.1024708	213	12030105	2/15/1965	6/14/2011	195
8062500	Trinity Rv nr Rosser, TX	Stream	32.42652988	-96.4630415	139	12030105	7/25/1924	6/22/2011	163
8056500	Turtle Ck at Dallas, TX	Stream	32.80735055	-96.8025013	113	12030105	12/17/1951	4/25/2011	69
8057448	Trinity Rv nr Wilmer, TX	Stream	32.6176342	-96.6222148	113	12030105	12/2/1998	1/26/2011	29
8061540	Rowlett Ck nr Sachse, TX	Stream	32.95984447	-96.6144378	113	12030106	3/12/1968	4/12/2011	372
8061750	E Fk Trinity Rv nr Forney, TX	Stream	32.7742947	-96.5035991	257	12030106	1/17/1973	5/25/2011	302
8058900	E Fk Trinity Rv at McKinney, TX	Stream	33.24400417	-96.6088797	85	12030106	7/9/1975	10/1/2010	262
8062000	E Fk Trinity Rv nr Crandall, TX	Stream	32.6387442	-96.4852651	257	12030106	1/27/1949	5/3/2011	246

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8059400	Sister Grove Ck nr Blue Ridge, TX	Stream	33.29455786	-96.4830413	85	12030106	7/9/1975	5/2/2011	215
8061700	Duck Ck nr Garland, TX	Stream	32.83290425	-96.595548	113	12030106	10/7/1985	1/28/1993	64
8061551	E Fk Trinity Rv blw Lk Ray Hubbard nr Forney, TX	Stream	32.7986111	-96.4941667	257	12030106	10/7/2008	6/17/2011	35
8059350	Indian Ck at SH 78 nr Farmersville, TX	Stream	33.225	-96.3730556	85	12030106	6/14/2007	5/2/2011	29
8059000	E Fk Trinity Rv nr McKinney, TX	Stream	33.20372724	-96.595824	85	12030106	8/22/1949	4/21/2011	26
8061000	E Fk Trinity Rv nr Lavon, TX	Stream	33.02373066	-96.4755429	85	12030106	10/7/1986	10/19/1989	25
8062800	Cedar Ck nr Kemp, TX	Stream	32.50347129	-96.1127508	257	12030107	10/7/1986	6/23/2011	81
8062895	Kings Ck at SH 34 nr Kaufman, TX	Stream	32.5561111	-96.3388889	257	12030107	3/12/2009	4/29/2011	18
8062900	Kings Ck nr Kaufman, TX	Stream	32.5134711	-96.3291479	257	12030107	10/7/1986	9/15/1987	8
8063100	Richland Ck nr Dawson, TX	Stream	31.9384908	-96.6813787	349	12030108	10/19/1984	4/19/2011	193
8063500	Richland Ck nr Richland, TX	Stream	31.95071375	-96.42137	349	12030108	11/29/1984	6/20/1989	32
8063048	White Rk Ck at FM 308 nr Irene, TX	Stream	31.97805556	-96.8733333	217	12030108	10/16/2007	4/19/2011	29
8063045	Richland Ck nr Irene, TX	Stream	31.97710044	-96.8147167	349	12030108	1/31/2001	8/1/2002	3
8064100	Chambers Ck nr Rice, TX	Stream	32.1984823	-96.5202639	349	12030109	9/7/1983	4/18/2011	206
8063800	Waxahachie Ck nr Bardwell, TX	Stream	32.2434807	-96.6402676	139	12030109	10/15/1984	4/7/2011	189
8063590	Waxahachie Ck at Waxahachie, TX	Stream	32.3822222	-96.8505556	139	12030109	7/23/2008	4/18/2011	24
8063685	Waxahachie Ck nr Waxahachie, TX	Stream	32.3076451	-96.7388821	139	12030109	3/9/1999	4/24/2002	10
8064500	Chambers Ck nr Corsicana, TX	Stream	32.10820817	-96.3708135	349	12030109	2/25/1967	2/25/1967	1
8065000	Trinity Rv nr Oakwood, TX	Stream	31.64850597	-95.7894029	1	12030201	10/17/1923	5/16/2011	741
8065200	Upper Keechi Ck nr Oakwood, TX	Stream	31.56989618	-95.8882938	289	12030201	4/23/1962	5/18/2011	417
8065350	Trinity Rv nr Crockett, TX	Stream	31.33851319	-95.6563407	225	12030201	3/31/1964	5/16/2011	393
8064700	Tehuacana Ck nr Streetman, TX	Stream	31.84849638	-96.2899755	161	12030201	2/1/1968	4/19/2011	199
8064800	Catfish Ck nr Tennessee Colony, TX	Stream	31.8809985	-95.8688514	1	12030201	4/26/1962	11/15/1988	122
8066500	Trinity Rv at Romayor, TX	Stream	30.4252067	-94.8507622	291	12030202	5/3/1924	5/23/2011	792
8066200	Long King Ck at Livingston, TX	Stream	30.716306	-94.9588237	373	12030202	6/11/1962	6/24/2011	414
8066300	Menard Ck nr Rye, TX	Stream	30.48138889	-94.7797222	291	12030202	8/21/1950	6/21/2011	390
8066170	Kickapoo Ck nr Onalaska, TX	Stream	30.9071324	-95.0885468	373	12030202	12/10/1965	5/20/2011	375
8066250	Trinity Rv nr Goodrich, TX	Stream	30.57214544	-94.9488223	373	12030202	12/17/1965	5/23/2011	366
8065800	Bedias Ck nr Madisonville, TX	Stream	30.8847222	-95.7777778	471	12030202	7/9/1962	6/6/2011	347
8066100	White Rk Ck nr Trinity, TX	Stream	31.05185075	-95.3779964	455	12030202	12/5/1965	5/23/1985	178
8066400	Big Ck nr Shepherd, TX	Stream	30.5165917	-94.9852116	407	12030202	10/22/1979	11/16/1988	79
8066191	Livingston Res Outflow Weir nr Goodrich, TX	Stream	30.63214193	-95.0199355	407	12030202	8/25/1970	12/6/1988	16
8065700	Caney Ck nr Madisonville, TX	Stream	30.9368559	-95.9355084	313	12030202	2/12/1965	1/13/2011	14
8067070	CWA Canal nr Dayton, TX	Canal	29.96132898	-94.8102003	291	12030203	2/10/1981	5/16/2011	149
8067098	Devers Canal at Pump Plant nr Moss Bluff, TX	Canal	29.942718	-94.7713104	291	12030203	7/27/2010	5/24/2011	5
8067000	Trinity Rv at Liberty, TX	Stream	30.05771539	-94.8182567	291	12030203	1/8/1931	2/19/2010	286
8067239	Cotton Bayou Ups WWTP 11449 nr Cove, TX	Stream	29.8072861	-94.839	71	12030203	7/13/2006	8/29/2006	2
8067244	Hackberry Gully at FM 3180 nr Cove, TX	Stream	29.80771667	-94.8491583	71	12030203	7/12/2006	8/29/2006	2
8068000	W Fk San Jacinto Rv nr Conroe, TX	Stream	30.24465738	-95.4571616	339	12040101	5/7/1924	5/27/2011	739
8069500	W Fk San Jacinto Rv nr Humble, TX	Stream	30.02716385	-95.2579888	201	12040101	10/23/1928	7/29/1954	309
8067650	W Fk San Jacinto Rv bl Lk Conroe nr Conroe, TX	Stream	30.34215289	-95.542998	339	12040101	10/5/1972	5/27/2011	265
8068090	W Fk San Jacinto Rv abv Lk Houston nr Porter, TX	Stream	30.0860514	-95.2999348	339	12040101	2/3/1984	5/27/2011	181
8067900	Lake Ck nr Conroe, TX	Stream	30.25377778	-95.579	339	12040101	11/12/1968	10/4/2004	178
8067548	W Fk San Jacinto Rv nr Huntsville, TX	Stream	30.6460298	-95.675224	471	12040101	2/9/2009	6/6/2011	24
8067610	Lk Conroe Outflow Weir nr Conroe, TX	Stream	30.35659665	-95.5604986	339	12040101	2/26/1974	2/27/1974	5
8072000	Lk Houston nr Sheldon, TX	Lake	29.91633316	-95.1413198	201	12040101	6/24/1993	4/13/2007	19
8069000	Cypress Ck nr Westfield, TX	Stream	30.0357753	-95.428827	201	12040102	7/2/1944	6/9/2011	690
8068740	Cypress Ck at House-Hahl Rd nr Cypress, TX	Stream	29.959112	-95.7177249	201	12040102	6/10/1975	5/11/2011	300
8068720	Cypress Ck at Katy-Hockley Rd nr Hockley, TX	Stream	29.9502237	-95.8082835	201	12040102	6/10/1975	5/11/2011	265
8068800	Cypress Ck at Grant Rd nr Cypress, TX	Stream	29.97355566	-95.5985545	201	12040102	5/14/1982	6/9/2011	186
8068450	Panther Br nr Spring, TX	Stream	30.13105	-95.4813287	339	12040102	4/30/1972	5/26/2011	175
8068780	Little Cypress Ck nr Cypress, TX	Stream	30.01605437	-95.6974463	201	12040102	5/14/1982	4/14/2011	158
8068400	Panther Br at Gosling Rd, The Woodlands, TX	Stream	30.192159	-95.4838288	339	12040102	3/19/1974	5/26/2011	149
8068500	Spring Ck nr Spring, TX	Stream	30.11049517	-95.4363275	339	12040102	10/18/1994	5/18/2011	109
8068325	Willow Ck nr Tomball, TX	Stream	30.10549526	-95.5466084	201	12040102	9/7/1984	5/18/2011	108
8068900	Cypress Ck at Stuebner-Airline Rd nr Westfield, TX	Stream	30.00660994	-95.511885	201	12040102	5/15/1982	9/8/2010	94
8068390	Bear Br at Research Blvd, The Woodlands, TX	Stream	30.19055556	-95.4911111	339	12040102	10/17/1994	5/26/2011	81
8068275	Spring Ck nr Tomball, TX	Stream	30.11993899	-95.6460559	339	12040102	4/5/2000	3/18/2011	74
8068438	Swale No. 8 at Woodlands, TX	Stream	30.1441051	-95.4693839	339	12040102	12/27/1974	3/24/1988	68
8068700	Cypress Ck at Sharp Rd nr Hockley, TX	Stream	29.92105823	-95.840229	201	12040102	6/9/1975	3/25/2008	63
8070000	E Fk San Jacinto Rv nr Cleveland, TX	Stream	30.33659809	-95.1040999	291	12040103	4/26/1939	5/17/2011	711
8070500	Caney Ck nr Splendora, TX	Stream	30.25965789	-95.3024361	339	12040103	1/8/1944	6/3/2011	410
8070200	E Fk San Jacinto Rv nr New Caney, TX	Stream	30.1454932	-95.1243756	339	12040103	7/8/1952	5/25/2011	229
8071280	Luce Bayou abv Lk Houston nr Huffman, TX	Stream	30.10966019	-95.0599294	291	12040103	2/2/1984	5/25/2011	186
8071000	Peach Ck at Splendora, TX	Stream	30.2327137	-95.1682662	339	12040103	4/28/1999	6/3/2011	89
8074910	Hummingbird St Ditch at Houston, TX	Ditch	29.66245399	-95.4866088	201	12040104	1/9/1985	2/19/1985	2
8075500	Sims Bayou at Houston, TX	Stream	29.67439687	-95.2893807	201	12040104	11/7/1952	9/7/2010	524
8076500	Halls Bayou at Houston, TX	Stream	29.86189143	-95.3349365	201	12040104	11/4/1952	6/9/2011	483
8075770	Hunting Bayou at IH 610, Houston, TX	Stream	29.79328217	-95.2679907	201	12040104	4/17/1964	6/6/2011	460
8075400	Sims Bayou at Hiram Clarke St, Houston, TX	Stream	29.61884399	-95.4460522	201	12040104	8/19/1964	6/20/2011	455

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8075900	Greens Bayou nr US Hwy 75 nr Houston, TX	Stream	29.95688886	-95.4179936	201	12040104	8/12/1965	5/25/2011	383
8074150	Cole Ck at Deihl Rd, Houston, TX	Stream	29.8513369	-95.4879965	201	12040104	4/17/1964	10/22/2009	349
8074800	Keegans Bayou at Roark Rd nr Houston, TX	Stream	29.65662136	-95.5621664	201	12040104	8/18/1964	7/2/2010	334
8075730	Vince Bayou at Pasadena, TX	Stream	29.69467363	-95.216323	201	12040104	5/5/1971	6/8/2011	325
8073600	Buffalo Bayou at W Belt Dr, Houston, TX	Stream	29.76217336	-95.5577213	201	12040104	7/28/1971	5/18/2011	319
8073700	Buffalo Bayou at Piney Point, TX	Stream	29.7468959	-95.5235538	201	12040104	12/26/1912	5/18/2011	319
8072730	Bear Ck nr Barker, TX	Stream	29.8307828	-95.6868912	201	12040104	7/12/1977	5/24/2011	275
8076000	Greens Bayou nr Houston, TX	Stream	29.9182784	-95.3068796	201	12040104	10/24/1979	6/14/2011	256
8072300	Buffalo Bayou nr Katy, TX	Stream	29.74328664	-95.8068951	157	12040104	7/13/1977	5/20/2011	253
8074250	Brickhouse Gully at Costa Rica St, Houston, TX	Stream	29.82800424	-95.469385	201	12040104	9/2/1964	7/8/2010	238
8073500	Buffalo Bayou nr Addicks, TX	Stream	29.7618958	-95.6057782	201	12040104	11/7/1979	5/17/2011	218
8072760	Langham Ck at W Little York Rd nr Addicks, TX	Stream	29.86717035	-95.646612	201	12040104	7/12/1977	5/19/2011	187
8076180	Garners Bayou nr Humble, TX	Stream	29.93386089	-95.2339608	201	12040104	1/22/1919	6/9/2011	159
8074500	Whiteoak Bayou at Houston, TX	Stream	29.77522777	-95.3971612	201	12040104	11/5/1979	5/10/2011	142
8075000	Brays Bayou at Houston, TX	Stream	29.69717469	-95.412162	201	12040104	10/29/1979	5/11/2011	132
8075780	Greens Bayou at Cutten Rd nr Houston, TX	Stream	29.94911178	-95.5196633	201	12040104	10/28/1964	7/8/2010	129
8074020	Whiteoak Bayou at Alabonson Rd, Houston, TX	Stream	29.87078073	-95.4804961	201	12040104	8/7/1984	5/26/2011	114
8074810	Brays Bayou at Gessner Dr, Houston, TX	Stream	29.6727317	-95.5282765	201	12040104	4/7/1977	5/17/2011	102
8074780	Keegans Bayou at Keegan Rd nr Houston, TX	Stream	29.66551017	-95.5952228	201	12040104	10/26/1964	2/11/1985	79
8074760	Brays Bayou at Alief, TX	Stream	29.7091197	-95.583	201	12040104	2/11/1977	5/23/2011	78
8076700	Greens Bayou at Ley Rd, Houston, TX	Stream	29.8371695	-95.2332671	201	12040104	11/28/1962	7/3/2010	71
8072800	Langham Ck nr Addicks, TX	Stream	29.8357824	-95.6257783	201	12040104	6/12/1973	10/16/2000	46
8072700	S Mayde Ck nr Addicks, TX	Stream	29.80106159	-95.692447	201	12040104	6/12/1973	10/17/2000	42
8074000	Buffalo Bayou at Houston, TX	Stream	29.76022829	-95.4085505	201	12040104	1/31/1980	4/28/2009	33
8075605	Berry Bayou at Nevada St, Houston, TX	Stream	29.65661915	-95.2291011	201	12040104	5/31/2006	6/9/2011	33
8075763	Hunting Bayou at Hoffman St, Houston, TX	Stream	29.80883745	-95.3132696	201	12040104	10/16/2006	6/6/2011	33
8074540	Little Whiteoak Bayou at Trimble St, Houston, TX	Stream	29.79277778	-95.3680556	201	12040104	12/13/1979	6/10/2011	29
8074610	Buffalo Bayou at McKee St, Houston, TX	Stream	29.76606119	-95.35216	201	12040104	5/5/1993	7/12/2007	19
8074598	Whiteoak Bayou at Main St, Houston, TX	Stream	29.76661676	-95.358549	201	12040104	5/5/1993	6/21/1993	18
8072050	San Jacinto Rv nr Sheldon, TX	Stream	29.87633426	-95.0938189	201	12040104	5/19/1989	10/18/2006	12
8072600	Buffalo Bayou at State Hwy 6 nr Addicks, TX	Stream	29.76938056	-95.6431667	201	12040104	9/23/2010	5/17/2011	11
8075110	Brays Bayou at MLK Jr Blvd, Houston, TX	Stream	29.71416667	-95.3388889	201	12040104	10/16/2006	9/21/2010	10
8076900	Carpenters Bayou nr Channelview, TX	Stream	29.77272687	-95.1560434	201	12040104	6/4/1986	6/3/1994	5
8075650	Berry Bayou at Forest Oaks St, Houston, TX	Stream	29.67661875	-95.2438238	201	12040104	6/22/1993	10/15/1994	4
8072350	Buffalo Bayou nr Fulshear, TX	Stream	29.7230092	-95.7671718	157	12040104	3/24/1986	3/24/1986	1
8076005	Greens Bayou Trib at Smith Rd nr Houston, TX	Stream	29.93055556	-95.2875	201	12040104	8/9/2004	8/9/2004	1
8042000	Taylor Bayou nr LaBelle, TX	Stream	29.875	-94.1594444	245	12040201	2/2/1952	2/1/1983	156
8042500	Hillebrandt Bayou nr Lovell Lake, TX	Stream	29.92888889	-94.1097222	245	12040201	2/2/1952	2/1/1983	138
8042534	Keith Lk Fish Pass nr Sabine Pass, TX	Estuary	29.77521665	-93.941835	245	12040201	3/21/1985	4/26/2007	8
8042532	Mouth of Salt Bayou nr Sabine Pass, TX	Estuary	29.79160483	-94.0098939	245	12040201	4/25/2006	4/26/2007	6
8042537	Sabine Pass nr Sabine Pass, TX	Estuary	29.71022007	-93.8529423	245	12040201	6/5/2006	4/26/2007	3
8042550	W Fk Double Bayou nr Anahuac, TX	Stream	29.76101667	-94.6334444	71	12040202	8/3/2006	8/3/2006	1
8042554	W Fk Double Bayou at FM 2936 nr Anahuac, TX	Stream	29.7306111	-94.6602944	71	12040202	8/3/2006	8/3/2006	1
8067500	Cedar Bayou nr Crosby, TX	Stream	29.97271914	-94.9857602	291	12040203	3/28/1946	5/24/2011	308
8067525	Goose Ck at Baytown, TX	Stream	29.77078197	-94.9996503	201	12040203	2/11/1985	5/27/2011	50
8067510	Cedar Bayou nr Baytown, TX	Stream	29.77022506	-94.9165921	201	12040203	10/17/1994	10/20/1994	4
8078000	Chocolate Bayou nr Alvin, TX	Stream	29.37154349	-95.3230476	39	12040204	8/19/1944	6/13/2011	649
8077000	Clear Ck nr Pearland, TX	Stream	29.59745458	-95.2866029	39	12040204	10/29/1979	2/22/1994	117
8076997	Clear Ck at Mykawa St nr Pearland, TX	Stream	29.5968991	-95.2974366	201	12040204	10/16/2006	4/21/2011	28
8077600	Clear Ck nr Friendswood, TX	Stream	29.51745517	-95.178544	167	12040204	7/27/1979	7/3/2010	16
8077540	Clear Ck at Friendswood, TX	Stream	29.54217714	-95.196878	201	12040204	5/19/1994	10/21/1994	4
8077647	Dickinson Bayou at SH 3, Dickinson, TX	Stream	29.45662094	-95.0479838	167	12040204	8/22/1995	1/29/1997	4
8077720	Marchand Bayou at FM 519, Hitchcock, TX	Stream	29.35777778	-95.0036111	167	12040204	7/10/2006	8/31/2006	2
8077725	Highland Bayou at Fairwood Rd, La Marque, TX	Stream	29.35194444	-94.9930583	167	12040204	7/11/2006	7/11/2006	1
8077780	Highland Bayou nr Texas City, TX	Stream	29.3322222	-94.945	167	12040204	7/10/2006	7/10/2006	1
8077700	Highland Bayou at Hitchcock, TX	Estuary	29.3536111	-95.0302806	167	12040204	8/2/2006	8/2/2006	1
8079575	N Fk DMF Brazos Rv nr Post, TX	Stream	33.24870448	-101.3384715	169	12050003	10/6/1987	10/19/1993	45
8080500	DMF Brazos Rv nr Aspermont, TX	Stream	33.0081577	-100.1806589	433	12050004	12/3/1922	5/10/2011	1242
8079600	DMF Brazos Rv at Justiceburg, TX	Stream	33.03843236	-101.1976302	169	12050004	11/30/1961	5/9/2011	315
8080700	Running Water Draw at Plainview, TX	Stream	34.17896048	-101.7026748	189	12050005	5/24/1937	6/17/2011	365
8080900	White Rv bl falls nr Crosbyton, TX	Stream	33.665918	-101.1601469	107	12050006	7/4/2010	7/4/2010	1
8082000	Salt Fk Brazos Rv nr Aspermont, TX	Stream	33.3339801	-100.2381622	433	12050007	4/27/1925	5/10/2011	317
8080950	Duck Ck nr Girard, TX	Stream	33.35620109	-100.705121	263	12050007	10/14/1987	10/10/1989	18
8080918	Red Mud Ck nr Spur, TX	Stream	33.32430833	-100.9251194	263	12050007	10/15/2006	4/17/2009	4
8082500	Brazos Rv at Seymour, TX	Stream	33.58092766	-99.2675756	23	12060101	11/30/1923	5/9/2011	1337
8082700	Millers Ck nr Munday, TX	Stream	33.32926607	-99.4650825	447	12060101	10/10/1962	5/9/2011	250
8082890	Brazos Rv nr Elbert, TX	Stream	33.27166667	-98.9302778	503	12060101	8/18/2005	8/18/2005	1
8082960	Brazos Rv nr Newcastle, TX	Stream	33.1761111	-98.7555556	503	12060101	8/18/2005	8/18/2005	1
8083100	Clear Fk Brazos Rv nr Roby, TX	Stream	32.78760777	-100.3887183	151	12060102	5/13/1965	5/4/2011	310
8084100	Deadman Ck nr Nugent, TX	Stream	32.67678588	-99.617031	253	12060102	10/3/1967	6/22/2011	284

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8084000	Clear Fk Brazos Rv at Nugent, TX	Stream	32.6901186	-99.6695326	253	12060102	5/27/1924	6/22/2011	233
8083420	Cat Claw Ck at Abilene, TX	Stream	32.47540219	-99.7492556	441	12060102	10/6/1970	4/11/2011	200
8083470	Cedar Ck at Abilene, TX	Stream	32.4490142	-99.7206435	441	12060102	10/1/1970	5/12/1982	132
8083480	Cedar Ck at IH 20, Abilene, TX	Stream	32.49956829	-99.7161995	441	12060102	5/27/1993	5/4/2011	130
8083230	Clear Fk Brazos Rv nr Noodle, TX	Stream	32.67455998	-100.0725999	253	12060102	8/16/2001	5/4/2011	88
8083240	Clear Fk Brazos Rv at Hawley, TX	Stream	32.59817587	-99.8150919	253	12060102	10/13/1987	10/3/1989	15
8084200	Clear Fk Brazos Rv at Lueders, TX	Stream	32.79275	-99.6120278	253	12060102	9/30/2010	6/16/2011	12
8083245	Mulberry Ck nr Hawley, TX	Stream	32.5678991	-99.7925909	253	12060102	10/13/1987	6/29/1989	11
8084300	Clear Fk Brazos Rv at Krooked Lodge nr Lueders, TX	Stream	32.98138333	-99.467475	447	12060102	1/19/2011	6/16/2011	5
8084800	California Ck nr Stamford, TX	Stream	32.93094435	-99.642588	253	12060103	5/6/1969	6/9/2011	312
8085500	Clear Fk Brazos Rv at Ft Griffin, TX	Stream	32.9345557	-99.2245215	417	12060104	7/1/1932	6/21/2011	233
8086212	Hubbard Ck bl Albany, TX	Stream	32.73289717	-99.1406299	417	12060105	10/18/1966	6/2/2011	365
8086290	Big Sandy Ck abv Breckenridge, TX	Stream	32.64845613	-99.0045146	429	12060105	6/12/1962	6/2/2011	230
8086050	Deep Ck at Moran, TX	Stream	32.55929085	-99.170074	417	12060105	10/30/1962	6/1/2011	206
8086150	N Fk Hubbard Ck nr Albany, TX	Stream	32.7076192	-99.2750778	417	12060105	10/15/1987	10/3/1990	23
8088000	Brazos Rv nr South Bend, TX	Stream	33.02428377	-98.6439481	503	12060201	10/2/1985	6/14/2011	241
8090800	Brazos Rv nr Dennis, TX	Stream	32.61568907	-97.9258703	367	12060201	4/26/1968	5/10/2011	235
8089000	Brazos Rv nr Palo Pinto, TX	Stream	32.8626236	-98.3025492	363	12060201	5/18/1935	5/9/2011	198
8088610	Brazos Rv nr Graford, TX	Stream	32.85817854	-98.411719	363	12060201	2/28/1995	5/9/2011	154
8088600	Brazos Rv at Morris Sheppard Dam nr Graford, TX	Stream	32.87206697	-98.425886	363	12060201	9/27/1989	2/3/1995	56
8088450	Big Cedar Ck nr Ivan, TX	Stream	32.8276216	-98.7239509	429	12060201	10/2/1985	10/24/1989	33
8088300	Briar Ck nr Graham, TX	Stream	33.21205664	-98.6186695	503	12060201	6/5/1986	9/19/1989	13
8096500	Brazos Rv at Waco, TX	Stream	31.53600056	-97.0733325	309	12060202	1898-09-14	5/25/2011	1308
8093500	Aquilla Ck nr Aquilla, TX	Stream	31.84460414	-97.2013961	217	12060202	9/11/1967	1/11/2005	278
8091000	Brazos Rv nr Glen Rose, TX	Stream	32.25903188	-97.7025268	425	12060202	10/4/1923	5/11/2011	195
8093100	Brazos Rv nr Aquilla, TX	Stream	31.8123822	-97.2977882	35	12060202	5/19/1939	4/28/2011	178
8091750	Squaw Ck nr Glen Rose, TX	Stream	32.2701423	-97.7325278	425	12060202	10/28/1985	10/18/2010	156
8093360	Aquilla Ck abv Aquilla, TX	Stream	31.8954362	-97.2030634	217	12060202	9/26/1979	5/4/2011	151
8091500	Paluxy Rv at Glen Rose, TX	Stream	32.23153166	-97.7772512	425	12060202	10/27/1923	5/11/2011	132
8092000	Nolan Rv at Blum, TX	Stream	32.15070534	-97.402794	217	12060202	7/30/1924	4/13/2011	74
8093260	Hackberry Ck bl Hillsboro, TX	Stream	31.9954336	-97.1441733	217	12060202	10/3/1984	9/6/2005	62
8093250	Hackberry Ck at Hillsboro, TX	Stream	32.00571108	-97.1500069	217	12060202	10/25/1984	6/17/1992	49
8093160	Aquilla Ck nr Peoria, TX	Stream	31.9779342	-97.2458436	217	12060202	10/25/1984	8/8/2005	33
8095300	Middle Bosque Rv nr McGregor, TX	Stream	31.50933179	-97.365845	309	12060203	8/19/1959	6/13/2011	298
8095400	Hog Ck nr Crawford, TX	Stream	31.5557199	-97.3564004	309	12060203	8/19/1959	5/11/2011	246
8095600	Bosque Rv nr Waco, TX	Stream	31.60127597	-97.1936165	309	12060203	2/11/1998	5/29/2008	15
8095000	N Bosque Rv nr Clifton, TX	Stream	31.785991	-97.5680748	35	12060204	12/16/1923	5/24/2011	931
8095200	N Bosque Rv at Valley Mills, TX	Stream	31.66960575	-97.4694602	35	12060204	8/18/1959	5/11/2011	527
8094800	N Bosque Rv at Hico, TX	Stream	31.9765366	-98.032812	193	12060204	9/26/1961	10/18/2010	195
8109000	Brazos Rv nr Bryan, TX	Stream	30.61408925	-96.4866328	41	12070101	9/11/1925	8/24/1993	764
8098290	Brazos Rv nr Highbank, TX	Stream	31.13407098	-96.8249826	145	12070101	10/15/1965	5/26/2011	391
8111500	Brazos Rv nr Hempstead, TX	Stream	30.12910626	-96.1877387	477	12070101	12/15/1938	4/13/2011	268
8098300	Little Pond Ck nr Burlington, TX	Stream	31.02657314	-96.9883214	331	12070101	10/11/1962	5/19/2011	196
8110200	Brazos Rv at Washington, TX	Stream	30.36131908	-96.1552366	477	12070101	5/13/1958	10/11/1983	182
8108700	Brazos Rv at SH 21 nr Bryan, TX	Stream	30.6268665	-96.544135	51	12070101	6/16/1992	5/31/2011	138
8108500	Brazos Rv at Valley Junction, TX	Stream	30.82741387	-96.6516392	395	12070101	3/7/2006	8/15/2006	2
8108990	Little Brazos Rv at SH 21 nr Bryan, TX	Stream	30.64103268	-96.5213563	51	12070101	3/10/2006	8/15/2006	2
8109500	Brazos Rv nr College Station, TX	Stream	30.5427027	-96.4227424	41	12070101	3/10/2006	8/16/2006	2
8097500	Brazos Rv nr Marlin, TX	Stream	31.28850993	-96.969713	145	12070101	3/9/2006	3/9/2006	1
8110000	Yegua Ck nr Somerville, TX	Stream	30.3218773	-96.5074683	51	12070102	6/30/1924	6/20/2011	726
8110100	Davidson Ck nr Lyons, TX	Stream	30.41965196	-96.5402466	51	12070102	8/28/1962	6/1/2011	436
8109800	E Yegua Ck nr Dime Box, TX	Stream	30.40743105	-96.8174791	51	12070102	8/30/1962	6/20/2011	434
8109700	Middle Yegua Ck nr Dime Box, TX	Stream	30.33937764	-96.9047037	287	12070102	8/1/1962	5/31/2011	392
8110500	Navasota Rv nr Easterly, TX	Stream	31.17018205	-96.297743	289	12070103	3/20/1924	5/25/2011	843
8111000	Navasota Rv nr Bryan, TX	Stream	30.8696352	-96.1924592	41	12070103	1/18/1951	12/5/1996	451
8110430	Big Ck nr Freestone, TX	Stream	31.5068396	-96.3246953	293	12070103	7/24/1975	5/25/2011	291
8110325	Navasota Rv abv Groesbeck, TX	Stream	31.57433657	-96.520814	293	12070103	7/24/1975	5/25/2011	208
8110800	Navasota Rv at Old Spanish Rd nr Bryan, TX	Stream	30.9737987	-96.2416274	395	12070103	8/20/1996	6/1/2011	127
8115000	Big Ck nr Needville, TX	Stream	29.47662987	-95.8127292	157	12070104	5/21/1947	6/7/2011	631
8111700	Mill Ck nr Bellville, TX	Stream	29.88106145	-96.2052402	15	12070104	8/22/1948	5/25/2011	381
8116650	Brazos Rv nr Rosharon, TX	Stream	29.3496858	-95.5824448	157	12070104	3/20/1967	6/22/2011	336
8114000	Brazos Rv at Richmond, TX	Stream	29.5824589	-95.7577275	157	12070104	5/28/1975	4/27/2011	238
8111600	Piney Ck nr Bellville, TX	Stream	29.95189163	-96.1724614	15	12070104	10/8/1957	7/28/1989	79
8111650	W Fk Mill Ck nr Industry, TX	Stream	29.9821677	-96.5002483	15	12070104	12/20/1967	6/30/1988	41
8116400	Dry Ck nr Rosenberg, TX	Stream	29.51190593	-95.7468942	157	12070104	12/12/2007	6/7/2011	25
8114500	Brazos Rv nr Juliff, TX	Stream	29.45551617	-95.5329996	157	12070104	6/19/1998	9/28/1999	5
8102500	Leon Rv nr Belton, TX	Stream	31.07017947	-97.4413967	27	12070201	10/5/1923	6/22/2011	700
8100500	Leon Rv at Gatesville, TX	Stream	31.4329422	-97.761967	99	12070201	9/27/1950	5/24/2011	599
8100000	Leon Rv nr Hamilton, TX	Stream	31.78876325	-98.1214238	193	12070201	1/8/1925	5/24/2011	424
8099100	Leon Rv nr De Leon, TX	Stream	32.1737502	-98.5331058	93	12070201	8/30/1960	6/1/2011	330

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8099500	Leon Rv nr Hasse, TX	Stream	31.9579235	-98.4592116	93	12070201	1/10/1939	6/2/2011	243
8099300	Sabana Rv nr De Leon, TX	Stream	32.11402957	-98.6056067	93	12070201	1/5/1988	6/2/2011	154
8101000	Cowhouse Ck at Pidcoke, TX	Stream	31.2848902	-97.8850244	99	12070202	9/26/1950	6/21/2011	593
8103800	Lampasas Rv nr Kempner, TX	Stream	31.0818402	-98.0166919	281	12070203	10/2/1962	6/21/2011	441
8104100	Lampasas Rv nr Belton, TX	Stream	31.0018485	-97.4925088	27	12070203	5/13/1957	6/22/2011	372
8103900	S Fk Rocky Ck nr Briggs, TX	Stream	30.91156805	-98.0369676	53	12070203	4/15/1963	6/21/2011	220
8104950	S Fk San Gabriel Rv Ups fr SH 418, Georgetown, TX	Stream	30.64408256	-97.6808425	491	12070203	7/31/1984	9/22/2004	113
8104310	Salado Ck bl Salado Spgs at Salado, TX	Stream	30.9521278	-97.5241757	27	12070203	10/8/1985	8/13/1996	66
8104290	Salado Ck abv Salado, TX	Stream	30.9451834	-97.541954	27	12070203	3/26/1986	8/13/1996	61
8106500	Little Rv nr Cameron, TX	Stream	30.83519047	-96.9466512	331	12070204	11/2/1916	6/23/2011	950
8104500	Little Rv nr Little River, TX	Stream	30.9665723	-97.346113	27	12070204	10/6/1923	6/20/2011	544
8106350	Little Rv nr Rockdale, TX	Stream	30.76074836	-97.0138754	331	12070204	3/18/1981	6/23/2011	130
8108200	N Elm Ck nr Cameron, TX	Stream	30.93129814	-97.020544	331	12070204	10/10/1962	1/3/1973	76
8108250	Big Elm Ck at SH 77 nr Cameron, TX	Stream	30.90324377	-96.9791531	331	12070204	6/8/2007	1/10/2011	21
8107950	N Elm Ck at Rosebud Rd nr Meeks, TX	Stream	31.01306944	-97.1100833	27	12070204	9/9/2010	6/22/2011	7
8105000	San Gabriel Rv at Georgetown, TX	Stream	30.6540824	-97.6552863	491	12070205	9/10/1921	9/22/2004	544
8104900	S Fk San Gabriel Rv at Georgetown, TX	Stream	30.6257499	-97.6911204	491	12070205	12/5/1967	6/13/2011	414
8105700	San Gabriel Rv at Laneport, TX	Stream	30.69436146	-97.2788849	491	12070205	7/15/1965	5/19/2011	398
8104700	N Fk San Gabriel Rv nr Georgetown, TX	Stream	30.6618592	-97.7113993	491	12070205	6/20/1968	5/18/2011	376
8105100	Berry Ck nr Georgetown, TX	Stream	30.69130304	-97.6561202	491	12070205	7/20/1967	10/2/2003	339
8105300	San Gabriel Rv nr Weir, TX	Stream	30.646028	-97.585284	491	12070205	12/3/1976	9/23/2004	199
8105095	Berry Ck at Airport Rd nr Georgetown, TX	Stream	30.70324685	-97.6663985	491	12070205	11/16/1984	5/17/2011	153
8106310	San Gabriel Rv nr Rockdale, TX	Stream	30.7276942	-97.0388761	331	12070205	5/13/1980	10/29/1992	139
8105200	Berry Ck at SH 971 nr Georgetown, TX	Stream	30.67602639	-97.614452	491	12070205	11/3/1964	9/22/2004	126
8104795	N Fk San Gabriel Rv Ups fr SH 418, Georgetown, TX	Stream	30.64574916	-97.6805648	491	12070205	7/31/1984	9/22/2004	115
8105160	Dry Berry Ck nr Georgetown, TX	Stream	30.68463687	-97.6375084	491	12070205	3/25/1986	9/22/2004	73
8105505	Willis Ck nr Granger, TX	Stream	30.70216667	-97.4341667	491	12070205	5/15/2008	5/19/2011	34
810464660	N Fk San Gabriel Rv at Reagan Blvd nr Leander, TX	Stream	30.69775	-97.8492222	491	12070205	8/21/2008	5/18/2011	23
8105886	Lake Ck at Lake Ck Pkwy nr Austin, TX	Stream	30.46555556	-97.7878889	491	12070205	6/15/2010	6/22/2011	10
8120500	Deep Ck nr Dunn, TX	Stream	32.57372368	-100.9078941	415	12080002	4/2/1953	5/12/2011	497
8121000	Colorado Rv at Colorado City, TX	Stream	32.39261865	-100.8787246	335	12080002	5/16/1980	5/12/2011	212
8117995	Colorado Rv nr Gail, TX	Stream	32.6287208	-101.2854044	33	12080002	3/1/1988	5/12/2011	140
8120700	Colorado Rv nr Cuthbert, TX	Stream	32.47733745	-100.9498382	335	12080002	5/10/1965	10/7/2002	135
8119500	Colorado Rv nr Ira, TX	Stream	32.53844624	-101.0537304	415	12080002	10/5/1987	7/24/1989	14
8123800	Beals Ck nr Westbrook, TX	Stream	32.1992913	-101.0140029	335	12080007	10/3/1958	6/1/2011	587
8123720	Beals Ck nr Coahoma, TX	Stream	32.2490097	-101.3620666	227	12080007	10/5/1987	2/26/1988	4
8123850	Colorado Rv abv Silver, TX	Stream	32.05374399	-100.762052	81	12080008	5/17/1980	6/1/2011	176
8124000	Colorado Rv at Robert Lee, TX	Stream	31.88542168	-100.4806543	81	12080008	8/19/1953	3/17/2011	169
8126380	Colorado Rv nr Ballinger, TX	Stream	31.71542973	-100.0264755	399	12090101	10/1/1979	5/31/2011	263
8127000	Elm Ck at Ballinger, TX	Stream	31.74931697	-99.9478636	399	12090101	5/1/1956	6/6/2011	164
8130500	Dove Ck at Knickerbocker, TX	Stream	31.27405465	-100.6309318	451	12090102	9/30/1960	10/6/2010	386
8129300	Spring Ck abv Tankersley, TX	Stream	31.33016396	-100.6403767	451	12090102	9/30/1960	2/9/2011	275
8128000	S Concho Rv at Christoval, TX	Stream	31.18711186	-100.5020388	451	12090102	2/27/1930	5/17/2011	254
8131400	Pecan Ck nr San Angelo, TX	Stream	31.30905356	-100.4459254	451	12090102	9/15/1936	5/16/2011	188
8130700	Spring Ck abv Twin Buttes Res nr San Angelo, TX	Stream	31.3309973	-100.600931	451	12090102	9/25/2001	5/17/2011	69
8131190	S Concho Rv abv Gardner Dam nr San Angelo, TX	Stream	31.2829432	-100.5078722	451	12090102	10/12/1999	10/2/2006	26
8128400	Middle Concho Rv abv Tankersley, TX	Stream	31.42738264	-100.7112125	235	12090103	3/17/1961	5/19/2011	408
8128100	Middle Concho Rv nr Barnhart, TX	Stream	31.4270971	-101.0970544	235	12090103	9/10/1986	8/29/1996	4
8133500	N Concho Rv at Sterling City, TX	Stream	31.83013918	-100.9937215	431	12090104	9/21/1939	5/12/2011	614
8134000	N Concho Rv nr Carlsbad, TX	Stream	31.5926549	-100.6370449	451	12090104	3/27/1924	5/18/2011	375
8134250	N Concho Rv nr Grape Creek, TX	Stream	31.54265769	-100.5550977	451	12090104	2/14/2000	5/18/2011	117
8134230	Grape Ck nr Grape Creek, TX	Stream	31.57515616	-100.5856544	451	12090104	9/5/2001	6/8/2011	110
8133900	Chalk Ck nr Water Valley, TX	Stream	31.64654097	-100.6906581	451	12090104	9/5/2001	5/18/2011	106
8133250	N Concho Rv abv Sterling City, TX	Stream	31.8973574	-101.105113	431	12090104	3/25/2000	5/12/2011	90
8135000	N Concho Rv at San Angelo, TX	Stream	31.46599438	-100.4478712	451	12090104	11/3/1987	8/20/1990	21
8136000	Concho Rv at San Angelo, TX	Stream	31.454606	-100.4106474	451	12090105	9/17/1936	5/16/2011	193
8136500	Concho Rv at Paint Rock, TX	Stream	31.5159908	-99.9195226	95	12090105	9/17/1936	6/6/2011	161
8136150	Concho Rv nr Veribest, TX	Stream	31.5376603	-100.2195303	451	12090105	10/7/1999	10/16/2000	8
8138000	Colorado Rv at Winchell, TX	Stream	31.46793807	-99.1622726	49	12090106	10/15/1930	6/8/2011	172
8136700	Colorado Rv nr Stacy, TX	Stream	31.49376898	-99.5739532	83	12090106	5/10/1968	6/7/2011	156
8143600	Pecan Bayou nr Mullin, TX	Stream	31.5173861	-98.740603	333	12090107	4/17/1984	6/7/2011	201
8143700	Browns Ck Trib nr Goldthwaite, TX	Stream	31.51690833	-98.5668083	333	12090107	7/25/2007	4/21/2010	11
8141500	Hords Ck nr Valera, TX	Stream	31.83431205	-99.5347911	83	12090108	11/4/1987	10/4/1990	16
8142000	Hords Ck nr Coleman, TX	Stream	31.84736747	-99.4239535	83	12090108	3/29/1989	11/18/1992	5
8146000	San Saba Rv at San Saba, TX	Stream	31.21322316	-98.7194871	411	12090109	5/21/1967	6/8/2011	166
8144500	San Saba Rv at Menard, TX	Stream	30.91906245	-99.7856254	327	12090109	7/23/1938	6/6/2011	150
8144600	San Saba Rv nr Brady, TX	Stream	31.0040595	-99.2689437	307	12090109	9/8/1980	6/1/2011	135
8143950	Clear Ck nr Menard, TX	Stream	30.90378433	-99.9245183	327	12090109	1/24/1984	6/3/2011	97
8145000	Brady Ck at Brady, TX	Stream	31.13822366	-99.3350553	307	12090110	10/6/1930	6/1/2011	109
8152000	Sandy Ck nr Kingsland, TX	Stream	30.557689	-98.4722511	299	12090201	9/15/1936	5/31/2011	381

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8147000	Colorado Rv nr San Saba, TX	Stream	31.21794515	-98.564484	281	12090201	9/11/1952	6/2/2011	177
8148500	N Llano Rv nr Junction, TX	Stream	30.5174101	-99.806179	267	12090202	9/30/1915	6/15/2011	710
8149400	S Llano Rv nr Telegraph, TX	Stream	30.26316667	-99.9335	137	12090203	1/26/1959	6/2/2011	189
8151500	Llano Rv at Llano, TX	Stream	30.7512899	-98.6697599	299	12090204	5/16/1939	6/10/2011	984
8150700	Llano Rv nr Mason, TX	Stream	30.66073685	-99.1092185	319	12090204	1/19/1968	6/1/2011	371
8150800	Beaver Ck nr Mason, TX	Stream	30.64351548	-99.0958848	319	12090204	9/23/1964	6/1/2011	223
8150000	Llano Rv nr Junction, TX	Stream	30.50435487	-99.7345097	267	12090204	6/14/1935	6/2/2011	162
8158000	Colorado Rv at Austin, TX	Stream	30.24465429	-97.694448	453	12090205	1897-12-21	6/14/2011	1781
8158600	Walnut Ck at Webberville Rd, Austin, TX	Stream	30.2832642	-97.655003	453	12090205	6/1/1966	6/22/2011	481
8158700	Onion Ck nr Driftwood, TX	Stream	30.08298924	-98.0077859	209	12090205	11/7/1961	5/9/2011	381
8159000	Onion Ck at US Hwy 183, Austin, TX	Stream	30.17798987	-97.6886138	453	12090205	5/16/1924	6/22/2011	362
8156800	Shoal Ck at W 12th St, Austin, TX	Stream	30.27659704	-97.7502834	453	12090205	11/23/1974	6/8/2011	281
8155400	Barton Ck abv Barton Spgs at Austin, TX	Stream	30.26354168	-97.772228	453	12090205	10/2/1958	6/8/2011	278
8155200	Barton Ck at SH 71 nr Oak Hill, TX	Stream	30.29631587	-97.925565	453	12090205	11/6/1975	5/10/2011	257
8158810	Bear Ck bl FM 1826 nr Driftwood, TX	Stream	30.15548749	-97.9400076	209	12090205	3/1/1978	5/9/2011	249
8158840	Slaughter Ck at FM 1826 nr Austin, TX	Stream	30.2090972	-97.9033409	453	12090205	2/10/1978	5/9/2011	233
8154700	Bull Ck at Loop 360 nr Austin, TX	Stream	30.37214825	-97.7847301	453	12090205	4/6/1976	5/11/2011	225
8155300	Barton Ck at Loop 360, Austin, TX	Stream	30.24465306	-97.8022283	453	12090205	6/10/1975	5/10/2011	202
8158920	Williamson Ck at Oak Hill, TX	Stream	30.23520806	-97.8602848	453	12090205	1/11/1974	6/22/2011	200
8155240	Barton Ck at Lost Ck Blvd nr Austin, TX	Stream	30.2740957	-97.8447296	453	12090205	1/30/1979	5/11/2011	184
8158050	Boggy Ck at US Hwy 183, Austin, TX	Stream	30.26326487	-97.6725032	453	12090205	1/16/1975	11/14/2001	170
8158930	Williamson Ck at Manchaca Rd, Austin, TX	Stream	30.22132064	-97.7936168	453	12090205	5/23/1975	5/10/2011	162
8158800	Onion Ck at Buda, TX	Stream	30.0860467	-97.8480606	209	12090205	11/7/1961	6/29/1995	120
8158860	Slaughter Ck at FM 2304 nr Austin, TX	Stream	30.1621554	-97.8322279	453	12090205	1/11/1979	6/22/2011	100
8158827	Onion Ck at Twin Creeks Rd nr Manchaca, TX	Stream	30.12632345	-97.8211161	453	12090205	4/2/2003	5/10/2011	79
8158819	Bear Ck nr Brodie Lane nr Manchaca, TX	Stream	30.14416667	-97.8611111	453	12090205	7/1/2002	10/5/2010	74
8158970	Williamson Ck at Jimmy Clay Rd, Austin, TX	Stream	30.189378	-97.732504	453	12090205	11/27/1974	6/9/2011	69
8158200	Walnut Ck at Dessau Rd, Austin, TX	Stream	30.375205	-97.6605601	453	12090205	5/8/1975	6/9/2011	66
8158922	Williamson Ck at Brush Cntry Blvd, Oak Hill, TX	Stream	30.22631976	-97.8413955	453	12090205	5/18/1992	10/2/2003	55
8157500	Waller Ck at 23rd St, Austin, TX	Stream	30.28576347	-97.7338942	453	12090205	2/3/1955	10/11/1973	53
8158380	Little Walnut Ck at Georgian Dr, Austin, TX	Stream	30.35437215	-97.6980609	453	12090205	5/21/1983	6/22/2011	53
8157600	E Bouldin Ck at S 1st St, Austin, TX	Stream	30.2521535	-97.754172	453	12090205	4/2/1997	6/20/2007	43
8155260	Barton Ck nr Camp Craft Rd nr Austin, TX	Stream	30.2702072	-97.8288959	453	12090205	12/30/1982	8/23/1988	42
8157700	Blunn Ck nr Little Stacy Pk, Austin, TX	Stream	30.24743158	-97.7438939	453	12090205	5/16/1997	9/7/2010	42
8158045	Ft Br Boggy Ck at Manor Rd, Austin, TX	Stream	30.30055556	-97.6855556	453	12090205	9/7/2007	6/9/2011	37
8156675	Shoal Ck at Silverway Dr, Austin, TX	Stream	30.35416667	-97.7388889	453	12090205	7/11/2007	6/8/2011	34
8156910	Waller Ck at Koenig Lane, Austin, TX	Stream	30.32277778	-97.7227778	453	12090205	7/17/2007	6/8/2011	34
8158030	Boggy Ck at Manor Rd, Austin, TX	Stream	30.2861111	-97.7086111	453	12090205	8/2/2007	6/9/2011	34
8158927	Kincheon Br at William Cannon Blvd, Austin, TX	Stream	30.2124722	-97.8288611	453	12090205	9/14/2007	6/7/2011	34
8155541	W Bouldin Ck at Oltorf Rd, Austin, TX	Stream	30.24666667	-97.7691667	453	12090205	7/20/2007	6/22/2011	33
8157000	Waller Ck at 38th St, Austin, TX	Stream	30.29715196	-97.7269497	453	12090205	2/8/1956	6/16/1972	30
8158035	Boggy Ck at Webberville Rd, Austin, TX	Stream	30.26305556	-97.7125	453	12090205	8/2/2007	6/9/2011	20
8158100	Walnut Ck at FM 1325 nr Austin, TX	Stream	30.40992537	-97.7116733	453	12090205	1/22/1980	12/17/1981	17
8158825	Little Bear Ck at FM 1626 nr Manchaca, TX	Stream	30.1254896	-97.862228	209	12090205	11/6/1978	3/21/1983	15
8158400	Little Walnut Ck at IH 35, Austin, TX	Stream	30.3493724	-97.6930607	453	12090205	11/23/1974	8/16/2007	11
8158824	Little Bear Ck at Stoneledge Quarry nr Manchaca,TX	Stream	30.12583333	-97.9038889	209	12090205	6/10/2004	11/17/2004	10
8158820	Bear Ck at FM 1626 nr Manchaca, TX	Stream	30.14048928	-97.8475057	453	12090205	3/20/1979	3/29/1983	9
8158806	Bear Ck at FM 1826 nr Driftwood, TX	Stream	30.1596538	-97.9552857	209	12090205	3/16/1993	4/5/1995	6
8154510	Colorado Rv bl Mansfield Dam, Austin, TX	Stream	30.39186795	-97.9080665	453	12090205	6/22/1987	6/22/1987	1
8158880	Boggy Ck (S) at Circle S Rd, Austin, TX	Stream	30.1807666	-97.7822272	453	12090205	5/14/1986	5/14/1986	1
8153500	Pedernales Rv nr Johnson City, TX	Stream	30.29186695	-98.3994674	31	12090206	5/4/1939	5/5/2011	598
8152900	Pedernales Rv nr Fredericksburg, TX	Stream	30.22048147	-98.8697609	171	12090206	6/1/1979	5/26/2011	255
8159200	Colorado Rv at Bastrop, TX	Stream	30.10466154	-97.3194368	21	12090301	4/8/1930	6/15/2011	471
8160800	Redgate Ck nr Columbus, TX	Stream	29.79911967	-96.5321933	89	12090301	2/1/1962	4/7/2011	411
8161000	Colorado Rv at Columbus, TX	Stream	29.7063454	-96.5369155	89	12090301	10/12/1979	5/25/2011	251
8160400	Colorado Rv abv La Grange, TX	Stream	29.9124474	-96.9038699	149	12090301	1/18/1980	6/16/2011	243
8159500	Colorado Rv at Smithville, TX	Stream	30.01272074	-97.1619321	21	12090301	5/20/1935	6/21/2011	167
8159150	Wilbarger Ck nr Pflugerville, TX	Stream	30.4546469	-97.6008373	453	12090301	8/9/1963	9/15/1965	41
8160700	Colorado Rv abv Columbus, TX	Stream	29.71940036	-96.5713609	89	12090301	11/27/1984	9/9/1985	9
8159750	Dry Ck at Buescher State Park nr Smithville, TX	Stream	30.05353056	-97.1699806	21	12090301	12/14/2010	2/24/2011	2
8162500	Colorado Rv nr Bay City, TX	Stream	28.9741462	-96.0124588	321	12090302	7/3/1940	2/23/2011	683
8162000	Colorado Rv at Wharton, TX	Stream	29.30913668	-96.1038482	481	12090302	11/7/1979	5/23/2011	253
8117500	San Bernard Rv nr Boling, TX	Stream	29.31357967	-95.8938421	157	12090401	5/14/1954	5/23/2011	517
8164000	Lavaca Rv nr Edna, TX	Stream	28.95998449	-96.6863668	239	12100101	8/30/1938	5/27/2011	740
8163500	Lavaca Rv at Hallettsville, TX	Stream	29.4432973	-96.9449819	285	12100101	8/29/1938	10/18/1994	721
8163800	Lavaca Rv at SH 111 nr Yoakum, TX	Stream	29.1572222	-96.8747222	285	12100101	4/3/2003	5/24/2011	4
8164500	Navidad Rv nr Ganado, TX	Stream	29.0258147	-96.5524733	239	12100102	8/30/1938	5/22/1980	549
8164300	Navidad Rv nr Hallettsville, TX	Stream	29.466908	-96.812756	285	12100102	9/12/1961	5/23/2011	445
8164503	W Mustang Ck nr Ganado, TX	Stream	29.07185833	-96.4680278	239	12100102	10/18/1977	5/24/2011	335
8164450	Sandy Ck nr Ganado, TX	Stream	29.1602539	-96.5463608	239	12100102	10/18/1977	3/9/2011	331

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8164390	Navidad Rv at Strane Pk nr Edna, TX	Stream	29.06553568	-96.6741434	239	12100102	6/21/1996	5/24/2011	186
8164504	E Mustang Ck nr Louise, TX	Stream	29.07081227	-96.4171913	481	12100102	6/20/1996	5/24/2011	182
8164350	Navidad Rv nr Speaks, TX	Stream	29.321914	-96.7091425	285	12100102	9/3/1981	10/18/2000	108
8164370	Navidad Rv at Morales, TX	Stream	29.1355328	-96.7444227	239	12100102	8/10/1994	10/18/2000	91
8165705	TPWD Diversion Canal nr Mountain Home, TX	Canal	30.15883889	-99.3463694	265	12100201	1/16/2008	11/18/2008	5
8166000	Johnson Ck nr Ingram, TX	Stream	30.10020707	-99.2831006	265	12100201	10/18/1941	5/6/2011	620
8167000	Guadalupe Rv at Comfort, TX	Stream	29.96523889	-98.8971667	259	12100201	7/7/1932	5/25/2011	586
8165500	Guadalupe Rv at Hunt, TX	Stream	30.06993074	-99.3217122	265	12100201	10/18/1941	5/5/2011	520
8165300	N Fk Guadalupe Rv nr Hunt, TX	Stream	30.06409747	-99.3869916	265	12100201	7/1/1932	5/4/2011	361
8167500	Guadalupe Rv nr Spring Branch, TX	Stream	29.8604957	-98.3836275	91	12100201	5/22/1924	6/7/2011	243
8166200	Guadalupe Rv at Kerrville, TX	Stream	30.053266	-99.163375	265	12100201	6/12/1986	6/13/2011	191
8166140	Guadalupe Rv abv Bear Ck at Kerrville, TX	Stream	30.06965378	-99.1953203	265	12100201	3/29/1978	6/13/2011	190
8167347	Unm Trib Honey Ck Site 1C nr Spring Branch, TX	Stream	29.85530556	-98.4848333	91	12100201	4/28/2000	1/18/2011	57
8167350	Unm Trib Honey Ck Site 1T nr Spring Branch, TX	Stream	29.85038889	-98.4728889	91	12100201	6/18/1999	1/19/2011	53
8166250	Guadalupe Rv nr Center Point, TX	Stream	29.98777778	-99.11	265	12100201	10/5/2007	6/8/2011	24
8167353	Unm Trib Honey Ck Site 2T nr Spring Branch, TX	Stream	29.85623889	-98.480075	91	12100201	6/10/2000	1/18/2011	12
8165250	N Fk Guadalupe Rv at Rk Bottom Rd nr Hunt, TX	Stream	30.0524	-99.4844389	265	12100201	1/15/2008	11/19/2008	5
8165290	Bear Ck nr Hunt, TX	Stream	30.06251944	-99.4178806	265	12100201	1/15/2008	11/19/2008	5
8165350	N Fk Guadalupe Rv at Herons Crsg nr Hunt, TX	Stream	30.08103889	-99.3449611	265	12100201	1/16/2008	11/19/2008	5
8165400	S Fk Guadalupe Rv Dws Sycamore Draw nr Hunt, TX	Stream	29.98018056	-99.4423	265	12100201	1/15/2008	11/18/2008	5
8165460	S Fk Guadalupe Rv at Seago Rd nr Hunt, TX	Stream	30.02781944	-99.3616	265	12100201	1/15/2008	11/19/2008	5
8165712	Fessenden Br nr Mountain Home, TX	Stream	30.1578	-99.3449	265	12100201	1/16/2008	11/18/2008	5
8169000	Comal Rv at New Braunfels, TX	Stream	29.70605788	-98.1225085	91	12100202	1/11/1928	6/20/2011	744
8175000	Sandies Ck nr Westhoff, TX	Stream	29.2152475	-97.4494353	123	12100202	3/15/1930	5/24/2011	547
8167800	Guadalupe Rv at Sattler, TX	Stream	29.85910758	-98.1800106	91	12100202	3/11/1960	6/7/2011	394
8174600	Peach Ck bl Dilworth, TX	Stream	29.47412787	-97.3166565	177	12100202	8/5/1959	5/26/2011	360
8168500	Guadalupe Rv abv Comal Rv at New Braunfels, TX	Stream	29.7149465	-98.1100083	91	12100202	1/10/1928	5/24/2011	305
8173900	Guadalupe Rv at Gonzales, TX	Stream	29.48440414	-97.4502702	177	12100202	6/14/1915	5/26/2011	223
8169792	Guadalupe Rv at FM 1117 nr Seguin, TX	Stream	29.53616667	-97.8809444	187	12100202	6/7/2005	6/2/2011	44
8168797	Dry Comal Ck at Loop 337 nr New Braunfels, TX	Stream	29.688	-98.1548333	91	12100202	4/29/2006	5/24/2011	38
8168932	Comal Rv (nc) nr Landa Lk, New Braunfels, TX	Stream	29.7089611	-98.1334417	91	12100202	6/18/2007	4/7/2011	33
8168913	Comal Rv (oc) nr Landa Lk, New Braunfels, TX	Stream	29.71007778	-98.1316611	91	12100202	6/18/2007	3/21/2011	18
8169500	Guadalupe Rv at New Braunfels, TX	Stream	29.69800265	-98.1066748	91	12100202	8/23/1919	4/5/2010	17
8169860	Guadalupe Rv blw H-5 Dam nr Gonzales, TX	Stream	29.47003056	-97.4901694	177	12100202	1/27/2010	4/14/2011	11
8174970	Sandies Ck nr Smiley, TX	Stream	29.29175556	-97.6207556	177	12100202	1/27/2010	4/15/2011	11
8169840	Guadalupe Rv nr Belmont, TX	Stream	29.49564167	-97.5868222	177	12100202	3/16/2010	4/14/2011	10
8174700	Guadalupe Rv at Hwy 183 nr Yoakum, TX	Stream	29.31446667	-97.3035	123	12100202	1/27/2010	4/6/2010	5
8171000	Blanco Rv at Wimberley, TX	Stream	29.9943808	-98.088898	209	12100203	8/7/1924	6/9/2011	782
8170500	San Marcos Rv at San Marcos, TX	Stream	29.88910804	-97.9341718	209	12100203	10/5/1993	6/20/2011	286
8171300	Blanco Rv nr Kyle, TX	Stream	29.97938297	-97.9100051	209	12100203	3/21/1957	5/13/2011	251
8172000	San Marcos Rv at Luling, TX	Stream	29.66634037	-97.6508314	55	12100203	11/22/1940	6/2/2011	218
8173000	Plum Ck nr Luling, TX	Stream	29.699673	-97.6036082	55	12100203	7/27/1982	3/22/2011	169
8172400	Plum Ck at Lockhart, TX	Stream	29.92299833	-97.6791667	55	12100203	10/4/1959	3/22/2011	152
8170000	San Marcos Spgs at San Marcos, TX	Stream	29.88910804	-97.9341718	209	12100203	1/3/1983	9/15/1997	132
8171290	Blanco Rv at Halifax Rch nr Kyle, TX	Stream	30.00555556	-97.9525	209	12100203	2/25/2009	6/10/2011	19
8171500	San Marcos Rv at FM 20 at Fentress, TX	Stream	29.75278333	-97.7809417	55	12100203	1/27/2010	4/5/2010	6
8169932	Sink Ck nr San Marcos, TX	Stream	29.929325	-97.9942583	209	12100203	10/4/2009	9/8/2010	2
8169935	Lower Sink Ck at Limekiln Rd at San Marcos, TX	Stream	29.89926667	-97.9258833	209	12100203	2/17/2010	2/17/2010	1
8176500	Guadalupe Rv at Victoria, TX	Stream	28.7930456	-97.0130429	469	12100204	3/3/1915	5/26/2011	893
8177500	Coleto Ck nr Victoria, TX	Stream	28.73110317	-97.1386004	469	12100204	6/29/1939	5/26/2011	561
8175800	Guadalupe Rv at Cuero, TX	Stream	29.09053147	-97.3297129	123	12100204	9/14/1952	5/24/2011	364
8176900	Coleto Ck at Arnold Rd Crsg nr Schroeder, TX	Stream	28.86165308	-97.2263791	175	12100204	3/23/1978	5/25/2011	280
8177300	Perdido Ck at FM 622 nr Fannin, TX	Stream	28.7516564	-97.3172142	175	12100204	3/23/1978	5/24/2011	195
8188800	Guadalupe Rv nr Tivoli, TX	Stream	28.5058337	-96.8847084	391	12100204	8/3/2000	5/25/2011	65
8176550	Fifteenmile Ck nr Weser, TX	Stream	28.89776103	-97.3549922	123	12100204	10/10/1984	6/22/2010	62
8176532	Smith Ck at Hwy 119 nr Yorktown, TX	Stream	28.9398861	-97.5004556	123	12100204	7/29/2009	6/21/2010	5
8176538	Yorktown Ck at Hwy 72 at Yorktown, TX	Stream	28.9807	-97.5059028	123	12100204	7/29/2009	6/21/2010	5
8176540	Yorktown Ck at CR 452 near Yorktown, TX	Stream	28.95105556	-97.4690556	123	12100204	7/29/2009	6/21/2010	5
8176544	Fifteenmile Ck at CR 449 nr Ander, TX	Stream	28.92110278	-97.4064389	175	12100204	7/29/2009	6/21/2010	5
8176555	Fifteenmile Ck at Fox Rd nr Ander, TX	Stream	28.8693861	-97.3115667	175	12100204	7/30/2009	6/21/2010	5
8176565	Eighteenmile Ck at Hwy 119 at Weesatche, TX	Stream	28.84546667	-97.4442583	175	12100204	7/29/2009	6/22/2010	5
8176523	Salt Ck at CR 317 nr Yorktown, TX	Stream	29.01620833	-97.5821139	123	12100204	7/29/2009	6/21/2010	4
8176526	Thomas Ck at Cottonpatch Rd nr Yorktown, TX	Stream	28.9893472	-97.6136083	123	12100204	7/29/2009	6/21/2010	4
8176529	Smith Ck at Hwy 72 nr Yorktown, TX	Stream	28.9555861	-97.5709972	123	12100204	7/29/2009	6/21/2010	4
8176580	Eighteenmile Ck at Hwy 77A/183 nr Ander, TX	Stream	28.857775	-97.3713417	175	12100204	7/29/2009	6/21/2010	4
8176590	Confl 18 and 15 Mile Coleto Cks nr Dobskyville, TX	Stream	28.84794444	-97.3053611	175	12100204	1/13/2010	6/22/2010	4
8176594	Twelvemile Ck at FM 2718 nr Yorktown, TX	Stream	28.9759972	-97.3996222	123	12100204	7/29/2009	6/21/2010	4
8176598	Twelvemile Ck at Wendel Rd nr Meyersville, TX	Stream	28.9154111	-97.3017028	123	12100204	7/29/2009	6/22/2010	4
8176750	Fivemile Ck at CR 400 nr Meyersville, TX	Stream	28.93370833	-97.2792167	123	12100204	7/29/2009	6/22/2010	4
8176825	Twelvemile Ck at FM 237 nr Mission Valley, TX	Stream	28.8815972	-97.2356528	469	12100204	7/29/2009	6/21/2010	4

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8176535	Yorktown Ck at CR 393 nr Yorktown, TX	Stream	29.0213611	-97.5104056	123	12100204	7/29/2009	6/21/2010	3
8176592	Fifteenmile Ck nr Lassman Rd nr Ander, TX	Stream	28.844275	-97.2996778	175	12100204	7/30/2009	1/12/2010	3
8176596	Twelvemile Ck at Hwy 77A/183 nr Meyersville, TX	Stream	28.92581667	-97.3445389	123	12100204	7/29/2009	6/21/2010	3
8176599	Fivemile Ck at Hwy 77A/183 nr Arneckville, TX	Stream	29.00305278	-97.3204139	123	12100204	7/29/2009	6/21/2010	3
8176675	Fivemile Ck at FM 3157 nr Arneckville, TX	Stream	28.98738889	-97.2771333	123	12100204	7/29/2009	6/21/2010	3
8177000	Coleto Ck nr Schroeder, TX	Stream	28.83165447	-97.1863786	469	12100204	7/29/2009	6/22/2010	3
8177270	Turkey Ck at FM 2987 nr Fannin, TX	Stream	28.76840278	-97.2161222	175	12100204	7/29/2009	6/22/2010	3
8176548	Fifteenmile Ck at Audilet Crossing nr Ander, TX	Stream	28.89823333	-97.3605833	123	12100204	1/13/2010	1/13/2010	2
8177520	Guadalupe Rv nr Bloomington, TX	Stream	28.66194444	-96.9652778	469	12100204	1/28/2010	3/18/2010	2
8176990	Coleto Ck Res Infl (Guad Div) nr Schroeder, TX	Stream	28.8394319	-97.1891564	469	12100204	2/3/1988	2/3/1988	1
8177310	Perdido Ck at Franke Rd nr Fannin, TX	Stream	28.74383333	-97.3105	175	12100204	7/29/2009	7/29/2009	1
8177350	Perdido Ck at FM 2987 nr Fannin, TX	Stream	28.71380278	-97.2306278	175	12100204	6/22/2010	6/22/2010	1
8178800	Salado Ck at Loop 13, San Antonio, TX	Stream	29.35718017	-98.4127925	29	12100301	8/15/1960	5/23/2011	487
8181800	San Antonio Rv nr Elmendorf, TX	Stream	29.2221853	-98.3558463	29	12100301	5/16/1962	5/24/2011	469
8178700	Salado Ck at Loop 410, San Antonio, TX	Stream	29.5160633	-98.4311271	29	12100301	8/15/1960	6/7/2011	420
8177700	Olmos Ck at Dresden Dr, San Antonio, TX	Stream	29.4991192	-98.5102958	29	12100301	7/9/1968	3/16/2011	316
8178565	San Antonio Rv at Loop 410, San Antonio, TX	Stream	29.32218127	-98.4502932	29	12100301	2/10/1987	5/26/2011	200
8178050	San Antonio Rv at Mitchell St, San Antonio, TX	Stream	29.39301189	-98.4947392	29	12100301	12/9/1991	6/1/2011	126
8178000	San Antonio Rv at San Antonio, TX	Stream	29.40967796	-98.495017	29	12100301	8/13/1987	5/13/2011	71
8177860	San Antonio Rv at Woodlawn Ave, San Antonio, TX	Stream	29.4513432	-98.478628	29	12100301	4/7/1989	10/3/1995	53
8178585	Salado Ck at Wilderness Rd, San Antonio, TX	Stream	29.63078135	-98.5655755	29	12100301	1/6/1998	6/6/2011	25
8178593	Salado Ck at Blanco Rd. San Antonio, Tx	Stream	29.5638611	-98.5196667	29	12100301	10/28/1998	6/7/2011	16
8178505	San Antonio Rv at Theo Ave, San Antonio, TX	Stream	29.38801205	-98.4986281	29	12100301	5/14/1999	10/27/1999	12
8178592	Salado Ck at Loop 1604 nr San Antonio, TX	Stream	29.60189348	-98.5397414	29	12100301	10/26/1998	10/31/1998	11
8178030	San Antonio Rv at Lone Star Blvd, San Antonio, TX	Stream	29.4021111	-98.4879444	29	12100301	5/1/2008	6/17/2010	6
8178627	Elm Waterhole Trib at Evans Rd nr San Antonio, TX	Stream	29.64666667	-98.4063889	29	12100301	4/23/2001	4/23/2001	5
8178628	Unm Trib Elm Wtrhole Ck at Evans Rd San Antonio,TX	Stream	29.6443722	-98.3965472	29	12100301	1/15/2010	1/15/2010	1
8177800	Olmos Res at San Antonio, TX	Lake	29.47356465	-98.4741836	29	12100301	3/25/1992	3/7/1995	12
8180000	Medina Canal nr Riomedina, TX	Canal	29.5055085	-98.9033619	325	12100302	3/30/1922	10/4/2007	452
8180003	Medina Canal at FM 2676 nr Riomedina, TX	Canal	29.4431222	-98.9231222	325	12100302	10/15/2002	10/4/2007	32
8180008	Medina Canal at Kelly Rd nr Macdona, TX	Canal	29.30395556	-98.7319778	29	12100302	3/14/2003	12/22/2004	6
8181500	Medina Rv at San Antonio, TX	Stream	29.2641276	-98.4908493	29	12100302	7/28/1939	3/17/2011	737
8180800	Medina Rv nr Somerset, TX	Stream	29.26218286	-98.5814074	29	12100302	11/10/1970	10/6/2004	278
8178880	Medina Rv at Bandera, TX	Stream	29.72383537	-99.070035	19	12100302	10/20/1982	5/11/2011	225
8180700	Medina Rv nr Macdona, TX	Stream	29.33495798	-98.689744	29	12100302	12/30/1980	5/10/2011	218
8181400	Helotes Ck at Helotes, TX	Stream	29.57856108	-98.6916896	29	12100302	9/5/1968	5/11/2011	211
8181480	Leon Ck at IH 35, San Antonio, TX	Stream	29.32995837	-98.5841856	29	12100302	7/27/1984	3/16/2011	192
8180500	Medina Rv nr Riomedina, TX	Stream	29.498	-98.9055	325	12100302	1/21/1922	10/11/2007	147
8180640	Medina Rv at La Coste, TX	Stream	29.3241246	-98.813081	325	12100302	10/7/1987	9/22/2005	88
8180750	Medio Ck at Pearsall Rd, San Antonio, TX	Stream	29.3279722	-98.6388056	29	12100302	12/16/1919	5/31/2011	60
8180720	Medina Rv nr Von Ormy, TX	Stream	29.2952371	-98.6422426	29	12100302	5/12/2003	5/10/2011	44
8180942	Laurel Canyon Ck nr Helotes, TX	Stream	29.55678333	-98.7459889	29	12100302	6/29/2004	1/14/2011	37
8178990	Medina Rv at English Crsg nr Pipe Creek, TX	Stream	29.6816143	-98.9758652	19	12100302	10/11/1995	2/9/2009	30
8179110	Red Bluff Ck at FM 1283 nr Pipe Creek, TX	Stream	29.6732811	-98.9603091	19	12100302	5/17/2001	11/25/2002	19
8179520	Medina Rv bl Medina Lk nr San Antonio, TX	Stream	29.5341187	-98.9353075	325	12100302	6/27/1995	11/20/2002	18
8180945	Leon Ck at Scenic Loop Rd nr Leon Springs, TX	Stream	29.67373056	-98.6755667	29	12100302	1/30/2001	9/10/2009	8
8180586	San Geronimo Ck nr Helotes, TX	Stream	29.61972778	-98.7951528	29	12100302	3/29/2011	6/7/2011	6
8181050	Leon Ck at Prue Rd, San Antonio, TX	Stream	29.54138889	-98.6316667	29	12100302	11/7/2000	4/8/2002	6
8178863	N Prong Medina Rv abv conf Wallace Ck nr Medina,TX	Stream	29.85394444	-99.2805278	19	12100302	1/5/2009	6/29/2010	4
8178865	N Prong Medina Rv at Freeman Crsg nr Medina, TX	Stream	29.8542222	-99.27975	19	12100302	1/5/2009	1/28/2011	2
8180015	Medina Rv bl Diversion Lk nr Riomedina, TX	Stream	29.50939727	-98.900584	325	12100302	8/7/2001	8/7/2001	1
8180941	Government Canyon Ck Site 2 nr Helotes, TX	Stream	29.53916667	-98.7513889	29	12100302	1/14/2011	1/14/2011	1
8181415	Helotes Ck at Braun Rd nr Helotes, TX	Stream	29.54	-98.6919444	29	12100302	5/11/2011	5/11/2011	1
817887350	Medina Rv at Patterson Rd at Medina, TX	Stream	29.79389167	-99.2485944	19	12100302	1/28/2011	1/28/2011	1
8183500	San Antonio Rv nr Falls City, TX	Stream	28.95164067	-98.0641723	255	12100303	4/22/1925	5/26/2011	826
8188500	San Antonio Rv at Goliad, TX	Stream	28.6492861	-97.3848583	175	12100303	6/19/1924	5/24/2011	809
8186500	Ecleto Ck nr Runge, TX	Stream	28.92025419	-97.7722221	255	12100303	10/24/1961	5/23/2011	326
8188570	San Antonio Rv nr McFaddin, TX	Stream	28.53125	-97.0426944	391	12100303	1/18/2006	5/25/2011	52
8183200	San Antonio Rv nr Floresville, TX	Stream	29.11	-98.1744444	493	12100303	3/14/2006	5/31/2011	46
8188060	San Antonio Rv at SH 72 nr Runge, TX	Stream	28.84869444	-97.7371389	255	12100303	4/18/2006	6/1/2011	7
8183700	San Antonio Rv at SH 123 nr Karnes City, TX	Stream	28.94208333	-97.9046944	255	12100303	4/18/2006	10/9/2007	5
8183550	San Antonio Rv at Hwy 181 at Falls City, TX	Stream	28.97735	-98.0101417	255	12100303	4/6/2011	6/1/2011	2
8186000	Cibolo Ck nr Falls City, TX	Stream	29.01413869	-97.9302808	255	12100304	9/30/1930	5/25/2011	828
8185000	Cibolo Ck at Selma, TX	Stream	29.5941166	-98.3111242	29	12100304	3/5/1946	3/16/2011	406
8183900	Cibolo Ck nr Boerne, TX	Stream	29.7741093	-98.6975246	259	12100304	3/3/1962	4/20/2011	314
8183850	Cibolo Ck at IH 10 abv Boerne, TX	Stream	29.81466345	-98.7536379	259	12100304	10/12/1995	4/25/2007	89
8185500	Cibolo Ck at Sutherland Springs, TX	Stream	29.2797222	-98.0533333	493	12100304	6/23/1924	5/25/2011	80
8185100	Martinez Ck nr Saint Hedwig, TX	Stream	29.44388889	-98.1688889	29	12100304	2/10/2006	6/1/2011	42
8185065	Cibolo Ck nr Saint Hedwig, TX	Stream	29.50144444	-98.18625	187	12100304	2/10/2006	6/1/2011	41
8183890	Cibolo Ck at Cibolo Nature Cntr nr Boerne, TX	Stream	29.7866111	-98.7151889	259	12100304	3/1/2006	6/3/2011	36

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8183950	Cibolo Ck at Ralph Fair Rd bl Boerne, TX	Stream	29.7437	-98.6233167	91	12100304	9/6/2001	7/22/2002	13
8183970	Cibolo Ck at Blanco Rd abv Bulverde, TX	Stream	29.74253333	-98.5141333	91	12100304	9/7/2001	7/13/2002	13
8184300	Cibolo Ck at FR 1863 bl Bulverde, TX	Stream	29.73266667	-98.3563833	91	12100304	9/8/2001	8/24/2004	13
8183990	Cibolo Ck at Bulverde Rd nr Bulverde, TX	Stream	29.733278	-98.4525173	91	12100304	7/8/2002	7/23/2002	7
8183995	Cibolo Ck at US Hwy 281 nr Bulverde, TX	Stream	29.71923333	-98.4434333	91	12100304	9/6/2001	9/10/2001	6
8184050	Cibolo Ck at Smithson Valley Rd nr Bulverde, TX	Stream	29.74826667	-98.4076833	91	12100304	9/10/2001	3/16/2011	4
8162600	Tres Palacios Rv nr Midfield, TX	Stream	28.92803769	-96.1710747	321	12100401	9/12/1967	5/26/2011	328
8164600	Garcitas Ck nr Inez, TX	Stream	28.8913759	-96.8191486	469	12100402	4/20/1965	3/22/2011	363
8164800	Placedo Ck nr Placedo, TX	Stream	28.72527137	-96.7688702	469	12100402	9/13/1967	3/21/2011	328
8188600	GBRA Calhoun Canal Pump Sta nr Long Mott, TX	Canal	28.496667	-96.7710941	57	12100403	10/7/1988	5/25/2011	101
8189200	Copano Ck nr Refugio, TX	Stream	28.30361693	-97.1124913	391	12100405	9/14/1967	5/23/2011	254
2.80847E+14	GIWW at Bludworth Island nr Lamar, TX	Estuary	28.1466786	-96.8999878	7	12100405	5/6/1999	5/6/1999	2
8189300	Medio Ck nr Beeville, TX	Stream	28.48305164	-97.656663	25	12100406	11/28/1961	5/23/2011	221
8189500	Mission Rv at Refugio, TX	Stream	28.29195088	-97.2791593	391	12100406	9/12/1971	5/23/2011	179
8189700	Aransas Rv nr Skidmore, TX	Stream	28.28250426	-97.620829	25	12100407	11/28/1961	5/23/2011	440
8189800	Chiltipin Ck at Sinton, TX	Stream	28.04695919	-97.5038832	409	12100407	2/7/1967	10/8/1991	215
8190000	Nueces Rv at Laguna, TX	Stream	29.42856679	-99.997287	463	12110101	9/21/1923	5/5/2011	321
818999010	Nueces Rv nr Barksdale, TX	Stream	29.71883333	-100.039575	137	12110101	2/5/2009	5/11/2011	16
8189979	Hackberry Ck at Hwy 335 nr Vance, TX	Stream	30.0236111	-100.0677778	137	12110101	7/22/2008	3/23/2010	3
818998070	E Prong Nueces abv Eagle Rh nr Vance, TX	Stream	29.9875	-99.9575	385	12110101	8/12/2009	3/26/2010	2
818998770	Bullhead Ck at RR 2631 nr Vance, TX	Stream	29.83083333	-99.9541667	385	12110101	8/11/2009	3/24/2010	2
818998970	Dry Ck nr Barksdale, TX	Stream	29.7522222	-100.0086111	385	12110101	4/8/2009	8/11/2009	2
818998008	Jow Hollow bl Morriss Spgs nr Rocksprings, TX	Stream	29.95083333	-99.9575	385	12110101	8/12/2009	8/12/2009	1
8190500	W Nueces Rv nr Brackettville, TX	Stream	29.48108333	-100.2391667	271	12110102	9/28/1939	5/11/2011	448
8192000	Nueces Rv bl Uvalde, TX	Stream	29.12385307	-99.8947822	463	12110103	4/5/1939	5/11/2011	718
8193000	Nueces Rv nr Asherton, TX	Stream	28.50026313	-99.6819935	127	12110103	2/11/1988	5/10/2011	138
8192400	Nueces Rv at US Hwy 57 nr La Pryor, TX	Stream	28.93305556	-99.7983333	507	12110103	4/18/2008	10/19/2010	17
8194000	Nueces Rv at Cotulla, TX	Stream	28.42637889	-99.2400322	283	12110105	10/17/1915	5/10/2011	788
8194500	Nueces Rv nr Tilden, TX	Stream	28.30888906	-98.5572384	311	12110105	11/15/1942	5/12/2011	581
8194200	San Casimiro Ck nr Freer, TX	Stream	27.96501329	-98.9669678	479	12110105	1/7/1962	5/11/2011	345
8195000	Frio Rv at Concan, TX	Stream	29.48856496	-99.7047756	463	12110106	9/18/1923	5/10/2011	821
8205500	Frio Rv nr Derby, TX	Stream	28.73664429	-99.1447556	163	12110106	10/3/1915	5/10/2011	751
8198000	Sabinal Rv nr Sabinal, TX	Stream	29.4910644	-99.4928241	463	12110106	10/8/1942	5/24/2011	674
8198500	Sabinal Rv at Sabinal, TX	Stream	29.31430556	-99.4804722	463	12110106	9/3/1952	5/12/2011	555
8196000	Dry Frio Rv nr Reagan Wells, TX	Stream	29.50467576	-99.7814452	463	12110106	8/21/1952	5/10/2011	553
8197500	Frio Rv bl Dry Frio Rv nr Uvalde, TX	Stream	29.2457934	-99.6744978	463	12110106	9/18/1953	5/11/2011	311
8204005	Leona Rv nr Uvalde, TX	Stream	29.1544077	-99.7433888	463	12110106	3/12/2003	5/10/2011	53
8204250	Leona Rv at FM 1866 nr Batesville, TX	Stream	28.90583333	-99.5772222	507	12110106	8/17/2006	10/19/2010	19
8196300	Dry Frio Rv at FM 2690 nr Knippa, TX	Stream	29.3736111	-99.7041667	463	12110106	3/31/2009	5/10/2011	14
8197800	Blanco Ck at SH 127 nr Concan, TX	Stream	29.41833333	-99.6052778	463	12110106	3/31/2009	5/10/2011	14
8203450	Leona Rv at CR 429A nr Uvalde, TX	Stream	29.34527778	-99.7488889	463	12110106	7/15/2009	5/10/2011	11
8194695	Kent Ck bl Evans Spgs nr Leakey, TX	Stream	29.86194444	-99.8005556	385	12110106	4/9/2009	3/22/2010	4
8194690	W Frio Rv abv Kent Ck nr Leakey, TX	Stream	29.85421667	-99.7702	385	12110106	7/21/2008	3/22/2010	3
8194850	Leakey Spg Run at Leakey, TX	Stream	29.723	-99.7565667	385	12110106	7/21/2008	3/22/2010	3
8197907	Sabinal Rv bl Wedgeworth Ck nr Vanderpool, TX	Stream	29.8027	-99.5750667	19	12110106	7/22/2008	3/24/2010	3
8197970	Sabinal Rv at Utopia, TX	Stream	29.61226667	-99.5294833	463	12110106	7/23/2008	3/24/2010	3
8197520	Frio Rv at Johnson's Rh nr Uvalde, TX	Stream	29.1875	-99.6413889	463	12110106	8/16/2006	6/7/2007	2
8197900	Frio Rv at SH 187 nr Sabinal, TX	Stream	29.10305556	-99.4458333	463	12110106	8/16/2006	6/7/2007	2
8198880	Sabinal Rv at SH 187 nr Sabinal, TX	Stream	29.1636111	-99.4725	463	12110106	8/16/2006	6/7/2007	2
8203000	Frio Rv at SH 140 nr Pearsall, TX	Stream	28.93833333	-99.1780556	163	12110106	8/16/2006	7/7/2007	2
8203120	Buck Ck at Derby Rd nr Derby, TX	Stream	28.77944444	-99.1622222	163	12110106	8/17/2006	6/8/2007	2
8204200	Leona Rv at SH 57 nr Batesville, TX	Stream	28.9636111	-99.6144444	507	12110106	8/17/2006	6/7/2007	2
8204500	Leona Rv nr Divot, TX	Stream	28.7930303	-99.2411468	163	12110106	8/16/2006	6/7/2007	2
8194750	E Frio Rv abv Circle Bluff nr Leakey, TX	Stream	29.8675	-99.6663889	385	12110106	8/13/2009	8/13/2009	1
8199990	Frio Rv at SH 57 nr Pearsall, TX	Stream	28.9836111	-99.2361111	163	12110106	6/7/2007	6/7/2007	1
8203970	Cooks Sl at SH 117 nr Uvalde, TX	Stream	29.17138889	-99.7725	463	12110106	8/16/2006	8/16/2006	1
8200000	Hondo Ck nr Tarpley, TX	Stream	29.57003056	-99.2476889	325	12110107	8/20/1952	5/13/2011	544
8201500	Seco Ck at Miller Rh nr Utopia, TX	Stream	29.573284	-99.4030997	325	12110107	6/17/1958	5/13/2011	335
8202700	Seco Ck at Rowe Rh nr D'Hanis, TX	Stream	29.37078917	-99.2878185	325	12110107	7/7/1960	5/12/2011	199
8200700	Hondo Ck at King Waterhole nr Hondo, TX	Stream	29.39078876	-99.1514252	325	12110107	7/7/1960	7/5/2006	190
8202450	Seco Ck Res Infl nr Utopia, TX	Stream	29.5263409	-99.3953215	325	12110107	9/24/1991	1/4/1999	43
8200720	Hondo Ck at SH 173 nr Hondo, TX	Stream	29.3761111	-99.1166667	325	12110107	7/18/2006	5/9/2011	35
8200977	Middle Verde Ck at SH 173 nr Bandera, TX	Stream	29.56777778	-99.0969444	325	12110107	1/5/2007	5/9/2011	33
8201200	Hondo Ck at SH 462 nr Yancey, TX	Stream	29.09555556	-99.0872222	325	12110107	8/17/2006	6/7/2007	3
8202780	Seco Ck at CR 5232 nr Yancey, TX	Stream	29.25333333	-99.2802778	325	12110107	8/16/2006	6/7/2007	3
8200020	Hondo Ck at CR 232 nr Hondo, TX	Stream	29.52694444	-99.2227778	325	12110107	5/27/1981	6/15/2004	2
8202950	Hondo Ck at SH 57 nr Pearsall, TX	Stream	29.00777778	-99.1402778	163	12110107	8/17/2006	6/7/2007	2
8201100	Hondo Ck at CR 545 nr Yancey, TX	Stream	29.22166667	-99.0772222	325	12110107	6/7/2007	6/7/2007	1
8206600	Frio Rv at Tilden, TX	Stream	28.46749279	-98.5475174	311	12110108	6/6/1978	5/12/2011	267
8206910	Choke Canyon Res OWC nr Three Rivers, TX	Stream	28.48610326	-98.2416752	297	12110108	10/10/1991	5/26/2011	120

Table A3.1. Continued.

Site No.	Site Name	Waterbody Type	Latitude	Longitude	County Code	HUC Code	Site Visit Begin Date	Site Visit Last Date	Site Visit Count
8203100	Frio Rv at FM 1581 nr Pearsall, TX	Stream	28.8147222	-99.1894444	163	12110108	6/16/2006	6/8/2007	2
8205900	Frio Rv at Natus Rd nr Fowlerton, TX	Stream	28.51416667	-98.9213889	283	12110108	8/16/2006	6/8/2007	2
8205920	Cibolo Ck at FM 85 nr Dilley, TX	Stream	28.65138889	-99.3697222	163	12110108	8/17/2006	6/8/2007	2
8205940	Cibolo Ck at IH 35 nr Millett, TX	Stream	28.59166667	-99.1930556	283	12110108	8/16/2006	6/8/2007	2
8205600	Frio Rv at FM 85 nr Dilley, TX	Stream	28.6922222	-99.0761111	163	12110108	8/16/2006	8/16/2006	1
8206000	Frio Rv at SH 97 nr Fowlerton, TX	Stream	28.4722222	-98.8047222	283	12110108	8/16/2006	8/16/2006	1
8206700	San Miguel Ck nr Tilden, TX	Stream	28.58748787	-98.5458513	311	12110109	1/25/1964	5/12/2011	379
8207500	Atascosa Rv nr McCoy, TX	Stream	28.86497693	-98.3383454	13	12110110	8/3/1951	5/11/2011	136
8207320	Galvan Ck nr Leming, TX	Stream	29.07113333	-98.5085167	13	12110110	4/5/2004	6/10/2004	5
8210000	Nueces Rv nr Three Rivers, TX	Stream	28.42749545	-98.1780625	297	12110111	5/9/1915	4/12/2011	1026
8208000	Atascosa Rv at Whitsett, TX	Stream	28.62220899	-98.2813988	297	12110111	9/23/1924	5/13/2011	875
8211000	Nueces Rv nr Mathis, TX	Stream	28.03834719	-97.8602769	409	12110111	8/5/1939	6/1/2011	843
8211200	Nueces Rv at Bluntzer, TX	Stream	27.93779594	-97.7758308	355	12110111	1/28/1966	6/1/2011	157
8211500	Nueces Rv at Calallen, TX	Stream	27.88307697	-97.625273	355	12110111	9/13/1971	6/17/2011	149
8210400	Lagarto Ck nr George West, TX	Stream	28.05973533	-98.0969482	297	12110111	9/12/1971	5/31/2011	97
8211503	Rincon Bayou Channel nr Calallen, TX	Stream	27.8969652	-97.6255509	409	12110111	5/1/1996	5/24/2011	42
8210100	Nueces Rv at George West, TX	Stream	28.33277778	-98.0855556	297	12110111	7/18/2001	4/17/2010	5
8210500	Lk Corpus Christi nr Mathis, TX	Lake	28.0383472	-97.8711104	249	12110111	12/15/1980	12/15/1980	1
8211520	Oso Ck at Corpus Christi, TX	Stream	27.71141879	-97.5019377	355	12110202	9/13/1971	6/2/2011	328
8211525	Unm Trib Oso Ck at FM 2444 nr Corpus Christi, TX	Stream	27.65194444	-97.4444444	355	12110202	10/12/2005	7/25/2008	18
8211900	San Fernando Ck at Alice, TX	Stream	27.77252575	-98.033613	249	12110204	9/9/1962	5/31/2011	330
8211800	San Diego Ck at Alice, TX	Stream	27.76669257	-98.0755584	249	12110204	7/4/1964	1/23/1985	130
8212400	Los Olmos Ck nr Falfurrias, TX	Stream	27.26448618	-98.1358378	47	12110205	11/4/1938	5/31/2011	193
8470500	Arroyo Colorado at FM 106, Rio Hondo, TX	Stream	26.23527778	-97.5847222	61	12110208	4/26/2005	4/26/2005	1
8471000	Arroyo Colorado at Laguna Atascosa NWR, TX	Stream	26.35118256	-97.3860907	61	12110208	4/28/2005	4/28/2005	1
8364000	RIO GRANDE AT EL PASO, TX	Stream	31.80288488	-106.5408218	141	13030102	12/30/2008	6/10/2010	20
8367050	Unm Trib Pow Wow Canyon Arroyo nr El Paso, TX	Stream	31.83899444	-106.0446222	141	13040100	10/16/2007	10/30/2008	6
8371500	Rio Grande abv Rio Conchos nr Presidio, TX	Stream	29.6210127	-104.4810367	377	13040201	6/29/2006	6/29/2006	1
8374325	Rio Grande at Rancherias Rapids nr Redford, TX	Stream	29.33705556	-104.0553333	377	13040203	6/20/2006	6/20/2006	2
8374200	Rio Grande bl Rio Conchos nr Presidio, TX	Stream	29.51962973	-104.2865896	377	13040203	6/29/2006	6/29/2006	1
8374550	Rio Grande nr Castolon, TX	Stream	29.13798	-103.5249033	43	13040205	6/8/2005	6/8/2011	56
8375300	Rio Grande at Boquillas Cpgd, Big Bnd NP, TX	Stream	29.1835386	-102.9754409	43	13040205	6/6/2005	5/5/2011	47
8375000	Rio Grande at Johnson Rh nr Castolon, TX	Stream	29.03492826	-103.3921204	43	13040205	2/7/2006	2/7/2006	2
8376300	Sanderson Ck at Sanderson, TX	Stream	30.12851998	-102.3848654	443	13040208	6/11/1965	5/4/2011	97
8418000	Ward County ID No. 1 Canal nr Barstow, TX	Canal	31.54068767	-103.4954524	475	13070001	10/6/1987	9/5/1990	33
8414500	Reeves County WID No. 2 Canal nr Mentone, TX	Canal	31.63263024	-103.5754569	389	13070001	4/20/1988	6/6/1990	14
8437700	Ward County WID No. 2 Canal nr Grandfalls, TX	Canal	31.3704165	-103.0071019	475	13070001	3/14/1989	6/5/1990	10
8436500	Pecos Co WID No. 2 Up Div Canal nr Grandfalls, TX	Canal	31.3120855	-102.9198778	371	13070001	9/1/1987	8/6/1990	9
8437500	Pecos County WID No. 2 Canal nr Imperial, TX	Canal	31.27736524	-102.7320952	371	13070001	7/10/1984	12/11/2007	8
8415000	Ward County WID No. 3 Canal nr Barstow, TX	Canal	31.57457595	-103.5015643	475	13070001	5/2/1989	8/7/1990	7
8437600	Pecos County WID No. 3 Canal nr Imperial, TX	Canal	31.28097623	-102.7409843	371	13070001	6/19/1979	9/4/1990	6
8412500	Pecos Rv nr Orla, TX	Stream	31.87262648	-103.8315824	389	13070001	9/26/1978	5/24/2011	225
8446500	Pecos Rv nr Girvin, TX	Stream	31.11320329	-102.4176419	371	13070001	3/9/1987	5/17/2011	166
8418010	PECOS RIVER NR BARSTOW, TX	Stream	31.54707644	-103.496008	389	13070001	9/16/1999	3/11/2003	40
8437710	Pecos Rv at RR 1776 nr Grandfalls, TX	Stream	31.3668055	-103.0059908	475	13070001	10/24/2007	5/16/2011	33
8420500	Pecos Rv at Pecos, TX	Stream	31.43652327	-103.467395	389	13070001	10/17/2007	5/18/2011	32
8431700	Limpia Ck abv Ft Davis, TX	Stream	30.61348635	-104.0015734	243	13070005	8/22/1965	4/4/2008	120
8433000	Barrilla Draw nr Saragosa, TX	Stream	30.95792694	-103.459619	389	13070005	9/26/1978	3/15/2011	89
8447000	Pecos Rv nr Sheffield, TX	Stream	30.65961373	-101.7701244	371	13070008	10/25/2007	5/17/2011	29
8447300	Pecos Rv at Brotherton Rh nr Pandale, TX	Stream	30.314	-101.7415556	105	13070008	10/25/2007	5/19/2011	29
8447020	Independence Ck nr Sheffield, TX	Stream	30.4521221	-101.7331788	443	13070010	1/17/1974	5/20/2011	174
8459200	Rio Grande at Pipeline Crsg bl Laredo, TX	Stream	27.4005766	-99.4886529	479	13080002	2/24/1998	10/22/2007	73

[1] Retrieved: 6/25/2011 07:34 EDT; URL: http://nwis.waterdata.usgs.gov/nwis/inventory

Appendix 4. Map of Historical TWDB Monitoring Sites

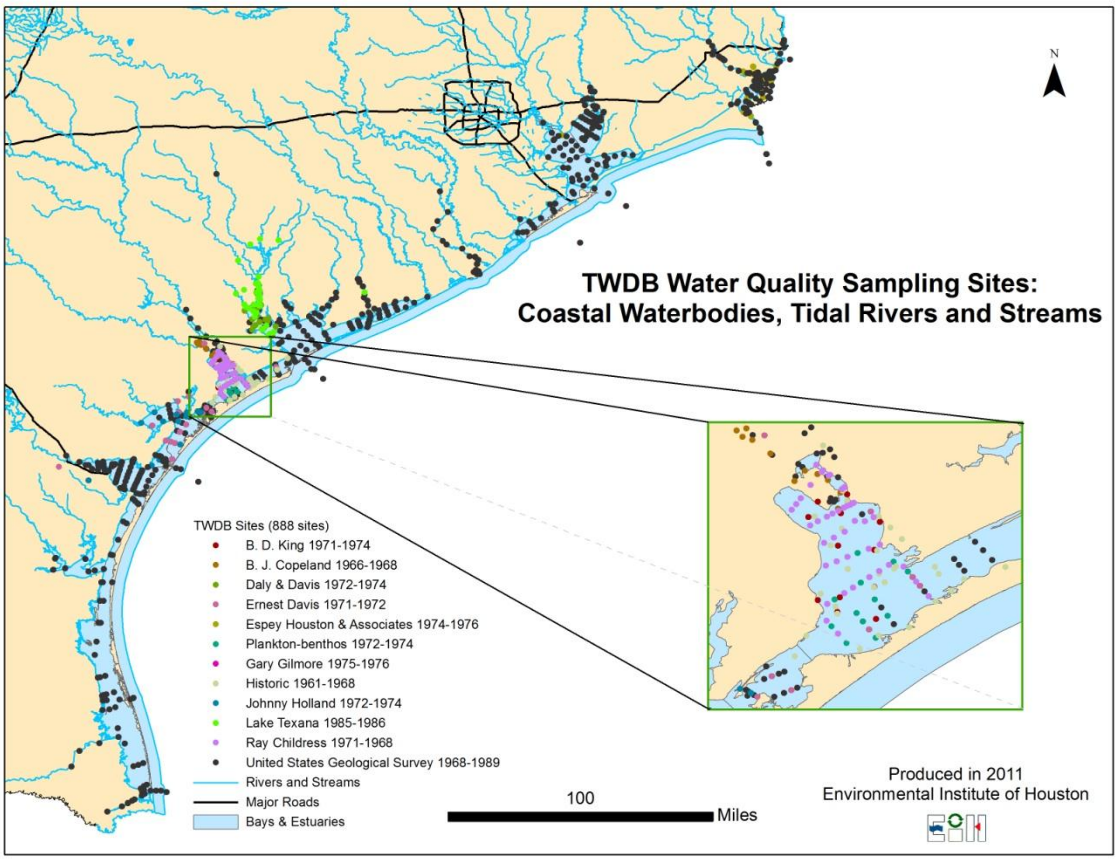

Figure A4. 1. Location of the 888 TWDB sponsored study sites including CDS and lake and stream surveys.

Appendix 5. Maps of Legacy STORET Monitoring Sites.

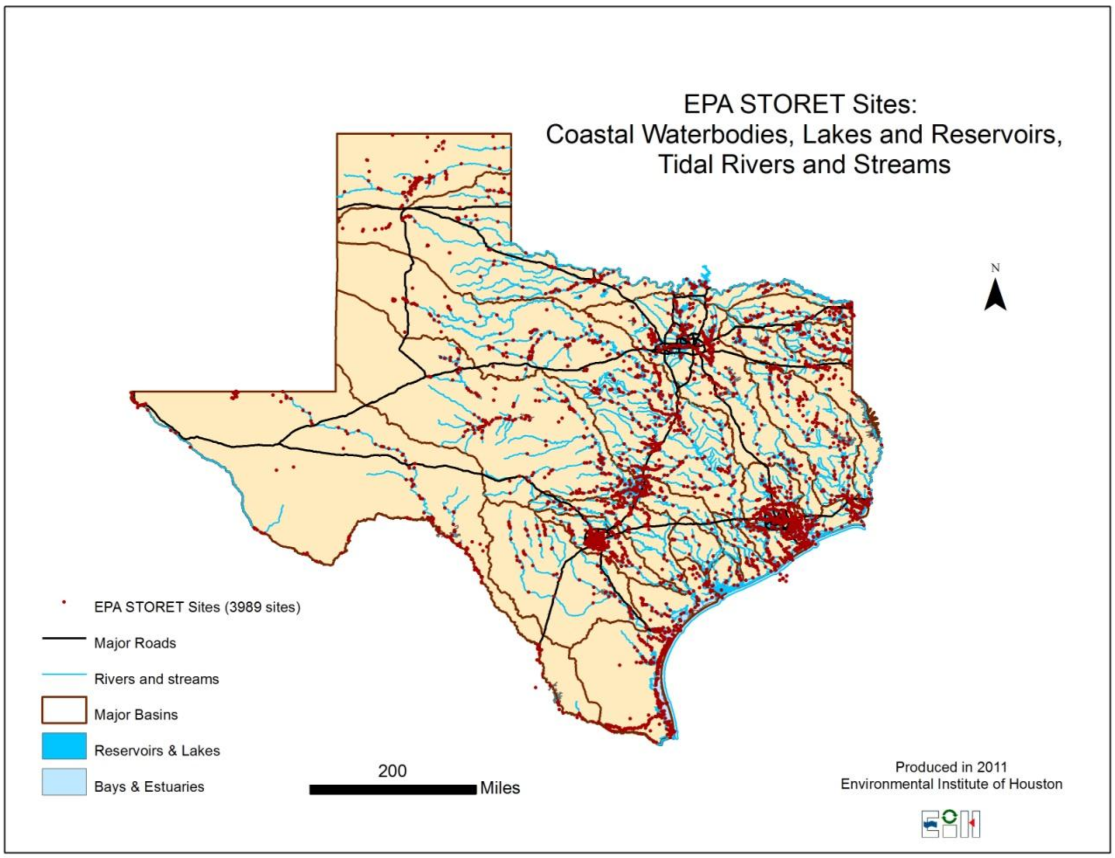

Figure A5. 1. Location of the legacy (pre-1998) STORET sites. A total of 3,989 legacy STORET sites were identified but only 980 contained data not in SWQMIS. The remainder contained data from TWC and/or TNRCC.

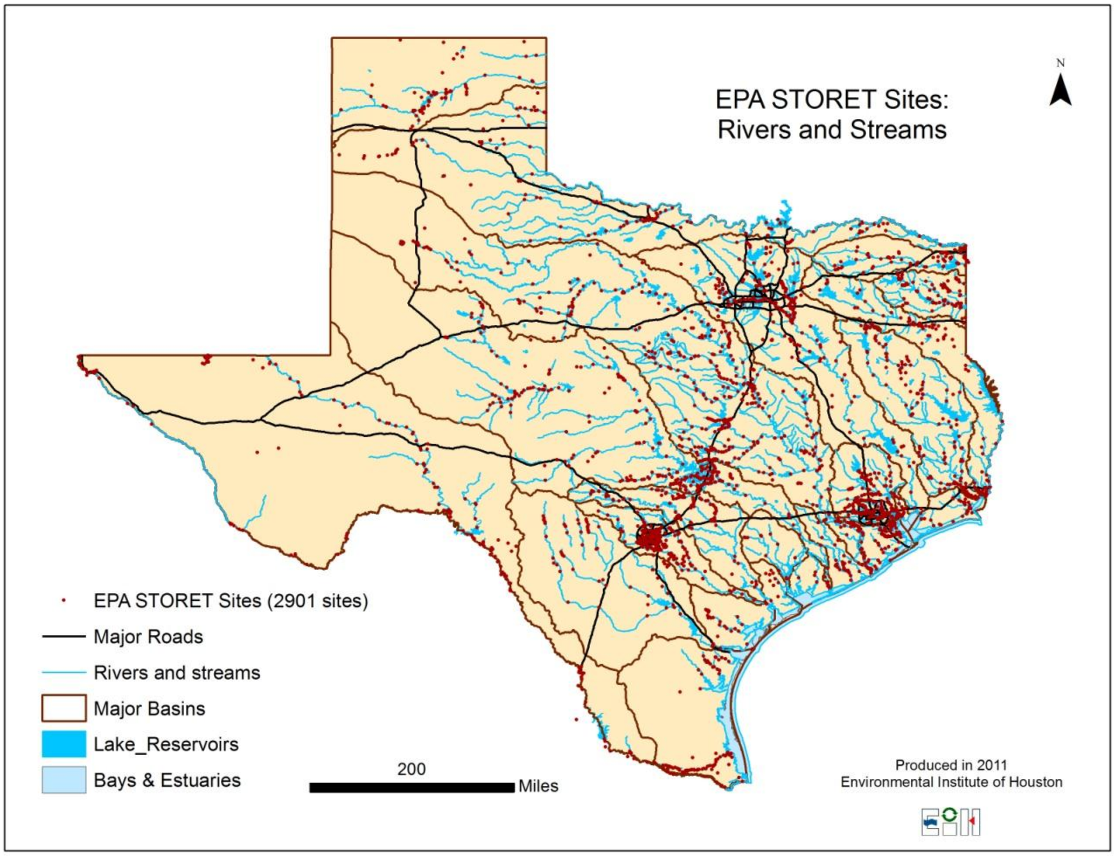

Figure A5. 2. Location of legacy (pre-1998) STORET river and stream sites. A total of 2,901 legacy STORET sites were identified but the majority of this data was collected by the TCEQ predecessor agencies and are contained in SWQMIS.

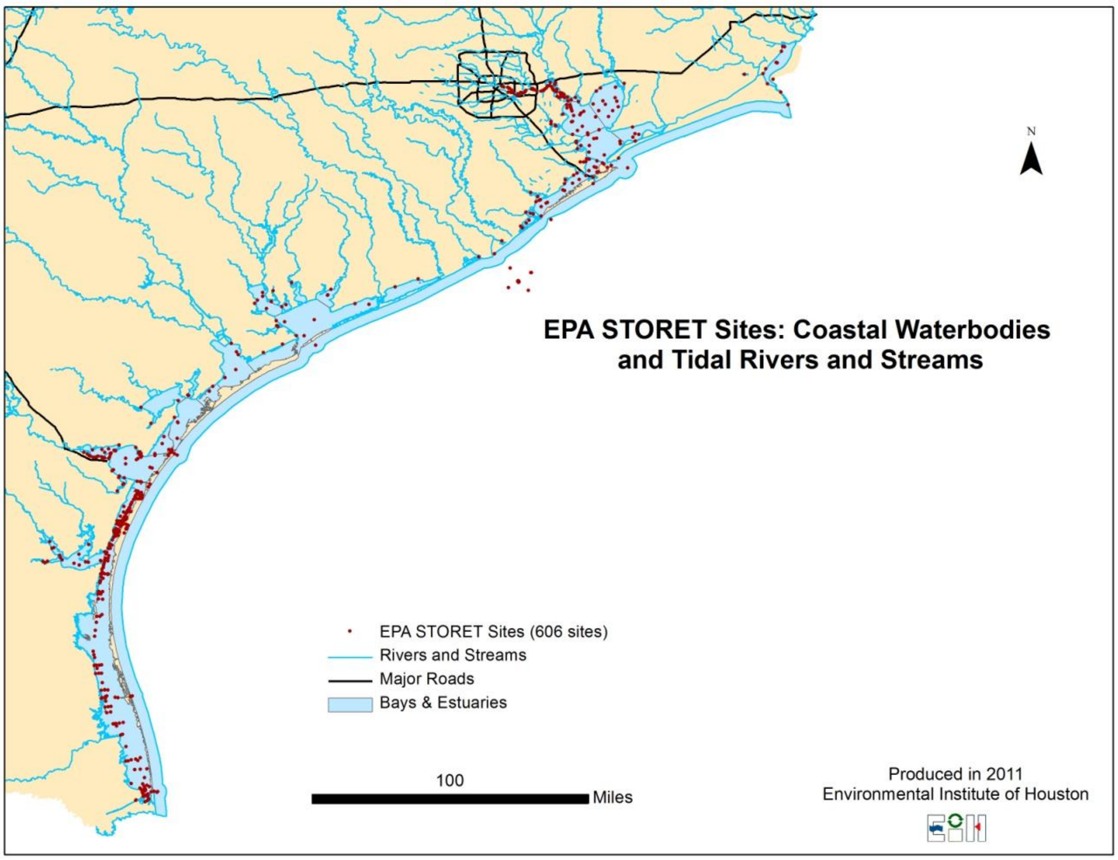

Figure A5. 3. Location of legacy (pre-1998) STORET coastal streams, estuaries and marine sites. A total of 606 legacy STORET sites were identified but the majority of this data was collected by the TCEQ predecessor agencies and are contained in SWQMIS.

Appendix 6. Maps of Modern STORET Monitoring Sites.

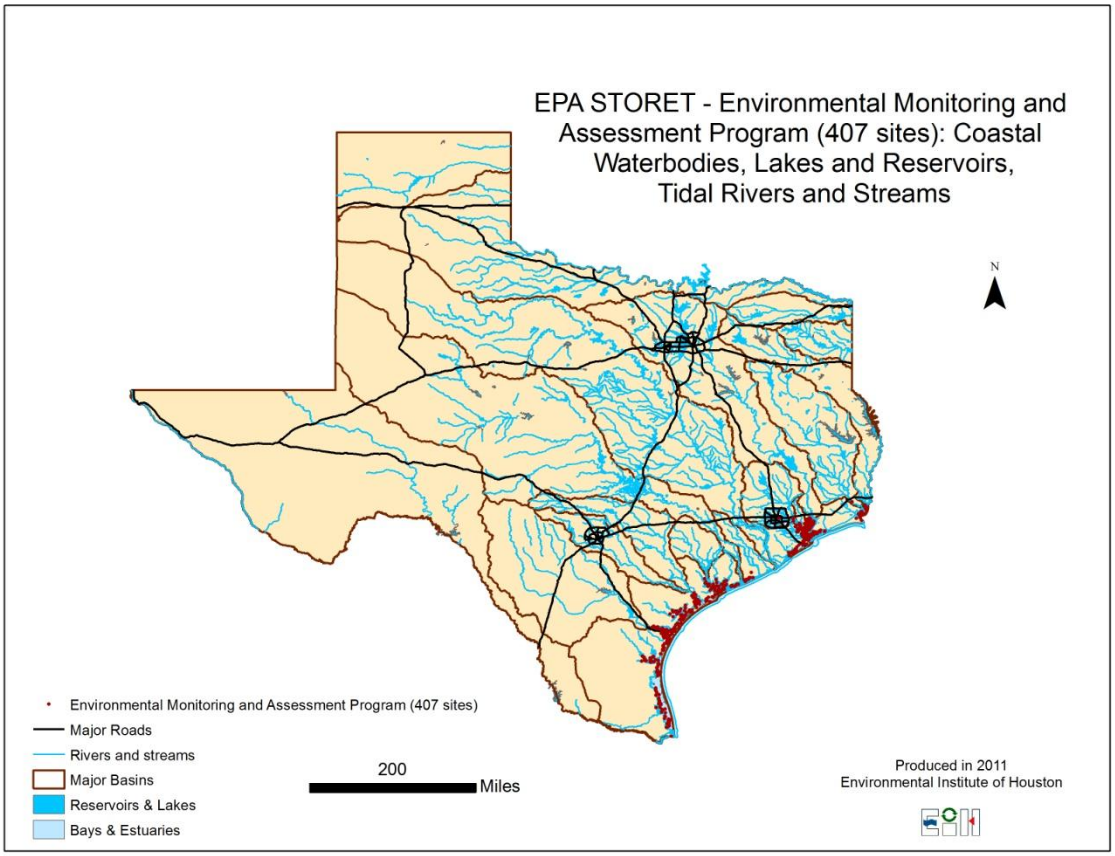

Figure A6. 1. Location of EMAP and REMAP monitoring sites archived in the modern STORET database (post-1997). A total of 407 coastal sites were identified. These data are also archived in the NCA/EMAP database.

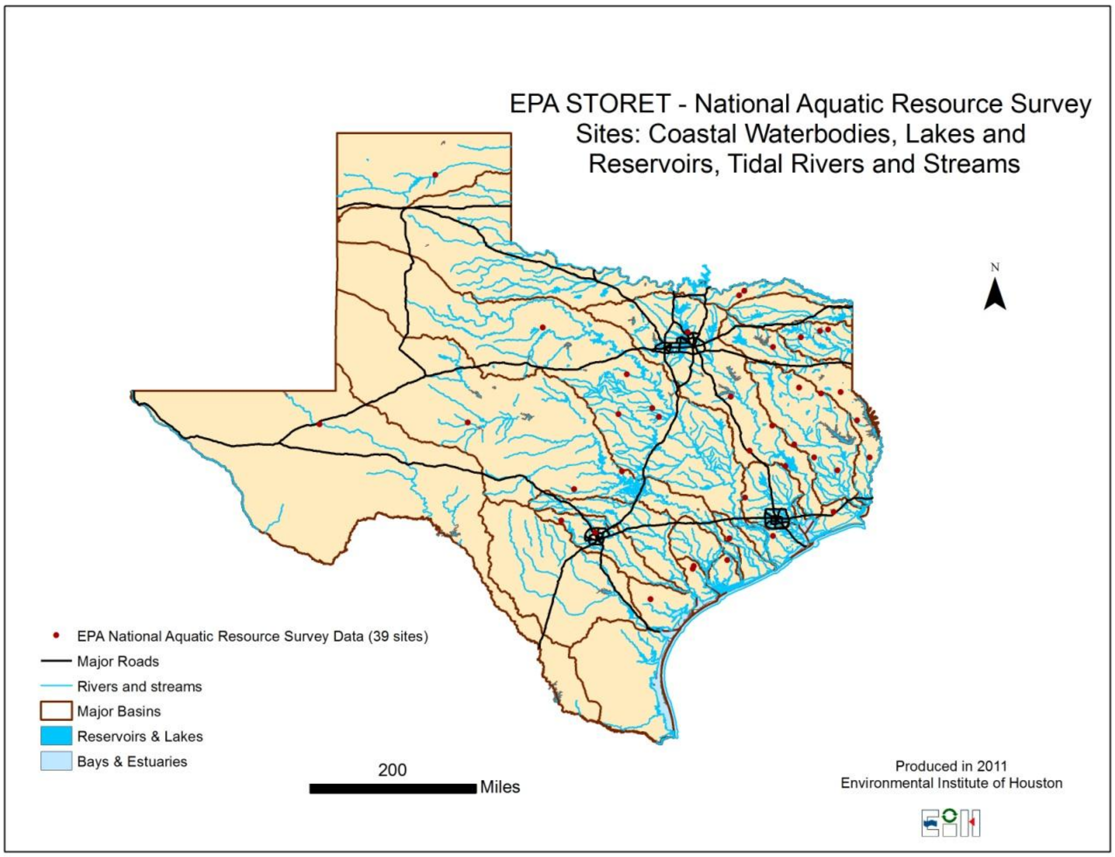

Figure A6. 2. Location of National Aquatic Resource Survey (NARS: NLA, NWSA) monitoring sites archived in the modern STORET database (post-1997). A total of 39 sites were identified.

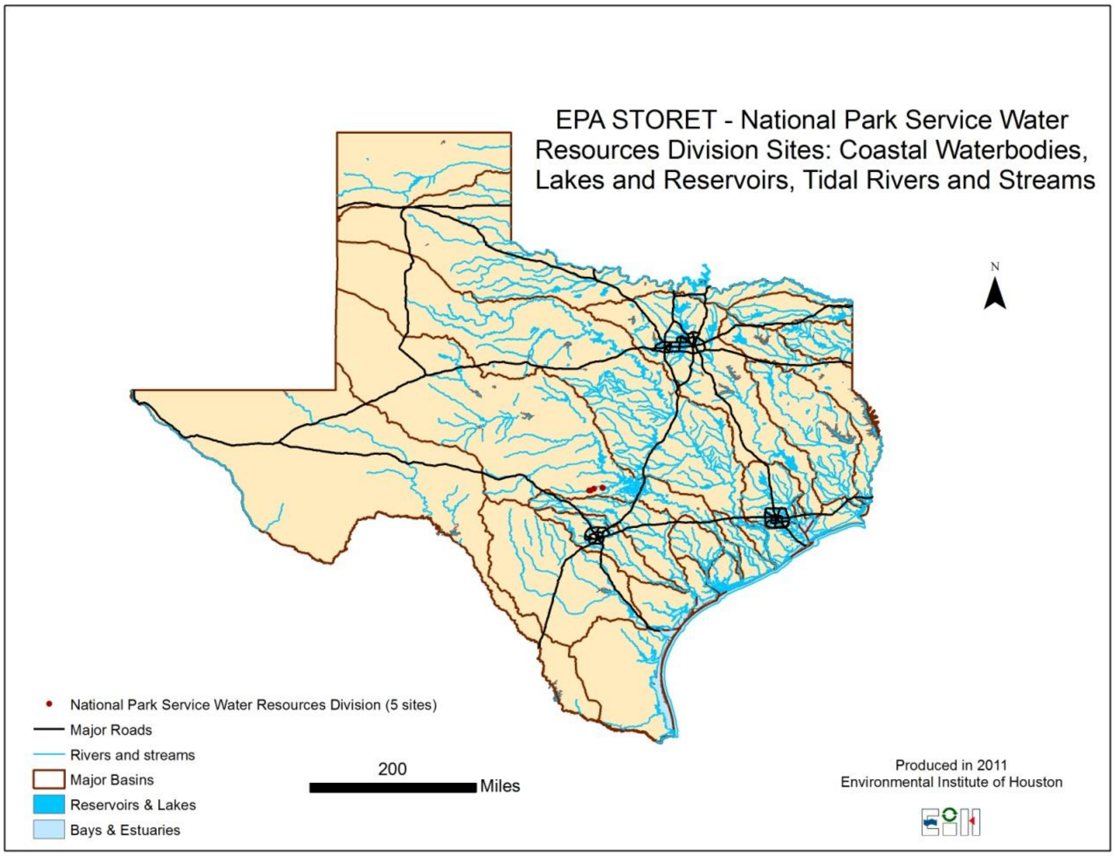

Figure A6. 3. Location of National Park Service (NPS) monitoring sites archived in the modern STORET database (post-1997). A total of 5 sites were identified.

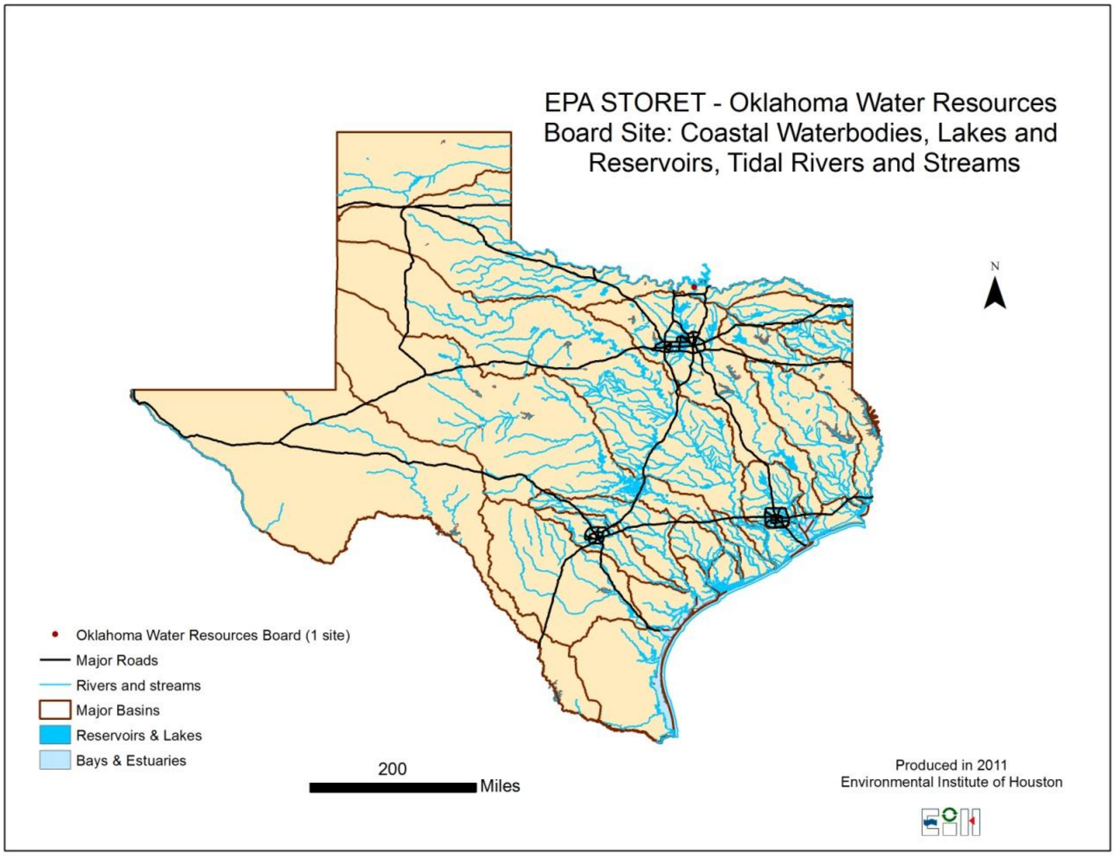

Figure A6. 4. Location of the Oklahoma Water Resources Board (OWRB) monitoring site archived in the modern STORET database (post-1997).

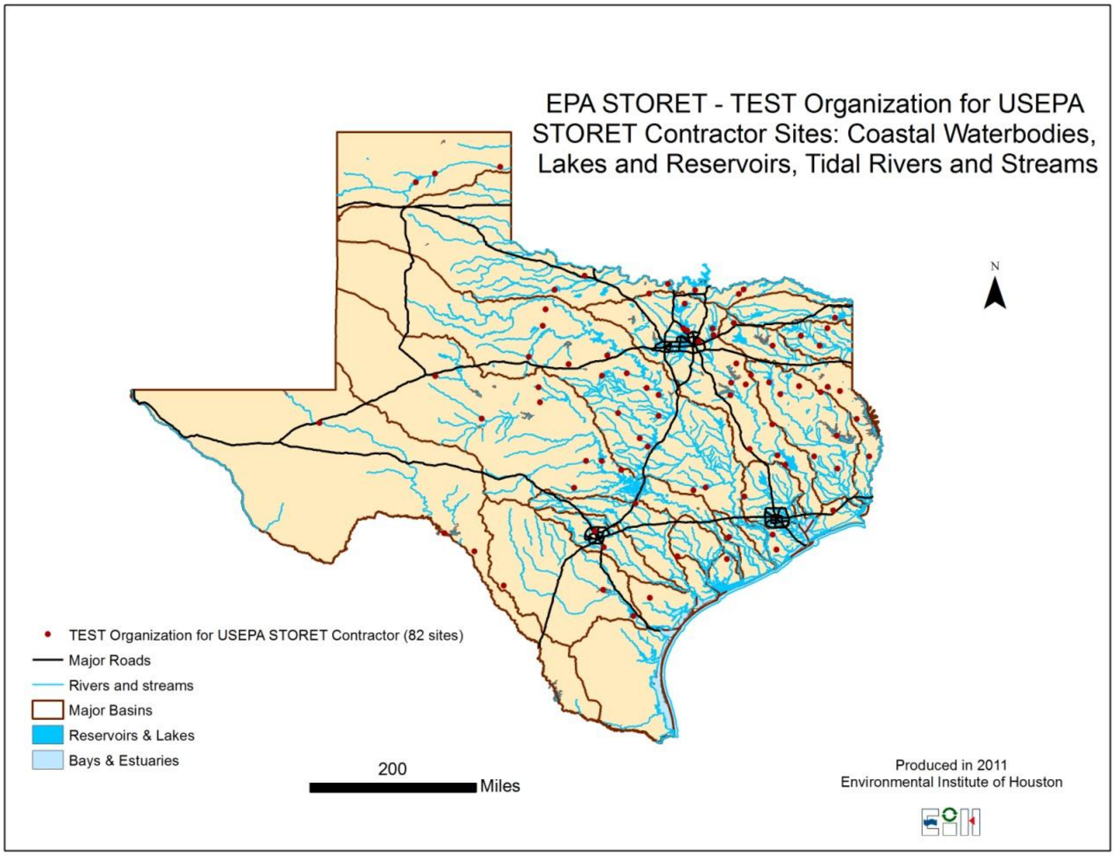

Figure A6. 5. Location of the EPA monitoring sites sampled during their contract TEST program, that are archived in the modern STORET database (post-1997).

Appendix 7. Maps of National Coastal Assessment Monitoring Sites.

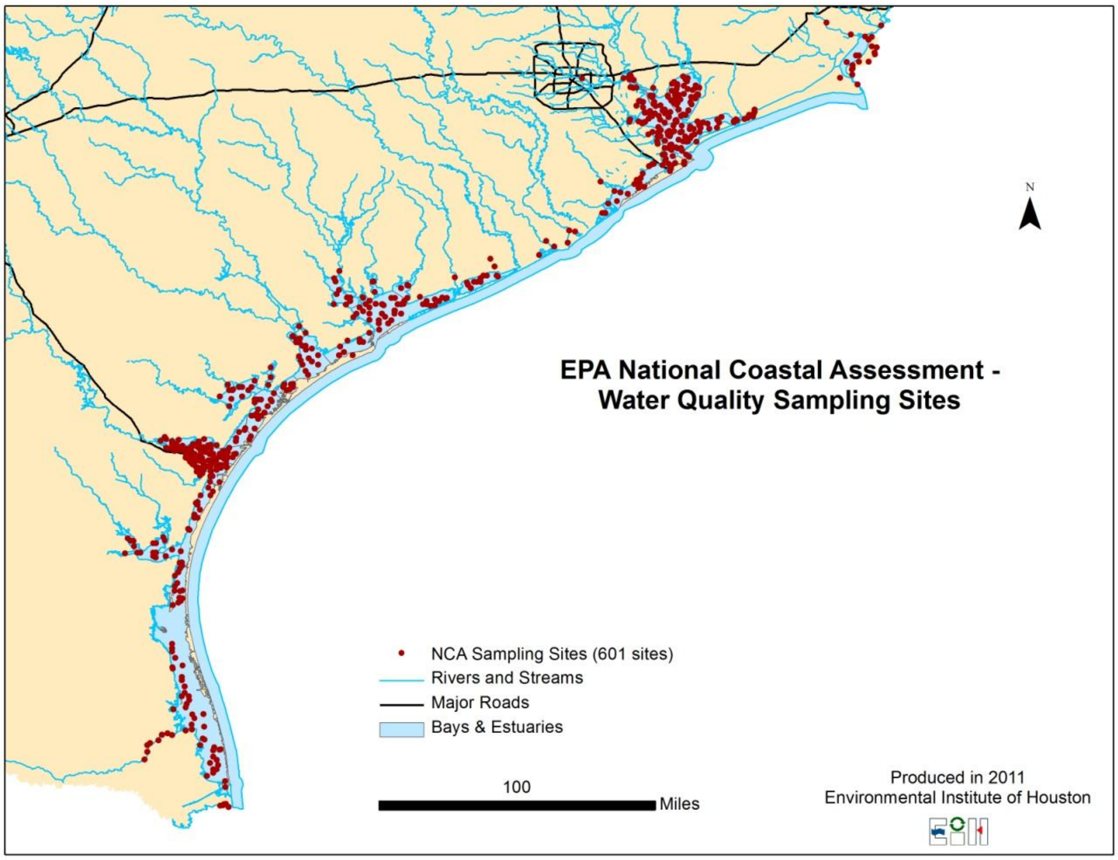

Figure A7. 1. Location of the EPA National Coastal Assessment (NCA) sites monitored from 1991 through 2004 that are archived in the NCA database and STORET database (post-1997).

Appendix 8. Map of the monitoring sites associated with data compiled by “Ward and Armstrong” studies.

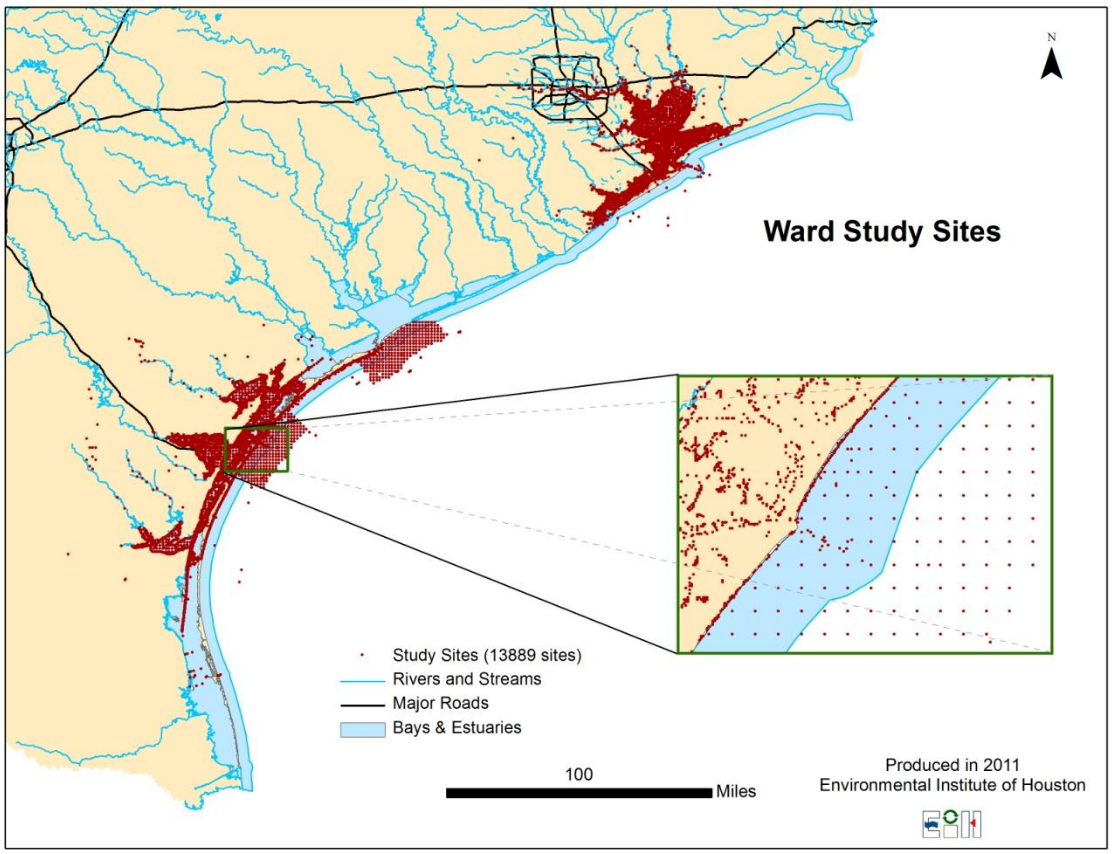

Figure A8. 1. Location of monitoring sites associated with data compiled for the Galveston Bay and Corpus Christi Bay systems that are contained in the Ward and Armstrong databases (Ward and Armstrong 1992a; Ward and Armstrong 1997b).

Appendix 9. Maps of University Study Sites

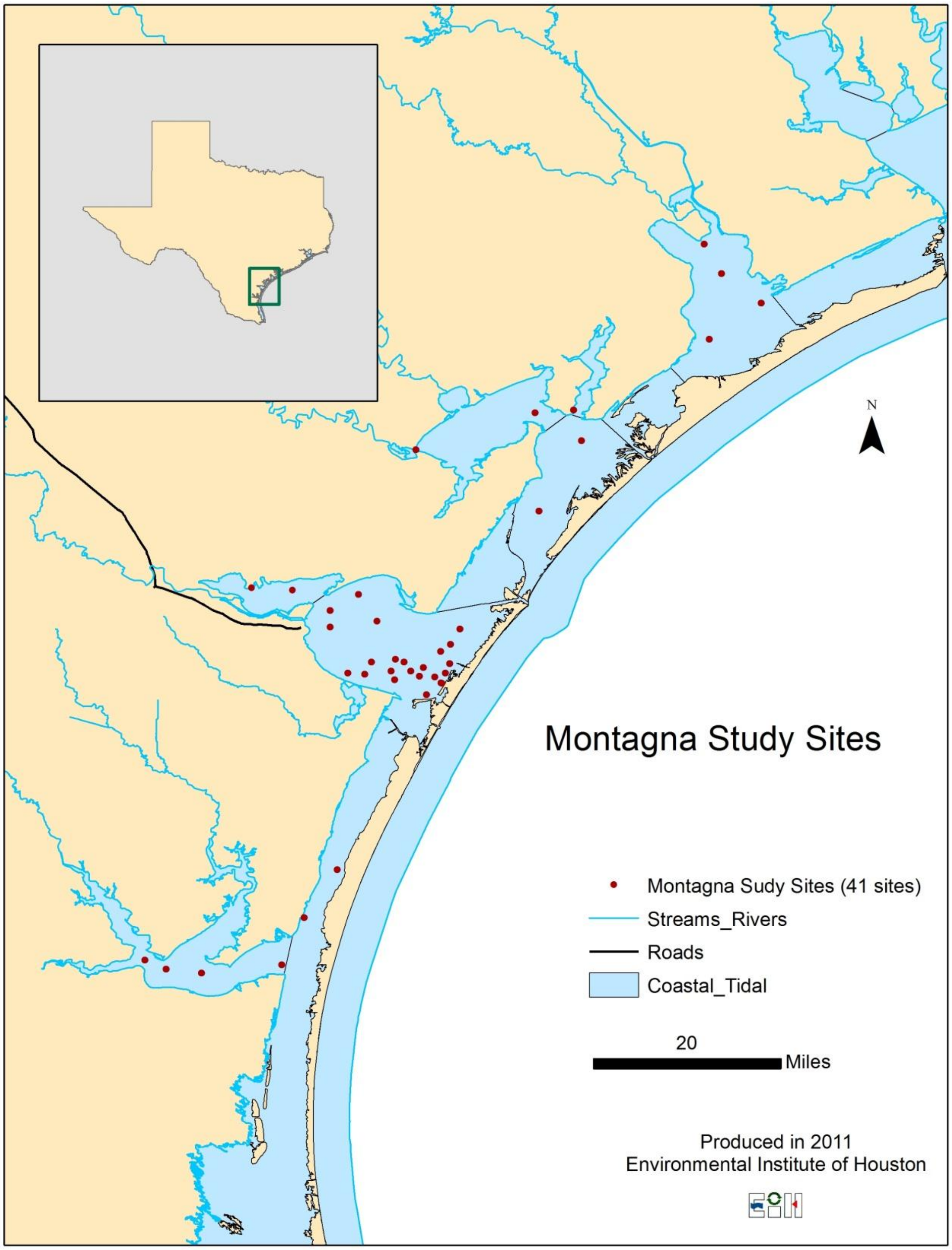

Figure A9. 1. Location of monitoring sites associated with data compiled by Dr. Paul Montagna for studies conducted along the lower Texas coast (Montagna et al. 2009; Montagna and Kalke 1995; Montagna et al. 2008).

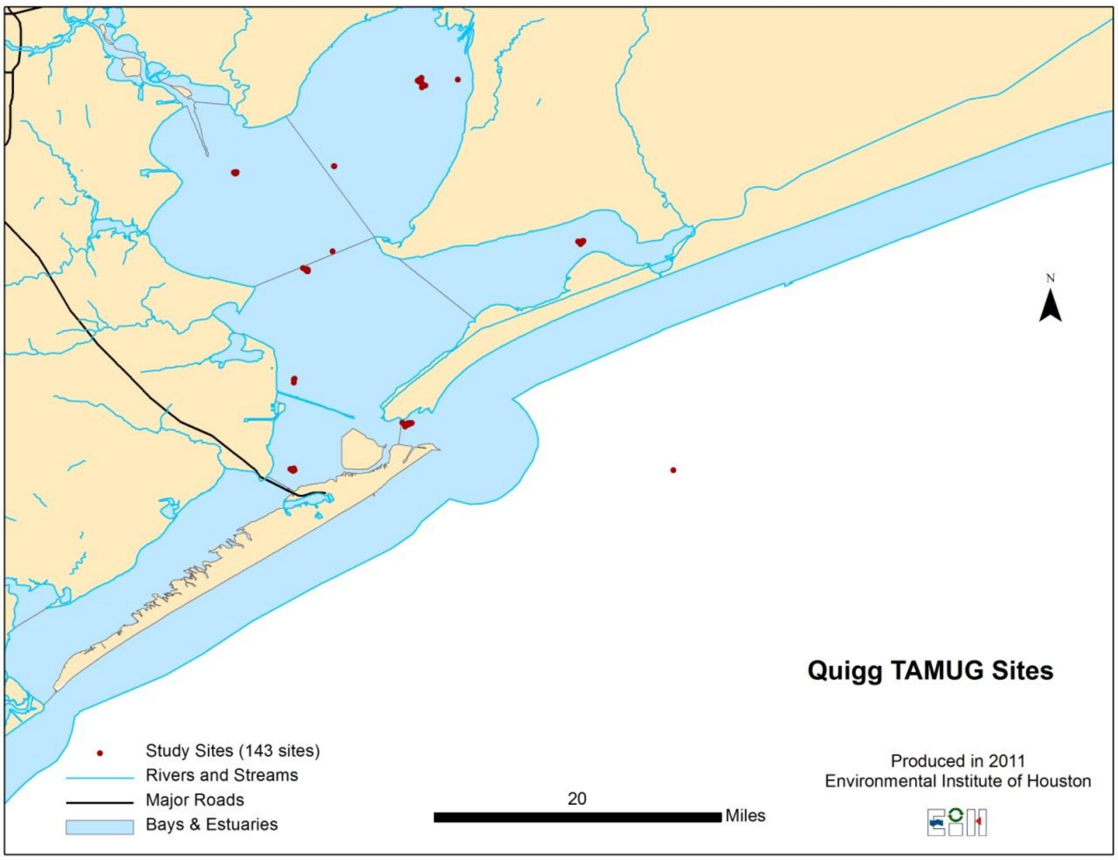

Figure A9. 2. Location of monitoring sites associated with data compiled by Dr. Antonietta Quigg for studies conducted within Galveston Bay (Quigg ; Quigg 2009).

Appendix 10. Maps depicting monitoring sites associated with multiple published studies.

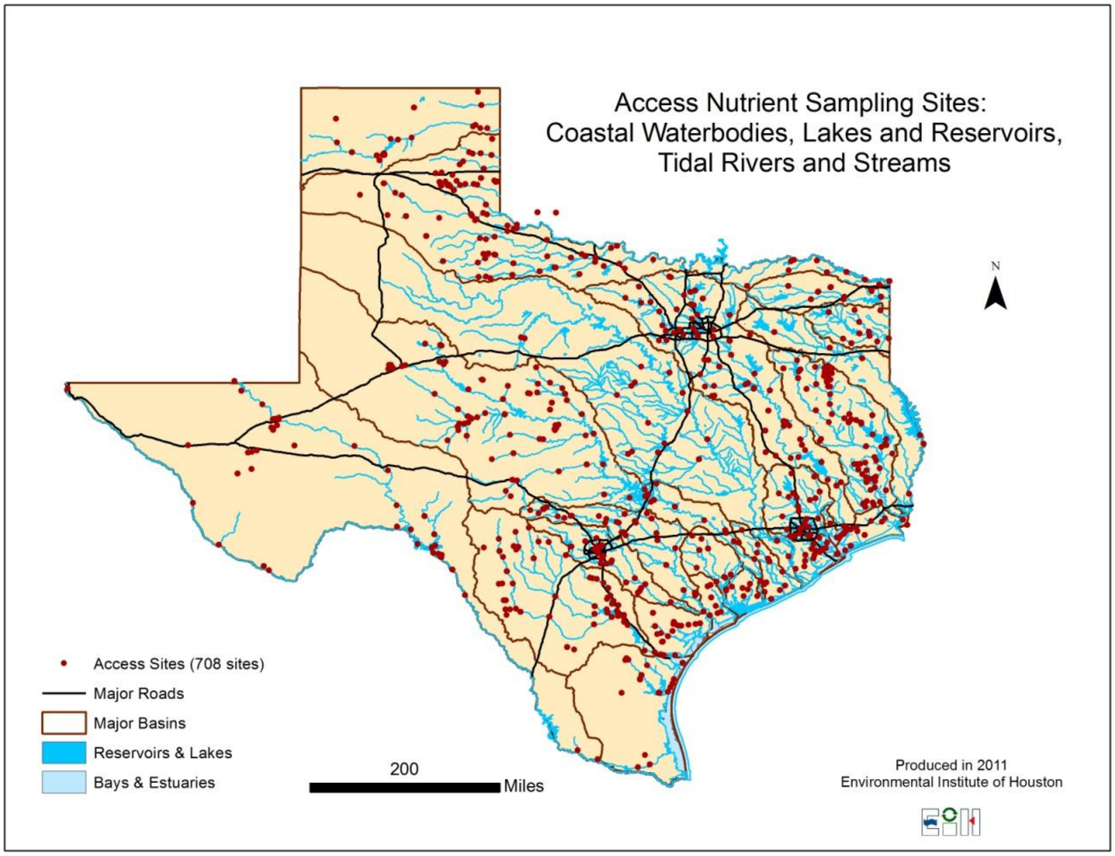

Figure A10. 1. Location of additional 708 monitoring sites associated with multiple published studies archived in the nutrient criteria Access database.