LOUISIANA TOTAL MAXIMUM DAILY LOAD TECHNICAL PROCEDURES

Revision 15

Water Permits Division

Office of Environmental Services

Louisiana Department of Environmental Quality

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Document Review and Revision Record

Note: Actions older than 5 years may be removed from this record

Approval Date	Revision No.	Record of Activity
10/10/2003	8	Minor Revisions
05/26/2005	9	Minor Revisions to Format
08/10/2006	10	Revised 2.2 Allocation of Loads; Minor Revisions
01/29/2008	11	Minor revisions including personnel changes, minor text and format revisions, and other document and model updates. Added new Section 3.4 Model Calibrations and renumbered the remaining paragraphs appropriately. Major revisions to: 2.3 removing the 10% rule from Phased TMDLs discussion; 3 expanding the discussion about water quality modeling and updating numerous subparagraphs under 3.3; Expanded and updated subparagraphs under 3.5 including 3.5.1.3 Dissolved Oxygen addressing 10% rule and 3.5.4 changing reduction allowance from 0.5 mg/l to 0.2 mg/l to be consistent with TMDL protocol; updated 3.7 concerning the discharger inventory.
5/28/2010	12	Minor revisions including personnel changes, addressing multiple dischargers, addressing MS4 permits, outline of TMDL reports, public participation, and Table of Contents update.
11/16/2012	13	Minor revisions including personnel changes, web address updates, grammar, and punctuation. Section 2.2.1.1 was updated to address how to bring remote dischargers into the model. Section 3.5 was updated to address load reductions. Section 3.5.1.1 was updated to address critical flows. Section 5 was moved to Section 1. Tables and figures were moved closer to text in which they were referenced.
3/24/2015	14	Organizational and personnel changes to the title page. Minor text update to Section 2. Introduction.
2/11/2016	15	Organizational and personnel changes to the title page. Minor text updates to provide clarity in sections 2.0, 2.2, 3.1, 3.2.1.1, 3.2.2, 3.4, 4.1.1, 4.1.2.1, 4.2.3, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.4, 4.4.1, 4.5.1.3, 4.5.2, 4.5.4, and 4.7.

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1 Definitions/Acronyms/Abbreviations

30Q2	30 day average low flow with recurrence of 2 years
7Q10	7 day average low flow with recurrence of 10 years
AT	Advanced Treatment
cfs	Flow in cubic feet per second
BAT	Best Available Technology
BMP	Best Management Practice
BOD_5	5 day Biochemical Oxygen Demand
$CBOD_5$	Carbonaceous BOD_5
CPP	Continuing Planning Process, documentation required by 303(e) of the CWA
CWA	Clean Water Act
DO	Dissolved Oxygen Concentration
EL	Effluent Limited
EPA VI	Region VI of the US EPA
K_2	Reaeration Rate
K_d	Carbonaceous BOD decay rate
K_n	Nitrogenous Decay Rate
K_s	CBOD Settling rate
LA	Load Allocation
LDEQ	Louisiana Department of Environmental Quality
LTP	Louisiana Technical Procedures
MGD	Flow in Million Gallons per Day
mg/L	Concentration in Milligrams per Liter
MOS	Margin of Safety
MOU	Memorandum of Understanding
MZ	Mixing Zone
NBOD	Nitrogenous BOD
NH_3	Ammonia
NH_3-N	Ammonia nitrogen concentration
NPDES	National Pollutant Discharge Elimination System, the system of Federal discharge permitting
POTW	Publicly Owned Treatment Works
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
SOD	Sediment Oxygen Demand
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TSD	USEPA Technical Support Document for Water Quality Based Toxics Control
TSS	Total Suspended Solids

UAA	Use Attainability Analysis
UBOD	Ultimate BOD
UCBOD	Ultimate Carbonaceous BOD
UOD	Ultimate Oxygen Demand
WLA	Wasteload Allocation
WQL	Water Quality Limited
WWTP	Wastewater Treatment Plant
ZID	Zone of Initial Dilution

2 INTRODUCTION

The Louisiana Total Maximum Daily Load Technical Procedures (LTP) outlines and defines procedures which will be followed in developing models, total maximum daily loads (TMDLs), wasteload allocations (WLAs) for Louisiana dischargers, and load allocations (LAs) for nonpoint sources. Activities that support the development of TMDLs and WLAs and various modeling activities are also described.

This document is the 15th revision of an LTP submitted to USEPA Region VI (EPA VI) as a draft memorandum of understanding (MOU) in 1988 by the Louisiana Department of Environmental Quality (LDEQ). Since the first LTP was developed, the State Water Quality Standards (www.deq.louisiana.gov/portal/default.aspx?tabid=1674) have been revised, newer water quality models have been developed, and additional guidance documents have been developed by the USEPA. Further, experience gained over the years in applying the LTP provides an improved perspective for needed revisions.

2.1 Purpose

Water quality based effluent limitations for point source permitting are based on the TMDL and WLA, while NPS water quality based implementation plans are based on the TMDL and the LA. The purpose of the water quality based approach is to establish pollution control limits for waters not meeting the State's water quality standards. In this context, the TMDL process includes assessment for water quality standards attainment, identification of water quality limited waters, the ranking and targeting of high priority waters, and the development of TMDLs that should result in the attainment of water quality standards when implemented (USEPA, 1991).

The purpose of the LTP is to:

* encourage a rational, holistic, geographic approach toward solving water quality problems from the perspective of instream conditions,
* facilitate the development of technically sound and legally defensible decisions for attaining and maintaining water quality standards,
* streamline the TMDL and WLA development process through establishment of specific modeling requirements, terminology, critical conditions, parameter values, and allocation procedures,

* reduce the technical justification verbiage in TMDL reports,
* specify the general technical management and planning procedures to be followed in TMDL development,
* document a standard report outline and format, and
* clarify these elements for interested parties outside LDEQ and EPA VI.

This document provides a consistent statement of policy and a basis for technical selection of parameters and procedures. It is not the purpose of this document to remove the requirement for scientific and engineering judgment from TMDL development. Many other references and sources of authoritative information are available. Selection of procedures, which are in conflict with the LTP, should only be made with caution, and be technically documented and justified. Approval of such deviations by LDEQ is required in order for such a procedure to provide a basis for permit modification or Water Quality Management Plan update.

Procedures and standards of practice for toxic pollutants are not yet fully developed; however, most sections of the LTP are equally as applicable to toxic pollutants as to conventional (oxygen demanding) pollutants. A section is also specifically dedicated to toxic pollutant TMDL development.

Additional information on the process the State uses to identify water quality limited (WQL) and effluent limited (EL) segments, to identify and prioritize waters requiring a TMDL, and the procedures for public review and participation are described in the Louisiana Water Quality Management Plan Volume 1, the Continuing Planning Process, and Volume 5, the Water Quality Integrated Report documents. These processes are, therefore, not included in this document. In addition, the requirements for project and survey planning and reporting have been revised and transferred to the LDEQ QA/QC document (QAPP #1018 – Quality Assurance Project Plan for the Development of Dissolved Oxygen and Nutrient Total Maximum Daily Loads).

2.2 Statement of Policy

The State of Louisiana is committed to the development of TMDLs that are consistent with the requirements of the Clean Water Act (CWA) and applicable State statutes and regulations. In this regard, permit limitations will be established at a level that will assure attainment of the applicable water quality standards.

It is also recognized that some of the existing water quality standards for specific sites are not attainable, even under natural conditions. In these cases, appropriate water quality standards revisions should be made and TMDLs developed based upon the revised standards. Revisions to water quality standards will be consistent with the CWA and associated regulations.

2.3 LTP Amendment and Revision

This document will require clarification and revision throughout its useful application lifetime. At any time, an update of the LTP may be proposed by LDEQ. This document will be revised frequently as necessary to reflect new procedures and knowledge gained as the TMDL experience base expands or changes in policy. At a minimum, these procedures should be reviewed every two years and revised, if necessary.

3 TMDLs

This section describes the concepts and terms that form the basis for TMDL development. The definitions provided in this section generally follow those provided by the USEPA (1986, 1991). In addition, the State policy for application of a factor for growth and safety, and allocation of loads is described.

3.1 Definitions

A load is the amount of matter or thermal energy that is introduced into a receiving waterbody. A load may be caused by man (a pollutant) or by nature (natural background load). For oxygen-demanding material, load may be expressed separately for separate components (e.g., CBOD, NH_3-N), or may be expressed as a total oxygen demand.

The TMDL for a waterbody is the greatest amount of loading that a waterbody can assimilate while maintaining water quality standards. The TMDL includes wasteload allocations (WLA, for point source loads), load allocations (LA, for nonpoint source loads), and a margin-of-safety (MOS) to account for uncertainties in data or modeling assumptions. It may also contain allocations for future growth, which may be included in the MOS. The TMDL may be determined on a seasonal, annual, flow, and/or temperature variable basis. If seasonality is not applicable to the determination of the load capacity, annual critical conditions are used in TMDL development. Critical conditions are discussed further in another section of this document.

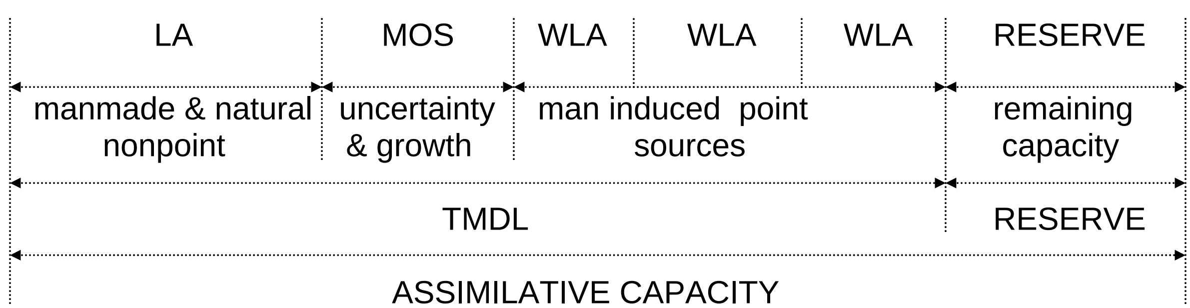
The load allocation (LA) is the portion of a receiving water's load capacity that is allocated to one or more of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading and may range from reasonably accurate estimates to gross allotments, depending on availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished. For calibrated modeling studies, the LA may often be estimated from the headwater flow, incremental flow loads, and nonpoint loads required for calibration. Nonpoint loads may include sediment oxygen demand (SOD) and resuspension.

A wasteload allocation (WLA) is the portion of a receiving stream's loading capacity that is allocated to one or more of its existing or future point sources of pollution. The WLA constitutes a type of water quality based effluent limitation.

Every TMDL developed will also have a margin of safety (MOS) to account for modeling uncertainty, data inadequacies, and future growth and safety, as necessary. The MOS may be explicit or implied. For reasonably conservative constituents such as metals, LDEQ typically uses an explicit MOS expressed as a percentage of the TMDL. For nonconservative constituents such as dissolved oxygen (DO), LDEQ uses a combination of explicit and implied MOS. The implied MOS is contained in the conservative assumptions and modeling uncertainties used in the projection analysis, i.e., 90th percentile temperature and 7Q10 flow occurring at the same time, assuming that the facility design flow occurs at the 7Q10 stream flow, assumptions related to the decay and other coefficients. LDEQ typically reserves an explicit MOS of twenty percent (20%) of each WLA and LA for nonconservative constituents. However, in many situations, LDEQ may determine that a smaller or larger MOS is appropriate. For example, if growth beyond that already incorporated into the design flows is considered to be unlikely, and if there is a high level of confidence in modeling projections, then the MOS might be decreased. Alternatively, waters in which a significant number of new dischargers are anticipated may require an increased MOS. If a facility plan with a population/loading projection is available, that projection may be used in determining the reserve for growth.

The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody that will achieve water quality standards for the constituent of concern, and thereby provides the basis for water quality based controls. The TMDL for a substance is the sum of the individual WLAs for point sources, the LAs for nonpoint sources and for natural background, and the MOS. The TMDL is less than or equal to the load capacity. The relationship between these quantities may be diagrammed as shown in Figure 1.

Figure 1 – TMDL Loading Breakdown



3.2 Allocation of Loads and the Calculation of the Total Maximum Daily Load

Allocations are normally determined in the modeling process and the TMDL is calculated by summing the allocated point and nonpoint loads and the margin-of safety. As shown by Figure 1, a TMDL is composed of nonpoint source load allocations, point source wasteload allocations, and a margin of safety. The following sections address first the allocation of loading and second the calculation of the TMDL.

3.2.1 Allocation of Loads

Allocation of loads to the various point and nonpoint sources is a difficult management decision. Within the constraints of the TMDL requirements, the selection of allocation methodology to be applied is a responsibility of the State.

Various allocation schemes have been proposed, and each may be most appropriate in a particular circumstance. The allocation strategy should:

* be protective of the environment and reduce the risk of violation of water quality standards,
* be equitable to all regulated parties, and
* provide a reasonable distribution of costs of load reductions, and attempt to minimize overall costs of meeting TMDL requirements.

3.2.1.1 Modeled and Other Significant Sources

If all modeled point source dischargers are of similar size, it will usually be most equitable to set equal concentration limits for each discharger. Where both small and large dischargers are involved, the Louisiana "Statewide Sanitary Effluent Limitations Policy" should be followed, so far as possible, in setting limitations on smaller sanitary dischargers. The policy is located on LDEQ's web page at http://www.deq.louisiana.gov/portal/Portals/0/planning/TMDL%20Docs/Water%20Quality%20Management%20Plan%20-Vol%208%20after%20CD%206%207%202012.pdf. Where water quality based limits are required, the state policy will not be used.

If point source dischargers are not similar, for example, if industries and municipalities are involved, it may be more appropriate to require percent removal, or equal reductions from technology based limits (e.g., secondary or Best Available Technology (BAT) guidelines), rather than simply requiring equal concentration limits. In such cases, equal concentration limits should be applied to facilities of similar size. Note, however, that for some industries such as food processors, LDEQ has determined that the character of the waste and waste treatment methods are sufficiently similar to sanitary waste to be included in an overall allocation without consideration of wastewater source or specific industry category.

If multiple point source dischargers are located in such close proximity as to approximate the impact on the stream of a single larger point source, then the analysis will be conducted in accordance with the policy for aggregate areal discharge flows stated in the Louisiana Continuing Planning Process.

If multiple point source dischargers are owned by a single entity, a city for example, it may be appropriate to consult with the permittee to determine the most cost-effective allocation. This consultation is at the discretion of LDEQ. If such an allocation strategy is pursued, contact with the regulated municipalities or industries should be initiated as early as practical during the TMDL development process, and final TMDL determination should not be delayed because of a lack of adequate response from the regulated dischargers.

Nonpoint source tradeoffs are allowed in the allocation process. If best management practices (BMPs) or other nonpoint source pollution controls make more stringent LAs practicable, then wasteload allocations can be less stringent. Because of the uncertainty that is usually associated with nonpoint source loading estimation and BMP reductions, a phased TMDL is likely to be required when such trades are proposed. The TMDL must provide documentation demonstrating that the nonpoint reductions will occur (reasonable assurance). In addition, the TMDL should be developed to allow for adaptive management practices.

The sensitivity of the load capacity of the stream to the location of discharge(s) must be considered in the allocation determination for TMDLs, especially on non-conservative constituents. This can also be a problem with conservative substances. For large, multiple point source discharger allocations, frequent updating of the TMDL could result in excessive costs in labor and delays in permit issuance and other management actions. Updating of the TMDL will, therefore, ordinarily only be performed if more than fifteen percent (15%) of the load changes discharge location, or if there is more than a ten percent (10%) change in the total of the WLAs allocated to dischargers.

For conservative constituents, near-field analysis of mixing zones or zones of initial dilution may be required in addition to the overall TMDL calculation. Occasionally, a similar mixing analysis will be required for nonconservative constituents if the effect of multiple dischargers within a localized area is significant. Additional guidance on these topics is provided in the section dealing with toxic pollutant wasteload allocations.

In some cases, there may be many significant point sources in a watershed, some of which discharge to small ditches and canals too numerous to all be surveyed and modeled. In this case, the significant point sources which are not modeled are typically given the same allocations as similar modeled dischargers of the same size category in that watershed.

If significant reductions are to be applied to point source discharges, it may be most appropriate to include all facilities in the model. This may be done by clustering dischargers in close proximity, bringing the discharger(s) directly into the main waterbody and allowing some percentage of decay of the loading, extending uncalibrated model reaches to the discharger(s), or some combination of technically appropriate means of incorporating the dischargers into the model.

All TMDLs must address any MS4 (Municipal Separate Stormwater Sewer System) permits that exist within the watershed. Load allocations may be partitioned from the nonpoint loading, based on drainage area ratios.

3.2.1.2 Remote Sources

LDEQ develops nonconservative pollutant TMDLs which apply to all or a portion of a watershed. The model, which is the basis of that TMDL, is typically developed for the principle waterbody(ies) in that watershed, but not for all tributary and other waters in the watershed. In such a case, the model considers only direct loading to the principle waterbody such as headwater, tributary, and stream bank loading, direct point source loading, benthic loading, and resuspension of benthic biochemical oxygen demand (BOD). Representative numbers for stream bank loading and some tributaries can present a challenge. LDEQ has taken some samples of stream bank flow to provide guidance with respect to the water quality of this loading. Tributaries that are not flowing at the time of an intensive survey may not, under no-flow conditions, afford the opportunity to take a sample representative of that tributary when it is flowing. In this case, data from a flowing tributary in the same watershed may be used in lieu of the non-flowing tributary, if necessary. TMDL model projections are run at critical flow and temperature conditions as appropriate for the pollutant of concern. The modeling of BOD is typically done at critical low flow and summer season critical temperature.

Remote sources, whether point or nonpoint, are those sources which are too small and/or too distant from the principle waterbody to have a significant impact on it. Such sources may be located in the watershed of either perennial or intermittent tributaries. Considerable effort is made to determine whether point sources which do not discharge directly to a principle waterbody should be incorporated directly into a model by the modeling of a perennial tributary, modeling separately in an uncalibrated model, or determined to be too small and/or too distant to have a significant impact on a modeled waterbody. Where the potential for impact of remote point sources is uncertain, uncalibrated modeling may be conducted to determine if the point source impacts reach the principle waterbody and if load reductions are required. Intermittent tributaries, portions of which contain no water at times during the year, are not subject to critical low flow modeling.

Remote sources are not included in the model as a direct load. It is quite common, however, for benthic loading from these sources to accumulate in the tributaries and be periodically washed downstream into the principle waterbody by repeated rainfall events. Some unknown fraction of point and nonpoint nonconservative loading from these remote areas of the watershed is represented in the benthic and resuspended loading of the model of the principle waterbody and in the calculated TMDL. It is not possible to differentiate between the sources causing this benthic load. Remote sources are not otherwise accounted for in the model, and allocations are typically given to remote point sources in accordance with state or area permitting policy.

If the waterbody is highly impaired (as indicated by water quality data) and reductions to loading along the main waterbody do not significantly improve the pollutant levels or DO values, it may be necessary to include remote dischargers in the model. This can be done by methods described in Section 3.2.1.1. It may be helpful to evaluate the water quality data to determine the necessity of modeling remote dischargers. Higher concentrations of water quality parameters such as total organic carbon and/or ammonia may indicate areas where point source dischargers are having a greater impact.

3.2.2 Calculation of the TMDL

Stream models allow the development of nonconservative pollutant TMDLs only for those waterbodies that are modeled, not for the entire watershed of that waterbody. The total nonpoint loading from that portion of the watershed that is not modeled with a stream model can be estimated using watershed models such as SWAT, but is not estimated by the stream model. The total loading from remote point sources is likewise not included in stream models. The TMDL resulting from the model of a waterway includes only the loading directly to that waterbody; headwater, tributary, and stream bank loading, direct point source loading, benthic loading, and the resuspension of benthic BOD. However, point and nonpoint sources remote to the waterbodies which have been modeled often have some impact on the model as accumulated benthic loading. Since the TMDL will already include some unknown quantity of benthic and resuspension loading due to remote point and nonpoint sources, it may not be appropriate to add remote point sources to the wasteload allocations of a TMDL. Allocations for remote point sources should, however, be considered and developed as described in Section 3.2.1.2 and listed separately in the TMDL report.

It is recognized that TMDLs of watersheds in which benthic loading is not a significant factor can be handled differently. Crystal clear, rock bottom, mountain streams would be an extreme example. Louisiana streams with relatively high bed slopes and bed material consisting primarily of sand may exhibit these characteristics. Such streams may include Kisatchie Bayou, Pearl Creek, and Meridian Creek. The dominant source of loading to these streams is loading from the headwater and flowing tributaries, and the critical flow in these waters may be higher than the 7Q10 condition. Remote point and nonpoint loading is carried by headwater and tributary stream flow to the main stem on a continuing basis. Since nearly all of the point and nonpoint loading from the watershed is incorporated in the headwater and tributary flow, all point sources in the watershed can be a part of the main stem TMDL calculation if they are reduced to compensate for hydrolysis/oxidation in the tributaries. This is typically a function of the travel time and decay rate, both of which can, in this case, be estimated. This sort of reduction of point source loading is accommodated by some modeling programs for this reason, and allows allocations for remote point sources to be estimated by the model. Remote nonpoint loading that is included by calibration is also considerably reduced. The resulting TMDL is still not representative of the entire watershed, but does include more of the remote watershed loading.

3.3 Phased TMDL

When developed according to a phased approach, the TMDL can be used to establish load reductions where there is impairment due to nonpoint sources or where there is lack of data or adequate modeling. Lack of information about certain types of pollution problems (e.g., those associated with nonpoint sources or with certain toxic pollutants) will not be used as a reason for delay of implementation of water quality based controls (USEPA, 1991).

The phased approach TMDL will include a margin of safety (MOS) to account for modeling uncertainty, data inadequacies, and future growth and safety.

The phased TMDL will include a schedule for the implementation of control mechanisms, and attainment of standards. Since additional monitoring may also be required by the TMDL to support the assessment of standards attainment and possible TMDL revision, the phased TMDL may include a monitoring plan. This plan should include a description and assessment of existing data and the design of additional monitoring or special studies that will be required. The objectives of the monitoring plan may include:

* assessment of water quality standards attainment,
* verification of pollutant source allocations,
* model calibration or modification,
* measurement of stream discharge, dilution, and development of mass balances, and/or
* evaluation of effectiveness of point and nonpoint source controls.

The monitoring plan will include a provision for appropriate QA/QC. Data from discharge monitoring reports (DMRs) and data collected by other agencies and organizations should also be considered. A proposed schedule for data collection and evaluation must also be included in the plan.

The phased TMDL may also be used where there is clearly a need to reevaluate the existing water quality standards and establish standards more appropriate to the waterbody. Such a case may occur when load reductions (benthic loads included) greater than 80% are required to meet the existing standards. Reference stream data and/or no load modeling analyses may be used to support a phased TMDL. Both point and non-point anthropogenic loading must be considered in calculating the point source WLA and nonpoint source LA; the estimated non-point anthropogenic loading may be reduced by an amount consistent with the implementation of non-point BMPs for this calculation.

This procedure is intended to prevent delays in providing protective TMDLs for waterbodies where a lack of data prevents an immediate revision to the standards (e.g. Use Attainability Analysis (UAA)), and where the waterbody receives discharges from smaller point sources and may therefore not rank high in priority for scheduling of standards revisions. Following completion of approved standards revisions for a waterbody, recalculation of appropriate TMDLs and WLAs should be performed.

3.4 TMDLs and WLAs for Toxic Substances

TMDLs and WLAs for toxic substances and toxicity may be developed using one or more of three technical approaches:

- chemical specific,
- whole effluent toxicity, and
- biocriteria/bioassessment.

In each situation, selection of the approach for protecting water quality in the receiving water body is dependent on the specific environmental conditions and regulatory resources available. The chemical specific approach is likely to be most commonly applied. Whole effluent toxicity (WET) has become a common test used in NPDES permitting of certain facility types. Therefore WET may be useful, under certain circumstances, in the development of TMDLs for toxic substances. Application of the biocriteria/bioassessment approach is more difficult and currently less practical because methodologies are not fully developed and resources are not as readily available.

It is not always necessary to meet all water quality criteria within close proximity to a discharge pipe to protect the integrity of the water body as a whole. Sometimes it is appropriate to allow for ambient concentrations above the criteria in small areas near outfalls. These areas are called mixing zones. The Louisiana Water Quality Standards allow for the application of a mixing zone for aquatic life criteria; however, human health criteria must be met below the point of discharge after complete mixing. Within the immediate area of the discharge, a small zone of initial dilution (ZID) may be allowed where aquatic life criteria may be exceeded. Acute aquatic life criteria must be met outside the ZID but to the edge of the mixing zone; chronic criteria must be met at the edge of the mixing zone. See LAC 33:IX.1115.C for more details on application of mixing zones.

The requirement for no acute toxicity applies to concentrations calculated from dilutions of whole effluent acute toxicity units, to DO, and to other specific chemicals. It is generally assumed that for dissolved oxygen, a minimum level of 2 mg/L must be maintained to avoid acute toxicity (septic conditions). For other specific pollutants, values for protection of aquatic life from acute toxicity are published in the State standards.

Toxic pollutant criteria apply to streams according to their uses, to both chronic and acute protection of fish and wildlife, and to the protection of human health. The toxic pollutant criterion on which a limitation is based will be that applicable criterion which results in the most stringent limitation. The next subsection of this document clarifies application of the water quality standards to intermittent streams and man-made watercourses.

Criteria relating to chronic human exposure including carcinogenicity or to chronic exposure of aquatic life will apply outside the mixing zone. Critical stream flow for application of these chronic criteria will be as defined in the water quality standards (LDEQ, 2015), and in EPA guidance documents. The appropriate critical flow for carcinogenic pollutants is the harmonic mean flow as defined in the state water quality standards.

Special attention is required to assure that discharges of persistent and/or highly bioaccumulative toxic pollutants do not result in a loss of use or standards violation. The numerical criteria for these substances have been selected to be protective of the designated uses based on the potential of the waterbody to contain concentrations of pollutants. The potential is determined based on dischargers and landuse present within the watershed. Additional analysis and modeling may be required in cases of diffuse sources or multiple discharges to a waterbody.

3.5 Intermittent Streams and Man-made Watercourses

For intermittent streams, standards and designated uses are typically seasonal. These seasonal criteria should be adhered to when determining effluent limitations. Several intermittent streams in Louisiana have no designated uses during the dry season and may require that limits be based on the standards and dilution capacity of the next downstream perennial water body. However, the Louisiana Surface Water Quality Standards clearly state that in the event of a wastewater discharge to an intermittent stream, several criteria must be met:

1) The discharge will not by itself or in conjunction with other discharges cause the general criteria to be exceeded;
2) the discharge will not by itself or in conjunction with other discharges cause exceedance of the applicable numerical criteria in any perennial water body which receives water from the intermittent stream;
3) sanitary discharges will be disinfected to protect the public from health hazards that may result from inadvertent secondary contact; and

4) the discharge will not exceed the general criteria for toxic substances.

Therefore, even if there are no uses designated for an intermittent stream during the dry season, the effluent must be limited in such a manner that the criteria listed above are not violated. In many instances, these criteria will call for end-of-pipe effluent limitations, particularly in the cases where the only water in the streambed is wastewater during the dry season.

The criteria for man-made watercourses are similar to those listed for intermittent streams. In the event that a wastewater discharge is proposed for an approved and designated man-made watercourse, the following conditions must be met:

1. Same as above for wastewater discharge to intermittent streams;
2. the discharge will not by itself or in conjunction with other discharges cause exceedance of the applicable numerical criteria in any water body which receives water from the man-made watercourse;
3. the discharge will not by itself or in conjunction with other discharges cause exceedance of the numerical criteria for toxic substances.

Man-made watercourses have criteria and designated uses as specified in the numerical criteria tables. Any effluent limitations must be determined in consideration of the waterbody's criteria and uses.

3.6 Non-Chemical Factors

Although chemical contaminant based loads and load reductions form the major thrust of all past, as well as most future, TMDLs, the State and EPA recognize that, in some situations, water quality standards can only be attained if non-chemical factors such as hydrology, channel morphology, and habitat are addressed. In such cases it may be appropriate to use the TMDL process to establish control measures for quantifiable non-chemical parameters that are preventing the attainment of water quality standards. Control measures in this case would be developed and implemented to meet a TMDL that addresses these parameters in a manner similar to chemical loads (USEPA, 1991). The phased TMDL approach may be particularly appropriate for development of non-chemical factor TMDL requirements.

4 WATER QUALITY MODELING AND ANALYSIS

Water quality modeling is central to the development of TMDLs. This section describes the approaches to modeling used by LDEQ for projection of water quality under specific environmental and pollutant loading conditions. In all cases, the primary consideration that should be given in application of these models is that the model must provide a reasonable scientific basis and allow a confident and defensible water quality decision. LDEQ follows a 3 stage process in developing TMDLs. Stage 1 covers the data collection activities, Stage 2 covers the calibration modeling and Stage 3 covers the projection modeling which results in the TMDL. Data collection activities in the field are conducted under the protocols of an approved QAPP and are not discussed in this document. Other data may be gathered from recognized quality sources such as the USGS, USACE, other State agencies, EPA, or similar organizations.

4.1 Levels of Water Quality Analysis

Four levels of water quality analysis are recognized by LDEQ. This section describes each level of analysis and recommends when each is to be used. For dissolved oxygen, the model should represent DO at a depth of either 1 meter when the depth is greater than or equal to 2 meters or 1/2 the depth when the depth is less than 2 meters.

4.1.1 Level 1. Dilution Models

In these analyses a simple mass balance of ultimate biochemical oxygen demand (UBOD) is performed. Only upstream critical flow, critical stream dissolved oxygen content, and the discharge design flow and UBOD concentrations are required. This analysis conservatively assumes that all discharged oxygen demand is instantaneously realized. If the minimum receiving water DO remains above the standard under secondary treatment then no further analysis is necessary. UBOD may be calculated as:

$$UBOD = 1.5*BOD_5 + 4.3*NH_3\text{-}N.$$

A similar approach, assuming toxic contaminants are conservative, may be applied to toxic pollutant discharge evaluations and limitations.

4.1.2 Level 2. Uncalibrated Models

In these analyses an uncalibrated DO projection model is employed. This DO model will frequently be an analytical Streeter-Phelps model; however, any other DO model may be applied without calibration. This type of model is used in setting permit limits for dischargers according to the Table 1 and for pre-survey analyses. This model should account for stream reaeration, CBOD deoxygenation, NBOD deoxygenation and sediment oxygen demand (SOD). Model inputs should be based upon field observations of stream width, depth, and velocity. A time-of-travel study may also be required. No water quality data is required.

4.1.2.1 Minimum Data Uncalibrated Models

In these analyses the model is based on hydrologic data for one or more short reaches representative of the length of stream that is impacted by a discharge or discharges. The model is calibrated to hydrologic data in the referenced reaches, but no water quality calibration is performed.

4.1.2.2 Full Data Uncalibrated Models

In these analyses the model is based on hydrologic data for most of the length of stream that is impacted by a discharge or discharges. These models may be hydrologically calibrated but are not calibrated to water chemistry.

4.1.3 Level 3. Calibrated Models

In these analyses model hydraulic and kinetic rates are estimated from data collected during an intensive survey. A model is said to be calibrated if these hydraulic and kinetic rates cause the model to adequately reproduce the measured hydraulic and water quality data. Development of a calibrated model requires extensive measurement of water quality, stream geometry and hydrology on at least one occasion. Procedures for performing such a survey may be found in the LDEQ QA/QC document (QAPP #1018 – Quality Assurance Project Plan for the Development of Dissolved Oxygen and Nutrient Total Maximum Daily Loads).

4.1.4 Level 4. Calibrated and Verified Models

In these analyses data from two separate water quality surveys are required. One survey is used to calibrate the model as described in Level 3. The calibrated model is adjusted to account for changes in stream loads and temperature during the second survey and is then used to predict water quality observations during the second survey. Any additional model parameters that are altered during verification from their calibration settings should be documented and a detailed rationale provided for the appropriateness of such a variation. The model is considered verified when it adequately reproduces this second set of data.

4.1.5 Guide to Levels of Analysis

Table 1 should be used as a guide to the minimum level of modeling analysis to be performed for the given discharge scenario to develop a WLA. This table applies to sanitary dischargers and conventional (nonconservative) pollutants in small watersheds with few point sources and few tributaries. For medium to large sized watersheds and in cases where significant reductions in nonpoint source loading are required, calibration is recommended. Treatment levels in this table are specified as mg/l of $CBOD_5$ and NH_3-N. An uncalibrated model may be used in any situation in which the facility flow is less than 10% of the critical stream flow. For sanitary facility flows less than 0.5 MGD, WLAs may be assigned according to the "Statewide Sanitary Effluent Limitations Policy" and the need for a TMDL determined on a case-by-case basis. An uncalibrated model may always be used as a screening model to estimate the level of resources that may be required for the TMDL. An uncalibrated model may always be used to determine the initial phases of a phased TMDL.

4.1.6 Data Requirements by Level of Analysis

This section outlines the field and laboratory data necessary for each of the four levels of analysis described in Sections 4.1.1 through 4.1.4.

4.1.6.1. Level 1. Dilution Models (Secondary Treatment Only)

No water quality or depth and velocity data is required. Upstream critical flow may be estimated from local flow data or default values may be used. Upstream DO is assumed to be at or between the criteria and 90% of the saturation value at the 90th percentile temperature for the season. Secondary discharge UBOD is calculated as:

$$UBOD=1.5\ (BOD_5) + 4.3\ (NH_3\text{-}N)$$

All UBOD is assumed to be instantly satisfied upon mixing with the receiving stream.

4.1.6.2. Level 2. Uncalibrated Models

Receiving stream characteristics may be estimated from field observations. No water quality data are required. Upstream critical flow may be estimated from local flow data or default values may be used. Upstream DO is assumed to be at or between the criteria and 90% of the saturation value at the 90th percentile temperature for the season. Upstream CBOD and NBOD may be estimated from appropriate reference stream data.

Table 1 - Guide to Levels of Analysis for WLAs

OXYGEN-DEMANDING TREATMENT LEVEL	FACILITY FLOW IN MGD			
	< 2.0	2.0 - 5.0	5.0 - 10.0	> 10.0
SECONDARY	DILUTION OR UNCALIBRATED	DILUTION OR UNCALIBRATED	DILUTION OR UNCALIBRATED	DILUTION OR UNCALIBRATED
FACILITY FLOW < 10% OF THE CRITICAL STREAM FLOW	UNCALIBRATED	UNCALIBRATED	UNCALIBRATED	UNCALIBRATED
20/10	UNCALIBRATED	UNCALIBRATED	UNCALIBRATED	FULL DATA UNCALIBRATED
10/10	UNCALIBRATED	UNCALIBRATED	FULL DATA UNCALIBRATED	CALIBRATED
10/5	UNCALIBRATED	UNCALIBRATED	FULL DATA UNCALIBRATED	CALIBRATED
10/2	UNCALIBRATED	FULL DATA UNCALIBRATED	CALIBRATED	CALIBRATED
5/2	UNCALIBRATED	FULL DATA UNCALIBRATED	CALIBRATED	CALIBRATED

Distributed CBOD and NBOD loading resulting from natural background loads or from unidentified or nonpoint source loads may be determined through reference to appropriate background stations, stations used in calibrated models, or survey data from appropriate reference streams. The selection of appropriate reference stream should be based on comparable hydrologic, geologic, and water quality characteristics, when available.

Other model inputs should be determined as discussed in Section 4.3, Determining Model Inputs.

4.1.6.3. Levels 3 and 4. Calibrated and Calibrated/Verified Models

For a calibrated modeling analysis at least one intensive water quality and hydraulic survey is necessary. The water quality portion should minimally include BOD series, nitrogen series, total suspended solids, chlorides or conductivity, dissolved oxygen, pH and temperature. Other parameters, such as TDS, TSS, TOC, COD, color, and chlorophyll-a, may be required, as determined on a case-by-case basis, based on model requirements and State manpower and laboratory resource availability. The hydraulic portion should include the flow of headwaters, point sources, and tributaries and depth, width, flow, and time of travel measurements at numerous stream sampling stations. Additional data, such as stream dispersion, sediment oxygen demand, reaeration, and algal activity may be necessary according to system complexities identified in past work, reconnaissance surveys, and pre-survey uncalibrated modeling analyses.

For calibrated/verified models, two intensive surveys as described above are necessary. The requirement for a calibrated/verified model will be determined on a case-by-case basis considering model accuracy and applicability, manpower and field equipment availability, and laboratory availability.

4.1.7 Model Characteristics

Models can be categorized according to various characteristics. Four important categories (USEPA, 1991) which should be considered in model selection are:

- temporal characteristics,
- spatial characteristics,
- specific constituents and processes simulated, and
- transport processes.

4.2 LDEQ Water Quality Models

The selection of a water quality model depends on a number of factors. Some of these factors are listed in Section 3.1 where the study level of effort and model characteristics is discussed. A model should be selected based on its adequacy for the intended use, for the specific waterbody hydrology and dischargers, and for the critical conditions applied to that waterbody. Typical TMDL studies which primarily consider point source impacts in non-tidal streams may require little justification for model selection. Other situations will require more extensive justification of model selection based on study site characteristics, model characteristics, and study objectives.

In general, the least sophisticated model capable of addressing all relevant receiving stream characteristics should be selected. Less sophisticated models usually require fewer resources and less data, and in some cases, may produce more robust and defensible results. When available and appropriate, models supported by the USEPA Center for Exposure Assessment Modeling (CEAM) are preferred over other models of similar applicability.

This section briefly describes those models most often used for Louisiana waterbodies. Additional documentation for each model is available at LDEQ or from EPA. These are just a few of the many public domain models available from EPA and other agencies. If the model selected is not listed below, then justification of the model selection and complete model documentation must be formally submitted along with the required TMDL report.

4.2.1 LIMNOSS/XLIMNOSS

LIMNOSS is a version of the USEPA AUTO QUAL model. It is written in FORTRAN and is available on the LDEQ server at \\Deqshares\owreng\models\xlimnoss. XLIMNOSS is the personal computer version of LIMNOSS. LIMNOSS/XLIMNOSS considers only a single stream channel. Tributaries are not simulated but may be included as point source loads to the simulated channel. The simplicity of the LIMNOSS/XLIMNOSS input makes it desirable for unbranched systems. Analysis of branched systems may be accomplished by sequencing the model output from tributaries as point sources to separate downstream models. XLIMNOSS was developed by the state of Louisiana (Waldon, 1988) to allow use of reaeration equations that more closely fit Louisiana conditions.

4.2.2 LACOULEE

LACOULEE is a windows executable version of the USEPA AUTOQUAL model. It is written in FORTRAN and is available on the LDEQ servers at \\Deqshares\owreng\models\lacoulee and on LDEQ’s website. This model considers only a single stream channel. Tributaries are not simulated but may be included as point source loads to the simulated channel. The simplicity of the LACOULEE input makes it desirable for unbranched systems. This model allows for use of the Louisiana reaeration equations. The output can be generated in both graphical and report formats. Additionally, LACOULEE can generate the sensitivity analysis both in report form and graphical form.

4.2.3 QUAL-TX, QUAL2E, LA-QUAL

These models are modified versions of the U.S. EPA QUAL-II model. QUAL-TX was developed by the state of Texas for use in water quality modeling and management. QUAL2E is supported by the USEPA CEAM in Athens, Georgia. All programs are written in FORTRAN and are available on the LDEQ server (\\Deqshares\OWRENG\models). QUAL2E and QUAL-TX are distributed in an executable form for the IBM-PC, as well as in source code. QUAL-TX and QUAL2E are steady state one-dimensional models that allow for complex branching. QUAL-TX is capable of simulating tidally averaged flows. The QUAL-TX and QUAL2E inputs are more complex than LIMNOSS input, and are less easily implemented or modified. LA-QUAL was developed by the state of Louisiana to allow use of reaeration equations that more closely fit Louisiana conditions and provide a user-friendly interface and graphical output. LA-QUAL allows for complex branching and is capable of simulating tidally averaged flows. LA-QUAL was based on QUAL-TX.

4.2.4 Branch, LTM, and BLTM

These models were developed by the USGS. They have been implemented on the IBM PC/AT, and are currently available on the LDEQ server (\\Deqshares\OWRENG). Branch is a hydrodynamic model, that is, it simulates flow in branched streams. LTM, the Lagrangian Transport Model, is a simple dynamic model that simulates unidirectional flow, dispersion, transfer, and chemical transformations. BLTM, the Branched Lagrangian Transport Model, is a modification of the LTM that incorporates bi-directional flow and branching. These models are particularly appropriate for modeling streams on which dye transport studies have accompanied water quality studies. Because flows in many of the streams in Louisiana are too slow for accurate measurement, and are also frequently bi-directional, these models are especially appropriate for modeling a large fraction of the Louisiana streams.

4.2.5 Mixing Models

CORMIX 2.10 is currently the only model that may be generally accepted for modeling near-field zone of initial dilution (ZID) and mixing zone (MZ) dilution. CORMIX can be used to model surface discharges as well as single-port and multi-port diffusers. As other models in this CORMIX family are released by EPA, they may also be utilized. Since these models have had limited field testing, applicability to the proposed conditions must be demonstrated.

In special cases the jet model of Fischer may be used, but applicability of this model to the proposed conditions must be demonstrated. At a minimum, centerline velocity must be greater than 0.5 feet per second, the jet diameter must be less than the water depth, discharge depth must be such that impingement on the surface or bottom does not occur, and the effluent must not be significantly affected by positive or negative buoyancy.

4.2.6 Other Models

Use of a limited number of models greatly increases the efficiency of model application and review. However, the models listed above may not be adequate or appropriate for all situations. Selection of additional models will depend on the system to be simulated and on computer hardware and software availability. In order to facilitate review and future applications, only public domain models with extensive documentation and support should be considered. Examples of such models are RECEIV, WASP, BASINS, HSPF, PLUMES, and DEM.

4.2.7 Support Models

To assist in developing modeling input data sets from the field survey data, several support models are used. Several BOD spreadsheets are available for use in calculating the ultimate carbonaceous and nitrogenous BOD species (UCBOD and UNBOD, respectively) in the water column samples. The type of laboratory BOD analysis used dictates which spreadsheet to use. These models, written by Waldon (1989) and frequently updated by LDEQ, use laboratory time trace data to calculate first-order decay constants, lag times and ultimate values for CBOD, NBOD and total BOD. In addition, a spreadsheet named COMPREAR has been developed to compute the reaeration coefficient from various equations that have been applicable to Louisiana waterbodies in the past. The appropriate coefficient is selected based on the limiting values that apply to each equation and best professional judgment of the modeler. The Leopold equations given below are used to scale the velocity (U), width (W), and depth (H) of a free flowing stream from a lower value of flow (Q) to a higher value or from a higher value of Q to a lower value. Note that the exponents add to one and the coefficients multiply to 1. This is known as the rule of ones. This method is not appropriate for streams in which the depth and width are not dependent entirely upon flow (such as waterbodies where flow approaches zero, but contain some depth).

$U = aQ^b$ $\quad H = cQ^d$ $\quad W = eQ^f$

$b + d + f = 1$ $\quad (a)(c)(e) = 1$

The Leopold equations presume that the velocity, water surface width and average depth of a stream are zero at zero flow. Most Louisiana streams retain a significant width and depth at zero flow. The equations have therefore been modified to allow for positive width and depth values at zero flows. The Modified Leopold equations are:

$U = aQ^b$ $\quad H = cQ^d+g$ $\quad W = eQ^f+h$

Note that the "rule of ones" does not apply to the modified equations.

All spreadsheets are available at \\Deqshares\OWRENG\TMDL_Guidance\Modeling_Tools.

4.3 Determining Model Inputs

This section describes the methods to be used in estimating the common water quality model inputs. When implementing these methods, the resulting model inputs should be deemed reasonable compared to literature or Louisiana based values for similar receiving waters.

4.3.1. Reaeration Rates, K_2 (day^{-1} @ 20 degrees C, base e)

For both uncalibrated and calibrated models, the methods cited in Table 2 are acceptable for the specified stream conditions.

For a calibrated model, an appropriate reaeration formula should be identified. Preferably, a reaeration formula should be selected which provides results similar to values measured using gas tracers at or near critical conditions. Alternatively, when field measurements are unavailable, the reaeration formula selection should be based on modeling experience on similar streams, on the similarity to streams used in development and testing of the formula (Bowie, et al., 1985), on reference stream values for the stream category, and/or on calibration of DO values.

4.3.2. Carbonaceous Deoxygenation Rate, K_d (day^{-1} @ 20 degrees C, base e)

For an uncalibrated model, LDEQ has historically relied on the following literature values:

$K_d = 0.5$; Depth $H < 1$ foot

$K_d = 0.4$; $1 \leq H < 2$ feet

$K_d = 0.3$; $H \geq 2$ feet

An empirical analysis of 191 in-stream BOD samples using the 60-day BOD test method, shows that the following values may be used for Louisiana's ambient waters:

$K_{d,CBOD1} = 0.127$/day, average value with a standard deviation of 0.05

$K_{d,CBOD2} = 0.031$/day, average value with a standard deviation of 0.01

Table 2 - Reaeration Equations and Applicability

Author(s)	Equation K_2 =	Units	Applicability
Bennett & Rathbun (1972) **	$20.2\ U^{0.607} / H^{1.689}$	English	Based on a reanalysis of historical data.
Churchill et. al. (1962) **	$11.6\ U^{0.969} / H^{1.673}$	English	Based on observed reaeration rates below dams from which oxygen deficient water was released. $2' \leq H \leq 11'$; $1.8fps \leq U \leq 5$ fps
Isaacs & Gaudy (1968) **	$8.62\ U / H^{1.5}$	English	Developed using regression analyses from data collected using a recirculating cylindrical tank. $0.6fps \leq U \leq 1.6fps$; $0.5' \leq H \leq 1.5'$
Langbein & Durum (1967) **	$7.60\ U / H^{1.33}$	English	Based on synthesis of data from O'Connor-Dobbins (1958), Churchill et al. (1962), Kernkel and Orlob (1963), and Streeter et al. (1936).
Long (1984) **	$1.923\ U^{0.273} / H^{0.894}$	Metric	Known as the "Texas" Equation. Based on data collected on streams in Texas.
Negulescu & Rojanski (1969) **	$10.9\ (U / H)^{.85}$	English	Developed from a recirculating flume with depths less than 0.5 feet.
O'Connor & Dobbins (1958) **	$12.9\ U^{0.5} / H^{1.5}$	English	Moderately deep to deep channels; $1'<H<30'$, $0.5fps \leq U \leq 1.6fps$; $0.05 \leq K_2 \leq 12.2$/day.
Owens et. al. (1964) **	$23.3\ U^{0.73} / H^{1.75}$	English	This is a second formula developed by Owens et al., and applies for $0.1fps \leq U \leq 1.8fps$; $0.4' \leq H \leq 11'$
Padden & Gloyna (1971) **	$6.9\ U^{0.703} / H^{1.054}$	English	Regression analysis performed on data where $9.8 \leq K_2 \leq 28.8$/day.
Tsivoglou & Neal (1976)**	0.11 (Îh / t)	English	Based on data collected on 24 different streams using radioactive tracer method. Applies for $1cfs \leq Q \leq 10$ cfs
Tsivoglou & Neal (1976)**	0.054 (Îh / t)	English	Based on data collected on 24 different streams using radioactive tracer method. Applies for $25cfs \leq Q \leq 3000$ cfs
Tsivoglou & Neal (1976) (Derivation)	3600 * 24 * 0.11 US	English	Based on data collected on 24 different streams using radioactive tracer method. Applies for $1cfs \leq Q \leq 10$ cfs
Tsivoglou & Neal (1976) (Derivation)	3600 * 24 * 0.054 US	English	Based on data collected on 24 different streams using radioactive tracer method. Applies for $25cfs \leq Q \leq 3000$ cfs
Louisiana (1996) ***	2.18[(1+6.56U)/H]	English	Based on empirical data collected by the LA DEQ. $0.3'<H<3.0'$, $.02fps<U<0.8fps$
Maximum K2	25	English	EPA Policy in the absence of a measured value
Minimum K2	2.3/H	English	Louisiana Policy

U = The average velocity for the sampled reach, fps or mps
H = The average depth for the sampled reach, feet or meters
Metric Conversion = fps or feet multiplied by .3048 to convert to mps and meters.
K_2 units are day $^{-1}$, at 20 degrees Celsius, base e
Îh / t = drop in water surface elevation, feet / time of travel, days
S = slope

** Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition), June 1985, EPA/600/3-85/040. Table 3-6 on pages 103-106.

*** Reaeration in Shallow, Low-Flow Louisiana Stream Reaches - Verification of the Louisiana Equation, Michael G. Waldon, March 27, 1996. Equation 2, Page 1.

Where available, "bottle" decay rates may also be used in uncalibrated analyses.

For a calibrated model, K_d will be obtained by matching calculated stream UCBOD profiles to observed profiles. General agreement with "bottle" decay rates may also be used as a guide for decay rate estimation prior to calibration.

4.3.3. CBOD Settling, K_s (day^{-1}, base e)

For uncalibrated models:

K_s = 0.1 for Secondary Treatment

K_s = 0.08 for 20/10 ($CBOD_5$/NH_3-N)

K_s = 0.05 for 10/10 and lower, and for ambient waters unimpacted by point source discharges

4.3.4. Nitrogenous Deoxygenation Rate, K_n (day^{-1} @ 20 degrees C, base e)

For an uncalibrated model, LDEQ has historically relied on the following literature values:

K_n = 0.4; Depth H < 1 foot

K_n = 0.2; $1 \leq H < 2$ foot

K_n = 0.1; $H \geq 2$ foot

An empirical analysis of 191 in-stream BOD samples using the 60-day BOD test method, shows that the following values may be used for Louisiana's ambient waters:

$K_{d,NBOD}$ = 0.10/day, with a standard deviation of 0.07

Suggested methods for estimating UNBOD are:

UNBOD = 4.3* NH_3-N (or TKN) (formula is based on ambient conditions, but may underestimate the UNBOD)

UNBOD = UBOD – UCBOD

For a calibrated model, K_n will be obtained by matching calculated stream UNBOD profiles to observed profiles, general agreement with "bottle" decay rates may also be used as a guide for decay rate estimation prior to calibration.

4.3.5. Sediment Oxygen Demand, SOD (gm/m^2/day @ 20 degrees C, base)

For uncalibrated models:

SOD = 2 for secondary - oxidation ponds or high TSS
1.5 for secondary - otherwise

SOD = 1.0 for 20 $CBOD_5$

SOD = 0.5 for 10 $CBOD_5$

For calibrated models, SOD may be determined by measurement or calibration, and may be reduced as listed above for TMDL projections.

4.3.6. Algal Photosynthesis and Respiration

For uncalibrated models, algal photosynthesis and respiration are assumed to be zero.

For calibrated models, algal photosynthesis and respiration will be estimated through calibration or special field studies. If algal effects are significant, then special algal field studies should be performed.

LDEQ documentation for modeling wide dissolved oxygen variations due to the influence of algae with a steady-state model (LA-QUAL) can be found at \\Deqshares\owreng\TMDL_Guidance\Part_3-model\Laqual_Model_Guidance.

4.3.7. Dissolved Oxygen

DO saturation will be in agreement with Standard Methods (Clesceri, et al., applicable edition) for both calibrated and uncalibrated models.

4.3.8. Temperature Correction of Kinetics

These corrections should be applied in both calibrated and uncalibrated analyses.

$K_2(T) = K_2(20)(1.024)^{(T-20)}$ Reaeration

(Except in cases where a temperature dependent temperature correction for the reaeration rate is used, as in LAQUAL)

$K_d(T) = K_d(20)(1.047)^{(T-20)}$ CBOD Decay

$K_n(T) = K_n(20)(1.02)^{(T-20)}$ NBOD Decay

$$SOD(T) = SOD(20)(1.065)^{(T-20)} \qquad \text{SOD}$$

4.3.9. Stream Flow Balance

For calibrated analyses and, where available, for uncalibrated analyses, stream flows will be measured and model flows will be balanced to approximate observed flow data. A mass balance on some conservative substances, such as chlorides or conductivity, should also be performed when possible.

4.3.10. Dispersion

For uncalibrated models, literature values of dispersion can be used if the value chosen does not dominate model calculations. Otherwise, model dispersions should be measured or based upon a measurement of dispersion on a similar Louisiana receiving stream.

For calibrated models, dispersion should be measured or calibrated to a conservative substance.

4.4 Model Calibrations

Model calibrations provide a platform for all subsequent projection modeling. The closer the calibration, the more confidence may be placed on the projections.
All of the measured and gathered data is organized into one or more useable forms from which the input data required by the model can be obtained or derived. Water quality samples, field measurements, and historical data must be analyzed and evaluated in order to determine a set of conditions which have actually been measured in the watershed. The findings are then input to the model. Best professional judgment is used to determine initial estimates for parameters which were not or could not be measured in the field.

These estimated variables are adjusted in sequential runs of the model until the model reproduces the field conditions which were measured. In other words, the model produces a value of dissolved oxygen, temperature, or other parameter which matches the measured value within an acceptable margin of error at the locations along the stream where the measurements were actually made. When this happens, the model is said to be calibrated to the actual stream conditions. At this point, the model should confirm whether or not there is an impairment and give some indications of the causes of the impairment. If a second set of measurements is available for slightly different conditions, the calibrated model is run with these conditions to see of the calibration holds for both sets of data. When this happens, the model is said to be verified, as discussed in Section 4.1.4.

4.4.1 Hydrologic Calibration

The model is considered hydrologically calibrated when the curves generated by the model for widths, depths, flows, velocities, and/or concentrations of one or more conservative constituents reproduce the measured values within an acceptable margin of error. In general, the flows are balanced (incoming = outgoing), and form the basis for the remaining parameters. The Leopold coefficients (typically modified for Louisiana streams) are varied in order to calibrate the widths and depths. One or more conservative parameters (Chlorides, Sulfates, Conductivity, etc), are then evaluated for calibration. LDEQ's practice is to calibrate to at least 2 conservatives, with one being the conductivity measured with the continuous monitors. This may involve adjusting incremental and nonpoint sources, preparing conservative constituent mass balances, or preparing anion-cation balances. For projects with insufficient flow data, the conservatives can be used to determine unknown flows.

In slow-moving Louisiana waters, flow is sometimes below the minimum detection capability of the measuring instrument but the waterbody may have significant width and depth, as discussed previously in Section 4.2.7. In that case, constant widths and depths may be used for a range of low flows and the model is unlikely to be very sensitive to these parameters. The model will usually reproduce the flow, width and depth as a matter of course if this option is selected. The key parameters for determining calibration will then be the conservative constituents and the time-of-travel (TOT). It is critical to the successful calibration of all remaining parameters that the hydrologic calibration be as close as possible.

4.4.2 Water Quality Calibration

Water quality calibration refers to the calibration of all remaining constituents being modeled except Dissolved Oxygen and Sediment Oxygen Demand. The typical parameters used to achieve the calibration are incremental, nonpoint source, and point source loads. Dispersion, algae and macrophyte growth may also be part of the calibration dynamics. Literature values are available as a starting point for many unmeasured values. LDEQ has published a considerable body of work on various aspects of Louisiana waters and there are numerous publications by USGS, EPA and other state and federal agencies that may be used to assist in the calibration process.

LDEQ has a rigorous data evaluation process which is described in the QAPP for Development of DO and Nutrient TMDLs. As a general rule, measured values which are validated under this process are not disregarded. However if some data seems unreasonable and calibration cannot be achieved with the use of reasonable values for parameters such as flow,dispersion, loading, or decay rates, some data may need to be adjusted. This includes laboratory values of decay rates which are derived from the measurements. Decay rates derived from the 60 day BOD test results have proved very reliable and stable compared to previous BOD test methods.

Again, the successful calibration of the water quality parameters is crucial to the successful calibration of the remaining parameters.

4.4.3 Dissolved Oxygen Calibration

Once the model is calibrated to both hydrology and water quality, it is then calibrated to Dissolved Oxygen. The typical calibration parameter used is SOD. If SOD is measured, then an attempt would be made to calibrate to both. Louisiana's reference stream work may provide a starting point for the SOD values to be initially used. Again, dispersion, algae and macrophyte growth may also be part of the calibration dynamics. Sometimes it is necessary to recalibrate the water quality parameters or select a more appropriate reaeration equation during the process of calibrating to DO. When the hydrology, water quality and DO are all satisfactorily calibrated, then the model is considered appropriate for use in the TMDL projection modeling.

4.5 Model Projections

Model projections form the basis of the TMDL, WLA, and LA determinations. The critical conditions of flow and temperature are determined for the waterbody. Then the existing or proposed pollutant discharge limits from the point sources (including flows) are determined; these limits may be adjusted to more or less stringent values during the projection modeling process. These conditions and limits are then substituted into the calibrated model along with any related condition changes which are required to perform worst case scenario predictions. The projection models are then used to analyze the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) at various levels and distributions until the model output shows that dissolved oxygen criteria are achieved, if possible. LDEQ's practice is to evaluate critical summer and winter conditions and, as needed, various no load scenarios. Loads should be adjusted incrementally. Unless modeling and/or data indicates that only a portion of the dischargers are dominating the waterbody, loads should be reduced equitably. Projections should be run at various reduction levels until criteria are met to ensure that the reductions recommended in the TMDL are accurate. LDEQ's spreadsheets titled "Calc point source reductions" and "Combined TMDL Loading Spreadsheet(01-31-2011)" may be used to assist in determining point source reductions. It should be noted that the spreadsheet titled "Calc point source reductions" treats all facilities as if they are currently permitted at limits of 30 mg/L for $CBOD_5$ and 15 mg/L for NH_3. Therefore, this spreadsheet may not be appropriate for all situations.

At the end of the projection modeling, a TMDL is produced which shows the point source permit limits (load allocations), and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the NPS pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams.

On occasion, no amount of reduction of the man-made load will lead to the attainment of established criteria. In these cases, various no load and achievable load reduction scenarios may be evaluated to identify potentially valid water quality criteria for the waterbody. Such projections may be used to recommend that a UAA be conducted to establish appropriate uses and/or criteria.

4.5.1 Critical Conditions, Treatment Options, and Sensitivity

This section outlines model inputs and critical conditions to be used in performing model projections. Treatment level alternatives to be analyzed are also specified as are those model inputs to be included in a model sensitivity analysis.

Critical conditions are also referred to in EPA guidance as design conditions, but are generally referred to in this document as critical flow and temperature to avoid confusion with treatment facility design flows. These conditions are the reasonable "worst case" conditions for the waterbody. The following sections provide the definitions that will typically be used for critical conditions. In general point sources with continuous discharges present the greatest impact on the waterbody during low-flow (drought) and high-temperature conditions. Under some conditions, such as flow-related discharges (hydrographically controlled limitations), or waterbodies heavily impacted by nonpoint source pollutants, more appropriate critical conditions may be selected, and must be technically justified in the TMDL report. Critical conditions for toxic pollutants are discussed in Section 3.4.

4.5.1.1. Summer Season Critical Conditions

1. Background flow = Non-tidal Streams: 7Q10 or 0.1 cfs (0.0028 cms), whichever is greater;

   Tidal Streams: 1/3 of the average or typical flow averaged over one tidal cycle irrespective of flow direction

2. Stream Temperature = 30 ^{o}C for summer months (typically May - Oct) or, when appropriate data are available, the 90th percentile daily water temperature for the months of interest.

Note that in nearly every situation appropriate data are available and should be utilized for determination of critical stream temperatures.

In the absence of a 7Q10 value, it is preferable to use 0.1 cfs for the summer critical flow. However, for some cases it may be appropriate to use the flow measured during the survey instead of 0.1 cfs, particularly if the survey was conducted during summer critical conditions and the measured flow was significantly less than 0.1 cfs. Flow data (7Q10 values) from a waterbody with hydrology and flow characteristics similar to the waterbody being modeled may also be used to estimate a 7Q10 for the modeled waterbody.

The use of incremental flow in summer and winter projection models may be appropriate if the waterbody was surveyed during the summer critical conditions and incremental flow was required to achieve a hydrologic calibration.

4.5.1.2. Winter Season Critical Conditions

1. Background flow =	Non-tidal Streams: 7Q10 or 1 cfs (0.028 cms), whichever is greater; Tidal Streams: 1/3 of the average or typical flow averaged over one tidal cycle irrespective of flow direction
2. Stream Temperature =	20 ^{o}C for winter months (typically Nov - Apr) or, when appropriate data are available, the 90th percentile daily water temperature for the months of interest.

4.5.1.3. Dissolved Oxygen

For model projections a headwater dissolved oxygen concentration of up to 90 percent of dissolved oxygen saturation at the 90th percentile seasonal temperature will be allowed. In the projections, the loading to the stream is reduced until the model projects that criteria will be met. Any recommended BMPs resulting from the TMDL may be implemented throughout the subsegment to achieve this reduced loading. Under these conditions, the headwater dissolved oxygen will improve along with the dissolved oxygen in downstream reaches. In almost all cases, therefore, if the model projects a dissolved oxygen levels that meet the criteria immediately downstream of the headwater, the headwater dissolved oxygen cannot be lower than the criteria. Therefore the fixed headwater boundary condition is typically set at a value at least as high as the criteria for model projections.

In accordance with USEPA guidance for Ambient Water Quality Criteria for Dissolved Oxygen, EPA Document 440/5-86-001, a TMDL can be used to establish load reductions where there is a clear indication that the dissolved oxygen criteria cannot be met under natural background conditions. From Page 35 of the above referenced document, “Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both, the minimum acceptable concentration is 90 percent of the natural concentration.” A TMDL can therefore be established in which the dissolved oxygen concentration is projected to meet at least 90 percent of the dissolved oxygen concentration resulting from the elimination of all man-made (anthropogenic) point and nonpoint source loading from the model. Reference stream data and no load modeling analyses may be used to support such a TMDL. A 10% allowance is very restrictive of man-made point and nonpoint source loading.

When reductions in loading are made to meet dissolved oxygen criteria, nonpoint loading will not be reduced below natural background. The procedure described in the paragraph above may be used, or projections may be run to meet several alternative dissolved oxygen targets.

When projecting to meet existing dissolved oxygen criteria, the criteria will be considered to be met if the projection dips below criteria by no more than 0.2 mg/l. Documentation regarding this practice can be found at \\Deqshares\owreng\TMDL_Guidance\DO 2 tenths rule.

4.5.1.4. UCBOD to $CBOD_5$ Ratio

UCBOD to $CBOD_5$ ratio = 2.3 for all facility treatment levels (Note: A ratio of 1.5 was allowed in the UBOD calculation for the dilution method because the method is confined to secondary treatment and 1.5 is a representative number for that level of treatment using the dilution method.)

LDEQ recognizes that using this estimating technique will probably overestimate the carbonaceous load from secondary treated loads and underestimate that from highly advanced treated loads.

4.5.1.5. Projections for Critical Stream Geometry and Hydrology

Projection of stream width and depth at critical flow will usually be made with the Leopold equations. Geometry projections may also be based on Manning's formula, or an exponential formula for stream discharge (Bowie, et al., 1985). It is preferable to estimate parameter and coefficient values from discharge and dye studies on the modeled stream. If these data are not available, literature values, or parameters from similar streams may be used. In either case, stream studies should be conducted as close to critical flow as possible to minimize hydrological projection errors.

4.5.1.6. Model Projection Kinetic Rates

1. K_d, K_n from calibration or default values

2. K_2 should reflect critical flow stream hydraulics

3. SOD and CBOD settling rates should reflect decreases in settleable CBOD with increased treatment.

4. Model projection algal activity should reflect observed activity unless some technical basis exists justifying a change. A large improvement in treatment plant effluent may affect algal activity.

4.5.1.7. Treatment Alternative Projections

Model projections of sanitary wastewater treatment facilities will generally be made and reported for the appropriate target levels of treatment as per the following protocol:

30 : 15 mg/l	($CBOD_5$: NBOD/4.3 or Org-N + NH_3-N)	Secondary treatment
20 : 10 mg/l	($CBOD_5$: NBOD/4.3 or Org-N + NH_3-N)	Advanced secondary treatment
10 : 10 mg/l	$CBOD_5$: NBOD/4.3 or Org-N + NH_3-N)	Advanced treatment
10 : 5 mg/l	($CBOD_5$: NBOD/4.3 or Org-N + NH_3-N)	Advanced treatment
10 : 2 mg/l	($CBOD_5$: NBOD/4.3 or Org-N + NH_3-N)	Advanced treatment
5 : 2 mg/l	($CBOD_5$: NBOD/4.3 or Org-N + NH_3-N)	Advanced treatment
5 – 6 mg/l	Dissolved oxygen	Post Aeration
No discharge		

If organic nitrogen and ammonia are modeled, the nitrogenous load will be proportioned between these parameters in accordance with data for the facility in question. If such data is not available, it will be assumed that the nitrogenous load is 1/3 ammonia for pond and lagoon systems and 2/3 ammonia for mechanical plants. The TMDL report will list the required treatment levels as though ammonia comprised all of the nitrogenous oxygen-demanding load.

Effluent DO of 2 mg/L will typically be assumed for secondary treatment, and 5 and/or 6 mg/L will be considered for more advanced treatment. In some cases, it may be necessary to evaluate all of the above levels to determine the minimum level that will support water quality criteria. Occasionally, plant specific levels of each constituent may be analyzed based on operating history. Certain alternative treatment systems such as rock-reed filters, artificial marshes and constructed wetlands, among others, are known to consistently produce effluents that are not represented by the above standard levels. Actual production numbers from similar facilities should be used in these cases.

4.5.2. Sensitivities

A sensitivity analysis should be performed on all calibrated wasteload allocation models. The analysis should be performed for the calibration and may be performed for the projection at the recommended treatment alternative. Sensitivity analyses should, at a minimum, include testing of K_2, K_d, K_n, benthic loading, algal activity, dispersion, stream depth, width, headwater flow, and background temperature. Each test parameter should be raised and lowered so as to cause a significant change in projection results. Each parameter should be varied by the same percentage (typically 30%) above and below the reference value. An exception is temperature, which should be varied by 2 degrees C above and below the reference value. Model temperature correction factors, particularly for nitrification, are not considered to be adequate for model projections above 32 degrees C.

4.5.3 Facility Flow

The flow of a treatment facility will be based on the Louisiana Water Quality Management Plan, permit application or permit, or an estimate of flow based on population serviced. The estimation of sanitary wastewater flow based on population serviced will be determined according to the "Sewage Loading Guidelines" developed by the Louisiana Department of Health and Hospitals (formerly Department of Health and Human Resources, LDHHR, latest edition). This document can be found at \\Deqshares\owreng\TMDL_Guidance\LA Sanitary Code. For single family residences, a population of 4 persons per residence may be used. A flow of 100 gallons per person per day may then be used to estimate anticipated flow. Other sanitary sources such as schools, restaurants, trailer parks, apartment buildings, hospitals, and multiple family dwellings are provided with applicable flow values in the Guidelines.

For industrial wastewater, the Louisiana Water Quality Management Plan, information from the permit application, or the maximum 30-day average flow for the last two years may be used as the flow.

4.5.4 Criteria for Outstanding Natural Resource Waters

Additional consideration must be provided if the waterbodies under study are classified as Outstanding Natural Resource Waters, or are tributary to an Outstanding Natural Resource Water (ONRW). In this case, in addition to the numerical criteria, State Water Quality Standards require that "no degradation" of water quality occur in the segment designated as ONRW because of the projected discharge from facilities that were not in existence prior to the ONRW designation of the waterbody. In this case, the more stringent water quality criterion, antidegradation or the numerical criterion should be applied for water quality planning.

For the purpose of WLA dissolved oxygen projections, "no degradation" will require that the concentration of dissolved oxygen must not be reduced by more than a statistically significant difference at the 90% confidence interval. In practice, this interval is difficult to estimate, and resource, time, and data requirements for such determinations would be generally prohibitive. Therefore, an acceptable alternative criterion allows a reduction of no more than 0.2 mg/L relative to the conditions existing at the time of designation of the ONRW to be consistent with the TMDL protocol (Sec. 4.5.1.3). In any case, the "no degradation" requirement will be applied or modeled under critical stream conditions.

Where a discharge enters a tributary to an ONRW, and the tributary has not been classified as ONRW, the tributary is treated as any other stream. Additionally, however, the "no degradation" criterion must be satisfied within ONRW.

4.5.5 Hydrograph-Controlled TMDLs

In some situations the development of a hydrograph-controlled TMDL may be appropriate. In these cases the TMDL is determined as a function of stream discharge. The hydrograph-controlled TMDL may be appropriate where stream discharge is highly variable, a zero discharge or extremely stringent limitation would result from a critical flow based TMDL, effluent storage is feasible and economical, and resources are available for the complex modeling development required to support such a study. As in other cases, an appropriate MOS is required for hydrograph-controlled TMDLs.

4.6 Other Analytical Approaches

There are several types of water bodies for which steady-state, one-dimensional dissolved oxygen water quality models are not generally reliable predictive tools. Swamps, wetlands, and some lakes fall into this category. For these waterbodies alternative methods for determining TMDLs should be used. Initially, however, a reconnaissance survey should be performed to support the determination of whether or not a model is appropriate, applicable, and available.

4.6.1 Lakes and Impoundments

Dissolved oxygen, nutrient enrichment and eutrophication of lakes present particular difficulties in analysis. Except in rare circumstances, large computerized, ecological models of lakes are not recommended for nutrient TMDLs. Large data requirements, lack of scientific consensus, as well as professional resource requirements makes these models impractical for most applications. From the standpoint of dissolved oxygen, if there are data which show that under current conditions water quality standards are being met and there are no nuisance problems associated with the discharger, then current effluent limitations should be adequate. For some impoundments of streams and bayous (sometimes referred to as run of the river lakes or stretch lakes), standard stream models may provide an adequate and appropriate management model. In this case dispersion and photosynthesis should be taken into account.

For nutrient loading in lakes, nutrient budget models may be used to determine if nutrient reductions should be considered, and the degree of reduction required. If nutrient loading is determined to be a problem, reduction of point source loading should be considered. The relative magnitude of nonpoint sources and their abatement possibilities should also be considered. Relocation of discharges or diffusers may be recommended to eliminate some localized or nuisance problems in lakes.

4.6.2 Swamps and Wetlands

Swamps and wetlands present another situation in which presently available, complex, computer models may not be appropriate for water quality management decisions. In some situations uses may be enhanced through such discharges, while in other cases, uses may be degraded or completely lost because of wastewater discharges to these water bodies.

For current dischargers to swamps and wetlands, the current impact can be evaluated in terms of its impact on uses, and the physical, chemical, and biological impact. A comparison should be made between upstream and downstream sites. For those waterbodies not sufficiently defined by a channel, sites near the discharge may be compared to control or reference sites that are not as heavily impacted. Where the discharger is having a detrimental impact in terms of water quality standards and/or reduced quality and diversity of species, reduced effluent limitations should be imposed, or an alternative treatment system and effluent discharge system may be considered. Swamps and wetlands may be able to receive and assimilate the wastewater with proper diffusion of the effluent.

If upstream or control site data for swamps and wetlands show contravention of standards then the standards should also be reviewed. To prevent delays, the TMDL should concurrently be developed, and if necessary, the phased TMDL procedures applied. Comparisons to existing discharges can be utilized to estimate the impact of a proposed discharge.

4.6.3 Bacterial Related TMDLs

At present it is assumed that bacterial limitations or disinfection are necessary to protect human health uses for all significant sanitary dischargers. Currently, bacteria related TMDLs are typically developed using the load duration curve methodology. Future experience, modeling developments, and EPA guidance may demonstrate the need for additional routine controls and TMDL procedures. These new procedures may include the use of modeling or alternative statistical analysis.

4.7 Outline for TMDL Reports

The following outline will result in a report that is self-supporting and capable of being a useful reference for persons not directly involved in its development. The appendix containing model input and output will allow analysts to duplicate the work in later years. Depending on the level of effort, some portions of the outline may not be applicable (e.g., verification). In addition, some of the topics on the outline may be addressed in a table or by a few statements. If an associated survey report is developed prior to or in conjunction with the TMDL report, duplicated information may be summarized with appropriate citations made to the survey report. A standardized procedure for determining the title of reports will be used for all TMDL reports as shown on the following pages.

Title Format:

?WATERBODY? WATERSHED TMDL FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES

Subsegment ??????

SURVEYED ?DATE?

TMDL REPORT

Report Outline:

TECHNICAL SUMMARY
EXECUTIVE SUMMARY
Table of Contents
LIST OF TABLES
LIST OF FIGURES

1. Definitions/Acronyms/Abbreviations
2. Introduction
3. Study Area Description
    - 3.1 General Information
    - 3.2 Water Quality Standards
    - 3.3 Wastewater Discharges
    - 3.4 Water Quality Conditions/Assessment
    - 3.5 Prior Studies
4. General TMDL Development Process
5. Calibration Model Documentation
    - 5.1 Program Description
    - 5.2 Input Data documentation
    - 5.3 Model Discussion and Results
6. Water Quality Projections
    - 6.1 Critical Conditions, Seasonality and Margin of Safety
    - 6.2 Input Data Documentation
    - 6.3 Model Discussion and Results
    - 6.4 Calculated TMDL, WLAs and LAs
7. Sensitivity Analysis
8. Conclusions
9. References
10. Appendices

APPENDIX A - Detailed TMDL Analyses
APPENDIX B - Calibration Model Input and Output Data Sets
APPENDIX C - Calibration Model Development
APPENDIX D - Projection Model Input and Output Data Sets
APPENDIX E - Projection Model Development
APPENDIX F - Survey Data Measurements and Analysis Results
APPENDIX G - Historical and Ambient Data
APPENDIX H - Maps and Diagrams
APPENDIX I - Sensitivity Analysis
APPENDIX J - Additional Projection Scenarios and Associated TMDLs
APPENDIX K - Public Comments and Response to Comments

It is recommended that a separate table – separate from the inventory of all dischargers in the subsegment, the table of model input parameters, etc. – be used to list proposed allocations. This will prevent confusion as to what is an allocation and what is a model input or data for information purposes.

Frequently, dischargers in the subsegment are not in the watershed of the modeled waterbody, these will be noted on the Discharger Inventory. Some dischargers in the modeled watershed by reason of size, distance from the modeled waterbody, or other circumstances, are not included in the model. Such dischargers will either be given state or area policy allocations, or will be given allocations typical of the modeled dischargers of the same size category.

Unmodeled sources have a residual effect that is captured in the TMDL model as part of the boundary conditions at the headwaters and unmodeled tributaries and in the benthic loads. Allocations in the form of suggested permit limits for unmodeled point sources and TMDL WLAs for modeled point sources are listed in the report for all known point sources in the modeled watershed.

4.8 Public Participation

As required by the CWA, LDEQ will make all TMDL reports available for public review and comment for a minimum of 30 days. In addition, LDEQ may notify all permitted facilities and municipalities that may be impacted by each TMDL report via a facility notification letter or index card.

4.9 Approval of TMDLs

In accordance with the requirements of the CWA, EPA VI will review and approve or disapprove TMDLs submitted by the State. In consultation with the State, and within the resource constraints of the State, and within State priorities, disapproved submittals will be revised, if appropriate, and resubmitted for reconsideration by the USEPA. All approved TMDLs will be incorporated into the Louisiana Water Quality Management Plan through the procedures listed in the CPP.

5 PLANNING

LDEQ procedures for surface water quality monitoring, assessment and analysis are described in Quality Assurance Project Plans (QAPPs) prepared by the LDEQ. These documents provide descriptions of project plan development, reconnaissance and intensive survey planning, survey reporting, and laboratory QA/QC procedures. TMDLs and related work performed by the LDEQ will be governed by these procedures. TMDLs and related work performed by others will be governed by project specific QAPPs submitted to, reviewed and approved by LDEQ and/or EPA (in-house QAPPs do not require EPA approval).

6 REFERENCES AND BIBLIOGRAPHY

Listed here are several documents and guidance manuals that are of special relevance to the TMDL process. The latest version should normally be used. This list is not all inclusive and in no way limits the usage of other suitable references. A review of EPA guidance documents related to the TMDL process is provided in Appendix A of the EPA's "Guidance for Water Quality Based Decisions: The TMDL Process," (USEPA, 1991).

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