COLORADO WASTEWATER UTILITY COUNCIL

Minutes of
May 9, 2007 Meeting
Littleton/Englewood WWTP

In Attendance:

Mary Gardner	L/E WWTP
Sharon Davis	Metro Water Reclamation District
Claudia Cummins	Aurora Water
Amy Woodis	Metro Water Reclamation District
Michelynn Hollister	Colorado Springs Utilities
Rick Koplitz	CDPHE
Dave Meyer	Westminster
Dennis Schump	Greeley
Bret Linenfelser	City of Boulder
Floyd Bebler	City of Boulder
Nancy Keller	Pueblo
Tim Grotheer	PCWA
Chris Laroe	Bear Creek W&S District
Mike Bittner	Silverthorne/Dillon
Lynette Myers	CDPHE
Tracey Yager	USGS
Paul Ferraro	Ferraro Associates, Inc.

I. Organic Wastewater Compounds in Biosolids, Tracy Yager (USGS)

Tracy Yager gave the Council an overview of the USGS studies conducted over the past 8 years that have evaluated Organic Wastewater Compounds in biosolids, consisting of (1) Methods Development, (2) Occurrence in Biosolids, (3) Transport and Fate in the Environment, and (4) Ecological Effects. The results of the studies will be available within a month and we will distribute them to each Member and post them on the Council's website.

Tracy also mentioned that American Water Resources Association (AWRA) and others will be sponsoring the 2007 AWRA Summer Specialty Conference on Emerging Contaminants of Concern in the Environment: Issues, Investigations, and Solutions at the Vail Cascade Resort, Vail, Colorado, June 25-27, 2007. Telephone: 540-687-8390.

II. Colorado Environmental Leadership Program (ELP), Lynette Myers (CWQCD)

Lynette Myers gave a summary of the ELP which is a voluntary program designed to recognize and reward organizations and businesses that demonstrate superior environmental performance and, as a result, consistently operate at a level that goes beyond mere compliance with environmental regulations. The Program consists of four levels: Bronze Achiever, Silver Partner, Gold Leader and Platinum Steward (new level). The present number of members per level consists of:

  - Gold Leaders - 20
  - Silver Partner - 1
  - Bronze Achievers - 10
  - Bronze Achiever - Mercury Switch Program - 14
  - Platinum Steward - 0

Click here for a copy of Lynette's presentation.

III. Updates

- RMWEA Liaison Report. No report. Mary Gardner offered to assist Steve Frank.
- Colorado Water Utility Council (WUC). Sharon Davis attended the recent WUC meeting and gave the following report:
  - The Division's Fee Bill passed the Legislature.
  - Ron Falco indicated that the Division is working on the requirements of SB 276 passed several years ago and is working to bring equality in funding and program implementation, especially for the stormwater program and the clean water program.
  - Joe Talbott, Engineering Section, sent a letter to the Council inviting its members to join the Colorado Design Criteria Revisions Stakeholder Group. To participate or if you have any questions, contact Joe Talbott at 719.545.4650, ext. 21.
- Permitting Seminar. The seminar is set for May 16, 2007 at Silverthorne, Colorado. The staff of the Silverthorne POTW will assist in the set up of the room and registration.
- Legislative Report. The Division Fee Bill passed as mentioned above and should be signed soon.
- Nutrients.
  - The next meeting of the Nutrient Subcommittee on Lakes and Reservoirs will be held on May 16, 2007, from 10-12 at the Northwest Water Treatment Plant in Westminster.
  - Nancy Keller sent the attached letter to Steve Gunderson on May 2, 2007, regarding the development of statewide nutrient criteria.

IV. Open Discussion

- Nancy mentioned that a new Permit Policy regarding monitoring has been issued recently by Andrew Neuhart of the Division. Click here to see the document. Amy Woodis recommended that the Council send the Division a letter stating its concerns and also recommended the Council invite Andrew Neuhart to the June Council meeting with Steve Gunderson to discuss the Water Quality Permits Policy and Procedures document.

The meeting adjourned at 2:45 P.M.

Next Meeting: June 13, 2007 @ 1 PM at L/E WWTP

May 2, 2007

Steve Gunderson, Director
Water Quality Control Division
Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530

Re: Development of Statewide Nutrient Criteria

Dear Mr. Gunderson:

The Colorado Wastewater Utility Council (Council) would like to take this opportunity to share its concerns with you over the current status of the development of statewide nutrient criteria (table values) for surface waters. It is our understanding that the Water Quality Control Division (Division) is committed to proposing nutrient basic standards for lakes/reservoirs and rivers/streams for consideration by the Colorado Water Quality Control Commission (Commission) at the 2010 Basic Standards Rulemaking Hearing. Because of the workgroup process, the Council appreciates that development of nutrient criteria is not just a Division responsibility, but depends upon input from all stakeholders. As such, the wastewater community has a vested interest that any proposed nutrient criteria be scientifically defensible while taking into account Colorado's unique water management system.

With respect to lakes and reservoirs, the physical and chemical inputs and mechanisms that result in different surface water trophic levels are both very complex and site-specific. For example, existing control regulations such as Regulations #71, #72, #73,and #74 (Dillon Reservoir, Cherry Creek Reservoir, Chatfield Reservoir, and Bear Creek), respectively, address each water body's unique trophic characteristics to better manage loadings from point and non-point nutrient sources. From the collective experience of these watersheds it appears that "one size" nutrient criteria will not fit all lakes/reservoirs.

Other watershed groups studying Front Range reservoirs (Standley Lake and Barr Lake, in particular) are coming to similar conclusions. Even though these two reservoirs have similar beneficial use classifications (warm water aquatic life, recreation, water supply, and agriculture) and are located relatively close by to one another, the nutrient issues in each appear to be very different. In the workgroup discussions to date, agreement has not been reached among stakeholders on the best basic standards criteria to protect the drinking water supply use for these two reservoirs, primarily because the trophic levels are so dissimilar.

Because nutrient removal from wastewater treatment facilities can be very costly, the Council is concerned that adoption of unrealistic nutrient table values will result in the development of numerous site-specific standards wherever there are discharges from wastewater treatment plants, even though such plants are not usually the major contributor of nutrient-related compounds to surface waters. Alternatively, many water segments may end up on the 303(d) List if attainment is tied to nutrient standards that do not take site-specific factors into consideration. It is also important to note that the contributions of unregulated non-point nutrient sources, such as agriculture and residential fertilizers, have not been factored into the workgroup discussions to date.

As an example to show the relative contributions of phosphorus to reservoirs by publicly owned treatment works (POTWs), the table below shows the respective nutrient allocations for the control regulations cited above. Clearly, POTWs are not a major contributor of phosphorus to these reservoirs. However, without adequate consideration of non-point sources, regulated facilities may end up shouldering a disproportionate responsibility for nutrient removal throughout the State.

Phosphorus Allocations to POTWs – Existing Control Regulations

Reg. #	Reservoir	Annual Loading: (lbs/yr)	Allocation to POTWs (lb/yr)	% to POTWs	Maximum Effluent Concen-tration (mg/L)	Chlorophyll-a Goal (mg/L)	Phosphorus Standard (ug/L)
71	Dillon	10,162	1,621	16.0%	0.5		7.4
72	Cherry Creek	14,270	2,094	14.7%	0.05	15	35
73	Chatfield	59,000*	7,358	12.5%	1	17	27
74	Bear Creek	65,000**	5,255	8.1%	1	N/A	N/A

* flow based

** Underlying number not in regulation

For these reasons, the Council recommends that the Division consider raising the following issues in the workgroup to make the development and implementation of nutrient criteria and standards credible, scientifically supportable, realistic, and practical:

- Does it make sense to develop statewide standards for nutrients (including rivers and streams), when the issues related to supporting beneficial uses (particularly water supply) are so site-specific that they could be addressed more effectively and efficiently on a site-specific basis, perhaps through control regulations?
- Are inputs of nutrient sources from sources other than wastewater treatment facilities (agriculture, dog parks, individual sewage disposal systems, horse boarding facilities, golf courses, Confined Animal Feeding Operations, etc.) being monitored and evaluated?
- Do site-specific water management practices affect the nutrient levels in reservoirs more or less than point or non-point loadings?

Because of these issues, the Council would like to suggest the workgroup discuss the possibility of adopting <u>narrative nutrient criteria</u> in the Basic Standards. This approach could build upon the existing "free from" language in section 31.11; however, there would need to be discussion regarding implementation timing since narrative criteria usually are adopted as standards throughout the state upon approval by the Commission in the Basic Standards.

The Council understands that narrative criteria must have a completed implementation guidance to assure approval by the Environmental Protection Agency (EPA). For consideration purposes, please find attached to this letter the State of Arizona's "Narrative Nutrient Standard for Lakes & Reservoirs Implementation Procedures." The Council understands that this Guidance has been approved by EPA for Arizona's narrative nutrient standards. The Council believes that the framework set forth in the Guidance is scientifically sound while integrating the unique water management characteristics and beneficial uses around the State. Variables considered in the Guidance include “competing” beneficial uses (water supply and aquatic life, for example), reservoir management practices, and differences among rivers and lakes as well as among the State’s lakes themselves.

The Council believes that discussion of this possible alternative approach in the workgroup may address various stakeholder concerns and could prove to be a reasonable “starting point” for additional discussion of nutrient criteria development.

At this time we also encourage the Division to hold more frequent meetings (to date there have been relatively few meetings and none is currently scheduled) and involve stakeholders other than members from the wastewater treatment and water treatment communities in the discussion.

We look forward to working with you and your staff on this important issue.

Yours truly,

Nancy Keller
Chair

Attachment

Narrative Nutrient Standard for Lakes & Reservoirs Implementation Procedures

Arizona Department of Environmental Quality
Water Quality Division
Hydrologic Support and Assessment Section
Surface Water Quality Standards & Monitoring

October, 2005

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List of Tables

Acknowledgements

This implementation procedures document was written by Susan Fitch, Lakes Program Coordinator within the Surface Water Monitoring and Standards Unit, Hydrologic Support & Assessment Section, Water Quality Division, at the Arizona Department of Environmental Quality. The document is based on a two-year contract with Malcolm Pirnie to develop a lake classification system and associated narrative nutrient endpoints. This work partially satisfies the EPA requirement for state development of nutrient criteria. Thanks to all internal and external reviewers for their assistance in organizing and presenting the material, particularly, Clifton Bell, P.E., Dr. David Walker, Diana Marsh, Melanie Diroll, Steve Pawlowski, Sam Rector, Jennifer Hickman, Jason Sutter, and Linda Taunt.

1.0 EXECUTIVE SUMMARY

This document sets forth implementation procedures as applied to lakes and reservoirs for the narrative nutrient water quality standard found in Arizona Administrative Code (AAC) R18-11-108(A)(7) and associated passages (A)(2-5,8). This document explains ADEQ's approach to determining compliance with the narrative nutrient standard in an objective way and how ADEQ will use the narrative nutrient standard in the Clean Water Act §305(b) water quality assessment and §303(d) listing processes applied to lakes and reservoirs. The central core of the narrative nutrient standard (A)(7) states:

> *"A surface water shall be free from pollutants in amounts or combination that…cause the growth of algae or aquatic plants that inhibit or prohibit the habitation, growth, or propagation of other aquatic life or that impair recreational uses…"*

This clause is often condensed into: "no excess algal and plant growth." The growth of algae or plants depends on the presence of light and nutrients, primarily nitrogen, phosphorus, and carbon, though trace elements are also necessary. "Excess growth" of algae or plants naturally implies the presence of "excess nutrients," given sufficient light and availability of trace elements. However, in practice, plant and algal growth, respiration, and decay are continual processes. This means that nutrient uptake, assimilation, and transformation are also in a continual state of flux and difficult to measure. The tradition in Limnology (study of lakes) has been to use the measure of chlorophyll-a as a surrogate measure of plant or algal biomass. Chlorophyll-a is the primary pigment in plants and algae and is required for photosynthesis, the production of plant sugars necessary for growth and reproduction. Thus, the narrative nutrient standard refers to a complex ecological process and must consider differences in space and time.

As a result of the national mandate for states to develop nutrient criteria, ADEQ submitted a Nutrient Criteria Development Plan to EPA in 2002. The Plan focused on development of nutrient criteria for lakes and reservoirs as a first priority. In keeping with national guidance, ADEQ suggested the development of a matrix of lake endpoints that, taken together in a weight-of-evidence approach, would provide the basis for interpretation of the narrative nutrient standard. In conjunction with this proposal, ADEQ proposed to establish lake and reservoir categories or classes, such that individual water bodies would be evaluated within a context of watershed attributes, land uses, climatology, morphology, and management practices. A two-year study was undertaken to first derive lake classes and second the associated matrix of water quality endpoints for interpretation of the narrative nutrient standard. This document is based on the results of this study and lays out the expectations by lake class for both standard compliance with and permit violation of the narrative nutrient standard applied to a lake or reservoir system. This document will be used for both assessment and enforcement.

ADEQ has created five functional lake classes: deep, shallow, igneous-based, sedimentary-based, and urban. For each class and each applicable designated use, ADEQ developed a matrix of threshold values expressed as ranges for chlorophyll-a, secchi depth, total nitrogen, total Kjeldahl nitrogen (TKN), total phosphorus, percent blue-green algae, and total count of blue-green algae. Lake classes were derived using statistical analysis of lake and watershed characteristics from 70 lakes and reservoirs in Arizona. A subset of 50 lakes and reservoirs was used to derive threshold ranges, evaluated through the lens of scientific literature review and policies adopted by other states. pH and dissolved oxygen (DO) standards have been added as relevant and supportive endpoints.

A lake or reservoir is attaining the narrative nutrient standard if the mean of *all* parameters fall below respective threshold ranges in Table 1 (except for Secchi depth, in which case, the result must all be above the threshold range).

ADEQ will determine an exceedance (equivalent to a violation) of the narrative nutrient standard in lakes by one of the following four ways:

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

2. The mean chlorophyll-a result is within the target range for chlorophyll-a for the lake category prescribed in Table 1, and the mean blue-green algae result is at or above 20,000 per milliliter or the mean blue-green algae count is 50 percent or more of the total algae count.

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

   a. Exceedances of dissolved oxygen or pH standards;
   b. Fish kills or other aquatic organism mortality attributed to exceedances of dissolved oxygen or pH, or to ammonia or algal toxicity;
   c. Secchi depth is below the lower threshold value for the lake category;
   d. The concentration of total phosphorus, total nitrogen, or TKN exceed the upper value in the range prescribed for the lake category in Table 1.

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

ADEQ will determine "impairment" for the Narrative Nutrient Standard if there are a minimum of two exceedances as determined above, within a two to five year assessment period.

A 303(d) listing for narrative nutrient standards will result in a TMDL or ADEQ-approved management plan developed within one year that shows attainment three years.

Delisting a lake will require the demonstration of attainment based on a minimum of two sample events collected in two consecutively-monitored peak seasons.

Table ES-1. Matrix for Implementation of the Narrative Nutrient Standard in Lakes and Reservoirs

		Response Variables								
Designated Use	Lake Category	Chl-a (g/L)	Secchi Depth (m)	Blue-Green Algae (per mL)	Blue-Green Algae (% of total count)	Tot. Phos. (mg/L)	Tot. Nit. (mg/L)	TKN (mg/L)	Dissolved Oxygen (mg/L)	pH (SU)
DWS	Any/All	10-20	0.5-1.5	20,000	NA	70-100	1.2-1.5	1.0-1.2	NA	5.0 – 9.0
Recreation										
FBC PBC	Deep	10-15	1.5-2.5	20,000	NA	70-90	1.2-1.4	1.0-1.1	NA	6.5 – 9.0
	Shallow	10-15	1.5-2.0		NA	70-90	1.2-1.4	1.0-1.1	NA	
	Igneous	20-30	0.5-1.0		NA	100-125	1.5-1.7	1.2-1.4	NA	
	Sedimentary	20-30	1.5-2.0		NA	100-125	1.5-1.7	1.2-1.4	NA	
	Urban	20-30	0.5-1.0		NA	100-125	1.5-1.7	1.2-1.4	NA	
Fisheries										
A&W/cold	Any/All	5-15	1.5-2.0	NA	<50	50-90	1.0-1.4	0.7-1.1	7 top m	6.5 – 9.0
A&W/warm	Any/All	25-40	0.8-1.0	NA		115-140	1.6-1.8	1.3-1.6	6 top m	
A&W/urban	Urban	30-50	0.7-1.0	NA		125-160	1.7-1.9	1.4-1.7		

NOTE: All lakes carry A&W as well as contact recreation (FBC or PBC) designated uses. Threshold ranges apply during "peak season" for lake productivity, including those for Domestic Water Source (DWS). Peak season for cold water lakes is May – September; peak season for warm water lakes is April – October. "NA" means not applicable

2.0. INTRODUCTION:

EPA published the *National Nutrient Strategy* in 1998, with the stated intent of compiling technical information on nutrients and working with states and tribes to adopt nutrient criteria as part of their water quality standards. The major focus of this strategy was the development of waterbody-type technical guidance and region-specific nutrient criteria. EPA published the *Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs* in 2000, followed by regional summaries of lake and reservoir data in 2000 and 2001. Each of these documents corresponded to an aggregate level III *ecoregion* that share broadly similar geographic and ecological characteristics. Initial EPA nutrient criteria were derived from calculating either the 75^{th} percentile of available data from reference water bodies in an ecoregion, or the 25^{th} percentile of data from all water bodies in the ecoregion.

Many Arizona "lakes" are really man-made impoundments, with the exception of a few shallow ephemeral systems. Most of the impoundments were constructed originally for irrigation purposes, but many are now popular recreational resources. Until recently, the Arizona Department of Environmental Quality (ADEQ) applied one set of water quality standards to both perennial streams and lakes. The national nutrient criteria did not include the broad diversity of Arizona lakes and reservoirs. In addition, Arizona only contains two level III ecoregions: the Western Forested Mountains and the Xeric West, two broad divisions that do not capture inherent variability.

ADEQ's approach for deriving nutrient targets relies on the best scientific knowledge available while also considering the distinctive characteristics of Arizona's lakes. The first step was to perform a thorough review of the scientific and lake/reservoir management literature, with a focus on identifying nutrient-related targets associated with specific designated uses. The observed water quality of Arizona's lakes and reservoirs was characterized, leading to the classification of Arizona's lakes into management categories based on similar characteristics or public expectations. The development of an Arizona-specific trophic state index has allowed ADEQ to set appropriate nutrient concentration targets for attainment of different chlorophyll-*a* targets.

In review of lake data collected since 1990, it became increasingly clear that Arizona lake systems not only behaved significantly different from streams, but also different from one another. Shallow lakes naturally tend toward heavy growth of macrophytes (submerged or emergent vegetation) and display a typical set of water quality problems that can be mitigated but not entirely remedied. Urban impoundments, for which setting plays a huge role, require attention to political boundaries and often aggressive and cooperative management practices. Large reservoirs with huge watersheds do not behave like small high-elevation lakes nestled in undeveloped forest land. Arizona has interpreted the need for refined nutrient criteria in a broader context than numeric criteria alone. The narrative nutrient implementation matrix is an example of a "translator approach", supported by EPA in the *Guidance for Development of Nutrient Criteria for Lakes and Reservoirs, 2000*. ADEQ has developed five lake classes with associated endpoints for interpretation of the narrative nutrient standard, more accurately reflecting the diversity of geography and lake setting, as well as specific levels of designated use protection.

3.0 NARRATIVE NUTRIENT STANDARD, A.A.C. R18-11-108 (A)(7)

3.1 Purpose of the Narrative Nutrient Standard Applied to Lakes & Reservoirs

The core of Arizona's narrative nutrient standard states: "A surface water shall be free from pollutants in amounts or combination that…cause the growth of algae or aquatic plants that inhibit or prohibit the habitation, growth, or propagation of other aquatic life or that impair recreational uses." This clause is often condensed into: "no excess algal and plant growth." The growth of algae or plants depends on the presence of light and nutrients, primarily nitrogen, phosphorus, and carbon, though trace elements are also necessary. "Excess growth" of algae or plants naturally implies the presence of "excess nutrients," given sufficient light and availability of trace elements. However, in practice, plant and algal growth, respiration, and decay are continual processes. This means that nutrient uptake, assimilation, and transformation are also in a continual state of flux. For this reason, grab samples for nutrients alone are not good indicators of the level of productivity. The tradition in Limnology (study of lakes) has been to use the measure of chlorophyll-a as a surrogate measure of plant or algal biomass. Chlorophyll-a is the primary pigment in plants and algae and is required for photosynthesis, the production of plant sugars necessary for growth and reproduction. Thus, the narrative nutrient standard refers to a complex ecological process with many compartments and factors influencing differences in space and time. In lakes, the best indirect way to measure "excess" is to sample chlorophyll-a in plankton-dominated systems, and percent plant cover in very shallow systems.

3.2 Applicability of Narrative Nutrient Standard

These implementation plans for narrative nutrients apply only to lakes and reservoirs because the existing research to develop the procedures is based on lake and reservoir data. ADEQ intends to continue this work and develop appropriate targets for perennial rivers and streams in the future.

3.3 Adverse Effects of "Excess Algae and Aquatic Plant Growth

The adverse effects of excess nutrients, translated into excess algae and plant growth in lakes, include several aspects cited in the Narrative Standards, A.A.C. R18-11-108, as well as some that are not cited:

- Objectionable odor
- Off-taste or odor in drinking water
- Off-flavor in aquatic organisms
- Changes in water color (noxious blooms of algae)
- Accelerated production of bottom deposits
- Low dissolved oxygen (DO)
- Radical swings in DO on a daily basis
- Very low or very high pH

- Fish mortality due to low DO, ammonia toxicity, or algal toxins
- Mortality of invertebrates from algal toxins
- Imbalances in the energy structure (trophic levels)
- Lack of biotic diversity
- Habitat changes
- Sub-lethal stress to organisms
- Visual impairment (swimming; boating)
- Mechanical interference (clogging boat motors; paint-fouling; expensive filtration)
- Production of hydrogen sulfide

This list is not exhaustive, but it does illustrate the point that assessment and remediation of excess plant and algal growth may require consideration of multiple variables.

4.0 STEPS in the DEVELOPMENT of the MATRIX

4.1 Lake Classification

From 2002 to 2004, ADEQ worked with a contractor to develop a statistically robust method of categorizing Arizona lakes into “classes,” based on similar attributes and functionality. Data were compiled from a cross-section of approximately 75 impoundments in Arizona. These data reflect monitoring efforts by several state and federal entities and span a twenty year period. Data were screened to meet quality objectives and placed in an Access database. A Geographic Information System was also constructed to include spatial data on watershed and lake attributes. The databases were linked to allow relational queries and application of various statistical tests. Statistical analyses included descriptive methods such as box and whisker plots, the multivariate method, Principle Components Analysis (PCA), and the multiple regression method, Classification and Regressions Tree (CART). A complete review of the tests applied can be found in the *Data Summary and Statistical Modeling Report* produced by Malcolm Pirnie (2004). The resulting classes are listed in Table 4-1. Each lake or reservoir in Arizona will be assigned a primary classification. In practice, some lakes may exhibit secondary class attributes that may also be considered in narrative nutrient evaluation.

Table 4-1. Arizona Lake and Reservoir Classes

Lake/Reservoir Class	**Primary characteristic**	**Class Description**	**No. Lakes/Class**
Deep	Avg. lake depth	Lakes w/mean depth > 18 m	
Shallow	Avg. lake depth	Lakes w/mean depth < 4 m	
Igneous	Dominant geology/soils	Lakes in volcanic/granitic lithology	
Sedimentary	Dominant geology/soils	Lakes in alluvial, sedimentary and metamorphic lithology	
Urban	Land use/setting/source water	Lakes in urban landscape	

NOTE: No. Lakes/Class is being determined by ADEQ and AGFD

4.2 Development of Arizona's Trophic State Index (TSI)

The approach for deriving TSI in Arizona was similar to that of Brezonik (1984) in that the sub-index for chlorophyll-*a* was based on the criteria that (1) doubling chlorophyll-*a* would increase the sub-index by 10 units; and (2) a sub-index value of 50 corresponds to a chlorophyll-*a* value of 10 μg/L. The resulting sub-index is: $TSI_{CHLA} = 16.8 + 14.4 \ln(chla)$. Least-squares linear regression analysis was used to develop separate sub-indices for Secchi depth, total phosphorus, total nitrogen, and TKN based on their correlation with chlorophyll-*a*. All data used in the regressions were expressed as the natural logarithms of growing season mean values for individual water bodies. Resulting sub-indices were as follows: $TSI_{SD} = 63.0 - 38.1 \ln(SD)$; $TSI_{TP} = 127.1 + 29.5 \ln(TP)$; $TSI_{TKN} = 51.4 + 39.1 \ln(TKN)$

The Arizona TSI (Table 4-2*)* will be used to track lake productivity. For lakes with sufficient data, both sub-index and primary index TSI values will be calculated for each assessment period. The index for TKN will be used based on the fact that TKN was shown to be statistically more significant than total nitrogen in relation to chlorophyll-a in Arizona lakes and reservoirs. The TSI scores will be used to track changes in nutrient-related conditions and set management endpoints.

Table 4-2. Arizona's Trophic State Index (TSI)*

Trophic State	TSI	Chlor-a (*ug*/L)	Secchi (m)	Total-P mg/L)	TKN (mg/L)
Oligotrophy	**0**	0.3	5.2	0.013	0.3
	10	0.6	4.0	0.019	0.3
	20	1.2	3.1	0.027	0.4
Mesotrophy	**30**	2.5	2.4	0.037	0.6
	40	5.0	1.8	0.052	0.7
Eutrophy	**50**	10	1.4	0.074	1.0
	60	20	1.1	0.103	1.2
	70	40	0.8	0.145	1.6
Hypereutrophy	**80**	81	0.6	0.203	2.1
	90	161	0.5	0.285	2.7
	100	323	0.4	0.400	3.5

* Derivation of TSI scoring and associated water quality values can be found in the document entitled *Potential Nutrient-Related Targets for Lakes and Reservoirs in Arizona* (Malcolm Pirnie, 2005). The literature cites the following *descriptive* thresholds, the first three related to nutrient limitation:

Oligotrophic: clear lakes w/low productivity
Mesotrophic: moderately productive lakes
Eutrophic: productive ("greener") lakes
Hypereutrophic: highly productive; light limited
Dystrophic: distinguished by suspended solids or humic acids causing color; light limited

4.3 Narrative Nutrient Implementation Matrix for Lakes & Reservoirs

Of the 75 lakes used to establish lake classes, data from a subset of fifty lakes collected within at least three peak seasons was used to develop the Arizona Trophic State Index (TSI) and to inform a matrix of numeric thresholds for interpretation of the narrative nutrient standard. The water quality endpoints in the matrix have been derived in association with lake classes and designated uses. These numeric targets, both causative variables (numeric nutrient thresholds) and response variables (chlorophyll-a, Secchi, and blue-green algae thresholds) were established using the following types of information:

- Arizona's existing numeric nutrient water quality criteria
- Numeric ranges from watershed and in-lake loading models/methods
- EPA proposed ecoregional numeric nutrient criteria
- Trophic-state indices developed for Arizona lakes and Reservoirs
- Numeric targets derived from the scientific and lake management literature
- Effects-based targets adopted by other states

The complete explanation of method development can be found in *Potential Nutrient-Related Targets for Lakes and Reservoirs in Arizona*, Malcolm Pirnie, 2005. Within the matrix, thresholds are expressed as ranges to account for spatial/temporal heterogeneity in the data and statistical uncertainty. As such, the range represents data values below which there is *no* narrative nutrient problem. Data that fall within a range *may* indicate a problem, whereas, data above the upper value of the range *will* be interpreted as indicative of a narrative nutrient problem. The matrix will be incorporated into Arizona Surface Water Standards.

4.4 Applicability of Matrix

The matrix of numeric thresholds found in Table 4-3 is intended for use in assessing lakes and reservoirs as a translator for the narrative nutrient standard. Table 4-3 includes chlorophyll-a, blue-green algae, and Secchi depth as response variables. Nutrient thresholds are included in the matrix as those ranges found to be statistically associated with the primary response variables, chlorophyll-a and blue-green algae. Blue-green algae, or Cyanophytes (similar to bacteria), are the type of algae most often associated with taste and odor problems, scums, and toxicity. An abundance of blue-greens correlates with the probability that one or more of these issues may be present. Ammonia production is another parameter reflected in plant and algal growth. Ammonia toxicity has a separate standard which is pH and temperature-dependent (A.A.C. R18-11-Appendix A). Although ammonia is not included in the Matrix, where data are available, ammonia results will be considered as part of the weight-of-evidence in evaluation of narrative nutrient compliance. The DO and pH standards have been appended to the Matrix because they are both ecologically relevant and more straightforward to display.

The narrative nutrient standard matrix will be applied to lakes listed in Appendix B of the Surface Water Quality Standards (A.A.C. R18-11) using a "weight of evidence" approach to interpretation. "Weight of evidence" in this context refers to the application of matrix thresholds taken together as a set of parameters that inform "excess plant and algae growth" (A.A.C. R18-11-108). In application of the matrix, chlorophyll-a will carry the highest weight. The measure of chlorophyll-a indicates the relative biomass in a lake or reservoir as well as nutrient availability. Blue-green algae thresholds will carry the second-highest weight in matrix application. Secchi depth may be influenced by non-algal turbidity, therefore, Secchi thresholds must be applied with evaluation of turbidity and suspended sediment data, as well as chlorophyll-a.

Arizona recognizes the following designated uses to which the narrative nutrient implementation matrix applies in lakes and reservoirs:

- Domestic Water Source (DWS)
- Aquatic & Wildlife (A&W)
  - i. Warm water (w)
  - ii. Cold water (c)
  - iii. Effluent dependent (EDW)
  - iv. Ephemeral (e)
- Full Body Contact (FBC)
- Partial Body Contact (PBC)

Because DWS use relates to surface waters that may be treated for human consumption, this use carries the most restrictive water quality thresholds. The next most stringent use is recreation, synonymous with FBC or PBC. The A&W use is often associated with fisheries. Matrix A&W thresholds are less restrictive than those for DWS or recreation, reflecting the fact that *relatively* higher nutrients and productivity are favored to promote a healthy fishery.

The lake classification study introduced a new sub-category of aquatic life protection, the "urban" lake category, in which thresholds have been set to reflect a level of protection particular to a "put and take fishery" in an urban setting with a variety of source water from groundwater to reclaimed water. Urban lakes may or may not carry the FBC beneficial use, though typically they do not. Lakes with reclaimed water carry only PBC.

EDW lakes and ephemeral lakes must be identified as such in Appendix B; they will be evaluated using the matrix but may ultimately require development of either site-specific or refined seasonal narrative nutrient criteria. The matrix will not apply to ephemeral lakes with an average depth of less than one meter or to EDW lakes that do not support a fishery. Note that matrix thresholds will apply during "peak season" only, or during the period of highest productivity.

Table 4-3. Numeric Thresholds for Implementation of the Narrative Nutrient Standard in Arizona's Lakes and Reservoirs

		Response Variables								
Designated Use	**Lake Category**	**Chl-*a* (µg/L)**	**Secchi Depth (m)**	**Blue-Green Algae (per mL)**	**Blue-Green Algae (% of total count)**	**Tot. Phos. (µg/L)**	**Tot. Nit. (mg/L)**	**TKN (mg/L)**	**Dissolved Oxygen (mg/L)**	**pH (SU)**
DWS	**Any/All**	10-20	0.5-1.5	20,000	NA	70-100	1.2-1.5	1.0-1.2	NA	5.0 – 9.0
Recreation										
FBC **PBC**	**Deep**	10-15	1.5-2.5	20,000	NA	70-90	1.2-1.4	1.0-1.1	NA	6.5 – 9.0
	Shallow	10-15	1.5-2.0		NA	70-90	1.2-1.4	1.0-1.1	NA	
	Igneous	20-30	0.5-1.0		NA	100-125	1.5-1.7	1.2-1.4	NA	
	Sedimentary	20-30	1.5-2.0		NA	100-125	1.5-1.7	1.2-1.4	NA	
	Urban	20-30	0.5-1.0		NA	100-125	1.5-1.7	1.2-1.4	NA	
Fisheries										
A&W/cold	**Any/All**	5-15	1.5-2.0	NA	<50	50-90	1.0-1.4	0.7-1.1	7 top m	6.5 – 9.0
A&W/warm	**Any/All**	25-40	0.8-1.0	NA		115-140	1.6-1.8	1.3-1.6	6 top m	
A&W/urban	**Urban**	30-50	0.7-1.0	NA		125-160	1.7-1.9	1.4-1.7		

NOTE: All lakes carry A&W and contact recreation (FBC or PBC) designated uses. " NA": the threshold does not apply to that particular designated use. Threshold ranges apply during "peak season" for lake productivity, including those for Domestic Water Source (DWS):
Peak season for cold water lakes is May – September (inclusive)
Peak season for warm water lakes is April – October (inclusive)

5.0 INTERPRETATION OF STANDARD for LAKE/RESERVOIR ASSESSMENT

5.*1* *"Attainment"*

Attainment of the Narrative Nutrient Standard will be based on representative lake data reflecting a complete set of matrix variables from two independent sampling events. A*ll* results, calculated as seasonal means, must fall below the threshold or within the appropriate threshold range for that particular class of lake or reservoir (unless otherwise specified under exceedance criteria in Table 5-1). Samples must be collected during the appropriate peak season (based on cold or warm water designation), and as otherwise defined in the previous section.

5.*2* *"Exceedance"*

An exceedance or violation of the narrative nutrient standard applied to lakes will be determined by *any one* of the four criteria found in Table 5-1.

Table 5-1 Exceedance of the Narrative Nutrient Standard for Lakes/Reservoirs

	Primary Decision Criteria	**Weight of Evidence Supporting Criteria**
1	The mean[1] chlorophyll-a result is at or above the upper value in the threshold range	None needed
2	The mean[1] chlorophyll-a result is within the range, **and**	The mean[1] blue-green result is at or above either blue-green threshold
3	The mean[1] chlorophyll-a result is within the threshold range, and there is additional evidence of nutrient-related impairments **such as**	3/10 exceedances of DO or pH, **or** Fish kills attributed to DO or pH exceedances or ammonia toxicity, **or** Fish kills or other aquatic organism mortality attributed to algal toxicity, **or** Secchi depth below the lower threshold value, **or** Nuisance algal blooms present in the littoral[2] portion of the lake or reservoir, **or** The upper threshold for TKN, Total Phosphorus, or Total Nitrogen is exceeded
4	The mean[1] chlorophyll-a result is within or below the range, but the lake is a shallow lake (mean depth less than 4 m), **and**	Submerged aquatic vegetation is greater than 50% of the aerial extent of the lake bottom, **and** There is greater than 5 mg/L swing in diel (24-hr) DO measured within the photic zone (depth of light penetration supporting algal or plant growth)

[1]"mean" refers to the average value of the parameter collected from a lake within one peak season based on a minimum of two sample events

[2] "littoral" refers to the shallow shoreline areas

5.3 "Impairment"

ADEQ will determine 303(d) "Impairment" for the narrative nutrient standard if there are a minimum of two exceedances, as determined above, within a two to five year assessment period. A 303(d) listing for narrative nutrient standards will result in a TMDL unless a suitable management plan for mitigation can show attainment of the standard within three years.

5.4 Inconclusive

Using the weight of evidence approach, a lake or reservoir may not be clearly "attaining" or "impaired" with regard to the narrative nutrient standard . A finding of "inconclusive" may result in the lake being placed on the Planning List for further investigation.

5.5 Avoid listing

Within one year following assessment as "impaired", a management plan is developed and approved by ADEQ and results in attainment demonstrated over two *consecutive* peak seasons.

5.6 De-listing

Within three years following completion of an EPA-approved TMDL, attainment is demonstrated over two *consecutive* peak seasons.

6.0 INTERPRETATION of STANDARD FOR LAKE/RESERVOIR PERMITS

6.1 Basis for Application of Narrative Nutrient Standard to Surface Water Permit

Matrix nutrient values, with related corresponding chlorophyll-a matrix values, have supplanted the previous numeric nutrient criteria for lakes and reservoirs.

6.2 Requirement for Background Lake Conditions

In order to issue a permit, the prospective receiving water lake or reservoir must be attaining the narrative nutrient standard, as described in Section 5.1.

6.3 Permit Nutrient Discharge Limits

Target nutrient limits for discharges of nutrients to a lake or reservoir will be set not to exceed applicable matrix nutrient threshold ranges, unless assimilative capacity can be demonstrated such that the applicable chlorophyll-a threshold is met within an acceptable zone of influence*, not to exceed 2 ug/L above background for that lake or reservoir.

* The zone of influence must meet the rule requirements for a *mixing zone* (A.A.C. R18-11-114) applied to a discharge of nutrients.

6.3 Narrative Nutrient Compliance for Permits with Nutrient Discharges

Compliance for narrative nutrients in a lake or reservoir will be met based on sampling that shows:

- End of pipe nutrient values meet and do not exceed the matrix threshold range(s) as determined by lake class and designated uses, **or**
- There is demonstration of sufficient nutrient assimilative capacity to meet the chlorophyll-a threshold range, not to exceed 2 ug/L above background, **and**
- There is no ammonia toxicity

8.0 REFERENCES

Arizona Department of Environmental Quality, 2000. ADEQ Lakes Program Quality Assurance Project Plan.

ADEQ, 2001. Lakes Program Procedures Manual.

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EPA, 2000. Guidance for Development of Nutrient Criteria for Lakes and Reservoirs.

EPA, 2000/2001. Ambient Water Quality Criteria Recommendations: Lakes and Reservoirs in Nutrient Ecoregions II and III.

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APPENDIX: SAMPLING FOR COMPLIANCE with the NARRATIVE NUTRIENT STANDARD for LAKES/RESERVOIRS

Sample Site(s)

A lake or reservoir sample site is chosen based on lake size, shape, and depth. "Simple" lake shape is round to oblong with a bowl-like topography, and usually relatively shallow. The deepest and most representative location on a simple lake is either the middle or close to the dam (if present). "Complex" lake shape refers to multiple arms or tributary inputs such that the lake may have characteristics peculiar to each arm. The most overall representative location in this type of lake is also the deepest site or close to the dam (if present). However, separate samples should be collected from any arms that display a depth profile differing from the main part of the lake. "Linear" lake shape refers to a reservoir that is fed by one main tributary and has three sections: riverine, transition, and bay (by the dam). This type of lake is best sampled at a minimum of three separate sites unless very small. Table 5-1 shows a general guideline for determining the number of sample sites on a lake based on size and shape.

Table 5-1 Guideline for Number of Lake Sampling Locations*

Lake Size (acres)	Lake Shape (descriptive)	Mean Lake Depth (m)	Min. No. Sample Sites
Less than or equal to 1,000	Simple Complex Linear	< 4m (> 4m) < 4m (> 4m) < 18m (> 18m)	1 (2) 1 (2) 2 (3)
>1,000 - < 10,000	Simple Complex Linear	> 4 m > 18m (> 1 arm) > 18m	2 2 (3) 3
10,000 - < 100,000	Complex Linear	> 18m (> 2 arms) > 18m	3 (4) 4
100,000 or greater	Linear/Complex	> 18m	5

* Sample sites must be at least 200 meters apart

Sample Depth

Matrix thresholds shall apply to samples collected within the lake photic zone only. The "photic zone" is defined as the zone of the water column contained within a depth profile from lake surface down to 1.5 X the Secchi depth. For example, if the Secchi depth is 1.5 m, the photic zone would be 2.25 m. Samples for nutrients, chlorophyll-a, DO, pH, and algae identification would all be collected within this depth zone in order to assess compliance with the Narrative Nutrient Standards. DO and pH shall be measured using a depth-compensated probe or multi-probe and recorded at a minimum of 1.0 m increments within a photic zone > 2 m, or at a minimum of 0.5 m within a photic zone of less than 2 m. Lake samples shall be collected using a depth-specific sampler such as a Beta Bottle or similar device (*Lakes Program Procedures Manual*, 2001).

Sample QC

Samples must be collected according to standard QA/QC protocols: use of appropriate and clean containers and preservatives, maintenance of samples at 4 degrees C, adherence to holding times, adequate lab detection limits to meet the threshold targets, etc.(*Lakes Program Quality Assurance Project Plan*, 2000)

Sample Frequency

In order to assess compliance with the Narrative Nutrient Standards, there must be a minimum of two independent sample events (more than 7 days apart) within the appropriate peak season: May-Sept for cold water lakes and reservoirs; April-October for warm water lakes and reservoirs, or two sample events within two peak seasons.