# STATE OF NEW MEXICO

# NUTRIENT REDUCTION STRATEGY

***FOR PROTECTING AND IMPROVING WATER QUALITY***

# 2014

Prepared by

Surface Water Quality Bureau
New Mexico Environment Department

**February 2014**

**This page left intentionally blank.**

# TABLE OF CONTENTS

**TABLE OF CONTENTS ........................................................................ 3**

Executive Summary ........................................................................ 4

1.0 Definition of the Problem ........................................................................ 5

2.0 Summary of New Mexico's Nutrient Reduction Strategy ........................................................................ 6

*Element 1: Prioritizing watersheds on a statewide basis ........................................................................ 7*

*Element 2: Setting load reduction goals based upon best available information ........................................................................ 9*

*Element 3: Ensure effectiveness of point source permits in targeted/priority watersheds 9*

*Element 4: Agricultural areas ........................................................................ 9*

*Element 5: Stormwater and septic systems ........................................................................ 10*

*Element 6: Accountability and verification measures ........................................................................ 10*

*Element 7: Annual public reporting of implementation activities and biannual reporting of load reductions and environmental impacts ........................................................................ 11*

*Element 8: Develop a work plan and schedule for nutrient criteria development ........................................................................ 11*

3.0 Overview of Nutrient Criteria Development in New Mexico ........................................................................ 12

*Planning for Numeric Nutrient Criteria Development (Activity #1) ........................................................................ 13*

*Collection of Information and Data (Activity #2) ........................................................................ 15*

*Analysis of Information and Data (Activity #3) ........................................................................ 15*

*Proposal and Adoption of Numeric Nutrient Criteria in WQS (Activity #4 and #5) ........................................................................ 23*

4.0 Schedule for Nutrient Criteria Development in New Mexico ........................................................................ 24

5.0 New Mexico's Nutrient Assessment ........................................................................ 25

*Wadeable, perennial streams (actively used since 2004) ........................................................................ 25*

*Lakes and Reservoirs (implemented for the 2014-2016 listing cycle) ........................................................................ 28*

*Non-wadeable Rivers (in development) ........................................................................ 28*

*Wetlands (not started) ........................................................................ 28*

6.0 Nutrient TMDL Development ........................................................................ 29

7.0 Implementing Nutrient Reduction and Control Strategies ........................................................................ 30

8.0 Requirements for Additional Data Collection ........................................................................ 31

*Physical, Chemical, and Biological Measurement Variables ........................................................................ 32*

9.0 Other Considerations ........................................................................ 32

*Stakeholder Input and Public Participation ........................................................................ 32*

*RTAG Coordination ........................................................................ 33*

*Scientific Review ........................................................................ 34*

*Other Issues ........................................................................ 34*

References ........................................................................ 35

## Executive Summary

The State of New Mexico has a narrative nutrient criterion, which states, "*Plant nutrients from other than natural causes shall not be present in concentrations that will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state*" (Subsection E of 20.6.4.13 NMAC). New Mexico's narrative nutrient criterion is challenging to assess as the relationships between nutrient levels and impairment of designated uses are not easily defined and distinguishing nutrients from "other than natural causes" is difficult. Despite these challenges, New Mexico has been employing an approach to the significant problem of excess nutrients that (1) emphasizes impairment threshold development that employs both cause and response nutrient-related water quality variables to ensure effective and appropriate assessment of the narrative nutrient criterion and (2) encourages and promotes near-term nutrient load reductions in impaired watersheds through Total Maximum Daily Load (TMDL) development and implementation.

In 2002, the Surface Water Quality Bureau (SWQB) developed a nutrient assessment protocol to assist in meeting the nutrient reduction challenge. While this protocol was applied and used to develop 100% non-point source TMDLs, it lacked impairment thresholds and quantitative endpoints necessary to develop TMDLs with both point and non-point sources. Therefore, in 2004, SWQB with the assistance of the United States Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS) refined the protocol. Threshold values for cause (total nitrogen (TN) and total phosphorous (TP)) and response variables (e.g., dissolved oxygen, pH, and chlorophyll *a*) were used in a weight-of-evidence assessment to determine impairment and to translate the narrative nutrient criterion into quantified endpoints. SWQB developed this weight-of-evidence approach that incorporated both cause and response variables to conduct a more comprehensive assessment and account for diverse lotic systems and dynamic nutrient cycling.

Application of the weight-of-evidence nutrient assessment protocol has resulted in the following:

I. Fifty-nine (59) assessment units identified as impaired for nutrients, representing 1,001 stream miles, and 13% of all impairments in New Mexico.

II. Thirty-three (33) EPA-approved nutrient TMDLs that have been adopted as part of the State's Water Quality Management Plan (WQMP).

III. Eight (8) wastewater treatment plants with nutrient (TN and TP) waste load allocations included in a TMDL document. As a result, nutrient effluent limits for these facilities have been included in National Pollutant Discharge Elimination System (NPDES) permits issued by EPA Region 6 (refer to Table 10). Four (4) more facilities are anticipated to have nutrient effluent limits in the near future based on waste load allocations assigned in nutrient TMDLs.

As documented in this strategy document, New Mexico is currently not pursuing adoption of numeric nutrient criteria. Instead New Mexico is pursuing the continued development and implementation of assessment protocols for wadeable streams, rivers and lakes that acknowledge that nutrients exist in all waters of the State but that excessive levels lead to impairment of designated uses. Further, New Mexico seeks to adopt nutrient TMDLs that recognize the threshold concentrations necessary to be protective of designated uses while developing approaches for implementation of the waste load allocations that are technologically achievable and are neither over- nor under-protective. The State is currently evaluating alternative approaches to the implementation of TMDL waste load allocations for point-source discharges that are scientifically based, environmentally sound, and consider the existing facility design, facility age and local economic factors.

# 1.0 Definition of the Problem

Phosphorus and nitrogen generally drive the productivity of algae and macrophytes in aquatic ecosystems, are regarded as the primary limiting nutrients in freshwaters, and are essential for proper functioning of ecosystems; however, excess nutrients cause conditions unfavorable for the proper functioning of aquatic ecosystems.

Several human-related activities can adversely affect nutrient concentrations in streams, rivers, lakes, and wetlands. Agriculture and urban development contribute nutrients by disturbing the land and consequently increasing soil erosion, by directly applying nutrients to the landscape, and/or by increasing the impervious area within the watershed. Residential areas contribute nutrients from septic tanks (a known and widespread contributor to water pollution in New Mexico; McQuillan 2004), landscape maintenance, as well as backyard livestock (e.g. cattle, horses) and pet wastes. Recreational activities such as hiking and biking can also contribute nutrients to the stream by reducing plant cover and increasing soil erosion (e.g. trail network, streambank destabilization), direct application of human waste, campfires and/or wildfires, and dumping trash near the riparian corridor.

Undeveloped, or natural, landscapes also can deliver nutrients to a waterbody through decaying plant material, soil erosion, and wild animal waste. Another geographically occurring nutrient source is atmospheric deposition, which adds nutrients directly to the waterbody through dryfall and rainfall. Atmospheric phosphorus and nitrogen can be found in both organic and inorganic particles, such as pollen and dust. The contributions from these natural sources are typically considered to represent background levels.

Nutrients generally reach a waterbody from land uses that are in close proximity because the hydrological pathways are shorter and have fewer obstacles than land uses located away from the riparian corridor. However, during the growing season (i.e., in agricultural return flow) and in storm water runoff or wildfires, distant land uses can become hydrologically connected to the waterbody, thus transporting nutrients to the water during these events. In addition, a waterbody's natural or altered flow regime can have a notable impact on nutrient concentrations. As flow decreases through water diversions and/or drought-related stressors, the waterbody cannot effectively dilute its constituents, which causes nutrient concentrations to increase.

Rain, overland runoff, groundwater, agricultural drainage networks, and industrial and residential waste effluents can transport nutrients to receiving waterbodies. Once present in the water nutrients may drive enhanced growth and reproduction of algae, macrophytes, and microorganisms either in the water column or on the bottom substrate. Nuisance levels of algae and other aquatic vegetation, such as macrophytes, can develop rapidly in response to nutrient enrichment when other factors (e.g., light, temperature, firm substrate, etc.) are not limiting.

The relationship between nutrient enrichment and nuisance algal growth in stream systems has been well documented in the literature (Welch 1992; Van Nieuwenhuyse and Jones 1996; Dodds et al. 1997; Chetelat et al. 1999). Nutrient impaired waters can cause problems that range from annoyances to serious health concerns (Dodds and Welch 2000). Documented impacts that can be attributed to nutrient impairment include:

- Taste and odor problems in drinking water supplies;
- Increased treatment required for drinking water;
- Human health problems, such as blue baby syndrome and non-Hodgkin lymphoma;
- Adverse ecological effects, such as large diel swings in dissolved oxygen that can stress (or kill) aquatic life or reduction of suitable habitat; and
- Harmful algal blooms[*].

Excess nutrients in aquatic systems can have large impacts, as noted above. Nutrient pollution can clearly lead to degraded water quality and non-attainment of the Federal Clean Water Act goal "to maintain the chemical, physical, and biological integrity of the Nation's waters" [CWA §101(a)] and the New Mexico Water Quality Act implied goal "to protect the public health, welfare, and to enhance the quality of water" (§§ 74-6-1 *et seq*., NMSA 1978).

## 2.0 Summary of New Mexico's Nutrient Reduction Strategy

Development of numeric criteria was stimulated by the U.S. Environmental Protection Agency's *National Strategy for Development of Regional Nutrient Criteria* (USEPA 1998) with the long-term goal being that states complete the task of developing numeric nutrient criteria for total nitrogen (TN) and total phosphorus (TP) for all waterbody types in the state. In the decade since then little progress has been made on numeric nutrient criteria nationally and alternative approaches have been attempted by a number of states as EPA continues to refine its approach. Most recently an EPA memo entitled, *Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions* (Stoner 2011), provided eight recommended elements of a state nutrient reduction framework. These eight elements include:

1. Prioritizing watersheds on a statewide basis;
2. Setting load reduction goals based upon best available information;
3. Ensure effectiveness of point source permits in targeted/priority watersheds;
4. Agricultural areas;

[*] New Mexico has two types of toxic algae, *Lyngbya* sp. and *Prymnesium* sp. Nutrients are reported to play a significant role in *Prymnesium* blooms (Johansson and Graneli 1999a, 1999b; Johansson 2000; Graneli and Johansson 2001; Legrand, et al. 2001; Graneli and Johansson 2003a, 2003b; Skovgaard, et al. 2003). It seems likely that nutrients play a role in *Lyngbya* blooms as well, although this has yet to be documented.

5. Storm water and septic systems;
6. Accountability and verification measures;
7. Annual public reporting of implementation activities and biannual reporting of load reductions and environmental impacts; and
8. Develop a work plan and schedule for nutrient criteria development.

New Mexico's nutrient reduction efforts are organized around a combination of waterbody type, indicator, and pollution source. The SWQB determines impairment by evaluating various indicators of nutrient impairment through a weight-of-evidence assessment. Thresholds for indicators are determined by waterbody type (e.g., streams, rivers, or lakes), ecoregion (e.g., Southern Rockies, Chihuahuan Desert, Arizona/New Mexico Plateau), aquatic life use (e.g., cold water, warm water), and/or site-specific conditions; however, a few waterbodies have site specific total phosphorus numeric criteria. The following provides a summary of New Mexico's plans and/or actions taken for each of these elements to develop a blueprint and implement a strategy for nutrient reductions in the state.

### *Element 1: Prioritizing watersheds on a statewide basis*

SWQB prioritizes waters based on rotational water quality surveys (Figure 1), waterbody type (e.g. wadeable streams, lakes and reservoirs, and non-wadeable rivers), water quality assessments, TMDL development, and TMDL implementation through the Clean Water Act (CWA) §319 Request for Proposal (RFP) process and point source discharge (NPDES) permits.

As documented in the *State of New Mexico 10-year surface water quality monitoring and assessment strategy* (NMED/SWQB 2010) SWQB, through its 8-year rotational survey schedule, is able to conduct a census of all perennial waters within the state. Because of this, New Mexico directly evaluates TN and TP loadings at the *Assessment Unit* scale (a scale somewhat larger than the USGS hydrologic unit code (HUC) 12 scale). Watersheds that account for elevated loads are identified through assessment of the state's narrative nutrient criteria (as detailed in Section 5 of this document) and assessment protocol, TN and TP reduction strategies are then developed through TMDLs and implemented (see Sections 6 and 7).

SWQB has also been working with EPA to design a *Recovery Potential Screening* tool for New Mexico. The recovery potential screening tool will help the state improve restoration programs by revealing and comparing factors that influence restoration success. The method is applicable to statewide watershed priority setting, impaired waters listing, TMDL implementation, 319/nonpoint source control, healthy watersheds assessment, and watershed plan development.

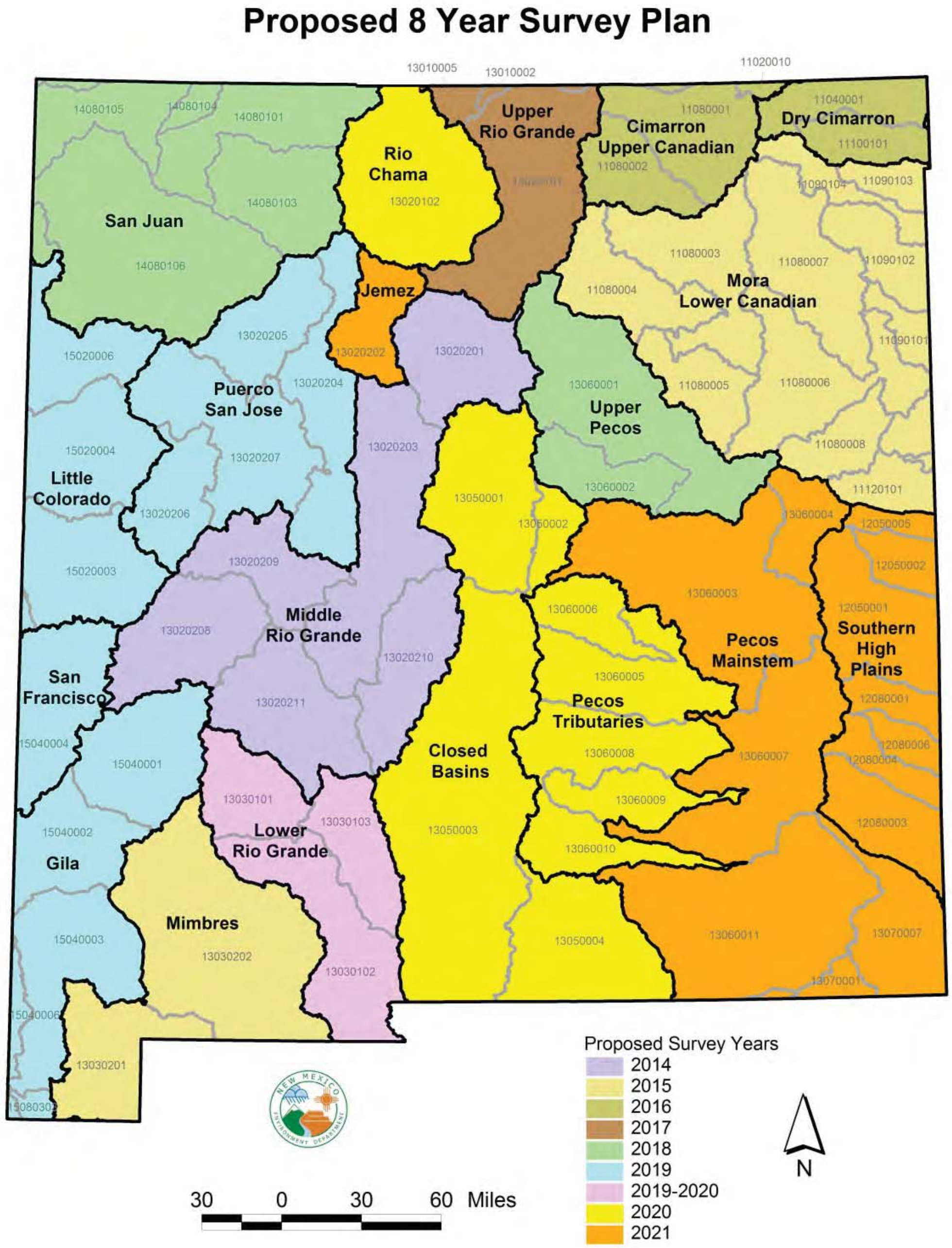


**Figure 1.** SWQB's rotational watershed survey plan

In an arid state like New Mexico source water protection for drinking water systems is of critical importance. The New Mexico Water Quality Standards recognize Public Water Supply as a designated use and explicitly includes a narrative nutrient criterion as one measure to ensure this use. The vast majority of drinking water systems in New Mexico, however, rely on ground water sources and those that utilize surface water systems are primarily from headwater systems (e.g. Santa Fe River) or on the mainstem rivers (e.g. Rio Grande) with no know nutrient impairments or issues. The NMED Drinking Water Bureau (DWB) does not have the authority to require nutrient reduction in source waters. The public water systems must, however, comply with the nitrate standard in the water distributed to the consumers.  Source Water Assessments and Protection Plans that are overseen by the DWB identify actual and potential sources of nutrient contamination within the source water protection areas. Areas such as West Clovis, where there is actual groundwater nitrate contamination, are being elevated in terms of priority for source water protection activities. DWB is hoping to steer the water systems in West Clovis towards a regional Source Water Protection Plan that would be of a sub-basin scale. DWB is beginning to work with other NMED water programs around Source Water Protection so that the Protection Plans will be considered in regional planning and regulatory and permitting activities for nutrients and other parameters; however, this activity is in the planning stages. With regard to underground water sources, nutrient reduction is performed by the permitting/prevention programs of the Ground Water Quality Bureau and Liquid Waste Programs.

### *Element 2:  Setting load reduction goals based upon best available information*

Load reduction goals are primarily based on TMDLs for nutrient impaired waters. As discussed in more detail in Section 7, New Mexico nutrient impairments are primarily realized at the local watershed scale and do not aggregate to impacts at the larger river basin scale (HUC 8). Nutrient TMDLs in New Mexico set loading limits for NPDES permitted discharges and general load allocation to non-point sources based on the best available chemical and hydrologic information for the watershed (Section 6), site-specific nutrient criteria, or ecoregion thresholds (Section 3). The State has adopted a site-specific criterion of 0.1 mg/L for TP in ten (10) regulatory segments, which include three lakes. Secondary reduction goals may be based on special studies, such as the development of watershed-based plans, which may be developed to understand the potential nonpoint sources that contribute to nutrient impairments. The proposed nutrient reduction goals are designed to achieve protection of local water sources, aquatic life uses, and downstream uses.

### *Element 3:  Ensure effectiveness of point source permits in targeted/priority watersheds*

As documented above, New Mexico has been targeting nutrient reductions through a combination of 303(d) listings, TMDL development, and implementation through NPDES permitting processes. Where stream impairment is found, a nutrient TMDL is typically written to address load and waste load allocations for pollution sources.  Nutrient limits are only required for those waters with an approved TMDL in place; monitoring requirements with a reopener clause are included in those that discharge to nutrient impaired waters without a TMDL. Beyond this there are no universal monitoring requirements or technology based limits required in NPDES point source permits for municipal wastewater, industrial wastewater, urban stormwater, and concentrated animal feeding operation (CAFO) discharges into New Mexico waters. Effectiveness of point source permits in priority watersheds (i.e., impaired watersheds) is addressed through rotational water quality surveys and re-assessment, or re-evaluation, of more recent data to determine the current status of the waterbody. Refer to *Implementing Nutrient Reduction and Control Strategies* section for more information on this element.

### *Element 4:  Agricultural areas*

Agricultural areas are not explicitly addressed in the nutrient reduction strategy at this time.

Through the New Mexico Nonpoint Source Management Program, nutrient impaired waters with an approved TMDL are eligible to received CWA’s §319 grant funding for planning or implementation efforts. New Mexico has developed watershed-based plans that address nutrient impairments and has funded on the ground §319 projects that have implemented agricultural best management practices (BMPs) to address nutrient loading. This has included rangeland BMPs to reduce cattle grazing in riparian areas (e.g. upland water sources and riparian exclosures) as well as irrigated agriculture BMPs (e.g. limiting field runoff) with additional support from the National Resource Conservation Service (NRCS) through the Environmental Quality Incentives Program (EQIP). SWQB has also recommended that NRCS select from among several watersheds with completed watershed-based plans to focus the National Water Quality Initiative (NWQI); these watersheds included some with nutrient impairments which is a focus for the NWQI program.

### *Element 5: Stormwater and septic systems*

SWQB is not aware of any state, county or local government tools (e.g. low impact development, green infrastructure or limits on detergents and lawn fertilizers) that address TN and TP reductions from developed communities outside of those areas already covered under the Municipal Separated Storm Sewer System (MS4) program.

New Mexico has adopted regulations (20.7.3 NMAC) to protect the health and welfare of present and future citizens of New Mexico by providing for the prevention and abatement of public health hazards and surface and ground water contamination from on-site liquid waste disposal practices. The regulations provide for minimum criteria for design and construction of liquid waste systems.

In addition Bernalillo County has enacted a new on-site wastewater ordinance (www.nmenv.state.nm.us/fod/LiquidWaste/Bern%20Co%20Onsite%20Ordinance.pdf). While this ordinance applies only to Bernalillo County, and is the only such ordinance in the State, it may serve as a template for other counties in New Mexico in the future. Liquid waste systems have also been addressed in some nutrient TMDLs either through "capture" (i.e., adding these households on to the centralized system) or by advocating proper maintenance, upgrade, or cluster systems depending on the community and available funding through NMED's Construction Programs Bureau.

### *Element 6: Accountability and verification measures*

Baseline TN and TP loads are documented through SWQB rotational surveys. Additional monitoring may be conducted to assess the effectiveness of nutrient loading reductions achieved through BMP implementation or NPDES permits. These rotational surveys also provide an accountability and verification check on impairments, TMDL progress, and the overall trend in water quality within the state's surface waters.

Accountability and verification for Element #3 will occur through the NPDES permitting program – including the required discharge monitoring report (DMR) required by facilities with nutrient loading limits.

Accountability and verification for Element #4 will be addressed through SWQB's Watershed Protection Section (WPS), which works with watershed groups and other stakeholders to develop and implement Watershed-Based Plans that detail pollutant sources, establish baselines for existing loads, calculate load reductions to meet standards, and identify appropriate BMPs that will reduce pollutant loading to the waterbody. See the Watershed Planning Section of SWQB's website (www.nmenv.state.nm.us/swqb/wps/#WatershedPlanning) for a detailed list of plans in New Mexico. Nutrient reductions through BMPs, when implemented, will be tracked through the CWA's §319 Grants Reporting and Tracking System (GRTS).

Accountability and verification for Element #5 is achieved through NMED's Liquid Waste Program (www.nmenv.state.nm.us/fod/LiquidWaste).

### *Element 7: Annual public reporting of implementation activities and biannual reporting of load reductions and environmental impacts*

Presently SWQB does not have a specific public reporting process for comprehensively documenting implementation of nutrient load reductions in New Mexico on an annual basis. With that said, this *Nutrient Reduction Strategy* document provides a structured overview of New Mexico's activities on this effort. SWQB will make the *Nutrient Reduction Strategy* publically available on its website and intends to complete regular updates to keep the information current. Additional documents, as detailed below, provide regular updates on specific aspects of this program.

SWQB prepares the Integrated List of Assessed Surface Waters ("the list") on a biannual basis. This report shares with the public the impairment status of surface waters in the state of New Mexico. During this process, the public is also invited to submit data for assessment and/or review and comment on the list. This report and its supporting materials can be found online at: www.nmenv.state.nm.us/swqb/303d-305b. Refer to the *Stakeholder Input and Public Participation* section for more information. While the list does not provide an indication of load reductions or environmental impacts, it does provide the public with an overall sense of the State's progress on improving water quality and justification for listing or delisting waters. The full report is the only document that summarizes all of NMED's programs and an overview of their major achievements during the reporting period.

In addition, SWQB prepares the Nonpoint Source (NPS) Annual Report, which provides an overview of NPS management-related activities conducted in New Mexico by the WPS of the SWQB. The report presents the state's progress in meeting the milestones outlined in the goals and objectives of the New Mexico NPS Management Program, and provides information on reductions in NPS pollutant loading and improvements to water quality of New Mexico watersheds. These annual reports can be found online at:
www.nmenv.state.nm.us/swqb/wps/2012NPSAnnualReport.

### *Element 8: Develop a work plan and schedule for nutrient criteria development*

As documented in this strategy, New Mexico is currently not pursuing adoption of numeric nutrient criteria. Instead, New Mexico is pursuing the continued development and implementation of assessment protocols for streams, rivers and lakes that acknowledge that nutrients exist in all waters of the State but that excessive levels lead to impairment of designated uses. From 2003 to 2008 EPA, through the CWA §104(b)(3) program, funded SWQB to develop nutrient criteria and assessment protocols. The funding EPA provided is directly responsible for the tangible results New Mexico has made in identifying and addressing nutrient impaired waterbodies that are discussed in more detail throughout this document. Refer to the next section, *Overview of Nutrient Criteria Development in New Mexico*, for more information on New Mexico's progress in nutrient criteria development.

New Mexico has developed an effective approach to address nutrient impairments and load reductions through assessment of our narrative nutrient standard, development of nitrogen and phosphorous TMDLs for impaired waterbodies, and implementation of TMDL targets through the NPDES permitting process. As such, SWQB is making strong progress toward reducing nitrogen and phosphorus pollution by setting priorities on a watershed basis and establishing nutrient reduction targets (EPA performance measure WQ-26); however SWQB is not currently addressing EPA performance measure WQ-01a that tracks state progress toward adoption of numeric nutrient water quality standards.

SWQB continues to believe that EPA should provide flexibility to states by allowing nutrient impairments to be addressed through effective programs that are within the state's financial and resource capabilities. Further, New Mexico seeks to adopt nutrient TMDLs that recognize the threshold concentrations necessary to be protective of designated uses, while developing approaches for implementation of the waste load allocations that are technologically achievable and are neither over- nor under-protective. The state is currently evaluating alternative approaches to the implementation of TMDL waste load allocations for point-source discharges that are scientifically based, environmentally sound, and consider the existing facility design, facility age and local economic factors.

## 3.0 Overview of Nutrient Criteria Development in New Mexico

EPA continues to place a high priority on states addressing excess nutrients through adoption of numeric water quality criteria for nitrogen and phosphorous in streams, rivers, lakes and reservoirs. Furthermore, EPA has encouraged states to undertake eight key actions to address TN and TP pollution from priority-setting to full implementation, as discussed above. The eighth recommended element is developing a work plan and schedule for nutrient criteria development, which is discussed in more detail here.

Nutrient criteria development plans have served as road maps for outlining the process states use to develop numeric nutrient criteria; however the schedule and milestones within the plans need to be updated periodically to accurately reflect any progress the state has made. Related to this need, EPA has requested that states provide target and completion dates for the following activities for each waterbody type (refer to Table 8):

1. Planning for numeric nutrient criteria development;
2. Collection of information and data;
3. Analysis of information and data;
4. Proposal of numeric nutrient criteria; and
5. Adoption of numeric nutrient criteria into the water quality standards.

EPA added state performance measures (WQ-1a and WQ-26) to track state progress toward adoption of numeric nutrient water quality standards.

### *Planning for Numeric Nutrient Criteria Development (Activity #1)*

Prioritization of water bodies and sites is necessary given limited resources allotted to meet the water quality objectives of the SWQB and EPA. SWQB will prioritize waters for the development of nutrient threshold values according to the waterbody type as follows:

1. wadeable streams;
2. lakes and reservoirs;
3. non-wadeable rivers; and
4. wetlands.

Wadeable, perennial streams were selected as the highest priority as they represent the majority of the waters assessed in New Mexico. Since a large body of data exists for reservoirs and they are a highly valued resource, they have been selected as the second priority. SWQB has a fairly large dataset of concurrently collected TN, TP, chlorophyll-*a* and secchi depth, which will be supplemented with data from other entities. The dataset for larger, non-wadeable rivers has significant gaps, particularly for response variables, so this waterbody type will be addressed third. Over the past couple of years, SWQB has been compiling a dataset that could be used to supplement existing data and develop threshold values for nutrient assessment of rivers. SWQB began a wetlands program in 2011, so the process of collecting wetlands data is in the early stages. It will likely take a number of years to compile a dataset sufficient to address this waterbody type. Therefore, nutrient threshold development for wetlands was given the lowest priority.

Monitoring of the various waterbody types will be on-going to develop datasets for use in classification, as well as threshold development and refinement. Monitoring will serve the dual purposes of filling in data gaps for nutrient variables and providing additional information on reference and/or expected conditions. SWQB's goals for developing numeric nutrient impairment thresholds for New Mexico's waters are listed in Table 1. The time frame is the anticipated completion date and assumes that the identified resource needs have been met. Resources are categorized into three major groups: time; funding (for contractor assistance); and staff.

Protection of aquatic life, recreation, and drinking water uses is the impetus for establishing nutrient criteria. Impairment thresholds (i.e., the level of a nutrient related water quality parameter above which designated are expected to be impaired) are not numeric criteria, but can be considered a step towards numeric nutrient criteria development. The magnitude of nutrient concentration that constitutes an "excess" (i.e., impairment threshold) and linking that excess to an *undesirable* shift in the biological community is difficult and varies by waterbody because the pathways by which nutrient concentrations affect aquatic life conditions are complex (EPA 2010, EPA 2012). Complicating this effort is the fact that New Mexico has an extremely high diversity of plant and animal groups. For example, New Mexico's landscape and climate regimes range from alpine-conifer forests at higher elevations to deserts and xeric shrubland at lower elevations. New Mexico also ranks second in number of species of native mammals (151) after California (161, not including marine mammals), which is 1.3 times larger in area. Due to New Mexico's complex landscape and high biological diversity, nutrient impairment thresholds will require testing and refinement to identify and confirm appropriate thresholds for each waterbody type. Then, depending on the approach that is currently being pursued by other states and accepted by EPA, the impairment thresholds may be proposed for adoption into the New Mexico water quality standards. If adoption of numeric nutrient criteria is undertaken in the future it will likely follow the approach that Maine has taken in which both cause and response variables are incorporated into proposed criteria (MDEP 2012), or the one that Ohio has proposed (epa.ohio.gov/dsw/dswrules/nutrientcriteria.aspx) in which cause and response variables are weighted to calculate a Trophic Index Criterion (OEPA 2013; Miltner 2010).

**Table 1.** SWQB goals for developing numeric nutrient impairment thresholds

| Waterbody Type | Goal/Implementation Plan | Resources Needed | Time Frame |
|---|---|---|---|
| Streams | Numeric nutrient impairment thresholds (TN, TP, and chlorophyll-a) based on percentiles within ecoregion/aquatic life use categories. Nutrient assessment protocol (AP) for wadeable, perennial streams incorporating TN and TP thresholds is complete (but subject to revision).<br>- Used in assessment and TMDL development. | None | Done |
| | Conduct analyses to link TN and TP concentrations to a biological response (macroinvertebrates and/or diatoms).<br>- Evaluate and revise numeric nutrient impairment thresholds (TN and TP) based on new information.<br>- Refine nutrient AP for wadeable, perennial streams. | Time and funding | 2012 - 2014 |
| Lakes and Reservoirs | Numeric nutrient impairment thresholds (TN, TP, chlorophyll-a, %cyanobacteria) based on SWQB analyses, WQS, and literature review. Weight-of-evidence nutrient assessment protocol (AP) for lakes and reservoirs is complete (but subject to revision).<br>- AP being implemented for the 2014-2016 listing cycle. | None | Done |
| | Validate and refine numeric nutrient impairment thresholds (TN, TP, chl-a, %cyanobacteria).<br>- Amend nutrient AP for lakes, as needed. | Time and funding | 2015 |
| Rivers | Conduct analyses to link TN and TP concentrations to a biological response (benthic macroinvertebrates and/or stream metabolism).<br>- Identify numeric nutrient impairment thresholds for TN and TP.<br>- Incorporate nutrient thresholds into weight-of-evidence approach to determining impairment.<br>- Develop and implement nutrient AP for non-wadeable rivers. | Time and funding | 2015 |

| Waterbody Type | Goal/Implementation Plan | Resources Needed | Time Frame |
|---|---|---|---|
| Wetlands | Complete all elements required for a monitoring and assessment program for wetlands. On-going monitoring of wetlands to compile a nutrient dataset suitable for analysis. | Staff, time, and funding | 2016 |
| All | Review and update *Nutrient Reduction Strategy (this plan)* | Time | Every 1-2 years |

### *Collection of Information and Data (Activity #2)*

According to New Mexico's 2012-2014 Integrated CWA §303(d)/ §305(b) Report (NMED/ SWQB 2012), *nutrient/eutrophication biological indicators* is the third leading cause of impairment of designated uses in New Mexico's streams and rivers and is the fifth leading cause of impairment in lakes and reservoirs behind dissolved oxygen, which may be related to excessive nutrients. With recognition of the pervasiveness and severity of nutrient-related problems, the need to accurately monitor and assess nutrient impairment and develop effective TMDLs for impaired waters is clear.

Development and refinement of nutrient impairment threshold values is an iterative process, therefore continued, on-going monitoring in all applicable waterbody types will serve multiple purposes including enhancing or developing datasets for threshold development/refinement, filling in data gaps, gathering information for classification purposes, and providing additional support for the definition of reference and/or expected conditions.

### *Analysis of Information and Data (Activity #3)*

#### Wadeable, perennial streams

New Mexico's narrative nutrient criterion can be challenging to assess as the relationships between nutrient levels and impairment of designated uses are not well defined, and distinguishing nutrients from "other than natural causes" is difficult. The SWQB nutrient criteria/assessment efforts have largely focused on wadeable, perennial streams as they represent the majority of assessed surface waters. Between 2002 and 2007 SWQB developed and refined the assessment approach for these waters.

Nutrient impairment threshold development for streams has taken place in three steps, thus far. First, EPA compiled nutrient data from the national nutrient dataset, divided it by waterbody type, grouped it into nutrient ecoregions, and calculated the 25$^{th}$ percentiles for each aggregate and Level III ecoregion (Table 2). EPA published the recommended water quality criteria for Total Nitrogen (TN) and Total Phosphorus (TP) to help states and tribes reduce problems associated with excess nutrients in waterbodies in specific areas of the country (USEPA 2000a). Refinement of the recommended draft ecoregional nutrient criteria was conducted in 2004 by Evan Hornig, a USGS employee assisting states in EPA Region 6 with development of nutrient criteria. Hornig used regional nutrient data from EPA's Storage and Retrieval System (STORET), the U.S. Geological Survey (USGS), and the SWQB to create a dataset specific to New Mexico. The revised TN and TP impairment threshold values were calculated based on EPA procedures (USEPA 2000b) but utilized the median value (50$^{th}$ percentile) for each Level

III ecoregion in New Mexico (Table 3), rather than EPA's preferred 25th percentile. This was done because, given the large amount of public lands and generally rural landscape of New Mexico the use of the 25th percentile for setting an impairment threshold, while perhaps appropriate on a national level, was too conservative for New Mexico.

**Table 2.** EPA draft ecoregion nutrient impairment thresholds for streams (mg/L), calculated using the **25th percentile** and EPA procedures

| | Southern Rockies | AZ/NM Mountains | AZ/NM Plateau | Chihuahuan Desert | Southwest Tablelands |
|---|---|---|---|---|---|
| TN | 0.04 | 0.12 | 0.085 | 0.543 | 0.26 |
| TP | 0.006 | 0.011 | 0.015 | 0.018 | 0.025 |

**Table 3.** Revised ecoregion nutrient impairment thresholds for streams (mg/L), calculated using regional data, the **50th percentile** and EPA procedures

| | Southern Rockies | AZ/NM Mountains | AZ/NM Plateau | Chihuahuan Desert | Southwest Tablelands |
|---|---|---|---|---|---|
| TN | 0.30 | 0.32 | 0.42 | 0.64 | 0.54 |
| TP | 0.025 | 0.020 | 0.070 | 0.062 | 0.025 |

In 2007, a third round of analysis was conducted by SWQB to refine nutrient threshold values for streams based on the ecoregion *and* designated aquatic life use. For this round of analysis, nutrient data (TP, total Kjeldahl nitrogen, and nitrate plus nitrite) from the National Nutrient Dataset (1990-1997) were combined with Archival STORET data for 1998, and the SWQB nutrient dataset (1999-2006) resulting in almost 7,000 data points for each parameter.

Once the dataset was compiled, the data were divided by waterbody type, removing all rivers, reservoirs, lakes, wastewater treatment effluent, and playas. Level III and IV Ecoregions (Griffith, et al. 2006) were assigned to all stream sites using GIS coverages and the station's latitude and longitude. Aggregate aquatic life use (e.g., coldwater, warmwater, and transitional) were also assigned to all stream sites according to the designated use applied in New Mexico's water quality standards. Sites with "limited aquatic life" designations were removed from the dataset as they generally represent waters with ephemeral or intermittent flow, naturally occurring rapid environmental changes, high turbidity, fluctuating temperatures, low dissolved oxygen content or unique chemical characteristics. The 50th percentiles (i.e., medians) were calculated for TN and TP according to the ecoregion/aquatic life use group (Table 4). The refined threshold values were incorporated into the 2008 Nutrient Assessment Protocol for Wadeable, Perennial Streams.

**Table 4.** Nutrient impairment thresholds for streams (mg/L) based on ecoregion *and* aquatic life use, using regional data and the **50th percentile** (NMED/SWQB 2008).

| | Southern Rockies | | AZ/NM Mountains | | AZ/NM Plateau | | Chihuahuan Desert | Southwest Tablelands | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ***ALU*** | *CW* | *T/WW (volcanic)* | *CW* | *T/WW* | *CW* | *T/WW* | *T/WW* | *CW* | *T* | *WW* |
| TN | 0.25 | 0.25 | 0.25 | 0.29 | 0.28 | 0.48 | 0.53 | 0.25 | 0.38 | 0.45 |
| TP | 0.02 | 0.02 (0.05) | 0.02 | 0.05 | 0.04 | 0.09 | 0.04 | 0.02 | 0.03 | 0.03 |

ALU = aquatic life use
CW = coldwater aquatic life
T = transitional (both cold and warmwater aquatic life)
WW = warmwater aquatic life

Data will continue to be collected by SWQB/MAS and used to refine the threshold values for streams. In future analyses, New Mexico will utilize an effects-based approach, such as change-point analysis, that more closely links water quality thresholds with attainment of specific designated uses. Once the impairment threshold values have been thoroughly tested they may be proposed for adoption into the New Mexico Water Quality Standards.

### Lakes and Reservoirs

Similar to EPA's approach for deriving criteria, SWQB calculated percentiles for its initial analysis in 2009. This was followed by an effects-based approach using change-point and regression tree analyses on environmental and biological data to identify TP and TN thresholds that were correlated with common biological response variables such as chlorophyll-a, secchi depth, and percent cyanobacteria (Scott and Haggard, 2011). For the first round of analysis, nutrient data from Archival STORET (1989-1998) were combined with the SWQB nutrient dataset (1999-2007) resulting in 406 sample events from 107 sites on 78 lakes and reservoirs. This dataset includes the 25 lakes sampled by SWQB in 2006 and 2007 as part of the CWA 104(b)(3) Nutrient Criteria Development Phase 3 Grant designed to fill data gaps.

An *a priori* classification system, based on lake characteristics and designated uses, was used for the preliminary analysis. In this manner, thresholds would vary according to major differences in lake functionality. This system separated natural lakes from man-made reservoirs and then further divided the natural lakes into high-altitude lakes or sinkholes. The natural lakes dataset is very small, consisting of only 21 sample events from 17 lakes, thus limiting the types of statistical analysis that could be performed. A number of classification variables were considered for reservoirs including surface acreage, drainage basin size, maximum depth, elevation, ecoregion, and designated uses (e.g., domestic water supply, coldwater aquatic life, etc.).

Simple correlations were examined as a preliminary analysis of the relationship between cause and response variables (Table 5). In addition to the chemical and physical data, phytoplankton and diatom community composition data were compiled and the proportion of cyanobacteria (i.e., blue-green algae) was determined for each sample event with phytoplankton data. Cyanobacteria are a group of phytoplankton that generally represent a higher proportion of biomass under nutrient-rich conditions. The strongest correlations in the reservoir data were observed during the growing season between chlorophyll-*a*, total nitrogen, and percent cyanobacteria (dark grey cells in Table 5). Slightly weaker correlations were also observed for chlorophyll-*a*, percent cyanobacteria, total phosphorus, and water clarity as measured by secchi depth (light grey cells in Table 5). This suggests that a suite of indicators will be useful in determining impairment of New Mexico lakes and reservoirs including transparency (secchi depth), causal variables (TN and TP), and algal metrics (chlorophyll-*a* and percent cyanobacteria). Dissolved oxygen (DO) may also be used as a secondary or supporting indicator because, although the vertical DO gradient is strongly influenced by stratification, it also shows some response to nutrient concentrations and algal biomass.

**Table 5.** Correlations of cause and response variables in New Mexico's lakes and reservoirs

| | Secchi Depth | Spec. Cond. | Alka-linity | TSS | nL TKN | nL Nitrate Nitrite | nL TP | nL TN | Hard-ness | Chloro-phyll_a | % depth < DO criteria | Avg. DO of top 3m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TSS** | -0.160 | 0.495 | 0.104 | | | | | | | | | |
| **nL TKN** | -0.159 | 0.311 | 0.363 | 0.050 | | | | | | | | |
| **nL Nitrate Nitrite** | -0.222 | -0.107 | -0.219 | 0.0003 | -0.151 | | | | | | | |
| **nL TP** | -0.261 | 0.059 | 0.197 | 0.025 | 0.547 | -0.035 | | | | | | |
| **nL TN** | -0.191 | 0.304 | 0.340 | 0.057 | 0.988 | -0.018 | 0.563 | | | | | |
| **Hard-ness** | -0.154 | 0.931 | 0.145 | 0.335 | 0.226 | -0.112 | 0.030 | 0.214 | | | | |
| **Chloride** | -0.074 | 0.865 | 0.072 | 0.409 | 0.288 | -0.088 | 0.107 | 0.294 | 0.817 | | | |
| **Chloro-phyll_a** | **- 0.349** | -0.032 | 0.237 | 0.027 | 0.423 | -0.105 | **0.379** | **0.431** | -0.069 | | | |
| **% depth <DO criteria** | -0.070 | -0.247 | -0.146 | -0.117 | -0.294 | 0.101 | -0.101 | -0.264 | -0.145 | 0.120 | | |
| **Avg. DO of top 3m** | 0.073 | -0.064 | 0.090 | -0.076 | 0.151 | -0.072 | -0.012 | 0.131 | -0.100 | 0.028 | -0.495 | |
| **%Cyano-bacteria** | -0.151 | -0.111 | 0.3128 | -0.1867 | 0.494 | -0.181 | **0.415** | **0.493** | -0.124 | **0.446** | -0.014 | 0.303 |

In 2011, analysis of the lake nutrient dataset was conducted by Thad Scott and Brian Haggard from the University of Arkansas (Scott and Haggard, 2011). They used change-point and regression tree analyses on environmental and biological data from New Mexico lakes and reservoirs to identify TP and TN thresholds that were correlated with common biological response variables such as chlorophyll-*a concentration*, secchi depth, and percent cyanobacteria. Median TP and TN concentrations in New Mexico lakes and reservoirs were correlated with median secchi depth, median euphotic zone thickness, and median chlorophyll-*a* concentration (Figure 2 and Figure 3). In addition, TP or TN concentrations were always the best predictors of these biological response variables in all but one analysis. The thresholds reported from this study provide quantitative evidence for the link between nutrient concentrations and commonly measured biological response data in the state's lakes and reservoirs.

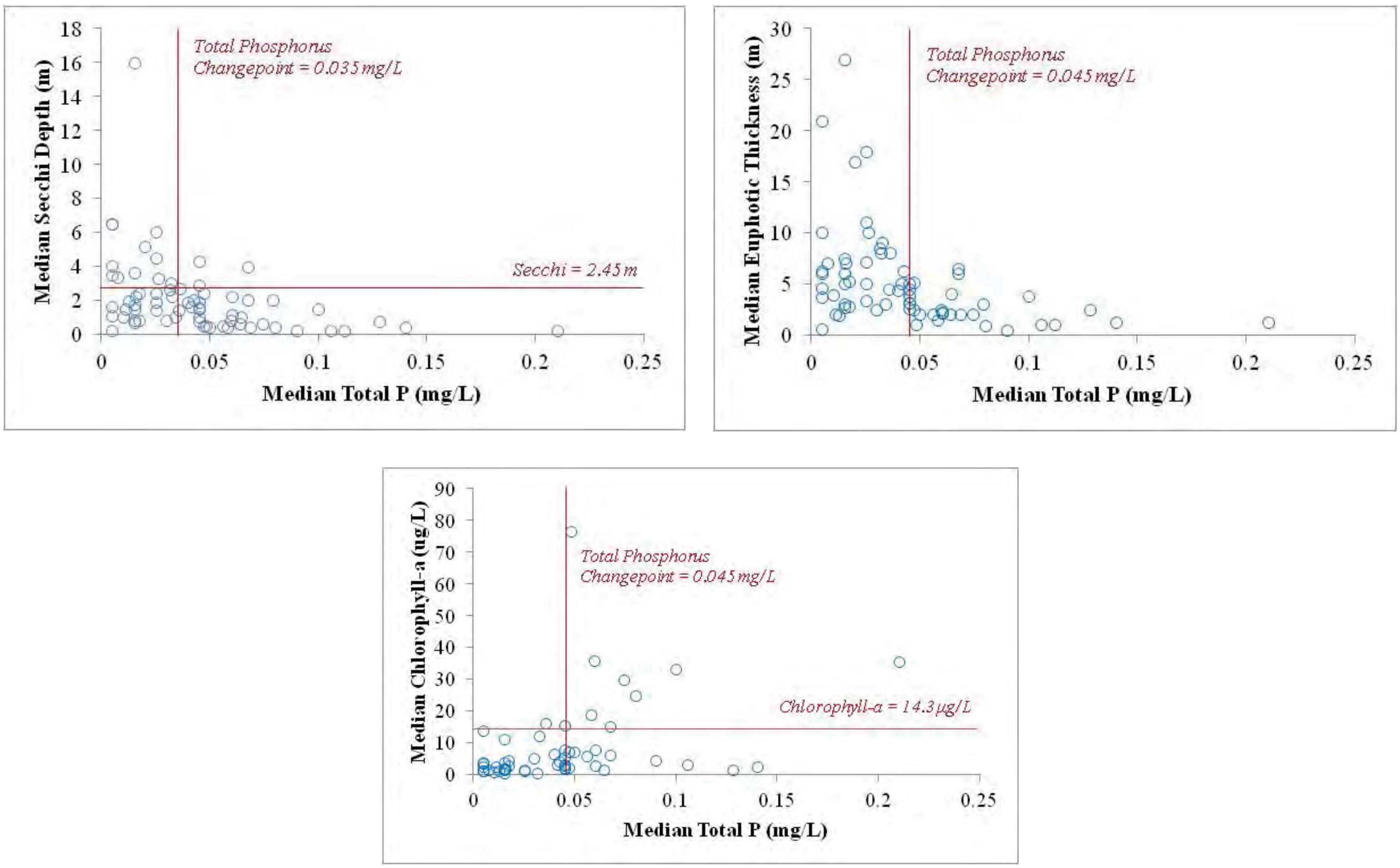


**Figure 2.** Results of change-point analysis on median TP values for all lakes and reservoirs (Scott and Haggard 2011)

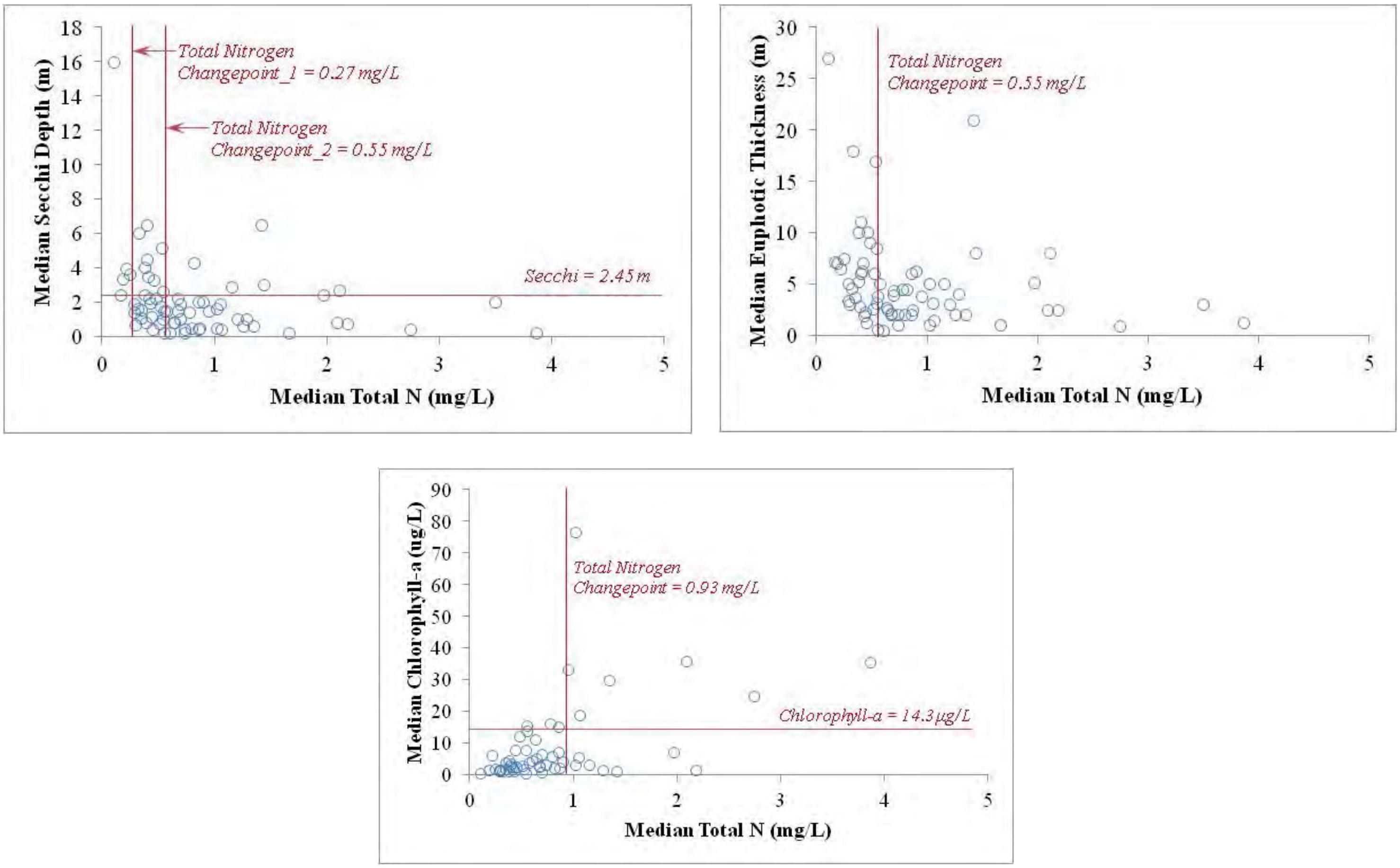


**Figure 3.** Results of change-point analysis on median TN values for all lakes and reservoirs (Scott and Haggard 2011)

SWQB developed a nutrient assessment protocol for lakes and reservoirs to be used for the 2014-2016 listing cycle. For lake and reservoir assessments, nutrient enrichment indicators are compared to impairment threshold values derived from water quality standards, analyses of SWQB data, and published literature. This assessment approach considers multiple lines of evidence to make a final impairment determination. The abundance of confounding factors and indirect and fluctuating nature of the relationships between these factors make the use of a single variable for assessment challenging. Because of this, a suite of indicators is used in a weight-of-evidence approach to provide a more comprehensive and defensible assessment. Lentic waterbodies are classified as either warmwater or coldwater or as a sinkhole lake, with each class having a threshold for the suite of nutrient enrichment indicators.

## Non-wadeable Rivers

For the preliminary analysis, SWQB has distinguished rivers from streams by defining systems that cannot be monitored effectively with the biological and habitat methods developed for wadeable streams. These rivers also generally meet the Simon and Lyons (1995) definition of great rivers as those having drainage areas greater than 2,300 square miles ($mi^2$). There are many systems in New Mexico that meet the great river definition but are suitable to wadeable streams monitoring methods due to the arid nature of the region. The systems included in the "rivers" waterbody type are:

1. The San Juan River from below Navajo Reservoir to the Colorado border near Four Corners;
2. The Rio Grande in New Mexico;
3. The Pecos River from below Sumner Reservoir to the Texas border;
4. The Rio Chama from below El Vado Reservoir to the Rio Grande;
5. The Gila River from below Mogollon Creek to the Arizona border near Virden, NM; and
6. The Canadian River from below the confluence with the Cimarron River to the Texas border.

The only river listed above that does not meet the great rivers definition is the Rio Chama, which has a drainage area of only 880 $mi^2$ below El Vado Reservoir. However, the flow of the Rio Chama is augmented with water diverted from the San Juan River drainage via the San Juan/Chama Project. The Rio Chama reaches a drainage area of 2,300 $mi^2$ below Abiquiu Reservoir.

Similar to EPA's approach for deriving nutrient criteria (Table 6), SWQB calculated percentiles for its initial analysis in 2009. Nutrient data from Archival STORET (1989-1998) were combined with river data from the SWQB water quality database (1999-2007). This dataset included the 43 river sites sampled by SWQB as part of the CWA 104(b)(3) Nutrient Criteria Development Phase 3 Grant designed to fill data gaps. USGS data from 25 river sites were also added to the dataset.

**Table 6.** EPA recommended river criteria for aggregate nutrient ecoregions in New Mexico

| Parameter | Western Forested Mountains | Xeric West | Great Plains Grass and Shrublands | South Central Cultivated Great Plains |
|---|---|---|---|---|
| TP (mg/L) | 0.010 | 0.022 | 0.023 | 0.067 |
| TN (mg/L) | 0.12 | 0.38 | 0.56 | 0.88 |

The special challenges of setting nutrient-related impairment thresholds and the unique conditions in New Mexico (i.e., limited number of rivers and associated data, as well as the highly altered flow regimes and salinity levels) have led SWQB to a different approach from other criteria derivation methods. Rather than deriving one set of targets to be applied to all rivers, SWQB investigated developing site-specific targets that vary according to the waterbody and, if the river crosses ecoregional boundaries, the ecoregion.

In addition to cause and response variables, waterbody classification variables were defined for each station. Classification variables included designated uses (e.g., coldwater aquatic life, warmwater aquatic life, domestic water supply), elevation, and ecoregion. The 25$^{th}$, 50$^{th}$, and 75$^{th}$

percentiles of various nutrient-related parameters were calculated (Table 7) for each river system. SWQB's preliminary analysis suggests that a suite of indicators will be useful in determining impairment of New Mexico rivers including both causal (TP and TN) and response variables (diel DO fluctuation and chlorophyll-*a*).

**Table 7.** Percentiles of nutrient-related indicators for New Mexico's rivers

| | Total Phosphorus (mg/L) | | | Total Kjehldal N (mg/L) | | | Nitrate + Nitrite (mg/L) | | | Diel DO Fluctuation (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***percentiles*** | ***25$^{th}$*** | ***50$^{th}$*** | ***75$^{th}$*** | ***25$^{th}$*** | ***50$^{th}$*** | ***75$^{th}$*** | ***25$^{th}$*** | ***50$^{th}$*** | ***75$^{th}$*** | ***25$^{th}$*** | ***50$^{th}$*** | ***75$^{th}$*** |
| **Canadian River** | 0.015 | 0.030 | 0.052 | 0.300 | 0.400 | 0.658 | 0.025 | 0.050 | 0.085 | 0.875 | 1.42 | 1.65 |
| **Gila River** | 0.040 | 0.070 | 0.140 | 0.195 | 0.310 | 0.560 | 0.128 | 0.255 | 0.466 | ND | ND | ND |
| **Pecos River** (Salt Crk to Sumner Rsv) | 0.010 | 0.020 | 0.070 | 0.160 | 0.260 | 0.353 | 0.025 | 0.025 | 0.100 | 1.39 | 1.47 | 1.71 |
| **Pecos River** (TX border to Salt Crk) | 0.015 | 0.040 | 0.090 | 0.480 | 0.700 | 1.00 | 0.050 | 0.180 | 0.600 | ND | ND | ND |
| **Rio Chama** (Rio Grande to El Vado ) | 0.024 | 0.060 | 0.100 | 0.200 | 0.300 | 0.400 | 0.025 | 0.050 | 0.050 | 0.850 | 1.13 | 1.26 |
| **Rio Grande** (Hwy 528 in ABQ to CO) | 0.040 | 0.090 | 0.230 | 0.300 | 0.440 | 0.710 | 0.050 | 0.110 | 0.280 | 0.835 | 1.22 | 2.22 |
| **Rio Grande** (TX to Hwy 528 in ABQ) | 0.090 | 0.200 | 0.320 | 0.470 | 0.660 | 0.930 | 0.130 | 0.300 | 0.720 | 0.998 | 1.18 | 1.70 |
| **San Juan River** | 0.030 | 0.093 | 0.280 | 0.200 | 0.320 | 0.560 | 0.050 | 0.150 | 0.260 | 1.73 | 1.87 | 1.99 |

NOTE: N = nitrogen DO = dissolved oxygen ND = no data

In 2011, Thad Scott and Brian Haggard from the University of Arkansas used change-point and regression tree analyses on environmental and biological data from New Mexico rivers to identify TP and TN thresholds that were correlated with common biological response variables (Scott and Haggard 2011). The high variability and small size of the dataset, produced a less robust analysis. However, TP and TN concentrations were correlated with benthic chlorophyll-*a* (Figure 4) and the Trophic Diatom Index across all New Mexico rivers. TP concentrations were always the best predictors of these biological response variables. TN concentrations were also useful in predicting biological responses, but these relationships were much weaker than TP and other environmental variables such as temperature, dissolved oxygen, and turbidity were actually stronger predictors in the Categorical and Regression Tree (CART) model. The thresholds identified in this analysis are similar to others published in the scientific literature (Scott and Haggard 2011). These results provide a quantitative framework that link specific nutrient concentrations to biological outcomes in New Mexico rivers, and may be used as guidance in setting nutrient impairment thresholds in non-wadeable rivers of New Mexico.

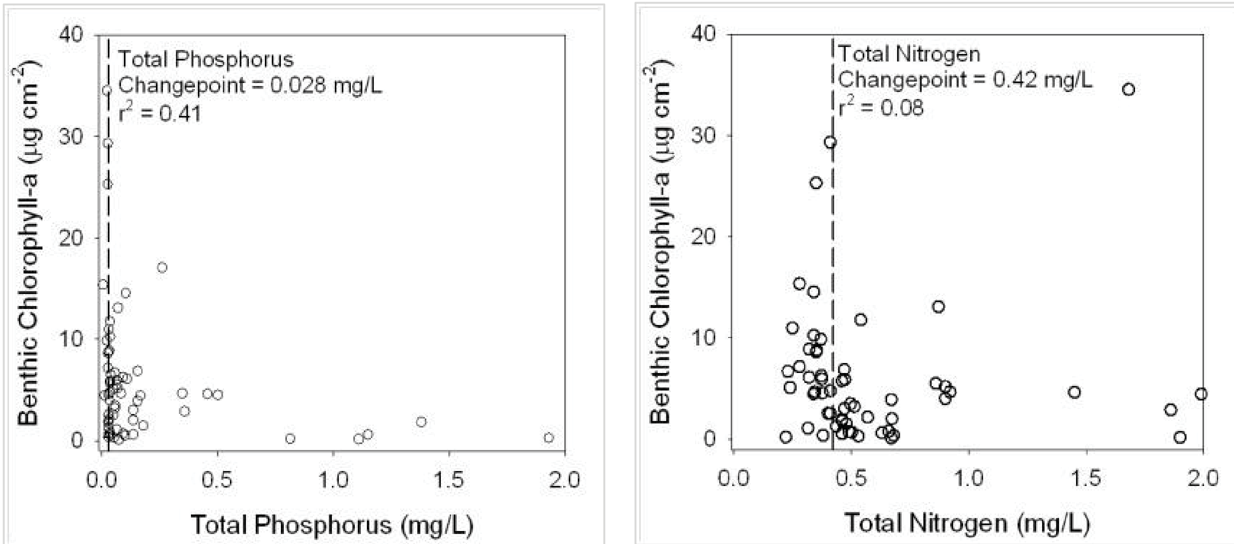


**Figure 4.** Results of change-point analysis on TP/TN and benthic chlorophyll-a using data from all non-wadeable rivers in New Mexico (Scott and Haggard 2011)

SWQB is in the process of developing a nutrient assessment protocol for rivers, but is awaiting further data collection and analyses. Due to the relatively small amount of data in the analysis (n = 67 samples that had nutrient and benthic chlorophyll-a data), the thresholds derived from the change-point and regression tree analyses will be compared to percentiles and literature-derived values to determine a final threshold value or range of values for each nutrient enrichment indicator for use in a weight-of-evidence approach to nutrient assessments of rivers.

### Wetlands

SWQB began collecting wetlands data in 2011, so the process of compiling data has just begun. It will likely take a number of years (possibly up to a decade) to assemble a dataset sufficient to address nutrient assessment and reduction in this waterbody type.

## *Proposal and Adoption of Numeric Nutrient Criteria in WQS (Activity #4 and #5)*

Data will continue to be collected by SWQB and used to develop and/or refine the nutrient threshold values, as described above, for each applicable waterbody type in New Mexico. Threshold values for nutrient variables are, and will be, used as numeric translators of the narrative standard and incorporated into the weight-of-evidence nutrient assessment protocol. After the threshold values have been thoroughly tested and refined, and depending on the approach that is currently being pursued by other states and accepted by EPA at that time, they may be proposed for adoption into the New Mexico WQS. If adoption of nutrient criteria is undertaken in the future it may follow the approach of states such as Maine and Ohio (MDEP 2012; OEPA 2011) in which both cause and response variables are incorporated into proposed criteria and/or weighted to calculate a Nutrient Water Quality Index.

The NM Water Quality Control Commission (WQCC) must approve proposed criteria before they can be incorporated into *State of New Mexico Standards for Interstate and Intrastate Surface Waters* (20.6.4 NMAC). A public review and comment period and a public hearing are required. Upon completion of the public review process, if substantive changes are not required, the WQCC can approve the final proposal, accepting the final rule for state purposes. This whole process typically takes six to twelve months. After the revised WQS are published through the state records office, they are sent to EPA Region 6 for review and approval. At the present time, New Mexico is not pursuing adoption of numeric nutrient criteria into the State's WQS.

## 4.0 Schedule for Nutrient Criteria Development in New Mexico

Nutrient threshold development is an iterative process and will require future data collection and analysis to evaluate impairment thresholds and attainment of designated uses. A general timeline for Activities #1-5 outlined in this document is listed in Table 8. This schedule will be reviewed and adjusted annually, as necessary, with input from EPA. If there is a need to deviate from the plan, EPA will be notified.

**Table 8.** General timeline for nutrient criteria development of different waterbody types in New Mexico.

| Milestone | Rivers and Streams | | Lakes and Reservoirs | | Wetlands | |
|---|---|---|---|---|---|---|
| | TP | TN | TP | TN | TP | TN |
| Planning for nutrient criteria development | *Nutrient Criteria Development Plan* for all waterbody types first drafted in **2004**. Revised in **2005**, **2006**, and **2008**. The *Nutrient Criteria Development Plan* was used, in part, in **2012** for the *State of New Mexico Nutrient Reduction Strategy* (this plan). **Revisit/Revise as needed every 1-2 years.** | | | | | |
| Collection of information and data | Data collection is **on-going**; initiated in **2004** with support from three CWA §104(b)(3) grants.<br>*Historical and current datasets were combined in **2007** and **2012** for streams; **2009** for rivers* | | *Historical and current datasets combined in **2009** for lakes/reservoirs.* | | Data collection for wetlands started in **2011** in the Upper Rio Grande; Upper Canadian Watershed is planned in **2013**; Data collection is **on-going** | |
| Analysis of information and data | Streams = **2004** and **2007**; Rivers = **2011**. Further analysis and refinement of thresholds is planned for **2013-2014**. | | Lakes = **2009** and **2011**. Further analysis and refinement of thresholds is planned for **2013-2014**. | | It is a goal of the SWQB to complete all elements required for a monitoring and assessment program for wetlands by **2016**. | |
| Proposal of numeric nutrient criteria | No date planned | No date planned | No date planned | No date planned | No date planned | No date planned |
| Adoption of numeric nutrient criteria (EPA-Approved) | No date planned | No date planned | No date planned | No date planned | No date planned | No date planned |

**TN:** Total Nitrogen; **TP:** Total Phosphorus

## 5.0 New Mexico's Nutrient Assessment

New Mexico's narrative nutrient criterion has been successfully applied using a weight-of-evidence assessment protocol. According to Dodds and Welch (2000), it is important to incorporate response variables into the assessment because ambient water column nutrient concentrations alone "…cannot indicate supply because large biomass of primary producers may have a very high nutrient demand and render inorganic nutrient concentrations low or below detection." Therefore, SWQB uses a weight-of-evidence approach to conduct a more comprehensive assessment and to account for diverse systems and dynamic nutrient cycling. In this approach, both cause (TN and TP) and response variables (e.g., DO, pH, chlorophyll-a, etc.) are evaluated to determine impairment.

If a stream reach is determined to be impaired based on the nutrient assessment protocol, Total Maximum Daily Loads (TMDLs) are generally scheduled. If there are NPDES permittees discharging into the impaired receiving water, the TMDL will generally be written to address both TN and TP because many receiving streams in New Mexico are generally co-limiting, meaning that overall loads of both TN and TP must be reduced to adequately address nutrient impairment. If SWQB has evidence that only one nutrient is causing the impairment, the TMDL will focus on that particular nutrient.

### *Wadeable, perennial streams (actively used since 2004)*

The first nutrient assessment protocol for streams was developed in 2002. This protocol was applied and used to develop 100% non-point source TMDLs; however it lacked impairment thresholds and quantifiable endpoints necessary to develop TMDLs for waters with both point and non-point sources. In a series of analyses between 2002 and 2011 SWQB developed and refined an assessment approach for these waters.

A two-tiered approach to nutrient assessment is utilized for streams because of the large number of stream segments in New Mexico and the need to prioritize data collection efforts and resources. The two levels of assessment are used in sequential order to determine if there is excessive nutrient enrichment. The Level I assessment is a screening level assessment that is more qualitative and based on a review of available data, including on-site qualitative observations (e.g., percent algal cover) and in-stream quantitative measurements (e.g., TN and TP concentrations). If a Level I assessment indicates potential nutrient enrichment, a Level II assessment is used to provide a quantitative evaluation. The Level II assessment is based on measurements exceeding both numeric nutrient threshold value(s) and one or more indicators of excessive primary production (e.g., large dissolved oxygen (DO) fluctuation, high chlorophyll-a concentration) that demonstrate an unhealthy biological community (Figure 5 and Figure 6). The reach is considered to be impaired if both occur, meaning both causal and response variables indicate impairment due to excessive plant nutrients.

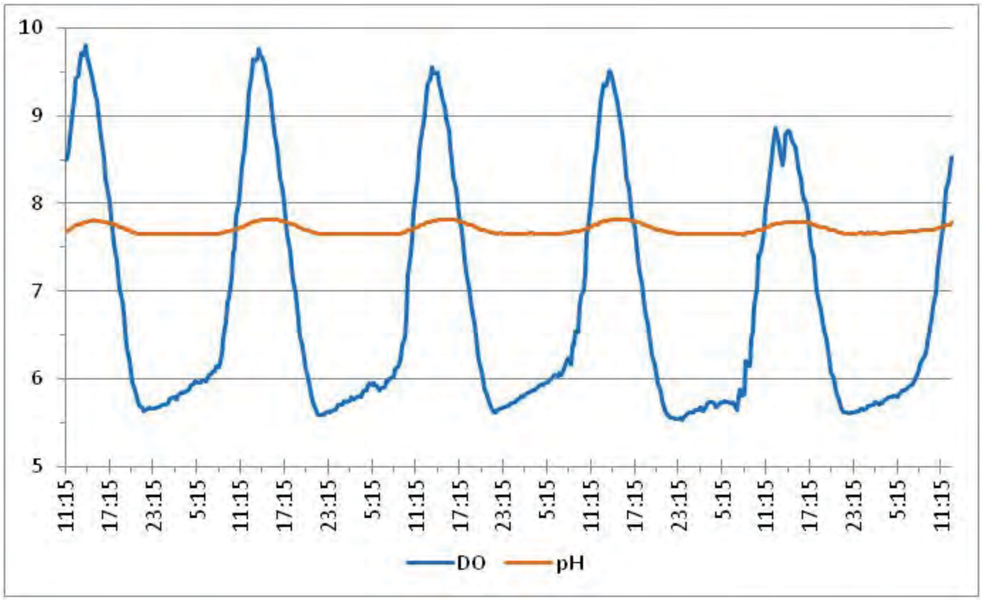


**Figure 5.** Nutrient influenced diel fluctuation in dissolved oxygen in La Plata River at La Plata, NM (September 16 – 21, 2010)

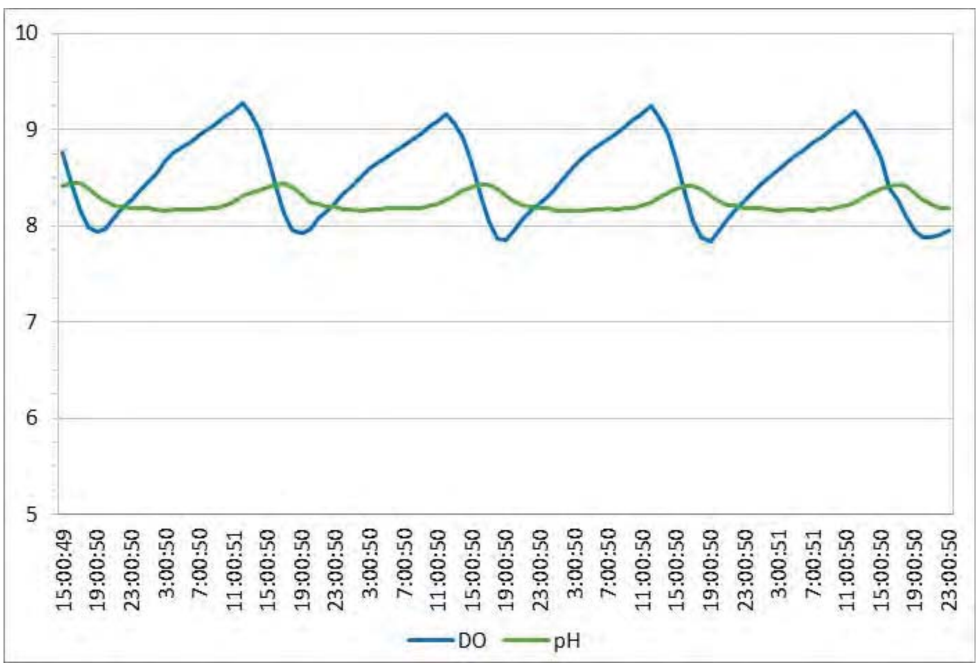


**Figure 6.** "Normal" diel fluctuation in dissolved oxygen and pH in Turkey Creek at Wilderness Boundary Forest Trail 155 (October 20 – 24, 2011)

Level I nutrient surveys are conducted at each water quality station to collect the data required for a preliminary screening; however, if a stream reach was previously listed as impaired for nutrients, a Level II nutrient survey must be performed to collect the data required for a full nutrient assessment. Both the preliminary and full assessments use a weight-of-evidence approach to evaluate various conditions in the stream and utilize both stressor (nitrogen and phosphorus) and response (DO, pH, algal biomass) variables in order to conduct a more comprehensive assessment and account for diverse lotic systems and dynamic nutrient cycling. The following indicators are collected during the nutrient surveys and used for assessment:

Level I Nutrient Survey Observations

- Percent algae coverage
- Periphyton growth (thickness)
- Presence of anoxic layer

Level I Nutrient Survey Measurements

- Dissolved oxygen (% saturation) and pH
- TN and TP concentrations

Level II Nutrient Survey Measurements

- 72 hour continuous dissolved oxygen and pH datasets (sonde data)
- TN and TP concentrations
- Periphyton chlorophyll-a concentration ($\mu g/cm^2$)

Dissolved oxygen and pH criteria are based on designated uses of an assessment unit, as indicated in section 20.6.4.900 of the *State of New Mexico Standards for Interstate and Intrastate Surface Waters* (NMWQCC 2011). TN and TP thresholds are based on New Mexico's nutrient criteria development process as discussed in the *Analysis of Information and Data* section above.

For chlorophyll-a, the 90$^{th}$ to 99$^{th}$ percentile of data from best available sites was used to calculate impairment thresholds for each ecoregion (Table 9).

**Table 9. Chlorophyll-a Level III Ecoregional Threshold Values in $\mu g/cm^2$**

| 21-Southern Rockies | 20/22-AZ/NM Plateau | 23-AZ/NM Mountains | 24/79-Chihuahuan Desert | 25/26-SW Tablelands |
|---|---|---|---|---|
| 3.9 – 5.5 | 7.4 – 7.8 | 5.8 – 11.0 | 16.5 – 17.5 | 8.2 – 14.0 |

**Note:** Since the number of samples used to calculate the thresholds is relatively small for each ecoregion, the 90$^{th}$ to 99$^{th}$ percentile range is used for threshold values.

For most streams, indicators are compared to thresholds values derived from water quality standards, SWQB analyses, or published literature. However, if the assessor determines that the established thresholds are not appropriate for the class of stream being assessed, a reference reach approach may be used. A suitable reference reach will be surveyed and indicators from the study reach will be compared to those of the assessed reach, rather than the established thresholds. This approach accounts for streams that may have naturally high productivity because of regional geology, flow regime, or other natural causes. For more information on the assessment process, please refer to *Nutrient Assessment Protocol for Wadeable Perennial Streams* (NMED/SWQB 2013a).

### *Lakes and Reservoirs (implemented for the 2014-2016 listing cycle)*

Similar to the stream assessment, the assessment approach for lakes and reservoirs considers a suite of indicators, including both stressor (TN and TP) and response (DO, Secchi depth, chlorophyll-a, and % cyanobacteria) variables, to provide a more comprehensive and defensible assessment and make a final impairment determination. Assessments are conducted on data collected at the station located in the deepest portion of the waterbody. Currently, the indicators are divided into four groups: nutrient concentrations (TP and TN); transparency (Secchi depth); phytoplankton (phytoplankton chlorophyll-a and percent cyanobacteria); and dissolved oxygen. Nutrient enrichment indicators are compared to impairment threshold values derived from water quality standards, SWQB analyses, or published literature. A lake is determined to be not supporting due to nutrient impairment if at least one stressor and one response indicator violates their respective threshold value or if chlorophyll-a and another response variable (Secchi depth, percent cyanobacteria, or dissolved oxygen) indicate enrichment. This second scenario is to account for situations in which the lake is receiving a considerable nutrient load, but the nutrients are quickly being assimilated into the biomass of the lake, hence low nutrient concentrations but undesirable effects. For more information on the assessment process, please refer to *Nutrient Assessment Protocol for Lakes and Reservoirs* (NMED/SWQB 2013b).

### *Non-wadeable Rivers (in development)*

Similar to the other nutrient assessments, nutrient assessments for large, non-wadeable rivers will use a weight-of-evidence approach that evaluates various conditions and utilizes both stressor (nitrogen and phosphorus) and response (DO, algal biomass) variables in order to conduct a more comprehensive and defensible assessment and account for diverse lotic systems and dynamic nutrient cycling. Currently, the indicators are divided into three groups: nutrient concentrations (TP and TN); dissolved oxygen (DO flux, DO concentration, and DO saturation); and algal biomass (benthic chlorophyll-a and percent algal cover). Data are being collected and analyzed to determine if a diatom nutrient index is correlated to nutrient impairment in New Mexico rivers. If the diatom community shifts significantly in response to nutrient enrichment, the Trophic Diatom Index will be added as an indicator in the weight-of-evidence assessment. Once the threshold values for the various indicators have been validated, a river will be determined to be not supporting due to nutrient impairment if both stressor and response indicators exceed their respective threshold value.

### *Wetlands (not started)*

SWQB recently began a wetlands program, so the process of collecting wetlands data has just begun. It will likely take a number of years (possibly up to a decade) to compile a dataset sufficient to develop nutrient impairment thresholds for assessment purposes.

## 6.0 Nutrient TMDL Development

*Every calculation based on experience elsewhere, fails in New Mexico* —
Lew Wallace, Territorial Governor of NM, 1881

Numeric nutrient thresholds are necessary to establish targets for TMDLs and allocate load and waste load allocations for nonpoint and point sources, to develop water quality-based permit limits and source control plans, and to support designated uses within the watershed.

If a waterbody is determined to be impaired based on the nutrient assessment protocol, TMDL development must be scheduled. The task of developing quantitative load models to implement the narrative water quality standard is not straightforward for obvious reasons. The State, in order to meet legal mandates, has to conduct TMDL development for nutrients on the basis of best information available at the time (Table 10). This has been done with EPA's encouragement and approval, typically by using the quantitative, ecoregion-based, threshold values developed by NMED for the causal variables (TN and TP) as TMDL targets. The intent of TMDL targets for phosphorus and nitrogen is to control undesirable aquatic life, such as the excessive growth of attached algae and higher aquatic plants, which can result from the introduction of these plant nutrients into streams. This goal is codified into the water quality standards [NMAC 20.6.4.13(E)] and serves to protect the existing and attainable uses of surface waters of the state.

In developing TMDLs, especially those involving a waste load allocation, determination of the limiting nutrient(s) should continue to be considered. Nitrogen and phosphorus are often "co-limiting" in New Mexico's wadeable streams and thus both pollutants ultimately require regulation to prevent impairment. If a single nutrient can be definitively established as "limiting," regulation of that single nutrient can be considered; however, great caution must be exercised to ensure that addressing only one nutrient (e.g., TP or TN) will not set off secondary problems such as a shift in algae community composition that leads to a dominance of blue-green algae.

**Table 10.** Nutrient TMDL development and waste load allocations in New Mexico

| Year | Waterbodies with Nutrient TMDLs *(waterbodies in BOLD have a Waste Load Allocation – WLA)* | NPDES Nutrient Effluent Limits | Phased Implementation | TMDL Implementation Options | # of Nutrient TMDLs |
|---|---|---|---|---|---|
| 2002 | Mangas Creek, Centerfire Creek, Canyon Creek, San Francisco River | none | - | - | 4 |
| 2005 | **Rio Hondo (Taos Ski Valley)** | **Yes** | no | none | 1 |
| 2005 | **Lower Animas River** | **Yes** | no | none | 1 |
| 2006 | **Rio Ruidoso** | **Yes** | no | none | 1 |

| Year | Waterbodies with Nutrient TMDLs *(waterbodies in BOLD have a Waste Load Allocation – WLA)* | NPDES Nutrient Effluent Limits | Phased Implementation | TMDL Implementation Options | # of Nutrient TMDLs |
|---|---|---|---|---|---|
| 2007 | **Rio Puerco**, Rio Moquino, Bluewater Creek (x2) | **Yes** | no | Seasonal limits; Zero discharge; Meet WLA | 4 |
| 2007 | **Mora River**, Little Coyote Creek | **Yes** | no | Meet WLA; Cluster systems | 2 |
| 2009 | **Jemez River**, Rio de las Vacas, Rito Penas Negras | **Yes** | no | none | 3 |
| 2009 | Oak Creek | none | - | - | 1 |
| 2010 | **Cienguilla Creek**, **Cimarron River** (x2), Moreno Creek, Ponil Creek, Rayado Creek, Sixmile Creek | ***Anticipated*** | **Yes** | none | 7 |
| 2011 | **Rio Chamita**, **Rio Chama** (x2), Rio Tusas | **Yes** | **Yes** | Seasonal limits | 4 |
| 2011 | Middle Ponil Creek | none | - | - | 1 |
| 2011 | **Pajarito Creek**, Canadian River, Una de Gato Creek (x2) | ***Anticipated*** | **Yes** | Year-round Phase 1 limits; Zero discharge, 100% reuse; Seasonal limits | 4 |

## 7.0 Implementing Nutrient Reduction and Control Strategies

Much of the work that has been done nationally on excessive nutrients is focused on issues in huge watersheds, such as the Susquehanna and Mississippi Rivers, to address impairments in the Chesapeake Bay and the Gulf of Mexico. These nutrient reduction strategies focus on the cumulative impacts that manifest as impairments far downstream from the actual point of discharge. In contrast, the nutrient impairments in New Mexico are typically because most streams and rivers are small with little downstream dilution (in fact stream flows typically decrease after a streams leaves the mountain front). Because of this the point of impact is most likely immediately downstream of the nutrient source. The closest problem that New Mexico has to the cumulative impact of a huge watershed to a large body of water is the potential nutrient concerns at Elephant Butte Reservoir, as manifested by anoxic bottom waters and toxic algae blooms.

The nature of nutrient impairments in New Mexico is important to consider when evaluating the cost/benefit values of nutrient reduction strategies – especially those implemented through the NPDES permitting program. A small wastewater treatment plant (WWTP) (< 1.0 mgd) in a very large system (e.g., Chesapeake Bay) has different relative impacts to the aquatic ecosystem than the same size or smaller plant that is discharging to a smaller stream. Nutrient impairment thresholds, discussed previously, are typically used as the in-stream target concentrations to calculate TMDLs for an impaired stream. Thus, the waste load allocation (WLA) in the TMDL for effluent dominated receiving waters often necessitate significant reductions in nutrient loading in NPDES permits. As a result, facility upgrades are almost always required for meeting nutrient effluent limits, however, the necessary technology is often expensive or the discharge limits exceed the limits of technology.

New Mexico does not have NPDES primacy and thus cannot control or set how the TMDL and NPDES permit will be implemented. In recognition of the challenge outlined above, the state, through the TMDL development process, actively works with EPA to draft appropriate and achievable strategies for implementation. Further, the funding for such process upgrades remains a challenge for small communities and has resulted in a variety of implementation discussions and options, such as phased implementation, longer compliance schedules, and seasonal effluent limits, where appropriate. Recent nutrient TMDLs have employed a “phased implementation” approach with interim effluent limits based on limits of current and affordable technology. This approach is an iterative process that will require future data collection and analysis to determine and evaluate the effectiveness of the load reductions achieved using interim effluent limits. SWQB will continue to monitor and assess the water quality conditions in the watershed and the impact of the interim permit limits after implementation. To date, in nutrient TMDLs with waste load allocations, the State has recommended, and EPA Region 6 has assigned, permit effluent limits based on the limits of technology, although this is not always the case.

Recently, SWQB has been working with EPA and the New Mexico Municipal League to develop a formal approach for implementation of nutrient TMDL waste load allocations for point source discharges that is scientifically based, environmentally protective, and considers the existing facility design, facility age, as well as local economic factors. The requirements of this alternative approach will apply only to stream segments that include NPDES permitted discharges where nutrient impairment has been identified and a TMDL will be or has been developed. Although not all of the details have been resolved and finalized, this approach is based on the idea of using interim nutrient effluent limits in NPDES permits that are both economically affordable and achieve substantial nutrient reductions in New Mexico surface waters, while also allowing for innovations in nutrient removal technologies to meet surface water quality standards in the future. This approach is currently being drafted and refined and is anticipated to be proposed by SWQB as an amendment to the state’s Water Quality Management Plan (WQMP).

Nonpoint source nutrient reduction strategies may be incorporated and included in Watershed-based Plans based on the pollutant, source, and landowner/stakeholder cooperation and interest, although implementation is currently on a voluntary basis.

# 8.0 Requirements for Additional Data Collection

Additional data will be collected to classify sites, develop and refine thresholds by linking them to impairment, identify data gaps, and re-evaluate water quality conditions after implementation of nutrient control measures.

### *Physical, Chemical, and Biological Measurement Variables*

**Rivers/Streams:** Physicochemical parameters, TP, TN, chlorophyll-a, periphyton (rivers only*) and benthic macroinvertebrates will be concurrently monitored. Whenever possible this will include a multiple-day deployment of multi-parameter sondes set to take at least hourly readings to examine diel fluctuations in DO and pH. Classification variables such as ecoregion, stream order, geology, and aquatic life use will also be refined and re-examined. Future data analyses will utilize an effects-based approach, such as change-point and/or regression tree analysis, that more closely links water quality targets with attainment of specific designated uses.

**Lakes, Reservoirs and Wetlands**: Soluble Reactive Phosphate (SRP) is thought by some to be more critical than TP because TP is tied to sediment and not biologically available. However, knowledge about rates of uptake processes is often needed to make SRP data meaningful and TP is used in Carlson Trophic State Index. TP, TN, chlorophyll-a, phytoplankton, Secchi depth, and depth profiles of physicochemical parameters will be concurrently monitored. Classification variables such as ecoregion, reservoir size, and elevation will also be refined and re-examined.

## 9.0 Other Considerations

### *Stakeholder Input and Public Participation*

An opportunity for public review is required as part of SWQB's various processes. The following is a list of areas where stakeholder input and public participation is sought:

1. ***Assessment Protocols*** – Prior to development of the Integrated List (see #2), SWQB solicits public comment on the draft *Procedures for Assessing Water Quality Standards Attainment for the State of New Mexico CWA §303(d)/§305(b) Integrated Report* (also known as the "Assessment Protocols") generally spring of every odd-numbered year. The Assessment Protocols document how the SWQB evaluates existing and readily available surface water quality data and other information to determine whether or not surface water quality standards are attained.

2. ***The biennial State of New Mexico CWA §303(d)/§305(b) Integrated List of Assessed Surface Waters (Integrated List)*** – The Integrated List identifies whether or not a particular surface water of the state is currently meeting its designated uses as detailed in the State of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC), through application of the Assessment Protocols. "Category 5" waters on the

* In 2007, SWQB contracted with the Academy of Natural Sciences in Philadelphia to analyze paired water quality and diatom data from New Mexico's wadeable, perennial streams with the end goal being to develop periphyton-based indicators of nutrient enrichment. A major conclusion from the analysis was that there is a great diversity of environmental conditions resulting in considerable variation in diatom assemblages in NM stream systems. There were no clear clusters or groupings of sites that would suggest a strong association of assemblage composition with ecoregion. Additionally, neither phosphorus nor nitrogen concentration explained a substantial amount of variation in species assemblage composition mainly due to the large variation in environmental conditions (i.e., "noise"). Based on these findings, SWQB decided to pursue the possibility of using benthic macroinvertebrate communities instead of diatom assemblages as indicators of nutrient enrichment in wadeable, perennial streams; however SWQB is continuing to collect periphyton in rivers because diatoms may still prove to be useful indicators of nutrient enrichment in these systems given the site-specific approach NM is taking with respect to non-wadeable rivers.

Integrated List specifically constitute the CWA §303(d) List of Impaired Waters. SWQB solicits comment on the draft Integrated List and Report generally during the winter of every odd-numbered year.

3. ***Total Maximum Daily Loads (TMDLs)*** – A TMDL is a planning document that establishes specific goals designed to meet water quality standards in water bodies where pollutant limits are exceeded (i.e., "Category 5" waters). They include current pollution loadings, reduction estimates for pollutants, information on probable sources of pollution, and suggestions to restore or protect the health of the waterbody. SWQB solicits public comment on draft TMDLs, including via a public meeting in the watershed, prior to finalization for WQCC approval.

4. ***Certification of NPDES Permits*** – The National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. Industrial, municipal, and other facilities must obtain an NPDES permit if their discharges go directly to surface waters. The NPDES permit program in New Mexico is administered by EPA Region 6; however the Clean Water Act requires "state certification" of permits issued by a federal agency under the Act. The purpose of state certification is to reasonably ensure that the permitted activities will be conducted in a manner that will comply with applicable water quality standards, including the antidegradation policy, and the statewide water quality management plan. The New Mexico Water Quality Act assigns the responsibility of State certification to the Environment Department.

Following the close of the public comment period for assessment protocols, the Integrated List, and TMDLs, the SWQB typically prepares the final draft document as amended and a response to comments. In the case of Assessment Protocols, the final document is reviewed by EPA Region 6 and used to draft the Integrated List. In the case of the Integrated List and TMDLs, the final draft document is presented to the NM Water Quality Control Commission (WQCC) for review and approval. The final draft document and response to comments are available to the public ten (10) days prior to the regularly scheduled WQCC meeting. The final document, as approved by the WQCC, is then submitted to the EPA Region 6 for approval. In the case of point source discharge permits, SWQB accepts written comments regarding the draft permit during the public comment period and considers all comments timely received in its preparation of the State Certification or Denial.

## RTAG Coordination

The SWQB has and will continue to participate in EPA's Regional Technical Assistance Group (RTAG). EPA's Region 6 office serves Arkansas, Louisiana, New Mexico, Oklahoma, Texas, and 66 Tribal Nations. RTAG meetings are held annually at EPA's regional headquarters in Dallas to bring together nutrient experts from federal, state, and tribal agencies. Recent efforts toward the development of numeric nutrient criteria, as well as the latest technical information available, is reviewed and discussed. New Mexico will continue to ask RTAG members to review and comment on any new or refined threshold values and monitoring and assessment protocols.

### *Scientific Review*

New Mexico is fortunate to have a scientific community actively involved in various aspects of nutrient ecology. SWQB plans to make significant use of that expertise to review future nutrient threshold development efforts.

### *Other Issues*

The most critical item to consider is availability of resources for monitoring, lab analysis, and data analysis. Only a small portion of this plan may be implemented without continued or additional funding from EPA.

As documented above, New Mexico has been addressing nutrient impairments through the weight-of-evidence assessment of our narrative nutrient criterion, evaluation and determination of nitrogen and phosphorous target concentrations used to develop TMDLs for impaired water bodies, and implementation of TMDL targets through the NPDES permitting process and Watershed-based Plans. SWQB continues to believe that EPA should provide flexibility to states by allowing nutrient impairments to be addressed through effective programs that are within the state's financial and resource capabilities. This is especially necessary in a state such as New Mexico that receives the minimum allocation of Section 106 monies.

## References


Barnard, James L., *Biological Nutrient Removal: Where we have been, where we are going.* Water Environment Federation, 2006. Page 20

Chetelat, J., F. R. Pick, and A. Morin. 1999. *Periphyton biomass and community composition in rivers of different nutrient status*. Can. J. Fish Aquat. Sci. 56(4): 560-569.

Dodds, W. K., V. H. Smith, and B. Zander. 1997. *Developing nutrient targets to control benthic chlorophyll levels in streams: A case study of the Clark Fork River*. Water Res. 31: 1738-1750.

Dodds, W. K. and E. B. Welch. 2000. *Establishing nutrient criteria in streams*. J. N. Am. Benthol. Soc. 19: 186-196.

Jeyanayagam, Sam, *True confessions of the Biological Nutrient Removal Process.* Florida Water Resources Journal, January 2005. Page 41

Graneli, E. and N. Johansson. 2001. *Nitrogen or phosphorus deficiency increases allelopathy in Prymnesium parvum*. In: Harmful Algal Blooms 2000, Hallegraeff, G.M., Blackburn, S.I., Bolch, C.J. and Lewis, R.J., (ed). Intergov. Oceanografic Commission of UNESCO, pp. 328-331.

———. 2003a. *Effects of the toxic haptophyte Prymnesium parvum on the survival and feeding of a ciliate: the influence of different nutrient conditions*. Mar. Ecol. Prog. Ser., 254: 49-56.

———. 2003b. *Increase in the production of allelopathic substances by Prymnesium parvum cells grown under N- or P- deficient conditions*. Harmful Algae, 2: 135-145.

Griffith. G.E., J.M. Omernik, M.M McGraw, G.Z. Jacobi, C.M. Canavan, T.S. Schrader, D. Mercer, R. Hill, and B.C. Moran. 2006. *Ecoregions of New Mexico* (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,400,000).

Johansson, N. 2000. *Ecological implications of the production of toxic substances by fish killing phytoplankton species grown under variable N:P ratios*. Department of Ecology, Marine Ecology, Lund University, Sweden, Lund - Dissertation.

Johansson, N. and E. Graneli. 1999a. *Influence of different nutrient conditions on cell density, chemical composition and toxicity of Prymnesium parvum (Haptophyta) in semi-continuous cultures*. Journal of Experimental Marine Biology and Ecology 239:243-258.

———. 1999b. *Cell density, chemical composition and toxicity of Chrysochromulina polylepis (haptophyta) in relation to different N:P supply ratios*. Marine Biology 135:209-217.

Legrand, C., N. Johansson, G. Johnsen, K. Y. Borsheim, and E. Graneli. 2001. *Phagotrophy and toxicity variation in the mixotrophic Prymnesium patelliferum (Haptophyceae)*. Limnology and Oceanography 46:1208-1214.

Maine Department of Environmental Protection (MDEP). 2012. *Working Draft of Chapter 583: Nutrient Criteria for Surface Waters*. Maine Department of Environmental Protection, Augusta, Maine. June 12, 2012.

McQuillan, D. 2004. *Ground-Water Quality Impacts from On-Site Septic Systems*. Proceedings, National Onsite Wastewater Recycling Association, 13th Annual Conference, Albuquerque, NM. November 7-10, 2004. 13 pp.

Miltner, R.J. 2010. *A Method and Rationale for Deriving Nutrient Criteria for Small Rivers and Streams in Ohio*. Environmental Management 45:842-855. April 2010.

Natural Resource Defense Counsel (NRDC). 2007. Discussion in NRDC's *Petition for Rulemaking Under the Clean Water Act Secondary Treatment Standards for Nutrient Removal*, November 27, 2007. Section III.B.6, Page 35

New Mexico Environment Department/Surface Water Quality Bureau (NMED/SWQB). 2008. *State of New Mexico Nutrient Criteria Development Plan, Revision 4*, January 18, 2008. Santa Fe, NM.

———. 2010. State of New Mexico 10-year surface water quality monitoring and assessment strategy. Santa Fe, NM. Available at: www.nmenv.state.nm.us/swqb/MAS/monitoring/10-YearMonitoringPlan.pdf.

———. 2011. *Procedures for Assessing Water Quality Standards Attainment for the State of New Mexico CWA §303(d)/§305(b) Integrated Report*. May 6, 2011. Santa Fe, NM.

———. 2012. *State of New Mexico 2012-2014 Integrated Clean Water Act §303(d)/§305(b) Integrated List*. April 2012. Santa Fe, NM.

———. 2013a. *State of New Mexico 2014 Assessment Protocol*. June 24. Santa Fe, NM. Appendix D1. *Nutrient Assessment Protocol for Wadeable, Perennial Streams*. 13pages. Available online at: www.nmenv.state.nm.us/swqb/protocols/2014/AssessmentProtocol-w-Appendices-2014.pdf#page=62

———. 2013b. *State of New Mexico 2014 Assessment Protocol*. June 24. Santa Fe, NM. Appendix D2. *Nutrient Assessment Protocol for Lakes and Reservoirs*. 13pages. Available online at: www.nmenv.state.nm.us/swqb/protocols/2014/AssessmentProtocol-w-Appendices-2014.pdf#page=75

New Mexico Statutes Annotated (NMSA). 1978. The Legislature enacted NMSA 1978, Section 74-6-1.

New Mexico Water Quality Control Commission (NMWQCC). 2011. *State of New Mexico Standards for Interstate and Intrastate Surface Waters*. 20.6.4 NMAC as amended through January 14, 2011, and approved by EPA as of April 18, 2011. Available at: www.nmenv.state.nm.us/swqb/Standards.

Ohio Environmental Protection Agency (OEPA). 2013. *Trophic Index Criterion: Rationale and Scoring.* Prepared by Ohio EPA, Division of Surface Water. March 2013. Available at: http://epa.ohio.gov/Portals/35/rules/TIC_rationaleandscoring.pdf.

Scott, J. T. and B. Haggard. 2011. *Analytical Support for Identifying Water Quality Thresholds in New Mexico Surface Waters*. Draft Final Report submitted to the New Mexico Environment Department – Surface Water Quality Bureau, June 2011.

Simon, T. P. and J. Lyons. 1995. *Application of the index of biotic integrity to evaluate water resource integrity in freshwater ecosystems*. Pages 245–262 *in* Biological assessment and criteria: tools for water resource planning and decision-making (W.S. Davis and T.P Simon, eds.). Lewis Publishers, Boca Raton, Florida.

Skovgaard, A., C. Legrand, P. J. Hansen, and E. Graneli. 2003. *Effects of nutrient limitation on food uptake in the toxic haptophyte Prymnesium parvum*. Aquat. Microb. Ecol. 31 (3): 259-265.

Stoner, Nancy K. 2011. Memo to Regional Administrators, U.S. Environmental Protection Agency, Regions 1–10. 16 March 2011.

U.S. Environmental Protection Agency (USEPA). 1998. *National Strategy for the Development of Regional Nutrient Criteria*. EPA 822-R-98-002. Available online at: http://water.epa.gov/scitech/swguidance/standards/upload/2009_01_21_criteria_nutrient_strategy_nutstra3.pdf

———. 2000a. *Ecoregional Nutrient Criteria Documents for Rivers & Streams*. EPA 822-B-01-013, -015, and -016. Online at: www2.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-documents-rivers-streams

———. 2000b. *Nutrient Criteria Technical Guidance Manual: Rivers and Streams*. EPA-822-B-00-002. Online at: www2.epa.gov/nutrient-policy-data/criteria-development-guidance-rivers-and-streams

———. 2007. *Advanced Wastewater Treatment to Achieve Low Concentration of Phosphorus*. EPA 910-R-07-002. Office of Water and Watersheds. April 2007.

———. 2008. *Municipal Nutrient Removal Technologies Reference Document (Volume 1 – Technical Report)*. EPA 832-R-08-006. Office of Wastewater Management, Municipal Support Division. September 2008.

———. 2010. *Using Stressor-response Relationships to Derive Numeric Nutrient Criteria*. See Figure 2-1, p. 10 and Figure 2-2, p. 13. EPA-820-S-10-001.

———. 2012. CADDIS website: Nitrogen & Phosphorus: Simple Conceptual Diagram. Available at: www.epa.gov/caddis/ssr_nut4s.html

Van Nieuwenhuyse, E.E. and J.R. Jones. 1996. *Phosphorus-chlorophyll relationship in temperate streams and its variation with stream catchment area*. Can. J. Fish. Aquat. Sci 53: 99-105.

Welch, E. B. 1992. *Ecological Effects of Wastewater*. Chapman and Hall, London.