DEVELOPING NUTRIENT CRITERIA FOR LOUISIANA

2006

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Executive Summary

The National Water Quality Inventory: 1996 Report to Congress Executive Summary[1] cites nutrients (nitrogen and phosphorus) as one of the leading causes of water-quality impairment in the Nation's rivers, lakes and estuaries. The Draft 1998 Report to Congress[2] further chronicled impairments attributed to excessive nutrients. Nutrients have been implicated as the source of elevated nitrates in drinking water in the mid-western portion of the United States and in *Pfiesteria*-induced fish kills and human-health problems in the coastal waters of several east coast states. In the coastal estuaries of the Gulf States, excessive nutrient levels have negative impacts by contributing to the hypoxic zone in the Gulf of Mexico, harming Gulf seagrass beds, reducing the abundance of recreationally and commercially important fisheries and contributing to harmful algal blooms[3].

In February 1998, the Clean Water Action Plan (CWAP), which provides the core of the President's Clean Water Initiative, called for Federal agencies, State and Tribal governments, and other stakeholders to work together to restore and protect the Nation's water bodies. A key element of the Action Plan provided for expanded efforts to reduce nutrient enrichment of the Nation's waters. In June 1998, the Environmental Protection Agency (EPA) released the National Strategy for the Development of Regional Nutrient Criteria[4] and subsequently produced manuals to provide technical guidance to assist States and Tribes in developing regionally-based numeric criteria for nutrient constituents nitrogen (N), phosphorus (P), and chl a (chl *a*) in water body types, i.e., rivers and streams, lakes and reservoirs, etc. EPA and US Geological Survey (USGS) also worked to statistically derive 'default' national numeric criteria (N, P, chl *a*, and turbidity) for rivers, streams, lakes, reservoirs, coastal estuaries, and wetlands using data from 14 ecoregions across the US. EPA has published nutrient criteria recommendations for rivers and streams in 13 of the 14 national (Level III) ecoregions and for lakes and reservoirs in 12 of the 14 ecoregions. In accordance with the EPA's guidance, in lieu of the national recommendations, States and Tribes can develop regional numerical nutrient criteria that better represent the physical, chemical, and biological conditions unique to specific ecoregions. The ecoregional approach to development of criteria may also help ensure that states and tribes are better prepared to implement their numeric nutrient criteria.

In January 2001, EPA published a notice[5] in the Federal Register strongly recommending that states submit to EPA a plan that outlines their process for adopting nutrient criteria. 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. This 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

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[1] Report To Congress: National Water Quality Inventory. 1996. USEPA, Cincinnati, Ohio. EPA841R97008.
[2] Clean Water Action Plan: Restoring and Protecting America's Waters. 1998. USEPA. http://cleanwater.gov/action/cwap.pdf
[3] Gulf of Mexico Alliance Governor's Action Plan for Healthy and Resilient Coasts. March 2006 – March 2009. http://gulfofmexicoalliance.org
[4] National Strategy for the Development of Regional Nutrient Criteria. 1998. EPA 822-R-98-002. http://www.epa.gov/waterscience/standards/nutstra3.pdf.
[5] Nutrient Criteria Development; Notice of Ecoregional Nutrient Criteria. January 9, 2001. FR 66: 6, 1671-1674. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2001_register&docid=01-569-filed

necessary. 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 will develop numeric nutrient criteria for water body types within its 12 ecoregion boundaries (as delineated by LDEQ, see Appendix A). Water body types 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). Nutrient data has been compiled 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.

Data gaps have been identified and further data will be collected to fill these gaps as part of the nutrient criteria development process. Studies have been initiated for the first priority water bodies – 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.

Three general approaches for nutrient criteria development are described in EPA's guidance: 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 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. EPA will review any analyses used in their development, and public review and comment will be part of the process for proposing changes to Louisiana's water quality standards.

1.0 Introduction and Background

Section 101(a)(2) of the Clean Water Act (CWA) sets as the national goal the attainment of water quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water. In response to this federal regulatory requirement Louisiana adopted its first water quality criteria in 1967 and designated seven uses for surface water (LAC 33:IX.1111.C). Louisiana streams were designated statewide for primary and secondary contact recreation and fish and wildlife propagation uses and in 1973, along with other criteria, a 5.0 mg/L dissolved oxygen (DO) criterion was adopted across the state. A general narrative nutrient criterion was adopted during October 1984, amended in September 1989, and again in August 1994 as part of the state's regulations pursuant to EPA's guidance at the time.

Louisiana's general nutrient regulation (LAC 33:IX.1113.B.8) provides that:

- The naturally occurring range of nitrogen-phosphorus ratios shall be maintained.
- This range shall not apply to designated intermittent streams.

- To establish the appropriate range of ratios and compensate for natural seasonal fluctuations, the administrative authority (LDEQ) will use site-specific studies to establish limits for nutrients.
- Nutrient concentrations that produce aquatic growth to the extent that it creates a public nuisance or interferes with designated water uses shall not be added to any surface waters.

As Louisiana adopts numeric criteria for nutrients, the existing narrative criteria may be changed depending on recommendations that come from the development of numeric criteria. For example, the use of nitrogen-phosphorus ratios contained in the general nutrient narrative criteria may not be appropriate for all water bodies; and may seem to indicate a "site-specific" approach different from the ecoregional approach Louisiana is proposing in this plan. However, in some cases, site-specific approaches may be appropriate and used for some water bodies (i.e., interstate rivers).

This plan for nutrient criteria development serves as a guide for the evolving approach, prioritization and development of appropriate numeric nutrient criteria for Louisiana and updates the previous nutrient plan submitted by LDEQ to EPA-6 during December of 2001. Amendments to the plan (i.e., annual updates) will be documented as separate documents rather than incorporating changes into this document.

1.1 Identifying the Problems

Louisiana is well known for its abundance of water bodies and according to the most recent Integrated Report for 2004 contains over 66,294 miles of rivers and streams; 1,684 square miles of lakes and reservoirs; 9,191 square miles of fresh and tidal wetlands; and 7,656 square miles of estuaries. For purposes of the Clean Water Act (CWA) 305(b) assessment, LDEQ's Integrated Report for 2004 cites low DO and nutrient constituents as among the most frequently named suspected causes of impairments found in Louisiana's waters[6]. Louisiana has also historically recognized that a large number of water bodies are characterized as "naturally dystrophic" because of certain natural hydrological or physical conditions (i.e., they contain high amounts of nutrients in the form of humic organic matter from allochthonous and other natural sources). The term "dystrophic" has been historically applied to bogs or lake ecosystems, but equally describes the naturally sluggish, low gradient bayous, streams, and shallow lakes of Louisiana which are surrounded by swamps and marshes or frequently inundated floodplains[7]. In these waters, periods of low DO and dynamic nutrient fluctuations are part of the natural cycle. Natural conditions[8] are also included as one of the most frequently cited suspected sources of impairment to fish and wildlife propagation in the 2004 305(b) assessment.

It is also apparent from the 305(b) assessment that there are a number of man-made problems contributing to the impairment of Louisiana's fish and wildlife propagation use, however, most suspected causes, which includes nutrients, can generally be related to nonpoint

[6] In Louisiana the CWA 305(b) assessment for nutrient constituents is currently applied to the fish and wildlife propagation use (DO and turbidity) and to the outstanding natural resource waters use (turbidity).
[7] A review of the literature on dystrophic waters in Louisiana was conducted during 1986-87 to document the occurrence of this natural phenomenon in a report entitled, "Documentation of Naturally Dystrophic Waters in Louisiana (1987)." The report formed the basis of the rationale for the "naturally dystrophic waters" category of excepted uses previously described in LAC 33:IX.1109 and currently under revision by LDEQ.
[8] Natural conditions as described in the IR 2004 consist of "Natural Conditions-Water Quality Standards Use Attainability Analyses Needed" and "Natural Sources."

sources of pollution caused by the runoff of stormwater from agricultural fields, forestry areas, construction sites, and urban areas, to name a few. The remaining causes of impairment are related to various forms of industry, small business, or municipal sources. LDEQ has numerous programs in place to address these problems that include the permitting of dischargers from industry, smaller businesses, and municipalities; enforcement and remediation actions to identify and correct problems when they occur; and the development and implementation of best management practices to address nonpoint sources of pollution.

1.2 Regional Collaboration for Coastal Waters

Louisiana shares its unique Gulf of Mexico habitat with Texas, Mississippi, Alabama, and Florida. As a result of a continuing shared vision for a healthy Gulf of Mexico, the Gulf States along with thirteen federal partners (including the Council on Environmental Quality, NASA, NSF, USDA, NOAA, EPA, and others) formalized the Gulf of Mexico Alliance on March 28, 2006[9]. The first action of the new partnership was to formalize the Governor's Action Plan for Healthy and Resilient Coasts which outlines 11 actions under the Alliance's five priority issues:

1. Water quality
   - WQ 1 - Improve harmful algal bloom detection and forecasting
   - WQ 2 - Improve beach water quality management
   - WQ 3 - Improve government efficiency in water quality monitoring
2. Wetland and coastal conservation and restoration
   - R 1 - Streamline coastal restoration and conservation efforts
   - R 2 - Increase the safety of Gulf communities by better understanding the risks of localized sea level rise, storm surge and subsidence
3. Environmental education
   - ED 1 – Galvanize local communities to protect the Gulf of Mexico
   - ED 2 – Conduct a public awareness campaign for the Gulf of Mexico
4. Characterization of Gulf habitats
   - ID 1 – Create and provide access to interactive habitat maps for priority Gulf of Mexico habitats
5. Reduction of Nutrient Inputs
   - N 1 – Increase regional coordination in the development of nutrient criteria
   - N 2 – Implement nutrient reduction activities during Gulf recovery and building
   - N 3 – Assert an aligned five Gulf State position on the need to address Gulf of Mexico hypoxia

Each of these actions presents specific 36-month outcomes and an Action Blueprint to describe critical steps to achieve the outcomes. The collaboration is especially relevant to and consistent with the development of nutrient criteria for Louisiana's coastal waters, the Mississippi River and the northern Gulf of Mexico.

2.0 Parameters and/or Translators for Nutrient Criteria

EPA guidance recommends that four primary water quality variables be addressed: total nitrogen (TN), total phosphorus (TP), chlorophyll a (chl *a*) as an estimator of algal biomass, and turbidity. The nutrient criteria technical manuals also suggest that states may use an ecoregional approach to develop criteria for the "causal variables" such as nitrogen and phosphorus constituents, and "response variables" such as DO, turbidity, secchi depth, and chl *a*. Therefore, nutrient criteria can be simultaneously evaluated with DO criteria as well as other response variables (i.e., chl *a*, secchi disk, turbidity) by using the ecoregional approach. This

[9] http://gulfofmexicoalliance.org

process may help identify predictive relationships as well as new reference water body types or systems for EPA's suggested nutrient "causal" and "response" variables.

At this point, LDEQ has determined that for most water bodies the best approach to developing nutrient criteria may be to use total phosphorus (TP) and total nitrogen (TN) as "causal variables" based on the following assumptions:

- Biomass (and biological resources) will utilize most available NO_2 + NO_3 and/or organic phosphorus (OP) for growth, resulting in low concentrations in the water column. There may be an abundance of plankton in the water body that is not reflected by the NO_2 + NO_3 and/or OP alone (periphyton studies outlined in Section 8.3 will help describe this relationship in ecoregion streams).
- There will be a time delay between NO_2 + NO_3 and/or OP concentrations and their resulting biomass growth
- TN and TP values will incorporate a better estimate of autochthonous nutrient cycling. TN and/or TP will correlate better with biomass factors than any individual N and/or P species.

While the best approach to developing nutrient criteria may be to use TN and TP data for most Louisiana water bodies, recent findings on the Mississippi River indicate that NO_3 may be a better indicator for nitrogen on large, fast-flowing rivers. This relationship will be a component of nutrient criteria development for the big rivers and floodplain/boundary waters. In Louisiana's nutrient criteria development process, criteria or translators (i.e., loading rates) for TN and TP will eventually be developed by water body classification; possibly seasonally, or by water body size (i.e., stream order) as well.

LDEQ routinely monitors for three of the four recommended primary water quality variables through its Surface Water Quality Monitoring Program: TN, TP and turbidity (see Table 2 in Section 7.1). LDEQ currently monitors chl *a* during intensive surveys for wasteload allocations and TMDLs so there is very little stream column periphyton chl *a* data available statewide. The review of available data and data gaps for nutrient criteria development in relation to this plan is discussed in Section 7.0. New or existing data are needed to define the relationships between nutrient variables and where possible, identify cause and effect relationships, and impairment thresholds (i.e. impacts on fish and wildlife propagation use).

3.0 Relation of Nutrient Criteria to Designated Use(s)

States and Tribes establish criteria for the specific purpose of protecting the designated uses of their waters, therefore the way nutrient criteria relate to Louisiana's use classifications is addressed in this plan. Louisiana currently has seven water uses adopted into the Louisiana Surface Water Quality Standards:

1) Primary Contact Recreation
2) Secondary Contact Recreation
3) Fish and Wildlife Propagation
4) Drinking Water Supply
5) Oyster Propagation
6) Agriculture
7) Outstanding Natural Resource Waters

LDEQ recognizes that the development of appropriate nutrient criteria will require balancing the consideration of multiple uses. EPA has described two general ways of relating nutrient

criteria to use classifications. The first is to select appropriate reference conditions that represent a level of water quality at which there are no known impairments of a use due to nutrient over-enrichment. EPA's 304(a) criteria recommendations for nutrients used a statistical method to describe reference conditions on a broad ecoregion or sub-ecoregion scale irrespective of designated uses or levels of refinement within the same type of designated use (i.e., warmwater fishery, coldwater fishery). These recommendations are considered by EPA to be protective for all assigned designated uses in these ecoregions, in the absence of information to the contrary.

EPA also encourages considering the designated use of waters when grouping and prioritizing them for nutrient criteria development and for characterizing reference conditions. For example, in Louisiana a subcategory of water bodies designated as naturally dystrophic[10] or as wetlands will ultimately have nutrient criteria derived specifically to protect their designated use(s). Subcategories of water bodies and uses would still be framed within the ecoregional 'reference' concept described in this plan – unless further studies show another approach is more appropriate. Generally, if reference conditions accurately reflect minimally disturbed conditions, then all attainable uses should be protected if water quality is equal to or better than the reference conditions.

General, numeric and narrative criteria have long been part of states' water quality standards and have historically followed EPA's recommendations. As of 1998, the only national numeric water quality criteria recommendations for nutrient constituents in existence were for nitrate nitrogen and phosphorus. In 1976, in EPA's publication entitled Quality Criteria for Water (also known as the Red Book), EPA presented ambient water quality criteria for nitrates, nitrites and elemental phosphorus (for protection of toxic effects only to estuarine and marine organisms). The criterion for nitrate nitrogen was 10 mg/L for the protection of domestic water supplies - intended to prevent over-enrichment and to protect human and animal health.[11] This level is consistent with the most current National Primary Drinking Water Regulations[12] which are adopted by reference and applicable to Louisiana's public water supplies through the State Sanitary Code (LAC 51:XII, Chapter 3)[13]. LDEQ's current narrative nutrient regulation was intended to be protective of all of the state's designated uses. For CWA 305(b) assessment nutrients are addressed primarily through the fish and wildlife propagation use (DO and turbidity) and in the outstanding natural resource waters use (turbidity). The general criteria for turbidity (LAC 33:IX.1113.B.9.a) also states that,

"Turbidity other than that of natural origin shall not cause substantial visual contrast with the natural appearance of the waters of the state or impair any designated water use…"

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[10] In response to the need for site-specific flexibility in applying dissolved oxygen criteria to Louisiana water bodies, LDEQ promulgated a section on water body exception categories in the surface water quality standards (LAC 33:IX.1109.C). This section includes a category for naturally dystrophic waters, but the criteria and uses are developed during the UAA process. The exception categories recognize that some water bodies do not meet the statewide water uses or criteria (i.e., 5.0 mg/L DO criterion) because of natural water quality or physical limitations as well as other factors. A UAA must be conducted to assign seasonal DO criteria or to change a designated use for a naturally dystrophic water body. The regulation has been revised and a protocol for this category is being developed for Volume 9 of the WQMP to characterize those water bodies that should be appropriately designated in the water quality standards as naturally dystrophic.

[11] From: http://www.epa.gov/waterscience/criteria/nutrient/nutsi.html

[12] EPA 816-F-02-013. July, 2002.

[13] http://www.state.la.us/osr/lac/51v01/51v01.pdf

Therefore, LDEQ recognizes that different approaches may be necessary to analyze whether nutrient levels limit a water body for swimming or fishing opportunities, or for aesthetics.

The general criteria (LAC 33:IX.1113.B.5) also require that state waters be free from the effects of toxic substances, which includes nutrient species such as nitrates and ammonia. Recently (2004), the USGS summarized data collected during 1999-2001 as part of its ongoing assessment of water quality in Louisiana's Acadian-Pontchartrain (NAWQA program) drainages[14] and found that forms of nitrogen varied among streams. For example, ammonia was generally minimal except in the urban study site, and nitrate was not a dominant form of nitrogen in any of the smaller study streams. However, this observation contrasted with the presence of nitrate in the Mississippi River (which is designated as a drinking water source) near St. Francisville, Louisiana. Apparently, for a variety of reasons, nitrate is not assimilated or removed as readily by natural processes in the larger Mississippi River as in the smaller streams and tributaries of the Acadian-Pontchartrain drainages. While nitrate concentrations in the Mississippi River were reported at about a median of 1.3 mg/L, this value is still well below the EPA recommended human health criterion of 10 mg/L for nitrates. Also, nitrate-nitrogen (N-N) is a chemical component of TN. Presumably, in terms of nitrates, for the rivers and streams that serve as drinking water sources, including the larger Red, Sabine and Mississippi Rivers, numerical nutrient criteria for TN that are developed to protect and maintain aquatic life uses would also be protective of human health for the drinking water use (TN = NO_2-NO_3 + TKN).

Another way to relate nutrient criteria to use classifications (as discussed in EPA guidance) is to construct quantitative relationships between the causal variables TN and TP, and the 'response' variables that are more directly related to or descriptive of the particular designated use. For example, regression analysis could help determine a threshold level for phosphorus and an index value of biological integrity developed from fish community data that represents the minimally acceptable community condition for a given habitat type. LDEQ will be examining this type of quantitative relationship in the project described as Study 1, discussed in Section 8.2 of this plan. The objective of the project is to assess the relationship between nutrients, DO, stream habitat, and the abundance and species composition of the resident fish assemblage in 16 least impacted streams representing four previously-described Louisiana ecoregions (map and descriptions of LDEQ ecoregions in Appendix A). Principal components analysis will be used to examine the assemblage structure as it relates to habitat and water quality variables. Study results will help identify those variables that have the most influence on fish distribution and abundance, and what concentrations are optimal in consideration of nutrient criteria and DO criteria development.

Other studies conducted by LDEQ in Louisiana in the past contain site-specific information and suggestions for further analysis. These studies are described briefly in Section 7.0. Information from "causal, predictive, or quantitative relationship" studies will be incorporated into nutrient criteria development, assessment and implementation as relationships and trends are identified.

4.0 Physical Classification – Water body Types and Ecoregions Classifications

Louisiana lies entirely in the Gulf Coastal Plain physiographic province and can be divided into five natural physiographic regions: Coastal Marsh, Mississippi Alluvial Valley, Red River Valley, Terraces, and Hills. The state has twelve major river basins, which are described in LAC 33:IX.1123 (Table 3 includes the numerical criteria and designated uses), and twelve

[14] USGS. 2004. Water Quality in the Acadian-Pontchartrain Drainages, Louisiana and Mississippi, 1999-2001. Circular 1232 (http://www.usgs.gov/).

ecoregions (Appendix A). Maximum elevations in Louisiana are located in the hills of the northwest, where the state's oldest geologic formations are found. The highest elevation in the state is only 535 feet at Mount Driskoll, Louisiana. The lowest elevations in the state are found in the Coastal Marsh area, which extends across the southern portion of Louisiana and represents a valuable fisheries and wildlife resource. Due to levee construction, marsh filling, and a high rate of subsidence, portions of south Louisiana, mostly urban areas, are below sea level.

4.1 Water Body Types

Louisiana's surface waters can be broken down into water body types as shown in Table 1. Louisiana's coastal resources differ significantly in physical, chemical, and hydrological characteristics from upland resources, therefore the categories for lakes and wetlands have been broken down into inland and coastal. Those water bodies categorized as coastal receive some tidal influx, even though some of the coastal lakes and wetlands are characterized by fresh water vegetation.

Table 1. Water Body Types

Inland Rivers and Streams:		
Total River Miles	66,294	miles
Big Rivers and Floodplains/Boundary Rivers and Water Bodies:		
Pearl River	74	miles
Mississippi River	333	miles
Sabine River (includes Toledo Bend Reservoir)	210	miles
Atchafalaya River	200	miles
Red River	321	miles
Ouachita River	188	miles
Freshwater Lakes and Reservoirs:		
Number of Fresh water Lakes/Reservoirs	6,603	
Number of Inland Freshwater Lakes and Reservoirs > 1 sq mi.	62	
Freshwater Swamp/Forest and Brackish/Saline Marsh Wetlands:		
Fresh Water Inland Wetlands	3,000,130	acres
Coastal Tidal Wetlands*		
Fresh Marsh	533,577	acres
Brackish and Saline	2,550,821	acres
Swamp	392,109	acres
Estuaries and Coastal Waters (includes Gulf of Mexico waters)		
Intermediate Estuaries and Coastal Waters	441,046	acres
Brackish Marsh Estuaries and Coastal Waters	820,378	acres
Salt Marsh Estuaries and Coastal Waters	363,711	acres

* Habitats may overlap with estuaries and coastal waters; these classifications may change.

4.2 Ecoregion Concept

As mentioned previously, the State of Louisiana developed its first water quality standards in 1967 and based them on national recommendations for uses and criteria, including the narrative criteria for nutrients. LDEQ's strategy for nutrient criteria development is based on the need for regional approaches in applying appropriate water quality standards to Louisiana water bodies. In an effort to develop regionally based water quality criteria for DO in Louisiana, LDEQ began establishing an ecoregional framework for surface water standards in 1990 with guidance from

the EPA and the experiences of other states including Arkansas[15]. The ecoregion approach integrates characteristics such as climate, land surface form, soils, vegetation, land use, and hydrologic modifications (levee systems) to form management units with similar biological, chemical and physical. EPA's ecoregion level III[16] delineations were used by personnel at the University of Southwestern Louisiana Center for Louisiana Inland Water Studies (USL-CLIWS) as a reference in the development of the LDEQ ecoregion boundaries. In addition, experience and general knowledge were applied in the development of the ecoregion boundaries similar to those described by EPA-Corvallis during the early 1990's. Significant revisions were made to the EPA-Corvallis ecoregion outlines to develop Louisiana's state-specific ecoregions. The first revision was the addition of the following draft ecoregions: the Terrace Upland Ecoregion, the Atchafayala Basin Ecoregion, and the Coastal Plain Ecoregion which is divided into the Chenier Plain and the Deltaic Plain. This revision by LDEQ to the EPA delineated ecoregion map also included the consolidation of the EPA designated Southeastern Plains, Mississippi Valley Loess Plains, and the Southern Coastal Plains ecoregions to form the Terrace Uplands Ecoregion. Further refinements that were necessary to delineate major rivers have also been added to the state specific Louisiana ecoregions map. The LDEQ designated draft ecoregions are illustrated and described in Appendix A.

The biggest challenge in developing attainable site-specific water quality standards for nutrients is the derivation of criteria that represent the best attainable, natural conditions or sources. An ecoregional approach would help provide the state with the best attainable criteria and goals for nutrients (and other criteria linked to nutrients such as DO) developed on a regional scale. Yet, there are limitations to the application of this approach. It is not always possible to identify the recommended minimum number of least-impacted reference sites in highly impacted ecoregions.

The ecoregion approach was originally designed for small, wadeable, headwater streams. Louisiana has a number of large, non-wadeable streams within the Mermentau, Vermilion-Teche, Calcasieu, and Ouachita River Basins, to name a few. Ecologically similar, least-impacted reference sites for the large, non-wadeable rivers are far more difficult to identify. It is feasible that once an appropriate reference is identified, analysis for criteria can be conducted as comparably as possible to previous analyses from the smaller, wadeable, ecoregion reference streams. This has been accomplished on a few larger water bodies in the Mermentau and Calcasieu River (on a watershed basis). However, one of the most limiting factors (and not unique to Louisiana) in using ecoregional "least-impacted reference stream" approach for criteria development remains the identification of appropriate references for larger water bodies.

The ecoregional approach being developed in Louisiana is consistent with, though not identical to, EPA's use of Omernik's ecoregions for the development of national nutrient criteria, and EPA also recommends the ecoregion approach to further refine states' nutrient criteria (i.e., *Nutrient Criteria Technical Guidance Manual Rivers and Streams, EPA 822-B-00-002, July 2000*). The nutrient criteria technical guidance manuals suggest that states may use an ecoregional approach to develop criteria for "causal variables" such as nitrogen and phosphorus constituents, and "response variables" such as DO, turbidity, secchi depth, and chl *a*. It is anticipated that criteria will eventually be developed seasonally, by water body classification, and possibly by water body size as well. In order to conserve resources and reduce duplication of work, DO and nutrients can be simultaneously evaluated using the ecoregional approach.

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[15] Quality Assurance Project Plan for Louisiana Ecoregion Project, LDEQ, 1997

[16] As of October 2004, Level IV delineations are nearly completed with the cooperation of a multi-agency task force (which includes LDEQ) and the EPA's Corvallis lab.

This process may help to identify new reference water body types for DO in addition to reference systems for nutrients.

5.0 Prioritization of Water body Types

LDEQ will be prioritizing the development of nutrient criteria by water body type within ecoregions. Ongoing and new studies will first address the small, wadeable rivers and streams that have been previously characterized by LDEQ in the Western Gulf Coastal Plains (WGCPE), South Central Plains (SCPE), Upper Mississippi Alluvial Plains (UMAPE), and Terrace Uplands (TUE) ecoregions. New studies are being initiated and results will be analyzed for criteria development in these streams, as well as for options or methods to apply nutrient criteria in rivers and streams statewide.

The prioritization of Louisiana water body types for nutrient criteria development was developed after careful consideration of many factors. A good summary of some of the factors considered for each water body type is contained in the water body specific approaches in Appendix B. Primary consideration was given to the availability of adequate data and information on each water body type; but consideration was also given to the status of LDEQ's regulatory authority for each water body type. LDEQ has the most regulatory authority for those inland rivers and streams which are wholly contained in Louisiana's state boundary. That along with years of long term and special water quality data and studies weighed heavy in selecting this water body type as the first priority for nutrient criteria development. The selection of freshwater wetlands as the second priority was based on the fact that LDEQ and a group of Louisiana scientists have over 10 years worth of environmental data from various freshwater wetland types collected through its Wetlands Wastewater Discharge Program. A good overview of data and information on Louisiana natural freshwater wetlands is contained in Appendix B. Through the Wetlands Wastewater Discharge program important wetland characteristics such as hydrology, stem growth and litter fall, trunk diameter growth, vegetative factors, nutrient dynamics and other water quality factors have been monitored for over 10 years at several wetland sites. LDEQ has also developed and promulgated vegetative criteria for freshwater forested and brackish marsh wetlands. Because of the extensiveness of this wetland data and information, consideration is being given by EPA to include several Louisiana freshwater wetlands study sites as part of a case study section in the EPA guidance document on nutrient criteria for wetlands.

The remaining priorities for nutrient criteria development follow the same considerations given for streams and wetlands. Water quality monitoring data in Louisiana is less for lakes and reservoirs than for streams and wetlands and will require significantly more monitoring to develop nutrient criteria recommendations. However, it's also recognized that most lakes and reservoirs are wholly contained in the Louisiana state boundary and helps to justify their priority. The last major study of Louisiana lakes and reservoirs was conducted during the 1980's and the proposed approach for lakes and reservoirs is outlined in Appendix B.

The last two water body types in the priority list for nutrient criteria and development, interstate boundary-rivers and floodplains, and estuarine and coastal wetlands (and waters) have several complicating factors to consider before defensible nutrient criteria can be developed. These are discussed in Section 7.3. LDEQ is working with national, multi-state and agency programs to address the interstate water quality concerns for the Sabine, Pearl, Red and Mississippi and Atchafalaya Rivers. It will take time and considerable effort to establish the interagency coordination needed with other states whose rivers drain into Louisiana to develop nutrient criteria approaches and LDEQ has attempted to address this in the plan. It is anticipated that further updates to the plan will be required. The last priority listing, estuarine and coastal wetlands and waters (and the Gulf of Mexico), will require collaboration with several state and federal partners.

It should also be noted that the coastal waters of several Gulf States (Texas, Louisiana, Mississippi, Alabama and Florida) have been dramatically impacted by hurricanes Katrina and Rita which complicates the program to develop nutrient criteria in these water body types. LDEQ anticipates that this will require some changes to the plan as the impacts are fully understood.

A prioritization list is given below. Criteria development for wetlands within ecoregions will be examined after rivers and streams, then freshwater lakes and reservoirs, followed by big rivers and interstate waters, boundary waters, estuarine and coastal wetlands and waters, and the Gulf of Mexico. Priorities may be shifted, i.e., for water bodies targeted by nonpoint watershed implementation plans and through the TMDL process.

Prioritization of Water Body Types
Rivers and Streams
Freshwater Wetlands
Freshwater Lakes and Reservoirs
Big Rivers and Interstate/Floodplain/Boundary Waters (Atchafalaya, Mississippi, Sabine, Red, and Pearl Rivers)
Estuarine and Coastal Wetlands and Waters, and the Gulf of Mexico

6.0 Approaches for Development of Nutrient Criteria

This section outlines the general objectives and procedures to be applied to Louisiana's nutrient criteria development process in general (water body-specific and regionally based). The ecoregion concept and LDEQ's ecoregion framework is described in more detail in Appendix A. An approach for each water body type (i.e., rivers and streams, lakes, etc.) is also outlined further in Appendix B.

The proposed procedures will also consider the statistical method described as part of the National Nutrient Strategy as a "default", but would be applied to Louisiana's delineated ecoregions (instead of the nationally derived Level II or III criteria). The statistical criteria development strategy is to follow the EPA guidance using the 25th percentile of all water bodies (by ecoregion and by water body type) to determine numeric criteria. This approach may be preferable when there is a lack of data for least impacted reference sites, and the 25th percentile of all sites is interpreted in the guidance to be the statistical "best attainable" condition. The percentile is only a recommendation and may be adjusted (EPA recommends 5-25%) to that which most appropriately fits Louisiana's water bodies. The actual distribution of the observations in reference water bodies should be the major determinant of any threshold points. However, LDEQ is not in favor of using a purely statistical approach to develop nutrient standards and this approach should be used only as a "default" until regional relationships (i.e., effects-based studies, or use of weight of evidence approaches) for least-impacted streams can be characterized.

6.1 Objectives

1) To develop appropriate ecoregional numeric nutrient criteria (including DO criteria) that represent the best attainable physical, chemical, and biological conditions unique to specific water body types and ecoregions in Louisiana.

2) To develop options for implementing water quality standards for nutrients and DO in CWA 305(b) assessment, TMDLs, and LPDES water discharge permits. This may also include targeting water bodies through a watershed implementation plan under CWA Section 319 nonpoint source program.

The goals are to modify nutrient and DO criteria to better reflect hydrology, geomorphology, natural organic loading, etc., and to develop appropriate nutrient criteria (i.e., not under- or over-protective) of Louisiana's water bodies, while protecting biological resources. Existing biological data from previous ecoregion work supports protection of fish and wildlife propagation uses, and using the ecoregion 'least-impacted' reference stream approach all attainable uses should be protected if water quality is equal to or better than the reference conditions.

6.2 Ecoregion Approach

An ecoregion approach is proposed to be used to develop ambient numeric nutrient criteria and to analyze the appropriateness of existing DO standards (DO as a response variable is highly appropriate). This approach can also be used to identify least-impacted reference water bodies and/or systems within each water body type in each ecoregion. The scope and order of these procedures may need to be modified as the plan develops and data are analyzed.

1. Compare EPA's national numeric nutrient compilation of ranges to Louisiana's ecoregional nutrient ranges. (This procedure includes evaluation of existing data, i.e., historical, long-term water quality data).

a. USGS is working with LDEQ to compile readily available nutrient data from LDEQ's ambient water quality monitoring network, STORET, NWIS, and other selected sources into a consolidated database compatible with EPA's national nutrient database format. USGS is concurrently compiling LDEQ's water quality monitoring network data for nutrients into the LDEQ ecoregion framework.

b. For LDEQ, the emphasis on statistical analysis of existing water quality data will include the development of trophic levels, or other ratios and tools, to compliment planned and ongoing nutrient studies. Trophic levels based on total nitrogen and total phosphorus ratios will be calculated for all water bodies by ecoregion (EPA guidance).

c. Aggregate data by ecoregion (both EPA's national ecoregion and LDEQ's ecoregion) to view distributions of nutrient data across ecoregions, and support development of ecoregion-specific nutrient criteria for Louisiana.

d. Identify gaps of critical data, i.e., parameters recommended in EPA guidance or through regional scientific studies and/or analysis as critical in the development of water body and ecoregion-specific nutrient criteria.

e. Provide for the collection of additional or new monitoring data determined to be critical in the development of water body- and ecoregion-specific nutrient criteria.

f. Analysis of response variable data, where available. Potential associations between seasonal and hydrological factors that affect the relation between nutrient concentration and algal production, or other response variables, will be investigated.

g. The USGS database for Louisiana will be provided to LDEQ on CD-ROM. The regional nutrient database will be provided by USGS to EPA in a format accessible through the internet on state or EPA web servers (to be developed by EPA).

h. Statistical analysis will be conducted and where applicable, spatial analysis will be performed using a geographic information system (GIS).

2. Describe a water body trophic classification approach within the LDEQ ecoregion framework that characterizes nutrients and DO in Louisiana water bodies.

3. To describe conditions under which nutrients contribute to DO falling below minimum levels needed to sustain a healthy biological community appropriate to the ecoregion and/or water body type. In other words, what levels of nutrients are expected to maintain the DO level for water bodies within the ecoregion?

a. Identify characteristics for water bodies in the Western Gulf Coastal Plains (WGCP), South Central Plains (SCP), Upper Mississippi Alluvial Plains (UMAP), and Terrace Uplands (TU) ecoregions that may influence nutrients and DO such as season, riparian characteristics (canopy), drainage area (size), hydrology, basin area (size), stream order, length, depth, flow, bed slope, width, geology, and land use.

b. Determine: 1) Which nutrients limit aquatic primary production in the ecoregion or water bodies; 2) What, if any functional relationships exist between the limiting nutrient and biomass production; 3) Can 'gradients' be identified in relation to these relationships and nutrient concentrations; and, 4) What are impacts on fish and wildlife propagation, i.e., assess the relationship between nutrients, DO conditions, stream habitat, and the abundance and species composition of the resident fish assemblage.

c. Identify seasonal variations for nutrients and determine whether seasonal criteria are appropriate.

4. Evaluate best attainable or reference conditions (i.e., develop a procedural framework for ecoregion based nutrients and DO and/or a modified framework for standards based on categories of water bodies for which a sufficient biological database exists.

5. Describe appropriate nutrient and DO criteria and relate data for GIS display of each water body classification within LDEQ ecoregions.

6. Develop implementation options for TMDLs, permits, monitoring, and assessment etc.

If the reference water body approach proves to be infeasible within an ecoregion, classification characteristics (i.e., depth) will be identified that have the strongest influence on nutrients and/or DO. Those relationships (i.e., low DO and/or high nutrients, low flow gradients, shading, etc.) may be developed into predictive models or equations. If successful (verifiable) these models could be used to predict nutrient and/or DO concentrations in water bodies of certain quantifiable characteristics. This type of model would apply where enough biological (i.e., biomass, chl *a*, fish assemblages, etc.) data exists to ensure an evaluation of the fish and wildlife propagation use.

6.3 Water Body Specific Approach

According to the 1998 *National Strategy for the Development of Nutrient Criteria*, EPA expects states to develop their own regional values in watersheds where applicable data are available and can use one of several approaches including EPA methodology described in water body-type guidance to develop criteria or employ their own approach as long as it is scientifically defensible. Consistent with the National Strategy, LDEQ expects to follow an ecoregional, water body-type approach which permits the variability in natural nutrient loadings to be recognized, and criteria to be established which account for this variability (i.e., recognizes that different water bodies respond differently to nutrient loadings). Numeric criteria and/or

ranges will eventually be developed for all water bodies within LDEQ's ecoregion classifications, including streams, rivers, wetlands, lakes and reservoirs, large rivers (and shared boundary rivers), coastal and estuarine water bodies.

Proposed approaches for each of Louisiana's water bodies are discussed in Appendix B. Additionally, LDEQ will continue to evaluate different methods for classifying water bodies in order to identify criteria (or ranges of criteria) on a broader regional scale such as stream order, watershed size and geology. Further classification by designated use (i.e., naturally dystrophic waters, etc.) may also be evaluated.

6.4 Shared Water Bodies

The approach for waters shared across political boundaries is one that needs to be developed over time and is discussed in Appendix B. For the Mississippi River/Northern Gulf of Mexico watershed EPA staff has participated along with LDEQ in the activities of the Gulf of Mexico Program, the Hypoxia Task Force and most recently in the EPA-sponsored Mississippi River Basin Nutrient Science Workshop. The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force was formed in the fall of 1997 to determine the causes and effects of hypoxia in the Gulf of Mexico, and to coordinate activities to reduce the size, severity, duration and effects of the hypoxic zone. The activities of the Task Force as well as the resulting studies and reports clearly demonstrate the extreme complexity of developing nutrient criteria for state waters in the Mississippi River Basin which includes the Atchafalaya River in Louisiana. LDEQ participates in and shares the short and long term goals of these programs. Nutrient criteria development approaches are only now being discussed across the political and geographic boundaries represented by the participating states. As for the other rivers Louisiana shares with boundary states such as the Sabine, Red and Pearl, LDEQ will be working with those states to develop an approach for developing nutrient criteria in shared waters. Precise descriptions of these actions are not developed at this time but will be added to the plan as LDEQ approaches the priority level of these water bodies. It is anticipated that what the states learn on developing criteria for inland rivers and streams will apply to shared boundary waters.

For the Sabine River and the Toledo Bend Reservoir it is anticipated that a working group with the Texas CEQ and Region 6 can come up with an approach that both Texas and Louisiana can put into their respective nutrient criteria plans. For the Pearl River, the same is true with the Mississippi DEQ and EPA Region 4 on the development of state nutrient plans. LDEQ has already discussed the nutrient criteria issue on the Red River with the states of Texas, Oklahoma and Arkansas. Region 6 can also participate in helping develop approvable nutrient criteria development approaches to be placed (i.e. as an update) in each state's nutrient plan.

7.0 Data Inventory - Existing Data, Past Studies and Data Gaps

7.1 Data Inventory

LDEQ has a variety of surface water monitoring projects to allow it to: 1) measure progress towards achieving the state's water quality goals, 2) gather baseline data used in establishing and reviewing the state water quality standards, 3) provide a database for use in determining the assimilative capacity of state waters for establishing permit limits, and 4) aid in the calculation of TMDLs. Included in the LDEQ's surface water quality monitoring program is the Fixed Station Long-Term Surface Water Quality Network (Ambient Water Quality Monitoring Network, or AWQMN). Louisiana has monitored its surface waters through a fixed station network since 1958. LDEQ has since expanded this network and established a comprehensive

monitoring program in the AWQMN. LDEQ's Surveillance Division collects surface water samples and field data at monitoring locations (in accordance with approved standard operating procedures or SOPs) and samples are analyzed following procedures detailed in the *Ambient Water Quality Monitoring Network* QAPP[17]. LDEQ reviewed EPA's STORET and the LDEQ Ambient Water Quality Monitoring Network (AWQMN) database for nutrient data to use in criteria development. The WQMN database has adequate data on EPA's recommended causal variables, nitrogen and phosphorus (Total Phosphorus or TP, NO_2+NO_3 and TKN -Total nitrogen or TN can be calculated by adding NO_2+NO_3 and TKN). LDEQ will base its ecoregionally-derived TN and TP criteria development on WQMN data, USGS NAWQA, and NWIS data. The database contains the following parameters for nutrient criteria development: TP, TKN, TSS, NO_2+NO_3, Secchi depth measurements, dissolved oxygen (DO), turbidity (NTU), and total dissolved solids (TDS) for a ten year period beginning in January 1990 through December 2003. Other parameters as listed in Table 1 below (i.e., chl *a*) are currently only collected as part of a special project or TMDL survey.

A summary of the EPA-recommended nutrient causal and response variables monitored in LDEQ's surface water quality monitoring, survey, and TMDL programs are shown in Tables 2 and 3 below.

[17] LDEQ Surface Water Monitoring and Assessment Program (Strategy). Revision: 0. Date 12/21/04.

Table 2. Summary of Nutrient Parameters (Potential Causal and Response Variables) Monitored in LDEQ's Surface Water Quality Monitoring Program

Parameter category	***Location***	***Frequency***	***Parameter***	***Designated Uses Evaluated***	***Other Critical Data Use(s)***
Conventional	All subsegments	1/mo. for 1 yr., every 4 yrs.	Ammonia Nitrogen (NH_3-N)	N/A	Intensive Survey; TMDL
			Dissolved Oxygen (DO)	Fish and wildlife propagation (including limited use)	Intensive Survey; TMDL, UAA, 305(b) assessment, criteria development
			Nitrite-Nitrate Nitrogen (NO_2-NO_3)	N/A	Intensive Survey; TMDL
			Secchi Disk (Secchi)	N/A	Intensive Survey; TMDL
			Total Suspended Solids (TSS)	N/A	Water quality permit limits; other
			Total Dissolved Solids (TDS)	Fish and wildlife propagation	TMDL, UAA, 305(b) assessment, criteria development
			Total Nitrogen (TN)	N/A	Intensive Survey; TMDL
			Total Organic Carbon (TOC)	N/A	Intensive Survey; TMDL, criteria development
			Total Phosphorus (TP)	N/A	Intensive Survey; TMDL
			Turbidity (NTU)	Outstanding natural resource; Fish and wildlife propagation	TMDL, UAA, 305(b) assessment, criteria development

Table 3. Summary of Nutrient Parameters (Potential Causal and Response Variables) Monitored in LDEQ's Surface Water Quality Monitoring Program continued.

Parameter category	*Location*	*Frequency*	*Parameter*	*Designated Uses Evaluated*	*Other Critical Data Use(s)*
Only for Intensive Surveys, Wasteload Allocations (WLAs), and TMDLs			Chl *a* (Chl *a*)	N/A	Intensive Survey; WLA, TMDL
Biotoxicity (would include ammonia)	Miss. River sites (3)	Bi-monthly every yr.	*Pimephales* survival	Fish and wildlife propagation	Investigate
			Pimephales growth	Fish and wildlife propagation	Investigate
			Ceriodaphnia survival	Fish and wildlife propagation	Investigate
			Ceriodaphnia reproduction	Fish and wildlife propagation	Investigate

LDEQ has reorganized the data from the current river basin format into the Louisiana ecoregion-based format. This data has also been provided to USGS (under EPA contract) for use in the compilation and preliminary analysis of a regional database. An electronic version of the Louisiana ecoregion-based map (in the process of being updated) will be made available to EPA-6 and is included in Appendix A (CD also to be included).

7.2 Past LDEQ Studies

A more recent and thorough evaluation (literature review) of scientific studies conducted towards developing nutrient criteria as well as implementation options for TMDLs, permits, assessment methods, and monitoring strategies is proposed as part of Louisiana's nutrient development plan**.** However, LDEQ has also evaluated past studies it has conducted in Louisiana regarding the development of nutrient criteria. In one study of Louisiana's rivers and streams, the relationship between controllable nutrients, particularly phosphorus and nitrogen, and oxygen depletion from algal respiration and decomposition was evaluated.[18] A linear and Monod[19] model were generated relating BOD_{20} to Total Kjeldahl Nitrogen (TKN), however, the relationship was restricted to nitrogen limited streams, summertime conditions, and low-turbidity streams with a high incidence of algal problems. As Louisiana streams may experience seasonal fluctuations in nutrient limiting conditions and have continuously high turbidity, such restrictions would make the model broadly inapplicable. Another monitoring study was conducted on 30 freshwater Louisiana lakes (surface area range 4 to 735 km^2) and included the development of a Condition Index System to relate water quality parameters to perceived water

[18] R.F. Malone and D.G. Burden 1985. Trophic Classification of Louisiana Freshwater Lakes. LDEQ Water Pollution Control Division, Baton Rouge, LA.

[19] Jacques Monod. 1942. Proposed that a mathematical relationship could be used to describe the effect of a growth limiting nutrient on specific growth rate *Recherches sur la croissance des cellules bactériennes*. Ph.D. thesis Actualités scientifiques et industrielles, Hermann, Paris

quality in lakes.[20] The study proposed the Condition Index System as useful in the qualitative evaluation of regularly collected lake water quality data for lake management decisions, but it could not be used to form a basis for the development of numeric nutrient criteria.

Even though these and other studies may not be practical for nutrient criteria development, they contain useful site-specific information and suggestions for further analysis. For example, a study completed by LDEQ during 1990[21] was conducted to establish the amount and type of data required to establish nutrient limits for the freshwater lakes of Louisiana. Of course, the amount and type of data needed depends on the method ultimately used to establish nutrient criteria. The 1990 study identified information required to characterize a lake so that nutrient standards could be developed which included current and historical baseline limnological data, trophic condition, and the identification of the limiting algal nutrient. The study also concluded that while it may not be feasible to collect enough data to establish site-specific nutrient limits, water quality standards could be developed for different types of lakes, located in significantly different geographic regions. The key information and approach from this study are highly consistent with the currently recommended EPA nutrient criteria guidance, and will be utilized to help determine the best approach for freshwater lakes and reservoirs, and freshwater coastal lakes.

To further characterize LDEQ's ecoregions, approximately ten least-impacted, wadeable reference streams were selected within each of four ecoregions – Western Gulf Coastal Plains (WGCP), South Central Plains (SCP), Upper Mississippi Alluvial Plains (UMAP), and the Terrace Uplands (TUE) (Footnote 2). Studies were conducted on the selected reference streams to characterize natural background conditions for each ecoregion and have been summarized in two reports[22, 23]. The characterizations included biological and habitat assessments that measured the condition of the aquatic communities of the least-impacted streams. Within the four ecoregions characterized to date, approximately 40 streams have been sampled. A map of stream sites in each ecoregion is shown in Appendix A. Each ecoregion was extensively sampled over a two-year period to capture two spring seasons (high flow, spawning) and two late summer seasons (low flow, high temperature period). Sampling protocols included water chemistry and, hydrologic measurements, fish and macroinvertebrate sampling, habitat assessment and continuous DO monitoring. Statistical analysis of fish and macroinvertebrate assemblages from ecoregion streams, as well as habitat assessment scores, showed statistically significant differences between ecoregions. Analysis of water quality parameters, including some nutrient constituents was also summarized, but nutrient relationships or continuous monitoring results for diurnal DO have not been fully evaluated. Results from these studies have been used in the UAA process to refine use designations and water quality criteria in the standards for similar water bodies within an ecoregion.

Information from further LDEQ studies may be incorporated into nutrient criteria development as relationships and trends are identified (i.e., LDEQ DO-Slope Study).

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[20] R.F. Malone and C.E. Mericas. 1984. Development of In-Situ Nutrient Criteria for Louisiana Rivers and Streams. LDEQ Water Pollution Control Division. Baton Rouge, LA.

[21] LDEQ. 1990. Data Compilation and Analysis – Freshwater Lake Nutrient Standard Development.

[22] DeWalt, R.E. 1995. Biological Communities of Reference Streams in the South Central Plains and Upper Mississippi Alluvial Plains Ecoregions of Louisiana. LDEQ, OWR.

[23] DeWalt, R.E. 1997. Fish and Macroinvertebrate Taxonomic Richness, Habitat Quality, and In-situ Water Chemistry of Ecoregion Reference Streams in the Western Gulf Coastal Plains and Terrace Upland Ecoregions of Southern Louisiana. LDEQ, OWR.

7.3 Data Gaps and Limitations

For 305(b) purposes, Louisiana has primarily linked numeric DO criteria and general nutrient criteria to the fish and wildlife propagation use (see LAC 33:IX.1113.C.3). Many natural freshwater streams in Louisiana are characterized by periods of warm temperature, low gradients, low water velocities, have minimal re-aeration potential from riffles, and high natural organic loads from natural riparian vegetation. A study (Project 1) being conducted in 16 least-impacted streams representing four Louisiana ecoregions will assess the relationship between nutrients, DO, stream habitat, and the abundance and species composition of the resident fish assemblage. This study is also briefly described in Section 8.2, and while it's being conducted in least-impacted ecoregion streams, the methods will be examined for applicability to other water body types (i.e., wetlands, lakes and reservoirs, etc.).

From the LDEQ WQMN database, data is available for EPA's recommended response variables such as turbidity, TOC, and secchi depth, however, WQMN chl *a* data for Louisiana is very limited. Some data for a relatively small number of sites is available from USGS's NAWQA Program. Without extensive long-term, temporal chl *a* data, relationships between chl *a* and biomass or nutrients for potential nutrient criteria development in Louisiana waters are not well described. In the absence of such data, inferences could be made from the USGS-EPA national database[24] that contains data from across states (regional) but are not refined for Louisiana.

The lack of chl *a* data in Louisiana water bodies has prompted LDEQ to seek 104(b)(3) funding to contract a periphyton study (Project 3) with USGS that is described in more detail in Section 8.3. The study is proposed to be conducted in the same 16 least-impacted ecoregion streams (representing four Louisiana ecoregions) used in the previously described study (Project 1), and again the method will be examined for applicability to other water body types (i.e., wetlands, lakes and reservoirs, etc.). Other parameters may also be investigated as response variables. For example, LDEQ has conducted a preliminary evaluation of TOC as a response variable using WQMN TOC data instead of chl *a*, but no significant correlations between TOC and nutrients were detected. This relationship (and others) should be re-examined after reducing the amount of 'noise' in the data. The proposed periphyton studies will add TOC samples taken concurrently with nutrient and chl *a* sample collection.

Periphyton and nutrient sampling will also be conducted simultaneously with continuous DO monitoring to document natural diurnal fluctuations. Correlations may help to characterize (and quantify) in natural waters the DO-nutrient relationship Louisiana has used to control nutrients in effluents and TMDLs. They may also help strengthen methodologies for 305(b) assessments. The limiting nutrient or nutrient that most influences biomass can be identified and addressed in future permit limitations, or as the basis for a nonpoint source allocation. This information can be added to information from existing ecoregion studies conducted during 1992-95 in the same streams. The data could also be aggregated with periphyton data from similar streams sampled in EPA Region 6 states (i.e., Texas, Oklahoma, and Arkansas) and tested for trends and relationships.

LDEQ has not yet analyzed the available nutrient database for relationships to water body size (i.e., drainage area for rivers and streams) or depth (i.e., for lakes and reservoirs), or other

[24] USGS Project funded by EPA, "Compilation and Preliminary Analysis of a Regional Nutrients Database to Support Development of Ecoregion-Based Nutrient Criteria for States within EPA Region VI" FY 2001-03 and "USGS Workplan for Nutrient Criteria Development Support to Region 6" FY 2004.

geographic or geologic characteristics. While summary statistics have been calculated in accordance with EPA guidance, the data needs to be analyzed further to develop numeric ranges for total nitrogen, total phosphorus, turbidity, and secchi depth.

8.0 New and Proposed Studies - Data and Requirements for Data Collection

8.1 New and Proposed Studies

With the available nutrient database identified and compiled and in a retrievable format, LDEQ has contracted with Louisiana investigators to gather field environmental data to support criteria development. These first studies will specifically address the environmental data needs (as identified above) in **rivers and streams** as one of the major water body types (as per EPA guidance). Studies to collect new data will require Quality Assurance Project Plans (QAPPs) consistent with federal guidance and subject to approval by LDEQ and EPA. It is highly recommended that QAPPs also be developed for studies using existing or previously collected data.

In cooperation with the contracted university researchers, LDEQ has revisited and verified 16 reference streams in the four major freshwater ecoregions of Louisiana that will be sampled for habitat conditions, water quality and fish populations.

In the first study, Project 1, scientists will assess the relationship between dissolved oxygen conditions, stream habitat, nutrients, and the abundance and species composition of the resident fish assemblage. If successful, relationships between fish community structure, DO and nutrients in sampled streams will be determined and metrics can be developed that describe fish community responses to low dissolved oxygen conditions and nutrients in Louisiana streams.

Project 2 provides for the development of approaches towards formulating ecoregional nutrient criteria (Project 2) based upon the nutrient conditions found in least-impacted reference water bodies in Louisiana. In order to further facilitate criteria development, data from Project 1 will be incorporated into this study as it becomes available.

Data from Project 3 will be used to evaluate the relationship between nutrients (including periphyton and/or chl *a*) and diurnal dissolved oxygen, to develop sound assessment procedures for diurnal DO data, and to develop stream nutrient criteria in least impacted, ecoregion streams.

Establishment of a scientific advisory committee in Project 4 provides guidance on the applicability of nutrient development approaches for Louisiana and on a regional level, as necessary, for adjacent states. While Project 4 is described for rivers and streams, the same approach could be applicable to other water bodies as well.

Goals and tasks from these studies are also described briefly below. The collected data will be compiled and analyzed in accordance with the project QAPP. As the studies progress and results are analyzed, the nutrient criteria development plan may need to be revised as well as the schedule for addressing short and long-term nutrient criteria needs.

8.2 New Studies

Project 1: "Relationship Between Nutrients, Dissolved Oxygen Conditions, Habitat, and Fish Assemblage Composition in Louisiana Streams"
Contract: Cooperative Agreement # 610941 (LDEQ and LSU)

Contact: Drs. William E. Kelso and D. Allen Rutherford, LSU
Mr. Ross Hartfield, Mr. Dugan Sabins, LDEQ

Goal: Assess the relationship between dissolved oxygen conditions, stream habitat, nutrients, and the abundance and species composition of the resident fish assemblage.

- Sample 16 streams located in the 4 delineated DEQ ecoregions for assessment of water quality conditions and fish assemblage composition
- Quantify habitat conditions, in situ water quality, lab water quality (for nutrients and chl *a*) and the species composition and abundance of resident fish assemblage in two reaches in each stream twice for two consecutive summers to document spatial (between streams) and temporal (within and between years) differences in environment-fish assemblage relationships.
- Determine if: 1) relationships between fish community structure, DO and nutrients in sampled streams exist; 2) relationships are consistent between years; and, 3) appropriate metrics can be developed that describe fish community responses to low dissolved oxygen conditions and nutrients in Louisiana streams.

Study and Data Analysis: After completion of sampling, fish community metrics will be developed to quantitatively describe community composition for comparison between streams. Metrics will include standard measures of community structure, such as diversity, evenness, and richness, but will also include taxonomic and functional groupings to better assess the relationships between physicochemical characteristics and fish communities in each stream.

Principal components analysis (PCA) of the most representative fishes in each ecoregion will be used to examine fish assemblage structure as it relates to habitat and water quality variables (i.e., DO and nutrients, etc.). Distribution regression analysis can be used to investigate the relationship between physicochemistry, species abundance, by regressing habitat and water quality variables on fish abundance. Analysis of variance of rank fish abundance will also be performed to identify differences in mean abundance between streams (and possibly habitats). Study results will help to identify those variables (i.e., water quality variables or habitat) that have the most influence on fish distribution and abundance, and what concentrations are optimal in consideration of DO and nutrient criteria development.

Tasks[25]:

- In consultation with DEQ, 16 similarly sized (1st to 3rd order) “least-impacted” reference streams will be selected based on watershed location, watershed land use, stream size and watershed position, and availability of historical water quality data. (July 2004 – August 2004). Products: Detailed map of site locations and watershed boundaries will be developed; Project 1, Task 1.1
- Develop QAPP (EPA QA/R5) for approval prior to initiating data collection activities. (July 2004 – August 2004). Products: QAPP and subsequent DEQ, EPA approval; Project 1, Task 1.2
- Develop and implement a standardized sampling program for collection of habitat, water quality (includes 24-hr continuous monitoring), and fish assemblage data. (Summer 2004 – March 2007). Products: All water quality, fish, and habitat data completed by September 2006; Project 1, Task 2.1

[25] Task timelines have been affected by post-Hurricane Rita and Katrina damage to reference streams. These will be amended as the contract extension for this project is finalized.

- Analysis of fish-habitat data, groups identified, measures of fish assemblage calculated and tested, metrics developed. If appropriate, regression analysis will be conducted to identify trends in fish assemblage structure with water body type, etc. in order to identify specific relationships between stream characteristics and fish assemblages. (July 2004 – March 15, 2007). Products: Comprehensive report assessing relationship between fish assemblage, stream water quality and habitat variables, and metrics that discriminate fish communities found in high and low DO streams (if metrics exist). Project 1, Task 3.1
- Develop and submit a draft final report for LDEQ review (March 2007). The report will provide a summary of all activities, results and findings. All finished deliverables will be re-submitted and thoroughly explained. Revisions based on LDEQ and EPA review will be incorporated, and the final report submitted to LDEQ. Product: Final Report; Project 1, Task 4.3

Project 2: "Approaches for Developing Attainable Nutrient Criteria for Louisiana Water bodies: Rivers and Streams"
Contract: Cooperative Agreement # 610940 (LDEQ and LSU)
Contact: Dr. John Day, LSU
Mr. Mel Landry, Mr. Dugan Sabins, LDEQ

Goal: Development of approaches for developing ecoregional nutrient criteria for Louisiana based upon the nutrient conditions found in least-impacted reference water bodies. A quantitative measure of trophic state could be used to evaluate present and future trends in the trophic conditions of Louisiana's waters. Trophic state indices are difficult to quantify, and approaches for would also need to factor Louisiana's unique natural adaptations, water quality, and geophysical characteristics.

- Evaluate reference conditions for rivers and streams in the four ecoregions where LDEQ wishes to develop nutrient criteria with this methodology
- Use previously collected data on nutrients, dissolved oxygen, and other pertinent parameters in identified water bodies
- Analyze data in other water bodies as necessary
- Analyze data to develop approaches for evaluating nutrient conditions in least-impacted reference water bodies

Study and Data Analysis: Once data are collected and standardized (LDEQ WQMN database, and Project 1 data), multivariate principal components and cluster analysis can be used to define trophic groups, or calculate trophic state indices for study streams (from Project 1) within the four ecoregions. Water quality, primary productivity, and the EPA recommended nutrient causal and response variables may be related or compared to the appropriate trophic state indices and derive logical trophic groups. Correlations can be used to evaluate nutrient levels and natural variations in trophic states due to changing environmental conditions.

Tasks[26]:

- Conduct literature review of historical and current ecological indicators of ecological health and water quality (Aug 2004 – Jan 2005). Products: Lit review, references, and data files; Project 2, Task 1.1
- All water quality data pertaining to rivers and water bodies will be catalogued and input into a single database for statistical analysis (Aug 2004 – Jan 2005). Products: Lit review, references, and data files; Project 2, Task 1.1
- Combine data collected in ecoregional studies (currently ongoing with Kelso and Rutherford and any historical) with data compiled in literature review (Jan 2005 – May 2005). Products: Draft data report and data files; Project 2, Task 1.2
- Provide summary statistics (of water quality parameters) by water body and by ecoregion, include data from Project 1 (Jan 2005 – May 2005). Products: Draft data report and data files; Project 2, Task 1.2
- Extensive review of nutrient indices used for trophic state characterization. Conceptual model of nutrient criteria analysis will be developed to guide statistical analysis and approach; experimental design underlying statistical analysis of data collected in Task 1.2. (April 2005 – Aug 2005). Products: Nutrient Indices for Trophic State Characterization – lit review, data files and draft report to LDEQ; Project 2, Task 1.3
- Summarize data compiled in Task 1.2 statistically using selected trophic state indices as indicators of ecosystem health. The conceptual model of nutrient criteria analysis developed in Task 1.3 will guide statistical analysis and approach. (May 2005 – October 2005). Products: Application of Selected Nutrient Indices for Trophic State Characterization – draft preliminary report to LDEQ; Project 2, Task 1.4
- Develop appropriate ranges of nutrients and dissolved oxygen for each ecoregion (May 2005 – October 2005). Products: Application of Selected Nutrient Indices for Trophic State Characterization – draft preliminary report to LDEQ; Project 2, Task 1.4
- Prepare a draft final report outlining appropriate ranges of nutrients and dissolved oxygen for each ecoregion and how they were developed. (Sept. 2005 – Feb. 2006). Products: Prepare Draft Final Report; Project 2, Task 1.5
- Make recommendations for approaches to developing nutrient criteria (Sept. 2005 – Feb. 2006). Products: Prepare Draft Final Report; Project 2, Task 1.5
- All finished deliverables, publications, etc. will be re-submitted and thoroughly explained in the final report. (March 2007). Products: Final Report; Project 2, Task 2.3

8.3 Proposed Studies

Project 3: "Effects-based Tools for Nutrient Criteria Development"

Contract: EPA Project (LDEQ and USGS) [FRL-7622-3] February 12, 2004
Notice of Request for Initial Proposals (IP) For Projects to Be Funded from the Water Quality Cooperative Agreement Allocation

NOTE: This project is being performed under a cooperative agreement between USGS and EPA and stands to be updated (i.e., task dates may need to be updated). USGS is working with EPA on providing a progress report. LDEQ will update the nutrient criteria development plan (i.e. by amendment or annual update) once the progress report is submitted to EPA and LDEQ is provided that information.

Contact: Dr. Richard Kiesling, USGS

[26] Task timelines have been affected by post-Hurricane Rita and Katrina damage to reference streams. These will be amended as the contract extension for this project is finalized.

Mr. Dugan Sabins, LDEQ

Goal: To evaluate the relationship between nutrients (including periphyton and/or chl a) and diurnal dissolved oxygen, to develop sound assessment procedures for diurnal DO data, and to develop recommendations for stream nutrient criteria in least impacted, ecoregion streams. The expected results will document the circumstances where water column and periphyton production play a role in diurnal DO concentrations and biomass (algal production) in Louisiana streams.

Tasks:

- Site selection and data collection – monitor in-stream nutrient gradient and biological response by monitoring water quality at each assessment site, perform periphyton surveys, and 24-hr continuous monitoring for dissolved oxygen (July-Sept. 2004 – Nov. 2005). Products: QAPP to EPA and LDEQ, field sampling data to LDEQ; Project 3, Task 1.

- Deploy in-situ periphytometers at assessment field sites to assess N and P limitation of periphyton production, C:N:P ratio of nutrient limited algae, and dominant algal groups as measured by algal pigment (July-Sept. 2004 – Nov. 2005). Products: Field sampling data to LDEQ; Project 3, Task 2.

- Determine net water productivity using light-dark bottle O_2 evolution methodology at assessment sites during periphytometer deployments (Nov. 2005 – December 2005). Products: Analysis of field data; Project 3, Task 3.

- Compare water column productivity estimates from light-dark bottle incubations with periphytometer and periphyton-based productivity measures. (Nov. 2005 – December 2005). Products: Analysis of field data; Project 3, Task 4.

- Analyze the "cause and effect" relationship between nutrients and biomass in Louisiana ecoregion streams and present options for development of nutrient criteria and assessment procedures. (Nov. 2005 – December 2005). Products: Analysis and report, all data to LDEQ and EPA; Project 3, Task 5.

Study and Data Analysis: The periphytometer study compares growth potential for biomass (chl *a*) between a control treatment and nutrient-added treatments and identifies the limiting nutrient (as either N or P). Biomass-based algal growth rates can be calculated using a simple exponential growth model.[27] Growth rate data can then be fit to a Monod[28] function using SAS. With the limiting nutrient identified, approaches to develop a predictive relationship between the limiting in-stream nutrient concentrations and biomass (chl *a*) can be formulated using a natural log function (regression) analysis. The periphytometer can be used to estimate stream trophic status as the ratio of control production to nutrient saturated production[29].

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[27] McFarland, et.al., 2001. *Characterization of a Central Texas Reservoir with Emphasis on Factors Influencing Algal Growth.* Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville, TX, TR0104 (April 2001).

[28] In the Monod model - $\mu = \mu_{max} \bullet S / (Ks + S)$, observed growth rate ($\mu$) is a function of the maximum nutrient sufficient growth rate (μ_{max}), the external nutrient concentration (S) and the half-saturation constant for growth (Ks).

[29] Matlock, et.al., 1998. *A quantitative passive diffusion periphytometer for lotic ecosystems.* Journal of the American Water Resources Association 34:1141-1147.

8.4 Scientific Advisory Committee

Ensuring scientific credibility is a major concern with nutrient criteria development. Preliminary work on developing nutrient criteria has shown that it will be a significant scientific and technical challenge. Nutrient conditions in Louisiana water bodies are related to a variety of complicating factors. In addition to human activities, nutrient concentrations are influenced by natural background concentrations, and seasonal variations in water flow and quality. Of particular concern with Louisiana water bodies is their tendency toward natural mesotrophic and eutrophic conditions due to the extensive development of riparian wetland environments and low elevation gradients. To address this, LDEQ has proposed to establish a Scientific Advisory Committee to be selected from a pool of nationally recognized experts and in consultation with EPA.

Several nationally known nutrient experts are available through those in-state universities that have direct experience with the wide range of Louisiana's water environments. LDEQ has also developed relationships with other respected out-of-state experts through work with the National Hypoxia Task Force. The Scientific Advisory Committee is proposed to meet two times a year and would oversee the nutrient criteria development plan and data from its associated projects. One approach for developing a scientific advisory committee has been devised in a proposal recently submitted to EPA and described in Part IV.B of this plan as Project 4. In addition to providing scientific review of Louisiana's nutrient studies, the Scientific Advisory Committee can offer guidance on the applicability of nutrient development approaches in adjacent states.

Project 4: "Establishing A Scientific Advisory Committee to Oversee the Development of Attainable Nutrient Criteria for Louisiana Water bodies – Rivers and Streams"

Contract: EPA Project # TBD (LDEQ and LSU)
Contact: Dr. John W. Day, Jr.,LSU
Mr. Dugan Sabins, LDEQ

Goal: Establishment of a scientific advisory committee to provide scientific credibility and to oversee results of two projects funded by the LDEQ for the development of nutrient criteria for Louisiana rivers and streams[30,31]. A team of nationally recognized experts will meet twice a year for two years and provide recommendations based on the LDEQ projects as well as guidance on the applicability of nutrient development approaches in adjacent states.

Tasks:

- Selection of advisory committee – in addition to Dr. John W. Day, LSU, also proposed is Dr. William Mitsch, Ohio State University, Dr. Robert W. Nairn, University of Oklahoma. One other committee member will need to be selected.
- First meeting of the advisory committee will be within three months of funding from EPA, subsequent meetings will be scheduled approximately every six months thereafter

Committee will review the progress of the two LSU-LDEQ projects and provide input toward nutrient criteria development for Louisiana and other states

[30] "Approaches for Developing Attainable Nutrient Criteria for Louisiana Water bodies: Rivers & Streams", Department of Oceanography and Coastal Sciences, LSU, Baton Rouge, LA 70803.
[31] "The Relationship Between Nutrients, Dissolved Oxygen Conditions, Habitat, and Fish Assemblage Composition in Louisiana Streams", School of Renewable Natural Resources, LSU, Baton Rouge, LA 70803.

9.0 Regional Technical Advisory Group Participation

LDEQ has participated in each Regional Technical Advisory Group (RTAG) meeting held by EPA Region 6 and also in the first States Nutrient Workshop hosted by EPA headquarters during February 6-8, 2006. A brief summary of LDEQ's participation in RTAG and related nutrient workshops (including collaboration with USGS) is given below. LDEQ will continue to participate in future RTAG meetings and utilize RTAG expertise in nutrient criteria development as much as possible.

RTAG Participation

First EPA 6 Nutrient RTAG in Dallas, TX, November 1999

LDEQ presented its strategy to begin evaluating data for nutrient criteria development. At this time states were expected to propose criteria by February, 2000. EPA guidance presents several approaches to developing criteria, including use of the 25th percentile of all water bodies within each ecoregion as a reference condition. EPA and USGS began compiling STORET data.

Second EPA 6 Nutrient RTAG, Dallas, TX, August 2001

George Gibson, EPA HQ emphasized that 25th percentile recommendations are a "starting point".

LDEQ submits first Nutrient Criteria Development Plan to EPA 6 in December 2001.

Third EPA 6 RTAG, Dallas, TX, November 2002

LDEQ presents update including statistical results of median and 25th percentile values for rivers and streams, and for lakes and reservoirs.

Fourth Region 6 RTAG, Dallas, TX, December 2003

LDEQ emphasizing ecoregional approach and identification of reference streams. USGS provides assistance in compiling and analyzing stream data for causal and response variables. LDEQ investigates correlations between variables and models; studies for responses of water bodies to nutrient changes; and implementation; identifies data gaps for further studies.

Fifth Region 6 RTAG, Dallas, TX, December 2004

LDEQ submits revised nutrient criteria development plan. Amy Parker, EPA headquarters, presents national update. LDEQ submits updated and expanded draft Nutrient Criteria Development Plan to EPA 6 December 2004.

New plan guidance – 13 components of "mutually agreed upon plans" is forwarded to EPA 6 states.

Sixth Region 6 RTAG, Dallas, TX, January 2006

LDEQ presents status of nutrient criteria development and an update on one study in ecoregion streams, "Relationship Between Nutrients, Dissolved Oxygen Conditions, Habitat, and Fish Assemblage Composition in Louisiana Streams" conducted by Drs. William Kelso and Allen Rutherford, LSU School of Renewable Natural Resources.

States Nutrient Workshop, Dallas, TX, February 2006

The workshop included technical presentations from states, EPA and academics on data analysis, nutrient criteria development and implementation issues. On a national level, most progress has been in nutrient criteria for lakes and reservoirs. LDEQ presents status of

wetlands assimilation projects that provide the basis for wetland criteria development and wetland monitoring.

10.0 Draft Schedule for Nutrient Criteria Development and Adoption

This schedule presents a timeline for general activities outlined in this document. The plan and schedule will be reviewed at least once per year and revised as necessary. EPA (and the RTAG) will be updated on progress, shifts in priorities, or funding needs (as shown in Section 11.0). As progress and priorities are evaluated, timelines may need to be adjusted accordingly.

Table 3. Nutrient Criteria Development Timeline and Tasks

Month/Year	Tasks
JULY 2004	Rivers and Streams Reference Stream Study - Project 1 initiated.
DEC 2004	Draft Nutrient Criteria Development Plan submitted to EPA. LDEQ will update the plan as necessary (at least on an annual basis).
JAN 2005	Approaches for Ecoregional Nutrient Criteria for Rivers and Streams – Project 2 initiated.
JAN 2006[1]	Projects 1 and 2 - extended due to post-hurricane damage to reference streams.
FEB 2006	Begin development of freshwater wetlands criteria – characterization and biological monitoring requirements based on UAA reference sites/studies.
JUL 2006[2]	Interstate big rivers watershed coordination with New Mexico, Oklahoma, Texas and Arkansas for nutrient criteria in the Red and Ouachita Rivers.
AUG 2006[3]	Develop Periphyton Reference Stream Study - Project 3 (anticipated start date TBA).
JAN 2007	Identify freshwater wetlands (and ecoregions) by classifications and for development of nutrient criteria (and translators); assess data gaps.
JUL 2007[2]	Interstate big rivers coordination with Texas (Sabine River Authority and Toledo Bend Reservoir) and Mississippi (Pearl River).
JAN 2008	Compile existing lake and reservoir nutrient dataset; assess data gaps.
MAR 2008[1]	Final report due to LDEQ and EPA for nutrient criteria approaches based on Projects 1, 2 and 3[2] for rivers and streams (ecoregion reference streams). Develop implementation and monitoring procedures (with scientific advisory committee).
JULY 2008	Draft options for freshwater wetlands nutrient criteria. Develop implementation and monitoring procedures.
JULY 2008	Aggregate lakes and reservoirs by ecoregion; draft classifications and develop nutrient criteria approaches for lakes and reservoirs.
JAN 2009	Complete aggregation of nutrient data for lakes and reservoirs; trophic status. Establish reference conditions; identify reference lakes and reservoirs; develop implementation and monitoring procedures.
JAN 2009[1]	Propose draft criteria for adoption of TN, TP and DO criteria (and other appropriate response criteria) for rivers and streams. Promulgation process will take 6 months – 1 year.
JAN 2009	Propose draft nutrient criteria regulations for freshwater wetlands. Promulgation process will take 6 months – 1 year.
JAN 2010[2]	Draft options for nutrient criteria in big, interstate rivers – Sabine, Red, Ouachita and Pearl Rivers (interstate cooperation).
JAN 2010	Propose draft nutrient criteria regulations for adoption of TN, TP and DO criteria (and other appropriate response criteria) for freshwater lakes and reservoirs. Promulgation process will take 6 months – 1 year.
JAN 2013[2]	Propose draft nutrient criteria regulations for adoption of TN, TP and DO criteria (and other appropriate response criteria) for big, interstate rivers. Promulgation process will take 6 months – 1 year.
TBD	Estuarine and Coastal Wetlands Including GOM (Brackish and Saline Wetlands) - Coincides with Louisiana Coastal Restoration Plan
TBD	Mississippi and Atchafalaya Rivers - Dates Pending National Hypoxia Task Force Results

Color Legend by Water Body Types					
Inland Rivers and Streams	Freshwater Wetlands	Freshwater Lakes and Reservoirs	Estuarine and Coastal Waters Including GOM (Brackish and Saline Wetlands)	Sabine, Red Ouachita and Pearl Rivers	Mississippi and Atchafalaya Rivers

TBD = to be determined

[1] Projects to be extended as new grants due to post-hurricane damage – this timeline includes new dates; details with LDEQ, LSU and EPA in progress – resolution of issues will determine when criteria can be proposed for adoption; timeline will be adjusted accordingly.

[2] EPA Regions 4 and 6 to participate in development of approvable nutrient criteria approaches or adoption of criteria as needed.

[3]USGS and EPA 104(b)(3) funding; project pending.

11.0 Funding Needs and Resources

This plan could not be implemented without the continued availability of resources and funds to support existing and additional monitoring for nutrient constituents statewide. A "needs analysis" based on the timeline in Section 10.0 is given in Table 4 below. Technical assistance and implementation concerns anticipated for each general water body type are summarized in Table 5. Technical assistance and implementation needs for the big interstate rivers, the estuarine and coastal waters (including the Gulf of Mexico), and the Mississippi and Atchafalaya Rivers will be addressed as they are identified.

Table 4. Needs Analysis Based on Timeline in Section 10.0.

Type of Technical Support	Anticipated Number of Requests for Criteria Development	Fiscal Year Support is Needed or Anticipated
Reviewing and/or recommending study/sample design of N, P and *chl a* response in rivers and streams	1-2	FY '07-'08
Study/sample design of N, P and biological responses and/or designated uses in rivers and streams	1-2	FY '07-'08
Implementation procedures; assessment and translating criteria into TMDLs or permits	1-3	FY '08-'09
Recommendations of index periods for sampling (or continued/additional monitoring)	1-3	FY '06-'09
Review of classifications/approaches beyond ecoregion approach	1-2	FY '06-'09
Translators for narratives or other translator mechanisms for standards		Ongoing
Assistance with implementation of methods from EPA's guidance		Ongoing

Table 5. Water Body Specific Needs and Implementation Concerns for Nutrient Criteria Development.

Water Body Type	Technical Assistance Needs	Implementation Concerns
Rivers and Streams	Data analysis; diurnal DO; Chl *a* data gaps	Relating biological data to nutrients and 305(b) assessment (use support)
Lakes and Reservoirs	Sampling methodology; data gaps are anticipated.	Relating biological data to nutrients and 305(b) assessment (use support)
Wetlands	None	Translator mechanisms for standards (i.e., productivity – nutrient relationship)
Big Rivers Interstate Waters	To be determined	To be determined
Estuarine Coastal Waters and GOM	To be determined	To be determined
Mississippi River, Atchafalaya	To be determined	To be determined

12.0 Water Quality Standards Rule Development, Promulgation and Implementation (EPA Oversight)

The state of Louisiana (LDEQ) establishes its water quality standards as authorized in Section 2074.B (1) of the Louisiana Water Control Law (R.S. 30:2017-2078) and in conformity with Section 303(c) of the Clean Water Act (P.L. 92-500 as amended) and 48 FR 51405, November 8, 1983.

The state and federal water quality standards regulations require that standards be reviewed and revised as appropriate from time to time; and at least every three years (triennial review). This ensures that criteria remain appropriate for water quality management goals. Revisions of the water quality standards are accomplished in conformity with state and federal guidelines, policies, and regulations. However, there is no restriction to proposing a regulation change when appropriate; LDEQ can and does revise the water quality standards as often as necessary.

Once a water quality standard recommendation is developed, a series of administrative steps must be followed in order for the standard to be adopted into the state regulations. The procedure for promulgating rules by Louisiana state agencies is found in the Administrative Procedure Act (APA) La. R.S. 49:950 et seq. The Regulation Development Section (RDS) of the LDEQ's Legal Affairs and Regulation Development Division (RDD) is assigned the duty of ensuring that all departmental rules, including Louisiana's water quality standards, are promulgated in accordance with the APA and the Environmental Quality Act.

The typical amount of time needed to process a draft rule, once it is submitted to the RDS and Legal Division until the time of publication in the *Louisiana Register* as a final rule, is six months (see attached time line). The APA does provide for expediting rules in emergency situations and also for rules which are identical to federal rules.

In addition to following the APA and LDEQ's Rule Development Procedures, there are federal requirements that apply to the state's water quality standards program. Certification of standards promulgation by the state legal authority is required as part of EPA's Clean Water Act authority as outlined in 40 CFR 131, Subpart C – Procedures for Review and Revision of Water

Quality Standards. Once a revision becomes adopted into state law (as part of the water quality standards), EPA must review and approve it prior to implementation in accordance with 40 CFR Sections 131.20 and 131.21. In addition, a Memorandum of Agreement (MOA) between the LDEQ and EPA Region 6 (EPA-6) prepared in accordance with 40 CFR 123.24[32] requires that EPA be notified of any water quality standards revisions prior to the initiation of rule making.

Since the LAC 33, Part IX, Chapter 11 Surface Water Quality Standards are subject to approval by EPA, EPA-6 is notified by the Office of Environmental Assessment, Water Quality Assessment Division, Standards and Assessment Unit before any rule making changes to the water quality standards are initiated. This helps facilitate preliminary agreement between LDEQ and EPA that a water quality standards revision is approvable and can be implemented for Clean Water Act purposes. EPA reviews the draft revisions (and any necessary justification documentation) and grants 'technical approval' or comments before LDEQ proposes a revision. The following paragraphs briefly outline the water quality standards rule development procedures and include the steps required to meet federal requirements.

12.1 Rule Development Procedures

1. Rule Authorization

The Assistant Secretary (or the Undersecretary) of LDEQ, and the Deputy Secretary must approve an initial request to begin rulemaking. Once approval is received, the LDEQ Regulation Development Section (RDS) will authorize a "Request to Initiate Rulemaking Activity".

2. Rule Development

Once the draft language is developed, the RDS will also work to ensure the rule is formatted, in plain language, grammatically correct, etc. The rule is provided to RDS with the administrator approval (memo or email) to begin rulemaking, the Fiscal and Economic Impact Statement (FEIS), and the Cost/Benefit analysis, if necessary.

3. EPA and LDEQ Concurrence

LDEQ submits the draft standards revision rule and documentation to EPA for review. LDEQ and EPA-6 meets and/or corresponds to discuss issues informally; EPA-6 will discuss with EPA HQ and/or US FWS as necessary. LDEQ will be provided with informal and then formal written comments. EPA provides technical approval to LDEQ.

4. Draft Stage

Rule originator prepares and delivers to the RDS (for editing) and the Legal Division (for authority, enforceability, and equivalency with federal regulations) for review at least one month prior to submittal to the Legislative Fiscal Office (LFO):

- Draft rule with preamble (if any)
- Corresponding federal regulation
- FEIS
- Cost/Benefit report or a certification that no report is required, and
- Family impact statement.

[32] The MOA between the LDEQ and the United States Environmental Protection Agency prepared in accordance with 40 CFR 123.24 is a required program element for states seeking assumption of the National Pollutant Discharge Elimination System Permit Program. See MOA, Part VII Program and Review, Parts VII.B and VII.F http://www.deq.louisiana.gov/permits/npdes/moa.htm).

Paper and electronic copies of the final edited Fiscal Office Draft rule, FEIS, and Cost/Benefit report (if required) are due to RDS by the fifteenth of the month in which the rule will be submitted to the LFO.

5. Proposal Stage
RDS generates a Notice of Intent (NOI) and submits it with the Fiscal Office draft rule and the FEIS to the LFO on or before the twentieth of the month. The FEIS is also submitted to the DEQ Financial Services Division for review. On or before the tenth of the following month, RDS submits NOI, approved FEIS, and proposed rule to the Office of the State Register, members of the LOC, the Agriculture Commissioner, and Chancellor of LSU – Agriculture Center. At this time the Cost/Benefit report, if required, is submitted to the Joint Legislative Committee on the Budget for approval and to the LFO for review.

The Office of the State Register publishes the NOI, the FEIS, and the proposed rule in the *Louisiana Register* on the twentieth of the month. The public notice, public comment period and the public hearing also occur during this stage. A LOC hearing is scheduled if necessary.

6. Final Stage
The approved regulation is sent to the Office of the State Register for publication in the *Louisiana Register* and in the Louisiana Administrative Code. RDS publishes the rule in the Environmental Regulatory Code (updated quarterly).

7. EPA Oversight – Certification (40 CFR 131.6)
Certification letter from LDEQ General Counsel to EPA-6 certifies that the promulgation process was followed.

8. EPA Oversight – Approval/Disapproval (40 CFR 131.21)
EPA will provide approval (via letter or email followed by letter) within 60 days or disapproval within 90 days and notify LDEQ accordingly.

More detailed, explanation of terms, procedures, document formats, and timetables for rule development can be obtained through LDEQ's Regulation Development Section, Legal Affairs and Regulation Development Division – see (http://www.deq.louisiana.gov/portal/Default.aspx?tabid=1674#Title33) and scroll down for contact information.

Appendix A
Louisiana's Ecoregions

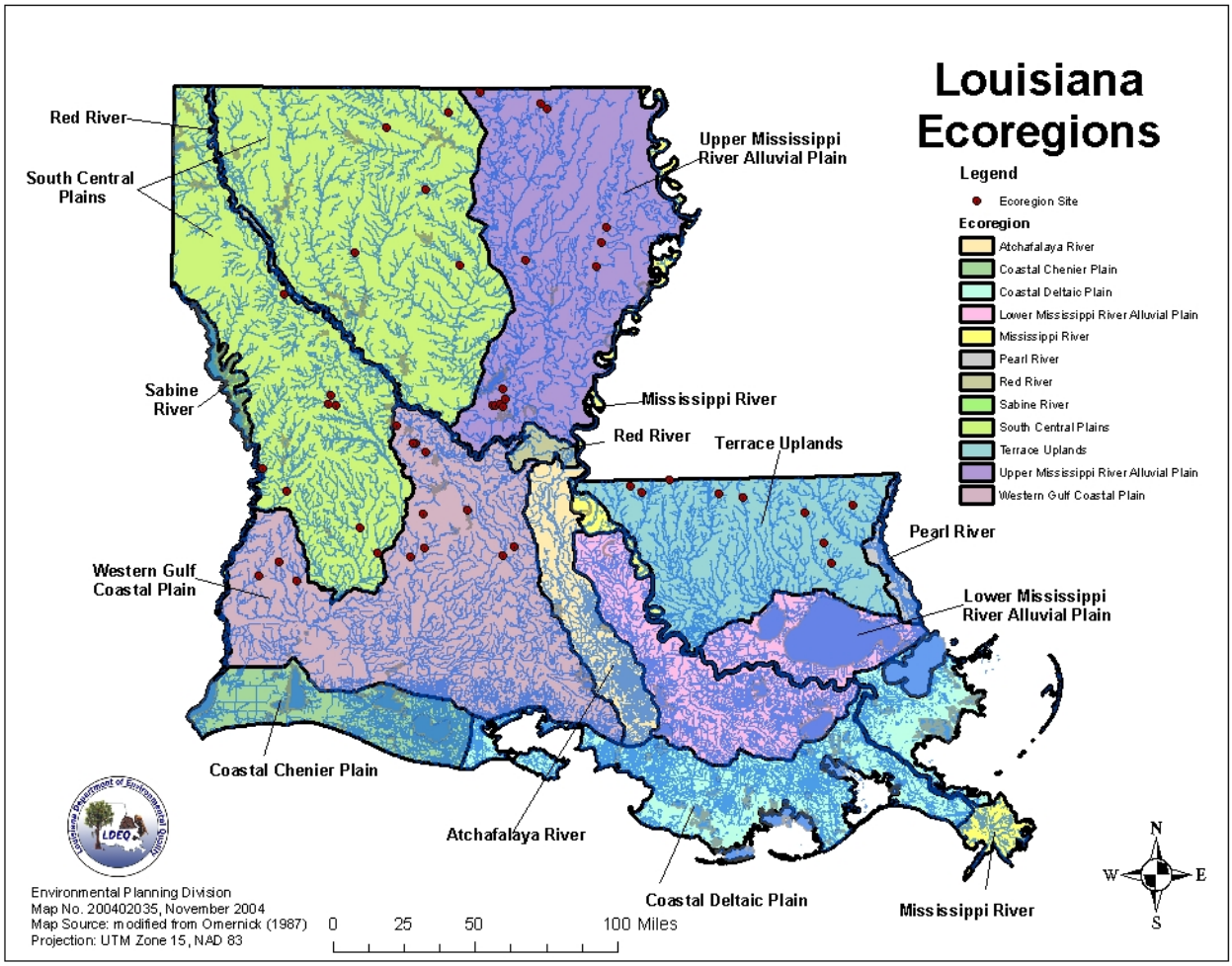

Figure 1 Louisiana Ecoregions 2004*

- CD of coverage can also be included.

Louisiana's Ecoregions - Descriptions

There are seven ecoregions described by LDEQ for Louisiana. EPA's guidance for developing nutrient criteria encourages states to refine their own ecoregion delineations[33].

a. Upper Mississippi River Alluvial Plains - This previously delineated EPA ecoregion, which extends from southern Missouri, Illinois, and Kentucky southward through Louisiana, has been slightly modified by LDEQ personnel. The continuity of this ecoregion southward through Louisiana is interrupted by the Red River and the Atchafayala River. The eastern boundary of the northern component of this ecoregion is formed by the Mississippi River levee system. The western boundary of the northern portion of the Upper Mississippi River Alluvial Plain Ecoregion is formed at the interface between the Red River Alluvium and the Coastal Plain soil associations near the Ouachita River. The southern extent of the northern portion of this ecoregion terminates at the Red River. This ecoregion contains natural levees of moderate elevation and slope; and vegetation includes both cypress forest and bottomland hardwoods. Many of the streams in this ecoregion have been hydrologically modified.

b. South Central Plains - This EPA designated ecoregion, located in northwestern Louisiana, is bisected by the LDEQ designated Red River Ecoregion. The South Central Plains ecoregion also overlaps eastern Texas and southwest Arkansas. The southern extent of this ecoregion, located west of the Red River Ecoregion, is formed by the boundary between the Coastal Plain and Gulf Coast Flatwoods soil associations. The South Central Plains ecoregion is characterized by maximum elevations and relief and longleaf and shortleaf vegetation types.

c. Western Gulf Coastal Plains - Typified by flat plains, this EPA designated ecoregion is located in southwestern Louisiana and ranges westward along the eastern coast of Texas. The southern boundary has been modified to coincide with the location of the Intracoastal Waterway. The eastern boundary is the western Atchafayala levee system. The northern boundary partially concurs with the divide between the Gulf Coast Flatwood and Coastal Plain soil associations and the original EPA delineation. Vegetation is characteristic of the bluestem/sacahuista prairie type (bluestem and cordgrass) and landuse consists of mainly cropland and some cropland combined with grazing land. The soil associations represented in this ecoregion are Gulf Coast Flatwoods and Coastal Prairie.

d. Terrace Uplands - LDEQ personnel utilized the Mississippi River levee system as the western boundary of the Terrace Uplands Ecoregion. The southern boundary of the Terrace Uplands Ecoregion is formed by the southeastern extent of the Mississippi Valley Silty Upland soil association and the southern boundaries of the original EPA delineated Mississippi Valley Loess Plains, Southeastern Plains and the Southern Coastal Plains ecoregions. The Terrace Uplands ecoregion consists mainly of intermediate elevations and relief. Vegetation in the area includes bluffland-woodland types, mixed longleaf forests, and some prairie grassland. The northeastern portion of this ecoregion is characterized by maximum elevations and relief as well as longleaf and shortleaf vegetation types.

e. Lower Mississippi River Alluvial Plains - The southern section of the Mississippi Alluvial Plain Ecoregion is bisected by the Mississippi River. The western boundary is formed by the Atchafayala River levee system and the southern boundary is formed by the

[33] *Nutrient Criteria Technical Guidance Manual Rivers and Streams, EPA 822-B-00-002, July 2000*

Intracoastal Waterway. Part of the northern boundary of the southern component of the Lower Mississippi River Alluvial Plain Ecoregion is formed by the west bank of the Mississippi River. The northern boundary east of the Mississippi River is formed by the southern limit of the Southern Mississippi Silty Upland soil association and the southern boundary of the EPA designated Mississippi Valley Loess Plains, Southeastern Plains and Southern Coastal Plains ecoregions. This ecoregion contains natural levees of moderate elevation and slope; and vegetation includes both cypress forest and bottomland hardwoods. Many of the streams in this ecoregion have been hydrologically modified.

f. Coastal Chenier Plain - This LDEQ designated ecoregion, located on the southwest Louisiana coast, is bounded on the north by the Intracoastal Waterway and on the east by the Vermilion Lock located on the western shoreline of Vermilion Bay. Low elevation and relief along with ridges or "cheniers" oriented parallel to the coastline are typical of this ecoregion. Vegetation consists of both fresh and salt marsh types.

g. Coastal Deltaic Plain - This second LDEQ designated coastal ecoregion is bounded on the west by the Vermilion Lock located on the western shoreline of Vermilion Bay and extends eastward around the Mississippi River levee system terminating at the Intracoastal Waterway east of the Mississippi River. The Intracoastal Waterway also forms the northern boundary of the Coastal Deltaic Plain west of the Mississippi River. This ecoregion is typified by low elevations and relief as well as both fresh and salt marsh vegetation.

h. Atchafayala River Basin Ecoregion[34] - This ecoregion is surrounded by a levee system on the north, east and western boundaries. The southern limit of this ecoregion extends to the Intracoastal Waterway. This ecoregion has low relief and much standing water. Vegetation is dominated by oak, tupelo and bald cypress.

i. Red River Ecoregion - This ecoregion bisects the EPA- and state-designated South Central Plains ecoregion. The southern boundary of the Red River Alluvial Plain ecoregion is formed by the northern extent of the Atchafayala Basin levee and canal system. This ecoregion is characterized by low elevation and relief and bottom hardwood vegetation confined within its levees.

j. Mississippi River Ecoregion - This ecoregion, bounded entirely by the Mississippi River levee network, extends 569 miles from the Arkansas-Louisiana state line to the delta in southeast Louisiana. Because of the unique attributes of this river system, it was designated as a separate ecoregion by LDEQ.

k. Sabine River Ecoregion - This ecoregion, located on the western (Texas) border of Louisiana, includes Toledo Bend Reservoir and the Sabine River. Due to their atypical qualities and extensive hydrological modification, these water bodies were considered to be a separate ecoregion by LDEQ personnel. Louisiana and Texas each share a portion of the Toledo Bend Reservoir, however, the Sabine River Authority in Texas generally maintains the water levels in the reservoir. Louisiana and Texas representatives cooperate in the management of water quantity and quality in both the Sabine River and Toledo Bend Reservoir.

[34] Big Rivers and Floodplains/Boundary Rivers and Water bodies - h through l: Ecoregions associated with the larger rivers and bordering rivers. All of these rivers have been leveed and altered for flood control and navigation.

l. Pearl River Ecoregion – This ecoregion is a border river between the state of Mississippi and Louisiana, located on the southern end of Mississippi and a small portion of southeastern Louisiana. The system is braided into various tributaries and terminates in a cypress swamp. The headwaters originate approximately 100 miles inland from Louisiana, near Jackson, Mississippi. The ecoregion includes a dredged navigation channel.

Appendix B - Water Body Specific Approaches

Inland Rivers and Streams
Freshwater Wetlands
Freshwater Lakes and Reservoirs
Big Rivers and Floodplains/Boundary Rivers and Associated Water Bodies
Estuarine Habitats, Coastal Wetlands and Waters and the Gulf of Mexico

1. Developing Nutrient Criteria for Inland Freshwater Rivers and Streams
Objectives: 1) Develop appropriate regional numeric nutrient and DO criteria that represent the best attainable conditions unique to rivers and streams in Louisiana's ecoregions. 2) To develop options for implementing water quality standards for nutrients and DO.

Procedures:
The ecoregion approach will be used to develop ambient nutrient criteria and to analyze the appropriateness of existing DO standards for Louisiana's rivers and streams. The scope and order of these procedures may need to be modified as the plan develops and data are analyzed.

1. Compile nutrient concentrations and trophic ratios for water bodies in both EPA III and Louisiana Ecoregions.

    a. Identify potential associations between nutrient causal and response variables and other factors, i.e., seasonal or hydrological.

2. Describe a water body trophic classification approach within the LDEQ ecoregion framework and characterize the DO and nutrients within each classification.

3. Characterize ecoregion nutrient and DO levels based on least impacted streams (size or watershed size to be determined).

4. Develop procedure to evaluate best attainable or reference conditions for nutrients and DO.

5. Identify characteristics that have the strongest influence on nutrients and DO. Examine periphyton and periphyton growth in ecoregion streams and potentially use to develop a predictive model or equation (especially in streams for which biological data is available).

6. GIS display and statistical summary of DO and nutrient data for rivers and streams within Louisiana's ecoregions.

7. Development of a scientific advisory committee – a university-based team to provide scientific expertise and leadership in developing nutrient criteria and implementation options.

8. Develop implementation options for TMDLs, permits, assessment, and monitoring strategies.

2. Nutrient Criteria for Freshwater Wetlands in Louisiana: Classification Approaches and Procedures

An ecoregion approach consistent with the national nutrient criteria development strategy can also be used to classify and characterize the different wetland types found in Louisiana. This approach specifically recognizes that nutrient criteria will vary by region, and these nutrient criteria will also vary as a function of wetland type. Therefore, technical guidance is needed that recognizes the variability in nutrient assimilation of different types of wetlands in Louisiana. The state of Louisiana is unique in regards to wetlands for a variety of reasons, including the influence of the Mississippi River, which is the largest river in North America. Extensive areas of freshwater and coastal/estuarine wetlands are affected by a high rate of subsidence and degradation, primarily due to a lack of sediment and nutrients entering the wetlands. Subsidence is a natural process, but the building of levee systems has restricted the Mississippi River's course therefore preventing the natural cycle of the river and the process of delta formation. A large portion of the state's coastal wetlands have undergone and continue to

undergo a severe deprivation of sediments and nutrients that has led quite literally to the breakup of the natural system. Impoundments, flood control projects, and oil and gas canals have all contributed to create a large number of hydrologically isolated wetlands (Day et al., 1990).[35] The high rates of subsidence in the Louisiana coastal zone combined with eustatic sea level rise result in a relative sea level rise that is about 10 times that of eustatic sea level rise (Breaux and Day, 1994).[36] In addition, relatively high year round temperatures allow a high rate of metabolism and nutrient cycling.

In short, wetland elevation in the Louisiana Coastal Zone is lowered due to sea level rise and geologic or local subsidence. Continual accretion is necessary if natural wetland communities are to be maintained. Wetlands in the Louisiana coastal plain have been estimated to deteriorate at the alarming rate of 65 km2/yr (25 mi2/yr) (Dunbar et al. 1992)[37]. Estimates of percentage land loss across wetland habitat types in four coastal regions for Louisiana's Coast 2050 Report[38] range from 10-42%. Accretion rates will be an important factor in the development of nutrient criteria for wetlands in Louisiana.

Another important role wetlands play is in water quality improvements. Wetlands can permanently remove nutrients via plant uptake, denitrification, and burial. Also, there are strong nutrient transformations as water flows through wetlands. In fact, wetlands have been used for water quality improvements for many years. The effectiveness of water quality improvement depends on many things including nutrient form (i.e., nitrate vs. ammonium, organic vs. inorganic), loading rate, residence time, season, and wetland type. As of 1987, more than 400 natural wetland systems had been approved to receive wastewater discharge in the southeastern U.S., and more than 100 more in the Great Lakes states (EPA, 1987).[39] While increased nutrients and/or sedimentation in wetlands might be considered a drawback in some geographic areas due to the filling in and resultant alteration of water levels, for Louisiana wetlands it is an asset in maintaining current land levels against the forces of subsidence.[40]

Objectives: The following procedure is designed to develop an appropriate methodology for quantifying the relationships between nutrient concentration, loading rates, assimilation capacity, and ecological responses to nutrients in Louisiana's wetlands. Since wetlands in Louisiana generally include a variety of swamps, marshes, bottomland hardwood forests, etc., it is important to develop wetland definitions and characteristics. This will enable the development of guidelines for loading rates that account for the unique aspects of Louisiana's wetlands, i.e., loading rates that are sensitive to watershed attributes, hydrologic characteristics, and geomorphic setting.

Procedures: To define a wetland classification approach within the ecoregion framework and characterize the nutrient constituents within each classification. Options for wetlands nutrient criteria will be developed. Other water quality attributes will also need to be considered in the

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[35] Day, R. D., R. K. Holtz, and J. W. Day, Jr. 1990. An inventory of wetland impoundments in the coastal zone of Louisiana. USA: Historical trends. *Environmental Management* 14(2): 229-240.
[36] Breaux, A.M. and J.W. Day, Jr. 1994. Policy Considerations for Wetland Wastewater Treatment in the Coastal Zone: A Case Study for Louisiana. *Coastal Management*: Volume 22, pp. 285-307.
[37] Dunbar, J.B., L.D. Britsch, and E.B. Kemp. 1992. *Land loss rates*. Report 3. *Louisiana Coastal Plain*. Technical Report GL-90-2 prepared for the US Army Engineer District. New Orleans, Louisiana.
[38] See http://www.lacoast.gov/programs/2050/MainReport/report1.pdf
[39] U.S. EPA. 1987. *Report on the Use of Wetlands for Municipal Wastewater Treatment and Disposal*. Office of Water. Office of Municipal Pollution Control. Submitted to Senator Quentin N. Burdick, Chairman of Committee on Environmental and Public Works. EPA 430/09-88-005.
[40] Breaux, A. M. and J.W. Day, Jr. 1994.

nutrient characterizations for Louisiana wetlands. The scope and order of these procedures may need to be modified. Consideration will also be given to the Louisiana Coastal Restoration Program in developing nutrient criteria for wetlands. Freshwater introduction of nutrient-rich Mississippi River water has been found to be beneficial to coastal wetlands and would make nutrient criteria compatible with coastal restoration.

1. Identify, delineate, and name the wetland types for Louisiana - both coastal inland freshwater wetlands as well as coastal marsh wetlands.

    a. Identify characteristics that may influence wetland nutrient constituents such as season (weather), vegetation, drainage area (size), basin area (size), depth, flow patterns (hydrology), geology, and land use.

2. Examine existing data and determine whether data are adequate to estimate loadings and/or criteria.

    a. Assess existing data (including continuous monitoring data) for the purpose of determining best attainable conditions for each wetland classification within each ecoregion

    b. Identify methods of "pooling" existing data to adequately estimate criteria.

    c. Identify existing gaps in the data that preclude accurate prediction of nutrient criteria for wetlands and suggest areas of future research.

3. Determine what baseline ecological data is necessary to provide for the development of biological assessment criteria for wetlands and/or wetland types. Determine types of monitoring parameters necessary for wetlands and/or wetland types.

4. Identify appropriate statistical analysis of data; identify seasonal variations if appropriate. Develop a procedure to evaluate best attainable or reference conditions for different wetland types based upon this data.

5. Calculate appropriate nutrient assimilative capacity (and criteria) of different wetland types. Display data for each wetland type/classification and ecoregion.

6. Synthesize and summarize information to develop relationships among factors such as nutrient cone, nutrient loading rate, and residence time on nutrient assimilation. Provide options for nutrient criteria in Louisiana wetlands that have been characterized.

3. Nutrient Criteria for Freshwater Lakes and Reservoirs

There have been several studies conducted by LDEQ over the years to inventory and assess the status of Louisiana's freshwater lakes and reservoirs. Based on work done in the 1980's[41], Louisiana has over 160 freshwater lakes and reservoirs with surface areas in excess of 2.6 square kilometers (1 square mile). This study also noted that most freshwater Louisiana lakes and reservoirs are located in shallow swamp basins with above average nutrient levels. Although the majority of these lakes fall into the eutrophic category when applying classification systems such as Carlson's Trophic State Index, most have productive fisheries and are

[41] Malone, R. F. and D. G. Burden. 1985. Trophic Classification of Louisiana Freshwater Lakes. LDEQ Water Pollution Control Division. Baton Rouge, Louisiana.

considered recreational assets. In addition, there are an abundance of Louisiana coastal lakes that are fresh to brackish, where freshwater predominates during the majority of the year[42]. One other study[43] (USEPA 1977) suggested that among studied Louisiana lakes and reservoirs most are predominately phosphorus limited with a small number indicating nitrogen limitation. Sizes among the 30 or more popular Louisiana lakes and reservoirs range from the 735.8 square kilometer Toledo Bend Reservoir to the 4.25 square kilometer Lake Concordia oxbow. Mean depths of popular lakes and reservoirs range from 7 meters or greater for Toledo Bend Reservoir and the False River and Lake Bruin oxbows to one meter or less for Lakes Cocodrie and Wallace.

In summary, Louisiana freshwater lakes and reservoirs exhibit a range of nutrient conditions, including extremes, and these ranges may vary according to geographic and geological regions. Consequently, it is necessary to determine the natural ambient background for each lake to both development of nutrient criteria and to address cultural eutrophication. However, this site-specific approach as described in Louisiana's current narrative criteria would be prohibitively time consuming and expensive. To expedite the criteria development process, lakes and reservoirs in Louisiana may be divided into regionally similar groups based on their physical characteristics within a proximal geographic region. Those lakes that exhibit reference type or least-impacted conditions can become a candidate benchmark or criterion. Also, a measure of best practical and professional judgment may be applied, particularly in beneficial use decisions about reference types. For example, in some lakes aesthetics could be a more important consideration than in others based on land uses or recreational uses.

Objectives: 1) Develop a lake classification scheme and approach to formulate appropriate regional numeric nutrient and DO criteria that represent the best attainable conditions unique to Louisiana lakes and reservoirs. 2) To develop options for implementing water quality standards for nutrients and DO.

Procedures: A lake classification approach will be used to: 1) analyze ecoregional nutrient and DO data; and, 2) develop appropriate nutrient and DO standards for Louisiana's lakes and reservoirs. The scope and order of these procedures may need to be modified as the plan develops and data are analyzed. The procedures are concurrent to the EPA-USGS/RTAG's and LDEQ's statistically derived regional criteria ("default" criteria).

1. Aggregate nutrient data for lakes and reservoirs by ecoregion (both EPA's national ecoregion and LDEQ's ecoregion) to view distributions of nutrient data across ecoregions.

2. Compile nutrient concentrations and trophic ratios.

    a. Identify potential associations between nutrient causal and response variables and other factors, i.e., depth, seasonal or hydrological.

    b. Identify candidate criteria variables for each ecoregion and lake/reservoir class.

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[42] Shampine, W.J. 1970. Gazetteer of Louisiana Lakes and Reservoirs. Louisiana Department of Public Works. Baton Rouge, LA. Basic Records Report No. 4.

[43] U.S. Environmental Protection Agency. 1977. National Eutrophication Survey of Louisiana Lakes: Working Papers No. 528-544. Corvallis Environmental Research Laboratory. Corvallis, Oregon and Environmental Monitoring Support Laboratory, Las Vegas, Nevada.

c. Select minimally impacted candidates in each class (and by percentile). Select frequency distributions of all lakes/reservoirs in each class (and by percentile).

3. Establish reference conditions and period of record.

4. Develop a physical classification scheme based on size (acres of surface area, watershed area) and/or depth and lake types, i.e., oxbow, impoundment, or other characteristics.
5. Use of models (i.e., Lake Waco – N. Bosque River ecosystem study[44]) to evaluate causal and response variables and to consider downstream effects (watershed approach).

6. Synthesize and summarize information to develop relationships among factors such as nutrient loading rate, and residence time on nutrient assimilation. Provide options for nutrient criteria in Louisiana lakes that have been characterized.

7. Provide for the development of assessment methods for lakes/reservoirs. Determine type(s) of monitoring and those parameters necessary for management responses to over-enrichment or other problems.

4. Big Rivers and Floodplains/Boundary Rivers and Associated Water Bodies

As discussed previously in Section I, Part C.1.d, Louisiana has a diversity of unique big river environments. Among them are the Mississippi River and its main distributary, the Atchafalya River, both of which receive drainage from one of the world's largest watersheds, the Red River, which flows through four states before it enters Louisiana. Also included in the big rivers are the Sabine River and Toledo Bend Reservoir shared with Texas, and the Pearl River, which borders Mississippi. Because the water quality in all these rivers is significantly influenced by drainage from outside Louisiana, developing nutrient criteria will be especially challenging and complex.

As they involve shared state boundary rivers, nutrient criteria development for the Sabine and Pearl Rivers will require coordination with the states of Texas and Mississippi, respectively. The headwaters of both rivers are located outside Louisiana. The Sabine River boundary is complicated by the presence of one of the southern region's largest reservoirs, Toledo Bend. In addition to working with the State of Texas, we anticipate working with the Sabine River Authority (SRA). The SRA manages both water quality and quantity associated with the Sabine River and Toledo Bend Reservoir and provides an avenue for working with the State of Texas. The use of Toledo Bend Reservoir for electrical power generation will also require consideration.

Much of the river channel of the Pearl River is braided into various tributaries and distributaries to form a river swamp environment south of the City of Bogalusa. The Pearl River Basin is further complicated by the presence of a deeply dredged navigation channel and scenic streams. The headwaters of the Pearl are near Jackson, Mississippi approximately 100 miles inland from Louisiana. In fact, most of the Pearl River Basin is contained within Mississippi.

Developing nutrient criteria for the Red River will necessarily require consideration of the water quality in the upper river watershed outside of Louisiana. The Red River headwaters are

[44] Kiesling, R. A. M. S. McFarland, and L. M. Hauck. 2001. USDA Lake Waco-Bosque River Initiative. Nutrient Targets for Lake Waco and North Bosque River: Developing Ecoystem Restoration Criteria. Texas Institute for Applied Environmental Research. Tarleton State University, Stephenville, TX. TR0107, 52 pp.

in New Mexico. The Red River then flows across the Texas Panhandle plains to form the boundary between Texas and Oklahoma, and thence to form Lake Texoma. From Lake Texoma, the Red River flows through Arkansas before entering Louisiana. Ambient nutrient data for the Red River in Louisiana shows unique nutrient concentrations compared to local stream systems indicating the impact of the upriver watershed. A cooperative effort on nutrient criteria development for the Red River by the states that share the watershed, New Mexico, Texas, Oklahoma, Arkansas and Louisiana, may be necessary.

The most challenging nutrient criteria development for Louisiana's big rivers for will be the Mississippi and Atchafalaya Rivers. Analysis of long-term water quality data on the Mississippi River clearly demonstrates the impact of upriver watershed drainage on water quality in Louisiana's reach of the Mississippi. The analysis shows that nutrient concentrations for nitrate-nitrites, total kjeldahl nitrogen and total phosphorus are statistically the same at Lake Providence on the Arkansas border and 300 miles south at Belle Chase south of New Orleans. The Atchafalya River flows through the largest remaining river swamp basin in the United States and receives part of its flow from the Red River. The Atchafalaya River still shows some of the highest nutrient concentrations of all state waters second only to the Mississippi River demonstrating the dominant impact of the Mississippi on its water quality.

To address excess nutrients in the Mississippi and Atchafalaya Rivers, Louisiana is participating in the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (National Gulf Hypoxia Task Force). Louisiana has participated in the Task Force since its inception in 1997. The Task Force is seeking to decrease nutrient concentrations and loads in the Mississippi River as a primary approach to reducing the size of a low oxygen hypoxic zone that forms each summer in the Gulf of Mexico off the Louisiana Coast. Causes of the Gulf of Mexico hypoxia are complicated as would be expected in such a large watershed, but have been shown as related to the discharge of elevated concentrations of nitrogen and phosphorus from the Mississippi River to the near shore shelf waters of the Gulf of Mexico.

Efforts are underway through the Hypoxia Action Plan (2001) to address the sources of nutrient runoff and discharges into the Mississippi River watershed and reduce the size of the hypoxia in the Gulf. One of the components of this effort is to assist in the development of nutrient criteria for the Mississippi River and watershed. The EPA has stated[45] that it is important to fully understand the causes and responses of nutrients in the Mississippi River and watershed prior to adopting numeric criteria and Louisiana agrees with those comments. We have also noted that the EPA, in order to better understand the science surrounding nutrient criteria in large rivers, is committed to convening key partners at a multi-day national workshop on the nutrient criteria issue. When the national workshop is announced Louisiana will participate. In summary, any nutrient criteria for the Mississippi and Atchafalaya Rivers will need to be developed in coordination with all upriver states. The National Hypoxia Task Force has all the river states involved and Louisiana will continue to work with the National Task Force states to seek appropriate nutrient criteria for the Mississippi and Atchafalaya Rivers.

5. Estuarine Habitats, Coastal Wetlands and Waters, and the Gulf of Mexico

Gulf coast estuarine habitats and wetlands and nearshore coastal waters of the Gulf of Mexico naturally vary in the type, characteristics, and geographic coverage of biological communities (Battelle, 2004, draft report). The factors associated with this variability are numerous but include characteristics such as water residence time, depth, water column

[45] EPA. 2004. EPA Response to Sierra Club Petition Regarding Defined Portions of the Mississippi and Missouri Rivers. Fact Sheet (EPA-823-F-04-018).

stratification, salinity, and temperature regimes. The Louisiana coastal plain remains the largest expanse of coastal wetlands in the contiguous United States. The coastal wetlands, built by the deltaic processes of the Mississippi River, contain an extraordinary diversity of habitats including swamp forest, fresh marsh, intermediate marsh, brackish marsh, saline wetlands, bottomland hardwoods, mangroves, scrub shrub, submerged aquatics, barrier islands, open water and upland habitats (www.lca.gov; LCA[46] draft study report, Visser, J. M. et. al 2004). Today, most of the Mississippi River's freshwater with its nutrients and sediments are channeled out to the deep waters of the Gulf of Mexico, bypassing the coastal wetlands where they would otherwise naturally build land and nourish the estuarine ecosystems. Deprived of the sediments provided by the deltaic processes, the estuarine wetlands continue to sink, or subside, as they have always done, but without the net land building effect of the unconstrained natural deltaic processes (www.lca.gov).

It is generally accepted that salinity and inundation (flooding for part of the year or longer) are the major driving forces in the distribution of coastal wetland habitats and that these forces may be modified by other factors such as fertility, herbivory, human disturbance, and burial (LCA draft study report, Visser, J. M. et. al 2004). Salinity predominantly drives change among fresh, intermediate, brackish and saline habitats, and the change may intensify with inundation. However, very little or no inundation restricts delivery of necessary nutrients and reduces vegetative productivity in either habitat. This type of relationship, which is only recently being characterized by scientists, emphasizes that nutrient criteria for Louisiana's coastal waters must be developed in a manner consistent with the uniqueness of its coastal ecoregion systems.

The Louisiana coastal zone is one of the most dynamic environments that exist in nature. To understand the complicated dynamic influences that constantly shape and influence Louisiana's coastal zone, LDEQ staff participates in several national, state and regional task forces, committees, and programs addressing Louisiana's coastal restoration and management. Among these is the Gulf of Mexico Program (GOMP), a multi-agency program aimed at focusing awareness of the Gulf's pollution (e.g. hypoxia), habitat, fisheries, and other problems, and finding effective, workable solutions to these problems. The Lower Mississippi River Conservation Committee (LMRCC), like the GOMP, works to identify and find solutions to problems that exist among states along the lower Mississippi River south of the Ohio River. Diversion of nutrient rich Mississippi River water is a key part of the Louisiana's coastal restoration program. The efforts made by this coalition, which includes LDEQ staff, ultimately affect the Louisiana coast and the Gulf of Mexico. LDEQ also participates with other state agencies on the Coastal Wetlands Conservation and Restoration Task Force to address coastal land loss. LDEQ maintains representation on the Lake Pontchartrain Basin Foundation (LPBF) board. The LPBF is charged with seeking solutions to and raising citizen awareness of pollution problems in Lake Pontchartrain (an estuarine lake) and the surrounding watershed. LDEQ will continue to coordinate with national, state and regional task forces and committees in the development of appropriate nutrient criteria for Louisiana's coastal estuarine waters.

To specifically address nutrient criteria development, the GOMP Office is coordinating and LDEQ staff participating in the process of data collection to perform a meaningful characterization and ecosystem assessment of nutrient loads/responses for the near coastal waters of Lake Borgne, Louisiana to Mobile Bay, Alabama, an area that comprises the northern Gulf of Mexico.[47] This characterization and assessment will be used to provide the best

[46] LCA = Louisiana Coastal Area Ecosystem Restoration
[47] From GMPO's Director's Report for Jan/Feb/March 2004: Nutrient Pilot Study Workshop

available information to the states of Louisiana, Mississippi, and Alabama in the development of nutrient criteria and standards for coastal waters. The first phase of this project is to identify nutrient data sources for the designated study area and to prepare a compendium and analyses of current and historical nutrient data. The report is entitled: *A Scientific Assessment of Nutrient Concentrations, Loads, and Biological Response in the Northern Gulf of Mexico* and may be viewed at http://www.epa.gov/gmpo/nutrient/npilot-study.html. As outlined in the report, the project objectives are consistent with the EPA's Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine waters.[48]

Objectives: To provide data and information that can be used by states to develop nutrient criteria and associated management responses. The ultimate goal is to provide the best available means to support the states of Louisiana, Mississippi, and Alabama in the development of nutrient criteria for coastal waters.

Procedures/Tasks:
Phase I

1. Develop QAPP
2. Select attributes to best characterize nutrient condition of study area (coastal area) and explain rationale behind selections
3. Identify and acquire existing data sets from agencies and universities
4. Perform QA/QC for all data sets
5. Compile datasets into uniform, electronic relational database (ORACLE)
6. Prepare draft interim and final reports detailing analysis strategy for the data, with specific information about each data set including
    a. Collection method
    b. Data gaps
    c. Preliminary evaluation of water bodies and corresponding nutrient data (data summaries)
    d. Recommendations for procedures for further analysis

[48] USEPA.2001. *Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters*. EPA-822-B-01-003, October 2001, USEPA, Office of Water, Washington, DC.

Phase II

1. Identify reference conditions for estuarine and coastal waters (especially within the study area)
    a. Scale
    b. Characterization/Typology
    c. Statistical power
        i. EPA Nutrient Criteria Technical Manual (EPA 2001)
        ii. NOAA's National Estuarine Eutrophication Assessment
        iii. The Louisiana Coast-wide Reference Monitoring System (CRMS) Louisiana Department of Natural Resources (LDNR)
        iv. Australia's National Estuaries Assessment and Management (NE) Project

2. Data Gaps Analysis
    a. Priority and representative water bodies within the study area
    b. Prioritize candidate reference sites for comparative studies
        i. Help evaluate current and future monitoring plans based on gaps in monitoring
        ii. Robustness of data for statistical analysis
    c. Collaboration with other investigators and agencies during planning and implementation

<u>Generalized sequence of milestones in the development of coastal nutrient criteria (from EPA guidance)</u>

Note: The sequence may change based on the review of the approaches outlined in 1.c. above or other approaches determined to be appropriate.

a. Historical Information – identification, collection and review of historical conditions
b. Development of Reference Condition
c. Models to estimate dose-response relationships
d. Antidegradation – "upstream" nutrient criteria must be considered downstream for estuarine and near-shore systems
e. Regional Technical Advisory Groups (RTAG) – regional experts assembled to work with the States in the review of water quality data, development of nutrient criteria, and monitoring plans