Florida Numeric Nutrient Criteria

History and Status

Background

In recognition of the need to more proactively address impairment of State waters due to nutrients, the Department of Environmental Protection (DEP) implemented a detailed, EPA-approved plan for the development of numeric nutrient criteria and recently proposed revisions to Chapter 62-302, FAC (Water Quality Standards) and Chapter 62-303, FAC (Impaired Waters Rule) to establish numeric nutrient criteria for lakes and streams. DEP selected the "dose-response" approach (investigating the effects of nutrients on biological communities) as the primary method for the development of scientifically defensible numeric nutrient criteria, and has invested significant resources in:

- the development of biological assessment tools;
- the documentation of minimally disturbed reference conditions;
- the collection of large amounts of water quality and nutrient data; and
- conducting a variety of studies to link nutrients to adverse effects on valued ecological attributes.

This process has required extensive methods development, staff training, and QA oversight to ensure the defensibility of the resulting products. The elements of this development and assessment process to date include such components as habitat assessment for streams and lakes, benthic invertebrate indices for streams and lakes, a vegetation index for lakes, and a periphyton index for streams. These activities represent significant investments in staff time and contractual services, with recent and planned funding associated with nutrient criteria development in Florida totaling nearly $20 million (Table 1). Extensive documentation of nutrient criteria study results, including statistical analyses and interpretation, are found at: http://www.dep.state.fl.us/water/wqssp/nutrients/

While the approved plan called for adoption of the criteria by the end of 2010, DEP accelerated its efforts to adopt numeric nutrient criteria in response to the Environmental Protection Agency's (EPA) January 14, 2009 determination that numeric nutrient water quality criteria are necessary in Florida to implement the Clean Water Act. The determination letter established a schedule for criteria development, with criteria for lakes and streams due by January 14, 2010, and criteria for estuaries due by January 14, 2011. A part of a recent settlement agreement with Earth Justice, EPA is obligated to promulgate numeric nutrient criteria for Florida streams and lakes by October 15, 2010, unless EPA approves DEP's proposed criteria prior to that date.

Table 1. Funding associated with nutrient criteria development in Florida.

Project or Activity	Cost to Date
Stream Condition Index/BioRecon Development	$3,737,500
Lake Vegetation Index Development	$358,750
Lake Condition Index Development	$1,180,000
Stream Periphyton Index Development	$1,020,000
Biocriteria Meetings and QA Activities	$530,400
Stressor Identification Study	$374,500
Nutrient Gradient Study	$132,675
Stream Benchmark Site Determination	$91,350
Longitudinal Study	$38,400
Springs Nitrate Studies	$384,000
Staff Technical Analysis and Coordination Time	$292,000
Statistical Consultants	$175,000
Nutrient Criteria Meeting Travel	$33,200
Everglades TP Criterion Development	$11,250,000
Total Numeric Nutrient Criteria Development	**$19,597,775**

Implementation of the Narrative Nutrient Criteria

Florida currently uses a narrative nutrient standard to guide the management and protection of its waters. Rule 62-302.530, FAC, states that “in no case shall nutrient concentrations of body of water be altered so as to cause an imbalance in natural populations of flora or fauna.” The narrative criteria also states that (for all waters of the state) "the discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter [Chapter 62-302, FAC]. Man-induced nutrient enrichment (total nitrogen or total phosphorus) shall be considered degradation in relation to the provisions of Sections 62-302.300, 62-302.700, and 62-4.242, F.A.C.”

DEP successfully established a numeric interpretation of this narrative criterion for Total Phosphorus (TP) in the Everglades through the use of the “dose-response” study approach. The criterion was ultimately based on maintaining TP concentrations at levels demonstrated to support healthy, well balanced populations of aquatic flora and fauna in minimally disturbed portions of the Everglades. However, there were extreme challenges associated with determining specific cause effect relationships in the Everglades and deriving an appropriately protective criterion. For example, biological response was not uniform across all microhabitats, and there were areas (*e.g.,* bird rookeries) where naturally higher TP values led to small scale, non-anthropogenic changes in community structure. Further, stressors such as hydrologic modification and natural low DO regimes had to be sufficiently understood and accounted for in criterion development. Extensive dosing studies were conducted to better establish the type and magnitude of adverse biological changes associated with specific levels of TP. DEP’s experience in the Everglades highlighted the complexity of assessing biological response across the natural system and the difficulty in establishing a criterion that was neither under- nor over-protective.

While DEP has also successfully implemented the narrative criteria in both its NPDES Permitting Program and the TMDL Program, numeric nutrient criteria will improve the efficiency of these programs. For example, the numeric criteria will help expedite development of water quality-based effluent limits (WQBELs) for wastewater facilities that discharge nutrients to State surface waters. WQBEL development for nutrients has historically required extensive site-specific evaluation to determine both the appropriate water quality target and the allowable loading to maintain that target, and the numeric nutrient criteria will expedite WQBEL development by providing clear targets for effluent limits. The criteria will also help DEP identify waters impaired by nutrients and provide water quality restoration targets for Total Maximum Daily Load (TMDL) development for these waters. The Impaired Waters Rule currently includes thresholds for nutrient impairment, but the thresholds are for response variables (chlorophyll a), and the numeric nutrient criteria will allow DEP to identify impaired waters based on nutrient concentrations alone. The nutrient criteria also provide clear water quality targets for nutrient TMDL development.

Public Involvement

DEP began the development of numeric nutrient criteria in 2002, when EPA first reached mutual agreement on DEP's Numeric Nutrient Criteria Development Plan. From 2002 through 2009, DEP conducted 22 meetings with the Nutrient Technical Advisory Committee (TAC), which consists of scientific experts from a variety of backgrounds including environmental groups, EPA, consultants, and state and local governments.

DEP formally initiated rulemaking on numeric nutrient criteria in January, 2009, following receipt of EPA's determination letter. Since then, DEP has held four publically noticed TAC meetings and three additional public rulemaking workshops. Issues and concerns rose by stakeholders, both verbally and in writing, were carefully considered, and modifications in the rules reflect the input.

EPA Numeric Nutrient Criteria Guidance

EPA's guidance for nutrient criteria development for streams (*Nutrient Criteria Technical Guidance Manual: Rivers and Streams)* describes three general approaches for the development of numeric nutrient criteria for streams. The most comprehensive and scientifically defensible approach (the state's preferred approach) is to establish criteria to protect against dependably measured adverse biological responses. EPA suggests that an observed "dose-response" relationship could be described by a model (*e.g.,* bio-criteria), which in turn would link nutrient concentrations to the relative risk of environmental harm. DEP supports the "dose-response approach", since it establishes a cause/effect relationship between nutrients and valued ecological attributes, and is directly linked to maintaining designated uses. FDEP has investigated the relationship between nutrients and biological measures such as the Stream Condition Index (SCI), Lake Vegetation Index (LVI), Stream Periphyton Index (SPI), and phytoplankton chlorophyll *a*.

In the absence of data quantitatively describing biological dose-response relationships (or the absence of statistically significant relationships), EPA recommends setting criteria based on an inclusive distribution of values obtained from minimally disturbed reference sites in a designated ecoregion. Using the "reference site approach", EPA recommends setting criteria at an upper percentile value to represent a level of nutrient concentration that will inherently protect aquatic life. It should be noted that EPA's guidance for streams and lakes suggests using the 75th percentile when identifying reference sites via a "desktop, Best Professional Judgment" method.

EPA states that a higher percentile can be chosen when there is higher confidence in the reference site selection procedure (including such steps as biological confirmation, which DEP conducted) since the uncertainty regarding protection would be reduced. EPA's more recent guidance for wetlands suggests that using the 75th to 95th percentile is appropriate. FDEP also supports the use of higher percentiles when there is high confidence that the reference sites are minimally disturbed, since it would ensure that nutrient concentrations associated with biologically healthy, well-balanced communities would be considered acceptable.

However, the "reference site approach" is an inference model, and does not definitively demonstrate that exceeding the threshold established by the distribution of reference sites results in harm (impairment) to the aquatic life in a particular waterbody. Multiple factors can strongly influence the expression of biological responses to nutrients across waterbodies, such as water residence time, presence of grazers, availability of light (due to tree cover and/or water transparency), and availability of suitable habitat. The "reference site approach" identifies concentrations that are presumed to be inherently protective of the waterbody (including downstream waters) because these concentrations are associated with demonstrated minimally disturbed systems with healthy biological communities. Actual biological thresholds can be site-specific and arguably more precise.

The third and least preferred approach of those suggested by EPA is offered for use in situations where sufficient known reference sites are unavailable (either absent or not identifiable). This approach is often referred to as the "all sites approach", and involves establishing criteria using a lower distribution (*e.g.*, 5th to 25th percentile) of a pool of sites of undetermined ecological quality, as long as the pool is sufficiently large enough to represent all waters and can be presumed to reasonably reflect the full range of ambient conditions with a disturbance gradient from least to most impacted. However, after careful review, DEP has concluded that the "all sites approach" has limited defensibility, and therefore did not pursue it.

Criteria Development

Biological Health

DEP has invested significant resources into the development of biological assessment methods for streams and lakes because they provide the ability to directly measure whether a water body's aquatic community meets the objective of the Clean Water Act (CWA). The primary methods are the Stream Condition Index (SCI), which consists of an examination of stream benthic macroinvertebrate communities, and the Lake Vegetation Index (LVI), which consists of sampling aquatic and wetland plants. For these indices, a human disturbance gradient (HDG) approach was utilized to identify community attributes that respond predictably to human stress (termed metrics). The HDG approach consists of landscape, habitat, hydrological, and water quality factors that are scaled to approximate the human disturbance present at series of sites. The SCI (with 10 metrics) and LVI (with 4 metrics) are scored from 0 to 100 points.

DEP, in consultation with EPA, used two lines of evidence to set the thresholds for exceptional and impaired aquatic life conditions for the SCI and LVI. The primary method involved an examination of the lower distribution of minimally disturbed, rigorously verified reference site scores, with the intent of setting the impairment threshold at a level that would limit the number of reference sites that would be deemed to be impaired to 2.5%. The second approach included an examination of the results of expert opinion that was elicited through Biological Condition Gradient (BCG) workshops, where it was determined that a BCG level of 4 and above met the CWA goal for biological integrity. For the SCI, the exceptional threshold is a score of 64

and above, while scores below 40 are considered impaired (see Figure 1 for the relationship between the SCI and BCG). For the LVI, the exceptional threshold is a score of 78 and above, while scores below 46 are considered impaired. Another assessment tool under development, the Stream Periphyton Index, was also used to evaluate nutrient effects, although it has not yet been validated and calibrated. These indexes, as well as component metrics and thresholds, were used for examining dose-response relationships related to nutrients.

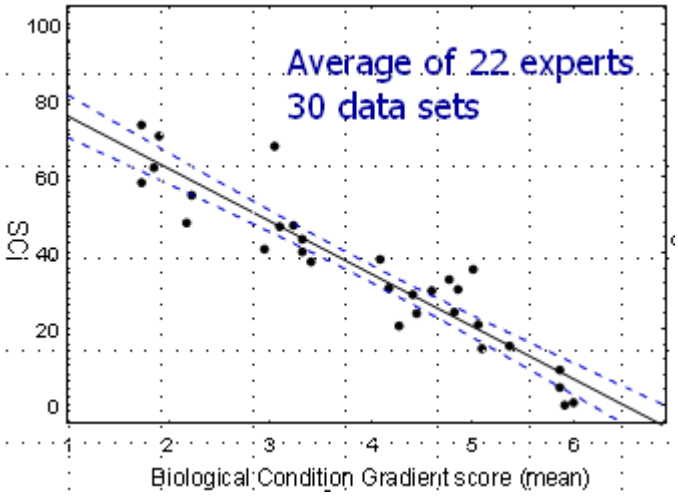


Figure 1. Relationship between the SCI and Biological Condition Gradient model.

Stream Criteria

Clear Stream Nitrate-Nitrite Criterion

DEP examined data from several stream studies specifically designed to identify relationships between nutrients and biological response, and then analyzed the data using a wide variety of statistical techniques. Significant adverse biological responses to nitrate-nitrite were detected in clear streams (streams with a color of less than 40 platinum cobalt units). Results from experimental dosing studies suggested that nitrate concentrations ranging from 0.230 mg/L to 0.261 mg/L stimulated the growth of nuisance algae under laboratory conditions. Although laboratory conditions do not accurately reflect ecological circumstances, where factors such as grazing, light limitation and other natural disturbances affect the growth of algae, they do demonstrate a cause-effect relationship nitrate and biological response.

Because of the limitations of laboratory studies, DEP also examined field responses to nitrate enrichment to derive a protective criterion. Results of periphyton field surveys conducted at a large number of clear streams indicated that nitrate concentrations above 0.454 mg/L were associated with increased nuisance algal abundance. In addition, nearly two decades of scientific results from periphytometers deployed in the relatively low color (generally <40 PCU) Suwannee, Santa Fe, and Withlacoochee (north) Rivers indicated that significant increases in cell density and biomass, as well as adverse alterations in taxonomic community structure, occurred at nitrate-nitrite concentrations above 0.441 mg/L (see results of change point analysis in Figure 2).

Since the 0.441 mg/ L to 0.454 mg/L thresholds represent the lower range of nitrate concentrations for sites with excessive algal growth, an appropriate safety factor was needed to translate the thresholds into a protective criterion. A margin of safety was derived by averaging

the upper half-range and full range 95 percent confidence intervals, and then applied to the 0.44 mg N/L change point to derive a nitrate-nitrite criterion of 0.35 mg/L. Given this approach, there is a high confidence (95% Confidence Interval) that adverse responses will not be observed at concentrations below 0.35 mg/L.

Because the studies that were used to determine the criterion reflect a relatively long-term exposure, the criterion was expressed as a monthly median. The DEP decided not to establish a minimum sample size requirement for calculating a monthly median, and instead decided to express the criterion as not to be exceeded more than ten percent of the time, in acknowledgment that algal species are not expected to respond to short term increases in nutrient concentrations.

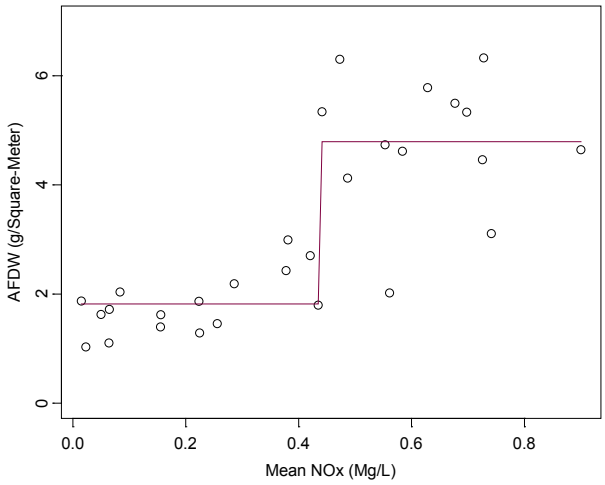
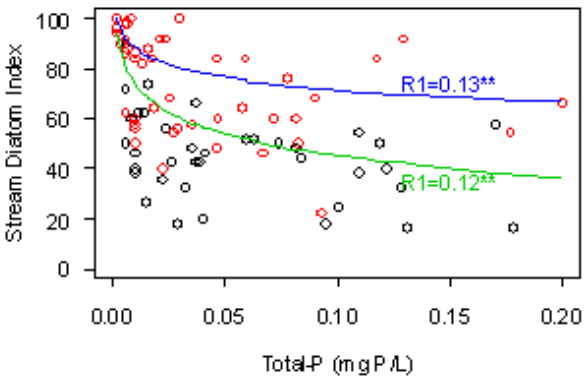


Figure 2. Change point analysis showing a significant threshold between periphyton biomass and nitrate-nitrite.

Total Phosphorus (TP) and Total Nitrogen (TN) Criteria

DEP also conducted several studies specifically designed to identify relationships between TP and TN and biological response. Several hundred individual statistical analyses of the resulting data were performed using an exhaustive array of statistical techniques, including ordinary least squares regression, quantile regression, conditional probability analysis, and change point analysis.



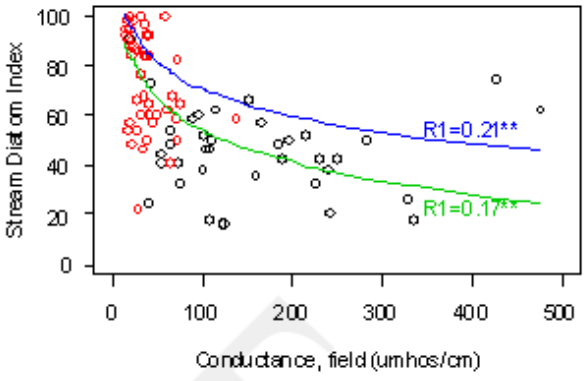


Figure 3. Example of weak dose-response relationships quantified via statistical analyses. Quantile regression of the Stream Periphyton Index and TP and specific conductance.

Although statistically significant relationships were found between nutrients and some biological responses, the variability in biological response explained by nutrients alone was statistically weak (see Figure 3 as an example), and the Department concluded that the analyses were inadequate to establish nutrient thresholds. The results were not surprising because the expression of nutrients is very site-specific, depending on residence time, canopy cover and color (light limitation), and grazing, and because the biological responses can also be impacted by other factors including habitat and hydrology.

Because dose-response thresholds could not be identified, the DEP established numeric nutrient criteria for TP and TN in streams using the "reference site approach", as recommended by EPA. As part of this approach, DEP divided the State into different regions based on their naturally occurring nutrient distributions and ecological attributes (Figure 4).

Figure 4. Stream and river nutrient regions for Florida.

Reference sites were determined through a comprehensive, multi-step evaluation process in which potential benchmark sites were thoroughly verified to assure that they represented minimally disturbed conditions. Because there is high confidence that these reference sites are minimally disturbed and fully meet aquatic life use support, DEP recommends the criteria be established at the 90th percentile of the reference site distribution, except for the Bone Valley nutrient region where the 75th percentile was recommended because of data limitations. The resultant criteria are shown in Table 2 in bold font, along with some information about the available data. These criteria are expressed as annual geometric means that cannot be exceeded more than once every three years.

Table 2. Stream reference site (benchmark site) distribution derived criteria.

Stream Benchmark Distribution Derived Criteria Limits							
Parameter	**Region**	**WBID Years**	**WBIDS**	**Mean LN**	**Std Dev LN**	**75th %tile**	**90th %tile**
TP (mg/L)	Panhandle	125	44	-3.662	0.768	0.043	**0.069**
	Northeast	54	20	-3.205	0.714	0.066	**0.101**
	North Central	180	18	-1.973	0.656	0.216	**0.322**
	Peninsula	193	42	-2.746	0.464	0.088	**0.116**
	Bone Valley	13	3	-1.211	0.491	**0.415**	0.559
TN (mg/L)	Panhandle	123	42	-0.76	0.45	0.63	**0.82**
	NE-NC-Pen-BV	400	85	-0.03	0.45	1.31	**1.73**

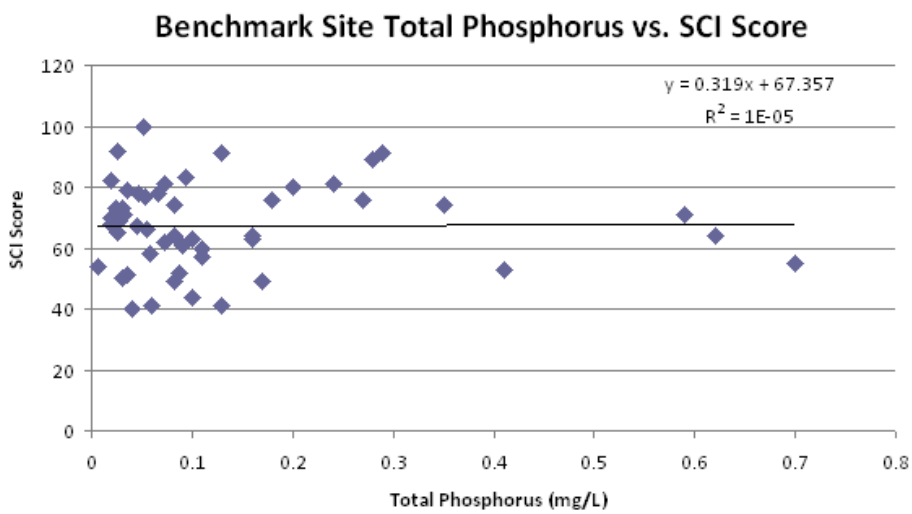


Figure 5. Note lack of relationship between TP and SCI throughout the range of reference site nutrient values, indicating full aquatic life use support, even at levels above the 90th percentile.

While criteria established using the benchmark approach are inherently protective of aquatic life, one disadvantage of using the benchmark approach is that **it does not identify the specific nutrient levels at which biological impairment occurs** (Figure 5). For this reason, it cannot be concluded *a priori* that adverse effects on aquatic life actually occur at concentrations above these values, and the Department recommends that a biological confirmation step is critical when determining impairment status. Although reference site derived values are inherently protective of downstream waters, quantitatively describing the protection of downstream waters is an extremely difficult challenge. Currently, there exists no adequate, statewide calibrated

model that could be used to numerically determine, without great uncertainty, protective nutrient loads for downstream lakes or estuaries. Until such models are developed, DEP has used a narrative statement to ensure downstream waters protection.

Lakes Criteria

After considering the stream nutrient regions and previously developed lake geographic regions, DEP determined regionalization was not needed or appropriate for lake nutrient criteria because color and alkalinity were the primary factors controlling lake response to nutrients. Color primarily affects lake response to nutrients by limiting light at very high color levels, but color is also an indirect indication of the source of the water reaching the lake. High water color (> 40 PCU), which is imparted from breakdown of natural leaf litter, indicates that a lake is influenced by surface water runoff from forests and wetlands, and would contain higher natural nutrient levels than a rainfall driven system. Low color lakes (< 40 PCU) derive their water primarily from rainfall, unless high alkalinity is also present, meaning higher phosphorus Floridan aquifer groundwater has influenced the system.

After dividing lakes into categories of color and alkalinity, the Department determined statistically strong, dose-response relationship between nutrients and chlorophyll *a* (an indicator of algal biomass or primary productivity). DEP then used multiple lines of evidence, including paleolimnology, fisheries success, expert opinion, lack of Harmful Algal Blooms, and user perception, to determine chlorophyll *a* levels that would be protective of designated aquatic life and recreational uses. DEP concluded that a chlorophyll *a* of 20 ug/L would protect human and aquatic life uses in both colored lakes and in clear, high alkalinity lakes. For clear, low alkalinity lakes, the protective chlorophyll *a* threshold was set at 9 ug/L. The 9 ug/L chlorophyll *a* threshold in clear, low alkalinity lakes was further supported by Lake Condition Index (LCI) evidence. Lake Condition Index scores in lakes with chlorophyll < 5 ug/L were not statistically different from those in lakes with chlorophyll between 5 ug/L and 9 ug/L.

Statistical regressions were employed to determine the associated TN and TP criteria that would maintain the target chlorophyll a. While the regressions are statistically significant, there is sufficient uncertainty in the relationship that DEP used statistical prediction intervals to establish a “performance-based approach” in which the TN and TP criteria vary depending on measured chlorophyll a levels.

Lake Type	Response (Chl-a µg/L)	Stressor	Lower Threshold	Upper Threshold
Clear and Low Alkalinity (≤ 40 PCU and ≤ 50 mg/L $CaCO_3$)	9	TP (mg/L)	0.015	0.043
	9	TN (mg/L)	0.85	1.14
Clear but	20	TP (mg/L)	0.030	0.087

High Alkalinity (≤40 PCU but > 50 mg/L $CaCO_3$)	20	TN (mg/L)	1.0	1.81
Colored	20	TP (mg/L)	0.05	0.157
	20	TN (mg/L)	1.23	2.25

In years when the chlorophyll *a* criterion is achieved, the draft rule automatically sets the nutrient criteria at the geometric mean of measured values. However, DEP added upper and lower boundaries to ensure that the criteria are not over- or under-protective. The chlorophyll *a* criterion and the TN and TP criteria are expressed as annual geometric means that cannot be exceeded more than once every three years.

Remaining Issues

Although comprehensive and credible scientific information was used to inform the proposed numeric nutrient criteria, a number of issues remain that DEP would like to address, including:

- Establishment of discrete biological response thresholds in streams to TP and TN. DEP recently initiated a study that will examine biological responses to nutrients upstream and downstream of nutrient point source discharges to further evaluate a concentration versus response relationship;
- Determination of endpoints for the Rapid Periphyton Survey and the Linear Vegetation Survey that would be used to establish the algal abundance and thickness levels and aquatic plant changes that indicate interference with aquatic life use. DEP has initiated a study to accomplish these goals;
- Determination of the appropriate chlorophyll threshold in lakes that may have had historically higher chlorophyll levels, as determined by paleolimnological studies or other information. DEP is working with groups such as the Florida lakes Management Society to gather these types of data;
- Further evaluation of the applicability of other lake models, such as the Morphoedaphic Index, to refine the allowable nutrient levels in specific lake systems (analyses are currently underway); and
- Quantitatively describing the maximum nutrient concentrations allowed for the protection of downstream waters. Currently, there exists no adequate, statewide calibrated model that could be used to numerically determine, without great uncertainty, protective nutrient loads for downstream lakes or estuaries. This is a daunting challenge with no current solution, prompting DEP to propose a narrative statement to ensure downstream waters protection.

Resolution of many of these above issues may lead to the establishment of Site Specific Alternative Criteria for particular waterbodies.

Type III Site Specific Nutrient Criteria

Because nutrient dynamics are complex and the impacts are so site-specific, there will always be cases where statewide criteria are over-protective for specific waterbodies. To address this possibility, DEP developed rule language for a new process for developing Site Specific Alternative Criteria (SSAC) for nutrients. This new "Type III" SSAC process would require a demonstration that the SSAC is fully protective of designated uses based on the SCI and LVI, for streams and lakes, respectively. Under the draft rule, a Type III SSAC would be adopted if two spatially and temporally independent biological health assessments indicated that the existing nutrient regime supported healthy biota. To ensure that the SSAC is also protective of downstream waters, DEP also added a requirement that all downstream waters attain water quality standards related to nutrients. To protect high quality waters, a SSAC would not be allowed if a 20 point drop in the SCI or LVI occurred, compared with historic values.

TMDLs and SSACs

DEP also plans to adopt previously adopted nutrient Total Maximum Daily Loads (adopted in Chapter 62-304, FAC) as SSACs. DEP recommends this provision because the TMDLs:

- Establish site specific and sensitive responses to nutrient enrichment for a particular area;
- Are generated using data appropriate for a site specific assessment;
- Establish a protective endpoint equivalent to numeric criteria; and
- Are more appropriate than a statewide criterion because they reflect geographically explicit protective conditions, and it would be counter-productive for statewide nutrient criteria to supersede the TMDL.

Florida has currently adopted 135 nutrient TMDLs with an additional 39 pending adoption.

The recommended revisions to Chapter 62-303 (Impaired Waters Rule, IWR) are designed to update the rule to implement the proposed revisions to Chapter 62-302. The revisions will allow the Department to assess waters for nutrient impairment using the numeric nutrient criteria in addition to the current narrative nutrient impairment thresholds in the IWR, and to assess waters for biological impairment using the new SCI and LVI thresholds.