Water Quality Standards Review: Carson River from US Highway 95A to Lahontan Dam

DRAFT Rationale Document

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Lahontan Dam and Reservoir (photograph by U.S. Bureau of Reclamation)

Prepared by:
Nevada Division of Environmental Protection
Bureau of Water Quality Planning

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Introduction

Section 303 of the Clean Water Act and 40 Code of Federal Regulations (40CFR) Part 131 require that States and authorized tribes routinely review and, as appropriate, modify surface water quality standards that protect the designated uses of a water body and provide a basis for controlling discharges or releases of pollutants. This rationale discusses the revisions proposed by the Nevada Division of Environmental Protection, Bureau of Water Quality Planning (NDEP-BWQP) to the water quality regulations for Carson River from Highway 95A to Lahontan Dam (NAC 445A.1792; 445A.1824).

Background

Through section 303 of the Clean Water Act (CWA), U.S. Environmental Protection Agency (EPA) has delegated authority to Nevada to establish water quality standards for all water bodies or segments of water bodies that lie within the state. Standards are composed of three parts: designated beneficial uses, water quality criteria, and antidegradation considerations. This review evaluates all three of the standard components for the Carson River from Highway 95A to Lahontan Dam. In support of this review, the following background information has been developed.

Reason for Review

The current Lahontan Reservoir water quality standards were set in 1984 based upon 1970s/80s EPA guidance and water quality conditions. There are multiple reasons that NDEP has decided to undertake this review at this time:

- One of the NDEP-BWQP's goals is to improve water quality standards through the assignment of more appropriate beneficial uses and water quality criteria. It has been nearly 30 years since the existing standards were set and last evaluated. Our understandings of beneficial uses and criteria have evolved and we believe that there are some areas for which the existing standards can be improved.

- Since the time the existing standards were set, there have been significant changes in nutrient loadings to Lahontan Reservoir from the Carson River and the Truckee Canal. Nutrient concentrations in the Carson River and Truckee Canal have shown a marked reduction following upgrades to the Truckee Meadows Water Reclamation Facility (TMWRF) in the 1980s and the removal of direct treated effluent discharges to the Carson River by 1987. As a result, average loadings of total nitrogen and total phosphorus have dropped by about 60% and 50%, respectively (Pahl, 2007).

- For several years, NDEP has been working with Reno, Sparks, TMWRF, Washoe County and TMWA in a 3rd Party review of the existing Truckee River Nitrogen and Phosphorus TMDL (Total Maximum Daily Load) which sets load limits for both point and nonpoint sources in the Truckee watershed. Any TMDL revisions will be constrained by Truckee River water quality standards (both Nevada and Pyramid Lake Paiute Tribe) and Lahontan Reservoir water quality standards. Before the TMDL is completed, it is desirable that appropriate standards are in place.

Newlands Project

Following passage of the Reclamation Act of June 17, 1902, the newly created US Reclamation Service (now known as the US Bureau of Reclamation) began work on the Newlands Project. Key components of the Project include Lake Tahoe Dam, Derby Dam and Truckee Canal, and Lahontan Reservoir. Construction of Derby Dam and Truckee Canal linked the Truckee River system with the Carson River (Figure 1). Currently, the project provides irrigation water from the Truckee and Carson Rivers for about 55,000 acres of cropland in Lahontan Valley near Fallon and bench lands near Fernley. Some project water from about 6,000 acres of project land has been transferred to wetlands in the Valley (US Bureau of Reclamation, 2013). Some hydroelectric power is generated with the release of water from Lahontan Reservoir. In 1926, the Truckee Carson Irrigation District assumed operation and maintenance responsibilities of the project (US Bureau of Reclamation, 1971).

Lahontan Dam and Reservoir is located on the Carson River and stores water from both the Carson River and the Truckee River (via Derby Dam and the Truckee Canal). The dam was completed in 1915 creating a reservoir with a storage capacity of 295,500 acre-feet. With 20-inch flashboards installed, an additional 23,900 acre-feet of storage capacity is available (US Bureau of Reclamation, 2013).

Reservoir Operations

Beginning in 1967, Operating Criteria and Procedures (OCAP) were established which placed restrictions on Truckee Canal diversions. Additional restrictions have been placed on the diversions over time (U.S. Bureau of Reclamation, 1987). Since 1967, Lahontan Reservoir has received on average about 288,000 acre-feet per year from the Carson River and 116,000 acre-feet per year from the Truckee Canal. About 1/3 of the reservoir inflows come from Truckee Canal on the average. However, there is considerable annual variability in the amounts coming from both sources (Figure 2). During periods of drought, Truckee Canal has provided about ½ of the total Lahontan Reservoir inflows (Bureau of Reclamation, 2013).

With annual fluctuations in inflow along with significant releases to meet downstream demands, storage levels in Lahontan Reservoir are highly variable (Figure 3). During about 1/3 of years during the 1967-2011 period, the annual maximum reservoir level exceeded the 295,500 acre-feet level. Levels during 1/3 of the years never exceeded 240,000 acre-feet. As a result of releases to meet downstream demands, levels during an average year fluctuate about 178,000 acre-feet. Minimum storage levels typically occur in September/October near the end of the irrigation season.

Recent events have affected Truckee Canal flows to Lahontan Reservoir. In January 2008, a portion of the canal embankment failed, flooding a residential area of Fernley. Since that time, the Bureau of Reclamation has imposed flow restrictions on the canal, which can complicate the ability of the Project to provide reliable supplies. The U.S. Bureau of Reclamation has developed a study report analyzing alternatives for the Truckee Canal while considering the dual objectives of safety and water supply for the Newlands Project (U.S. Bureau of Reclamation, 2013). Until improvements can be made, Truckee Canal flows have been limited to about 1/3 of its original capacity.

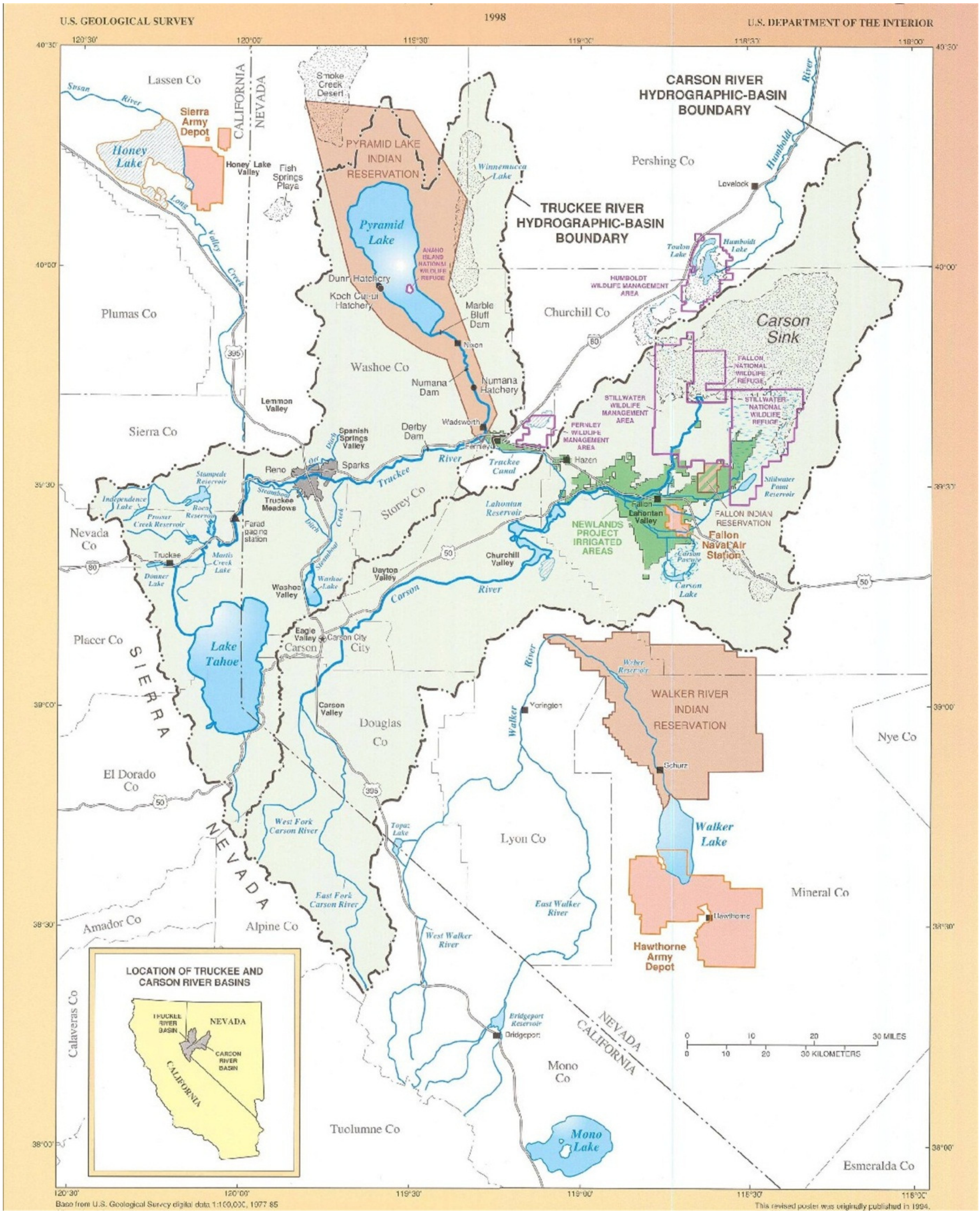

Figure 1. Truckee and Carson River Watershed (map provided by U.S. Geological Survey)

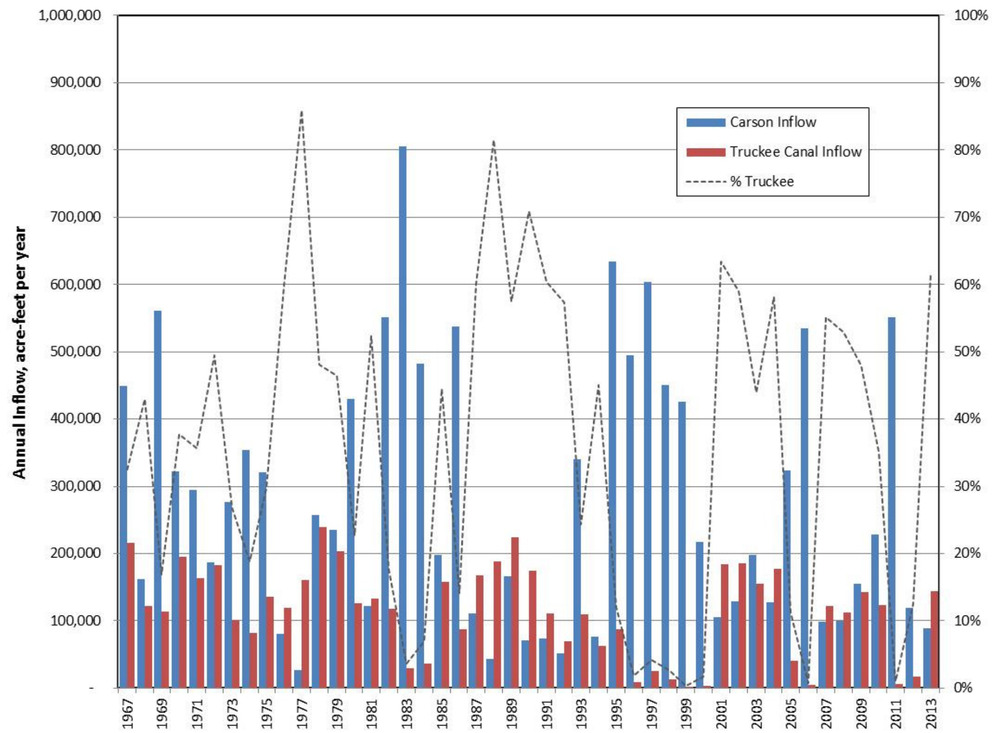

Figure 2. Lahontan Reservoir Inflows, 1967-2013

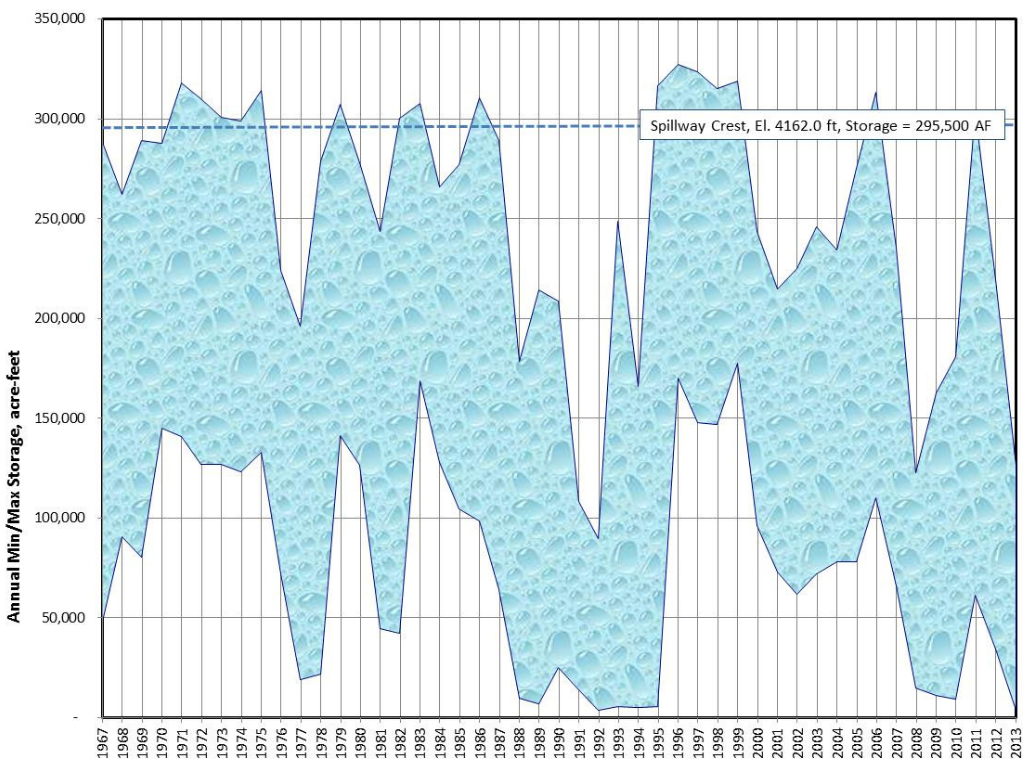

Figure 3. Lahontan Reservoir Storage Levels, 1967-2013

Recreation Uses

While Lahontan Reservoir was created primarily for irrigation, the reservoir has become a very popular recreation site. Lahontan State Recreation Area is the third most visited state park in Nevada, surpassed in visitor count by Lake Tahoe and Valley of Fire State Parks (LVEA, 2009). The recreation area is primarily used for boating, water skiing, fishing, camping at developed campgrounds, and undeveloped camping around the shoreline. Visitation rates are fairly consistent from year to year up through July 4 holiday. Use then drops significantly as water levels decline and water quality worsens (Beauregard, 2013). Boating access can become challenging in some years. When the reservoir is full, there are 69 miles of shoreline and 12,000 acres of lake area available for recreation. The Division of State Parks closes the Silver Springs boat ramp when storage levels fall below 105,000 acre-feet, and the North Shore Marina boat ramp when levels are below 85,000 acre-feet. Based upon these criteria, both boat ramps would have been closed for some period of time during 28 of the 47 years from 1967-2013.

Fisheries

The Nevada Department of Wildlife (NDOW) manages Lahontan Reservoir as a warmwater fishery with the prominent sport fishes include white bass, largemouth bass, wipers (a white bass and striped bass hybrid), smallmouth bass, channel and white catfish, white and black crappie, yellow perch and walleye. The eutrophic conditions create a very productive fishery. All of these fishes, with exception of walleye and wipers, are believed to successfully reproduce in the reservoir without augmentation from stocking. While walleye do occasionally reproduce, reproduction does not occur at level sufficient to maintain the desired fishery. As a result, wipers and walleye are periodically stocked as needed (NDOW, 2012).

The health of the fishery and the level of angler activity are directly tied to water levels in the reservoir. Low water years lead to reductions in the extent of suitable habitat thereby affecting fish propagation and survival. Concurrently, water quality tends to degrade during lower storage periods and angler uses decline.

In 1990, the Carson River basin, from New Empire to Stillwater and the Carson Sink (including Lahontan Reservoir), was designated a Superfund Site due to mercury contamination associated with Comstock era mining activities. Due to high levels of mercury in the tissue of fish in these waters, the Nevada Health Division issued a fish consumption advisory. Under the advisory, it is recommended that no fish be consumed from these waters. The mercury consumption advisory has greatly impacted angler perceptions and reduced harvest levels (NDOW, 2002).

Lahontan Reservoir has experienced significant fish die-offs in 1980, 1981 and 1991. In 1980, a heavy mortality of carp occurred from mid-July through early September. About 99 percent of the carcasses found on the beaches were believed to be mature carp. Investigations indicated that the algal community was dominated by *Aphanizomenon sp*., a cyanobacteria capable of producing toxins known to cause fish kills. However, test results indicated that a low level of toxins existed in the water column. Additional investigations indicated that stress from unsuccessful spawning and an extensive Columnaris infection were the major factors leading to the fish kill. (NDOW, 1981).

Another fish kill occurred in August 1981 with an estimated 20,000 fish involved (80% carp, and 20% Sacramento blackfish (NDOW, 1982). Possible factors causing the fish kill included: *Flexibacter columnaris* infection and toxins produced by *Aphanizomenon sp.* However, available evidence was inconclusive as to the actual cause.

Most recently, a fish kill occurred in early August 1991. NDOW biologists counted nearly 20,000 fish carcasses at the reservoir, 98% carp and 2% Sacramento blackfish (Lahontan Valley News, August 14, 1991). While the newspaper states that the fish kill was caused by toxins produced during an cyanobacteria bloom, no scientific evidence is provided to definitely make that case.

Quagga Mussels

In 2011, Lahontan Reservoir was reported as testing positive for the existence of non-native quagga mussels. Quagga mussels can alter the ecology of a waterbody and can cause significant clogging of water infrastructures such as power generation facilities and irrigation values, etc. Since 2011, sampling has not shown any evidence of quagga mussels in Lahontan Reservoir. NDOW has continued to monitor.

Reservoir Stratification

Thermal stratification is an important consideration as it affects how water quality can vary throughout the water column. Thermal stratification exists in a reservoir when an upper layer is warmed (epilimnion) and essentially floats upon a colder undisturbed region (hypolimnion) (Figure 4). The transition zone is referred to as the metalimnion[1]. During periods of stratification, there is little to no water quality interaction between the epilimnion and hypolimnion. Once stratification ends, the water quality may become mixed throughout the water column.

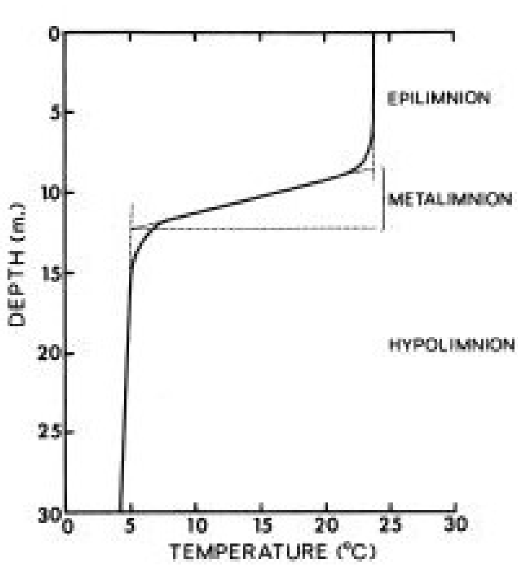

Figure 4. Typical thermal stratification of a lake (from Wetzel, 2001)

[1] It is generally accepted that the metalimnion occurs in that area where the temperature changes at a rate > 1 °C per meter (Wetzel, 2001)

Lahontan Reservoir consists of 3 basins: the upper basin which receives Carson River inflow, the middle basin, and the lower basin which receives Truckee Canal inflow (Figure 5). The upper basin is rather shallow (~ 15 feet) and has gone dry in about 1/3 of the years during the period 1967-2011. According to Cooper and Vigg (1984), the reservoir is generally well mixed during the cold winter months, with water quality rather uniform with depth.

Cooper and Vigg (1984) characterized the upper basin as polymictic, i.e. too shallow to develop thermal stratification and water can mix from top to bottom throughout the ice-free period. As a result, fine sediments tend to remain suspended with reduced clarity. Cooper and Vigg characterize the northern half as meromictic (interuption of stratification patterns at irregular intervals). They concluded that the northern half of the reservoir weakly stratifies for about 50-60 days during the summer (roughly July through August). In both 1980 and 1981, the summer stratification disappeared during September. Richard-Haggard (1983) also states that weaker stratification tends to occur during low flow years when water depths occur and during high flow years when the snow-melt runoff extends well into the summer. Cooper and Vigg (1984) reported that the lower basin did not stratify during the high flow year of 1983.

NDEP investigations of 2003-05, 2012-13 yield similar stratification conditions as discussed by Cooper and Vigg (1984) and Richard-Haggard (1983). During this time period, there was little evidence of stratification in the upper basin. For the northern 1/2 of the reservoir, stratification occurred at most sites for a short period of time during June-September, and then disappeared by September/October.

Nutrient Loading

Since the 1980s, there have been significant changes in nutrient loadings to Lahontan Reservoir from the Carson River and the Truckee Canal. Nutrient concentrations in the Carson River and Truckee Canal have shown a marked reduction following upgrades to the Truckee Meadows Water Reclamation Facility (TMWRF) in the 1980s and the removal of direct treated effluent discharges to the Carson River by 1987. As a result, average loadings of total nitrogen and total phosphorus have dropped by about 60% and 50%, respectively (Pahl, 2007). As with previous estimates, the Carson River is the largest contributor of TN and TP loads (Table 1).

In addition to loading from the Carson River and Truckee Canal, Richard-Haggard (1982) estimated that approximately 30 tons of TP is released from the sediment into the water column during an average year. This equals about 25 percent of the total TP loads to the reservoir.

During the summer of 2012, there were minimal inflows from Carson River and the Truckee Canal. However, reservoir-wide average TP concentrations nearly tripled from June to September due to internal loads. A mass balance analysis using the 2012 water quality data indicated that about 15 tons of TP entered the reservoir during this period. This estimate is much lower than the 30 tons estimated by Richard-Haggard (1983) due to extreme low storage levels in 2012 resulting in a smaller area of submerged sediments compared to average years.

Based upon these loading and flow estimates, the flow-weighted TN concentrations attributed to the Truckee Canal (0.66 mg/l) are estimated to be slightly higher than the Carson River concentrations (0.52 mg/l), while the flow-weighted TP concentrations attributed to the Carson River (0.20 mg/l) are quite a bit higher than for Truckee Canal (0.08 mg/l).

Figure 5. Lahontan Reservoir and Its Three Basins

As the Truckee Canal discharges into Lahontan Reservoir near the outlet structure, there has been some discussion regarding the extent to which Truckee Canal water co-mingles with Lahontan Reservoir water and affects reservoir water quality. French et al. (1983) concluded that there is no evidence that the Truckee Canal water entering Lahontan Reservoir is short-circuited to the nearby outlet structure, and that these flows appear to completely mix with the water in the extreme northern end of the reservoir.

Table 1. Estimated Average Nutrient Loading to Lahontan Reservoir (from Richard-Haggard, 1983 and Pahl, 2007)

	1990-2005 Average Load (tons/year) or Flow (AF)	Flow-weighted TN/TP Concentration (mg/l)
Carson River		
TN (tons/year)	192	0.52
TP (tons/year)	74	0.20
Avg. Annual Flow (AF)	270,000	---
Truckee Canal		
TN (tons/year)	80	0.66
TP (tons/year)	10	0.08
Avg. Annual Flow (AF)	88,000	---
Sediment Release		
TP (tons/year)	30	0.13[1]
Total		
TN (tons/year)	272	0.56
TP (tons/year)	114	0.17[2]
Avg. Annual Flow (AF)	358,000	---

[1]Based upon loading distributed throughout average storage amount of 170,000 AF
[2]Based only upon Carson River and Truckee Canal loading

Water Quality Overview

The current Lahontan Reservoir water quality standards were set in 1984 based upon 1970s/80s EPA guidance and water quality conditions. An evaluation of changes in the reservoir water quality will be an informative part of this standards review. Fortunately some rather extensive water quality monitoring data exists for multiple years (1980-81, 1983, 2003-05 and 2012-13) at multiple sites on the reservoir (Figure 6). An examination of these data suggests how water quality conditions have changed (or not changed) over the last 30+ years. It must be noted that the water quality conditions for Lahontan Reservoir are highly variable from site to site, month to month, and year to year, making it difficult to make any strong statements regarding water quality trends.

Nutrients: Though calculations show that nutrient loads from the Carson River and Truckee Canal have dropped since the 1980s, the June-September data do not show any strong changes in lake-wide nutrient levels over the years (Figure 7). However it becomes complicated evaluating these data for trends due to a number of factors:

- A portion of the decline in loads since the 1980s is the result of decreased Truckee Canal flows.
- Load estimates have not accounted for potential variations in sediment releases of phosphorus.
- Load estimates have not accounted for potential nitrogen loads introduced by nitrogen-fixing algae (see following section on algae conditions).

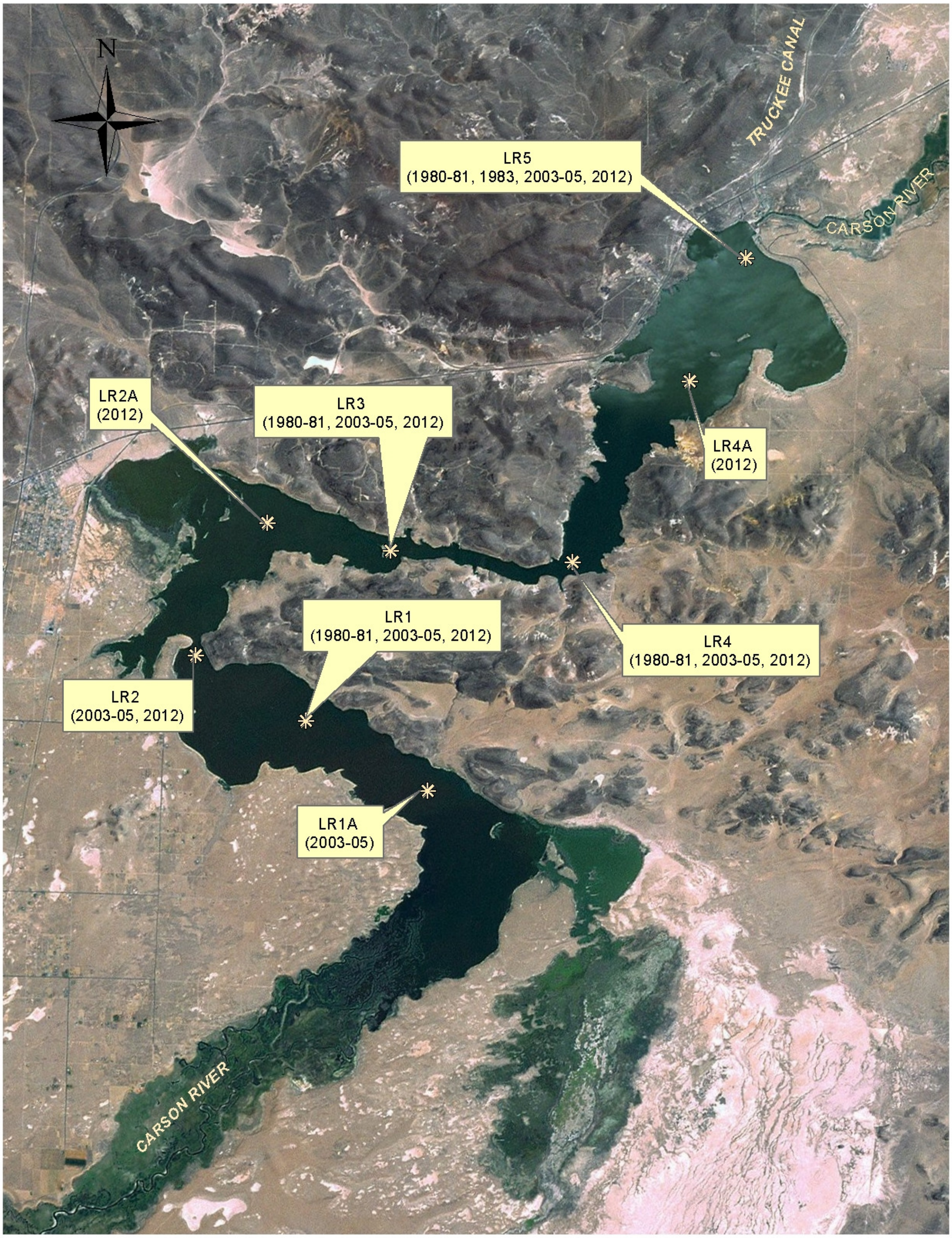

Figure 6. Lahontan Reservoir Monitoring Sites during 1980-81, 1983, 2003-05, 2012-13

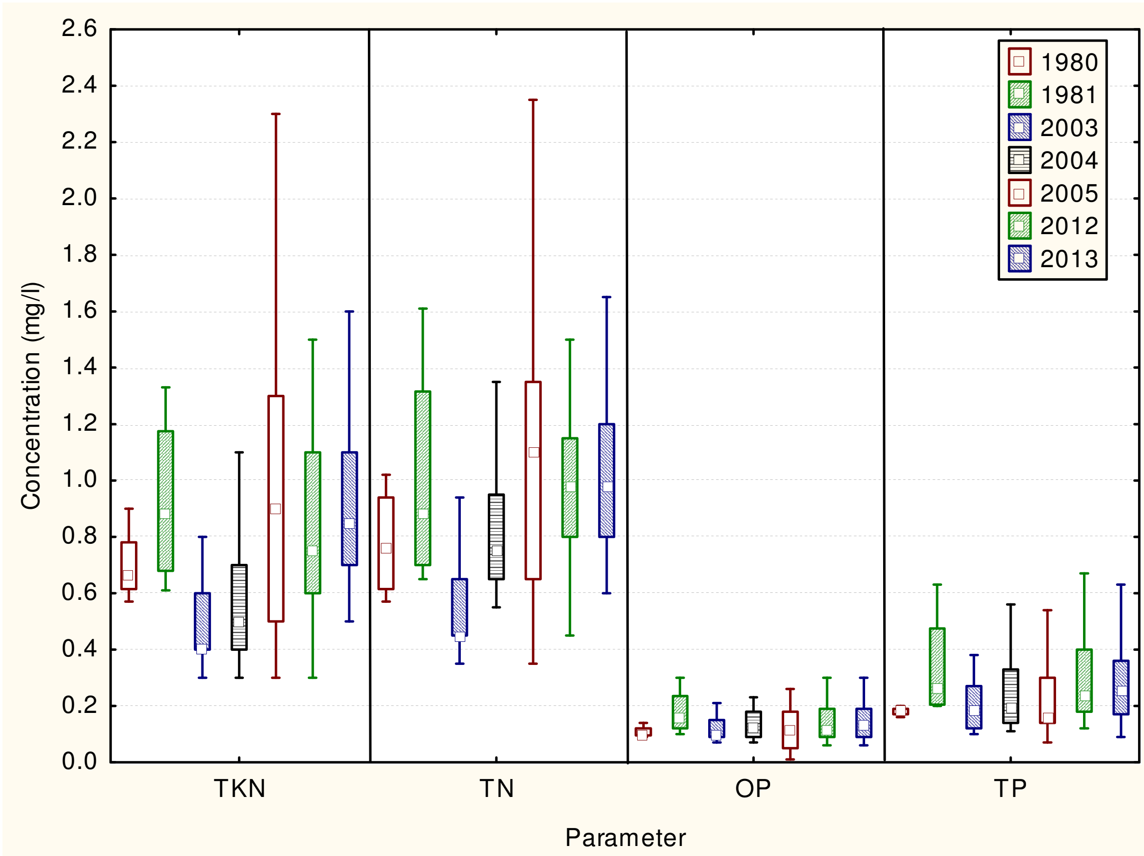

Figure 7. June-September Nutrient Concentrations in the Upper Meter over the Years. TKN = Total Kjeldahl Nitrogen, TN = Total Nitrogen, OP = Orthophosphates, TP = Total Phosphorus

In general, it can be said that water quality in the reservoir improves from the upstream sites to the lower basin site due to settling and the inflow of Truckee Canal water with typically higher water quality. Nevertheless, phosphorus levels throughout the reservoir consistently exceed the existing water quality standard of 0.06 mg/l (Figure 8).

Nutrients levels are typically at their worst during low water conditions. Internal loading resulting from the release of phosphorus from the sediments is believed to have a significant impact especially during low water years. As shown in Figure 9, total phosphorus concentrations increased up to 4 times from June to September 2012 during a period of limited inflows from both the Carson River and the Truckee Canal. A similar significant increase in TP was observed during 2013 when limited Carson River inflow occurred.

For algae to grow in a reservoir, both nitrogen and phosphorus need to be available. However, algae growth may be limited if one or both of these nutrients are in limited supply. The nitrogen-phosphorus ratio (N:P) is a common measure used in evaluating which nutrient (or both) may potentially limit the algae growth. The literature suggests that a N:P ratio above 17 indicates potential P limitation, a ratio below 10 indicates potential N limitation, and values between 10 and 17 indicate that either N or P may be potentially limiting. Emphasis is on "potential" because the measured N and P concentrations may be so high that neither is currently limiting algae growth. In this case, the N:P ratio can be used to predict which nutrient could be used up first during an algal bloom.

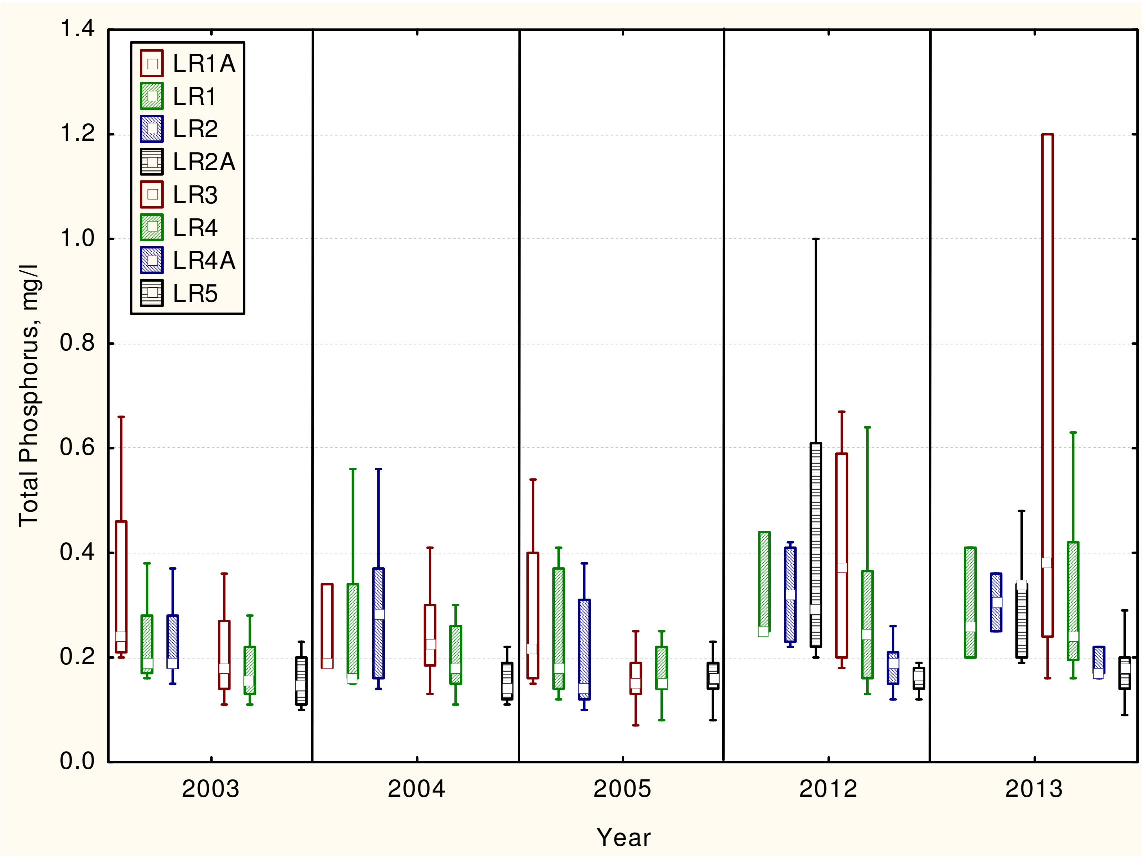

Figure 8. Total Phosphorus Levels, 2003-05, 2012-13

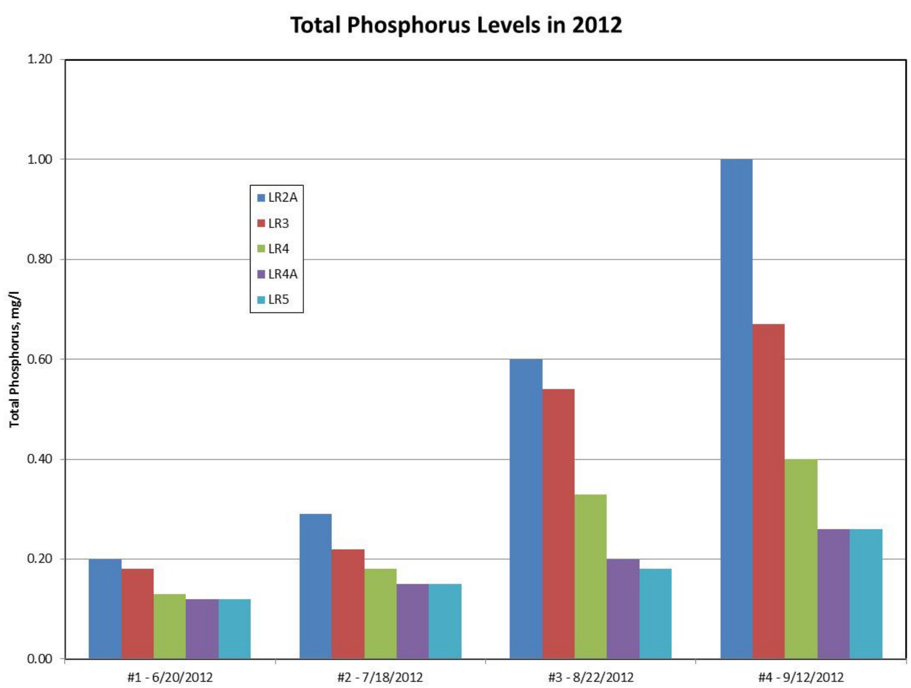

Figure 9. Total Phosphorus Levels in 2012

Cooper et al. (1983) reported that N:P ratios during the growing period in 1980-81 were consistently less than 6. More recent data (2003-05, 2012-13) show N:P ratios ranged from 1.2 to 16.9, 90% of the value below 6.0. Spikes in the N:P ratio (above 6.0) occurred in July 2005 as the result of nitrogen increases due to cyanobacteria fixation from the atmosphere. Based upon this information, it would appear that the reservoir remains nitrogen limited.

Another method to characterize nutrient limitation is through the examination of actual concentration levels of the more readily available forms of nitrogen (total inorganic nitrogen, TIN) and phosphorus (orthophosphates, OP). According to Jones-Lee and Lee (2005), growth rate limiting concentrations for phosphorus are about 5 µg/l (0.005 mg/l) available phosphorus (OP) and for nitrogen, about 20 µg/l (0.02 mg/l) available nitrogen (TIN). Since the 1980s, Lahontan Reservoir OP levels have been consistently greater than 5 µg/l (0.005 mg/l) suggesting that phosphorus has not been a limiting nutrient. During 1980-81, Cooper et al. (1983) measured TIN levels near and below the 20 µg/l (0.02 mg/l) threshold identified by Jones-Lee and Lee for nitrogen limitation. During 2003-05, TIN levels often dropped to <0.2 mg/l (reporting limit for laboratory). This reporting limit is too high to make any conclusions regarding the possibility of nitrogen limitation beyond those conclusions drawn based upon the N:P ratio. During 2012-13, TIN levels most frequently ranged from 0.1 to 0.3 mg/l indicating that nitrogen was not limiting. Nonetheless, N has the potential to be limited as nitrogen is taken up during an algae bloom.

Algae Conditions: Algae conditions (based upon chlorophyll-a concentrations) in Lahontan Reservoir have varied considerably over time and location as depicted in Tables 2 and 3. During the early 1980s, the higher algae levels appear to have occurred in the lower basin (LR4 and LR5). However during 2003-05, the higher algae levels were measured in the upper basin (LR1 and LR2) with a peak level of 256 µg/l at LR1 during July 2005. During one of the 2013 sampling events (6/26/2013), an algae bloom was occurring at LR4 but was limited in spatial area. One sample indicated chlorophyll-a levels of 390.0 µg/l while a sample on the other side of the boat registered chlorophyll-a levels of < 0.5 µg/l. Due to low water levels in 2013, June-September statistics were only calculated for the sites closest to the dam.

Table 2. Average June-September Chlorophyll-a Levels (µg/l) in Upper Meter

Year	LR1A	LR1	LR2	LR2A	LR3	LR4	LR4A	LR5	Entire Reservoir
1980	---	6.5	---	---	7.0	12.0	---	25.0	12.6
1981	---	5.5	---	---	10.3	17.5	---	14.0	12.7
1983	---	---	---	---	---	---	---	9.0*	---
2003	19.1	3.1	2.3	---	1.7	2.2	---	1.9	4.5
2004	9.1	17.2	10.8	---	4.5	3.4	---	3.2	7.7
2005	41.7	55.3	33.1	---	10.7	11.6	---	10.9	20.1
2012	---	5.8	9.8	10.1	8.4	3.3	3.9	5.1	6.4
2013	---	---	---	---	---	51.3	1.6	2.8	18.6

*Value is an average for the upper 2 meters. Maximum algae levels on the surface were found to be 356 µg/l

Table 3. Maximum June-September Chlorophyll-a Levels (µg/l) in Upper Meter

Year	LR1A	LR1	LR2	LR2A	LR3	LR4	LR4A	LR5	Entire Reservoir
1980	---	12.0	---	---	15.0	25.0	---	51.5	51.5
1981	---	7.0	---	---	14.0	26.0	---	16.0	26.0
1983	---	---	---	---	---	---	---	18.0*	18.0*
2003	43.8	3.8	3.7	---	2.7	3.1	---	2.4	43.8
2004	12.7	24.6	19.8	---	6.2	4.9	---	5.5	24.6
2005	153.7	256.0	119.2	---	24.7	39.3	---	42.0	256.0
2012	---	8.0	16.0	13.0	21.0	8.0	7.1	11.0	21.0
2013	---	---	---	---	---	390.0	3.2	1.8	390.0

*Value is an average for the upper 2 meters. Maximum algae levels on the surface were found to be 356 µg/l

During 1980-81 and 1983, the algal community was dominated by *Aphanizomenon flos-aquae*. *A. flos-aquae* is a cyanobacteria that can fix nitrogen from the atmosphere once it is depleted from the water column. In 2004, *A. flos-aquae* was present but only dominated at certain locations periodically during the summer. It is unknown if *A. flos-aquae* dominated in 2003, 2005 and 2012 as no algal taxonomic work was performed. The occurrence of *A. flos-aquae* is of concern as it can outcompete other more desireable forms of algae and can potentially produce toxins which can affect the liver, the nervous system, and/or the skin. However in general, toxin production by cyanobacteria is rare. Information is lacking as to when or why these toxins are produced.

Water Clarity: Water clarity is another useful characteristic to examine when evaluating water quality trends for Lahontan Reservoir. Secchi disk depth is a good indicator of those water quality conditions that affect clarity, such as total suspended solids, turbidity, chlorophyll-a (algae level), etc. The seven years of data shows some variability in the Secchi readings, but with little indication of any trend up or down (Figure 10). The lowest Secchi readings occurred during 2012 and 2013, both extremely low flow water years and not a good indicators for a trend.

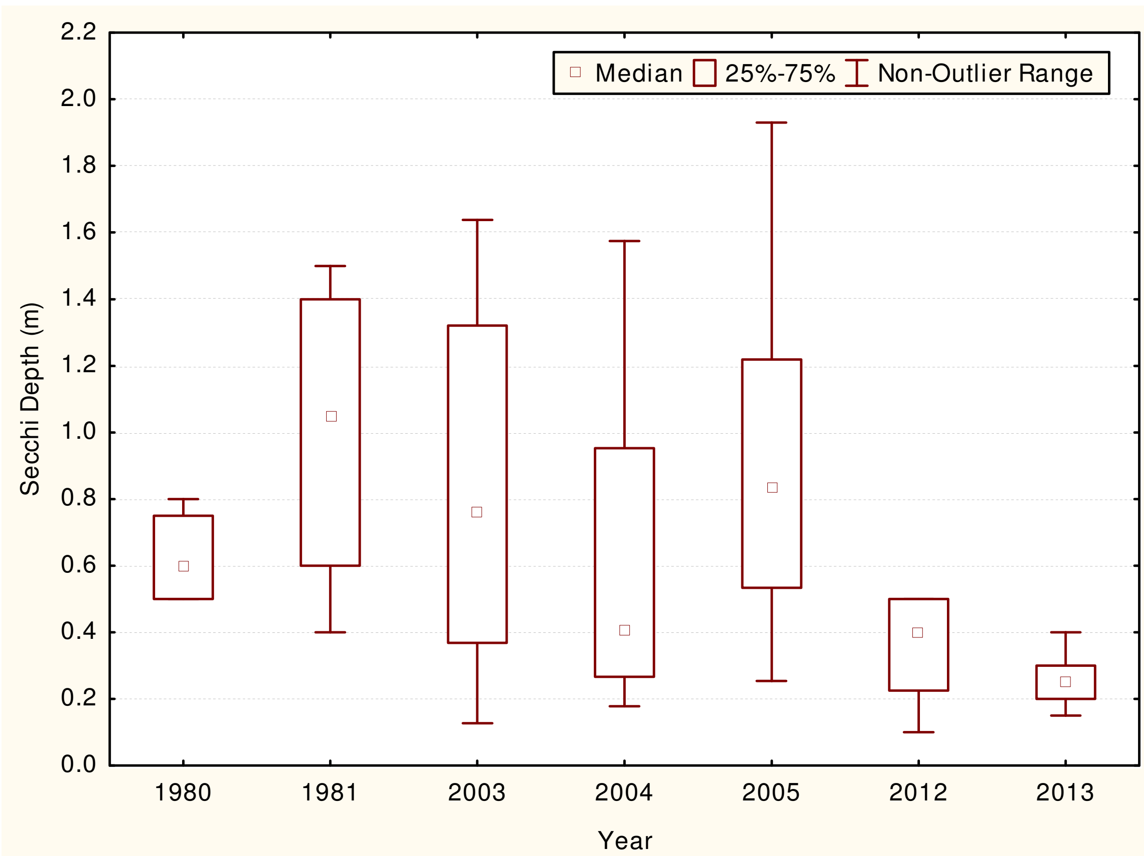

Figure 10. June-September Secchi Depths Throughout the Reservoir

303(d) Impaired Waters List: Every two years, Nevada is required by the federal Clean Water Act to conduct a comprehensive evaluation of Nevada's surface waters to determine whether water quality standards are being met. The resulting list of impaired waters with the problem pollutants is commonly referred to as the 303(d) List. Nevada's 2012 303(d) List identifies the following parameters as exceeding water quality standards: iron, mercury in fish tissue, mercury in sediment, dissolved oxygen, total phosphorus, total suspended solids and turbidity.

Review of Water Quality Standards and Proposed Changes

In the Nevada Administrative Code, water quality standards have been established for particular stream reaches, and lakes/reservoirs. The water quality standards for these reaches/waterbodies are composed of three parts: designated beneficial uses, beneficial use water quality criteria, and antidegradation water quality criteria. Following is a review of the existing reach description for the Carson River section from US Highway 95A at Weeks to Lahontan Dam, and the associated beneficial uses, and water quality criteria.

Reach Description

Currently, the Carson River section from US Highway 95A at Weeks to Lahontan Dam is defined as a single reach in NAC 445A.1824. As a result, the reach includes both a free-flowing river section and a reservoir section (Lahontan Reservoir). However since streams and reservoirs have different water quality dynamics, they typically have a different set of water quality standards. Therefore, it proposed that the river reach be separated from the Lahontan Reservoir segment and added to upstream Carson River reach with no changes to the water quality criteria. NAC 445A.1822 describes water quality standards for the Carson River from Dayton Bridge to US Highway 95A at Weeks. NDEP proposes to revise NAC 445A.1822 so as to be applicable from Dayton Bridge to Lahontan Reservoir. No water quality criteria revisions are planned at this time for this reach. Following is a summary of the proposed reach description revisions:

- Revise limits of NAC 445A.1822 from “Dayton Bridge to US Highway 95A at Weeks” to “Dayton Bridge to Lahontan Reservoir”
- Revise limits of NAC 445A.1824 from “US Highway 95A at Weeks to Lahontan Dam” to “Lahontan Reservoir: entire reservoir”

Beneficial Uses

The current set of beneficial uses were assigned to Lahontan Reservoir as part of the 1984 standards revisions (NDEP, 1984). As was typically done for other waters in Nevada, a suite of beneficial uses were assigned to Lahontan Reservoir, including existing uses and potential future uses:

- Watering of livestock
- Irrigation
- Aquatic life
- Recreation involving contact with the water
- Recreation not involving contact with the water
- Municipal or domestic supply
- Industrial supply
- Propagation of wildlife

Following is a brief description of these uses as they pertain to Lahontan Reservoir. All of these uses have been found to be appropriate and should be protected. Therefore, no changes to these beneficial uses are proposed.

Watering of Livestock: Reservoir releases are used for livestock watering throughout Lahontan Valley.

Irrigation: Reservoir releases are used for irrigation throughout Lahontan Valley

Aquatic Life: The current regulations identify walleye, channel catfish and white bass as species of concern. According to the latest NDOW Fishable Waters Map, the following game fish can be found in Lahontan Reservoir:

- Bullhead Catfish
- Largemouth Bass
- Walleye
- White Catfish
- White Crappie
- Wiper
- Channel Catfish
- Spotted Bass
- White Bass

Both walleye and wipers are often stocked by NDOW to improve the fishery.

Recreation Involving Contact with the Water: Reservoir is frequently used for contact recreation activities, such as swimming and water skiing.

Recreation Not Involving Contact with the Water: Reservoir is frequently used for noncontact recreation activities such as boating and fishing.

Municipal or Domestic Supply: While the reservoir is not directly used as a drinking water supply, it potentially influences springs and wells used by State Parks at the camping facilities. Additionally, reservoir releases recharge groundwater in Lahontan Valley that is subsequently used for drinking water.

Industrial Supply: Some hydroelectric power is generated with the release of water from Lahontan Reservoir.

Propagation of Wildlife: A variety of wildlife species utilize Lahontan Reservoir and the subsequently releases in the Lahontan Valley.

<u>Review of Beneficial Use and Antidegradation Criteria</u>

The beneficial use standards (BUS) are set at values necessary to protect the most sensitive designated beneficial uses, taking into account downstream beneficial uses. In general, BUS are derived from EPA guidance, other agency guidance, or site specific studies. The following sections provide a review of the existing beneficial use standard changes and any recommended changes.

NRS 445.253 requires that any surface waters of the state whose quality is higher than the applicable water quality must be maintained in their higher water quality. One method Nevada uses to implement these antidegradation requirements is through the establishment of RMHQs (**R**equirements to **M**aintain existing **H**igher **Q**uality). RMHQs are generally set for routine parameters where the existing water quality exceeds levels necessary to protect the beneficial uses.

The existing RMHQs for the Carson River section from US Highway 95A at Weeks to Lahontan Dam (NAC 445A.1824) were established in 1984. Though not clear from the documentation, these RMHQs appear to have been generally calculated based upon water quality conditions in the reservoir near the dam. Limited data exist upon which the 1984 RMHQs can be evaluated. Most recently, NDEP has sampled Lahontan Reservoir in 2003-05, and 2012-13 with a focus on the summer conditions. These data are not deemed adequate upon which to base a review of the RMHQs. The focus on summer sampling does not provide an adequate characterization of conditions throughout the year. Also, conditions during 2012-13 were poor due to low water levels and would not be indicative of higher quality water. Therefore, no changes to the existing RMHQs or additions of new RMHQs are recommended under this proposal.

Temperature: Temperature is an important for the health of a waterbody for two main reasons. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. If temperatures get too far outside this preferred range, the number of individuals of the species decreases. Additionally, temperature is important because it influences water chemistry. The rate of chemical reactions generally increases at higher temperatures, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be "saturated" with oxygen but still not contain enough for survival of aquatic life (Washington Dept. of Ecology, 1991).

The beneficial use standards for temperature are directly related to the requirements of the aquatic species that exist in the waterbody. It is assumed that temperatures that are protective of the fish species in a reach will also be protective of other aquatic life forms. The river between US Highway 95A and Lahontan Reservoir are considered warm water fisheries with the following species of concern: walleye, channel catfish and white bass. The current temperature standards were set as following to protect these species:

Nov-Mar ≤ 11 °C
Apr-Jun ≤ 24 °C
Jul-Oct ≤ 28 °C

These criteria were set in 1984 and, according to the rationale, were based upon Nevada Department of Wildlife recommendations and the US EPA's "Quality Criteria for Water" (1972) – often referred to as the Red Book. In addition to the above criteria, a beneficial use temperature standard of $\Delta T \leq 2°C$ was established in 1984. This represents the maximum allowable increase in temperature at the boundary of an approved mixing zone, and is intended to limit degradation due to the potential discharge of heated effluent. The source for the $\Delta T \leq 2°C$ criterion is not known. Nevertheless, this criterion has been in place for years for the main rivers in northern Nevada (Carson River, Humboldt River, Truckee River, Walker River).

A majority of the recent (2003-05, 2012-13) temperature data were collected between May and October. Over 99% of these measurements met the water quality standards with highest temperatures typically occurring in July-August. Limited temperature measurements were taken in February 2004. All of these February measurements met the November-March criterion.

pH: The pH of waters is a measure of the acid-base equilibrium, with low numbers being more acidic and high numbers being more basic. pH levels can affect a variety of beneficial uses. However, EPA guidance has identified aquatic life as the most sensitive to pH. Additionally, pH can impact water treatment process and distribution piping.

The existing NAC pH standard of 6.5 – 9.0 was set in 2002 for the protection freshwater fish and bottom dwelling invertebrates, as described in US EPA's "Quality Criteria for Water" (1986) – otherwise known as the Gold Book. Current EPA recommendations are still 6.5 – 9.0 for the protection of aquatic life and 5.0 – 9.0 for drinking water supplies. Therefore, no revisions are proposed for the pH criteria.

Approximately 98% of the pH measurements in 2003-05, 2012-13 met the current pH standard. All of the pH exceedances occurred in July 2005 during the algae bloom. When algae remove carbon dioxide during photosynthesis they raise the pH by increasing the level of hydroxide in the water.

The current regulations identify contact recreation and wildlife as the most restrictive beneficial use that is protected by the pH standard. It is proposed that aquatic life be designated as the most restrictive beneficial use, rather than these two uses. Current EPA guidance (Gold Book) provides pH criteria recommendations for a variety of uses, with the aquatic life criteria being the most restrictive.

Nutrients and Algae: Nutrients, such as phosphorus and nitrogen, are essential for the health and diversity of our surface waters. However excessive levels can lead to overgrowth of algae, with an associated impact to aquatic life and recreational uses. Typical nutrient levels do not directly impair uses. It is through the responses (algae growth, depressed dissolved oxygen, reduced clarity) to the nutrient levels that the beneficial uses are generally impaired. EPA encourages the adoption of standards for both causal (nutrients) and response (chlorophyll-a) variables.

The current total phosphorus, total nitrogen, nitrate and nitrite criteria were set in 1984 as follows in Table 4. The following discusses the review of these standards and any proposed changes.

Table 4. Current Nutrient Water Quality Standards for Lahontan Reservoir

Parameter	RMHQs	Beneficial Use Criteria	Most Restrictive Beneficial Use
Total phosphates (aka total phosphorus	None	Single value ≤ 0.06 mg/l	Aquatic life; contact recreation
Total nitrogen	Annual Avg: 1.3 mg/l Single Value: 1.7 mg/l	None	Not applicable
Nitrate	None	Single value ≤ 10.0 mg/l	Municipal or domestic supply
Nitrite	None	Single value ≤ 1.0 mg/l	Municipal or domestic supply

<u>Chlorophyll-a:</u> NDEP is proposing to establish a chlorophyll-a standard of 15 µg/l as a June-September average of all sites combined (within a basin) in the upper 1 meter of the water column. This standard has been based upon literature values and other information and is designed to protect contact and noncontact recreation, and aquatic life as the most restrictive uses in the reservoir (Appendix A). The June-September period has been selected as this is the time of highest recreation use and highest algae levels. As a more direct measure of impairment, the chlorophyll-a criterion greatly increases the protection of the beneficial uses than would reliance solely on a total phosphorus standard.

<u>Total Phosphorus:</u> The current total phosphorus criteria were set based upon studies performed by the Desert Research Institute (DRI) in the 1980s. DRI evaluated relations between nitrogen, phosphorus and algae and concluded that phosphorus loading was the major contributor to the eutrophic (highly productive, high algae levels) conditions in the reservoir. In other words, the control of nitrogen levels beyond existing levels was not thought to impact algae levels (Cooper et al., 1983). Therefore, only total phosphorus standards were set for the control of algae (with the intent of protecting aquatic life and contact recreation uses). However, NDEP has identified problems with the current total phosphorus standard and is proposing a revised criterion. A detailed discussion of the proposal is provided in Appendix A.

NDEP is proposing to establish a total phosphorus standard of 0.14 mg/l as a June-September average within each basin as measured in the upper 1 meter of the water column. The proposed standard has been designed to meet June-September average chlorophyll-a levels of 15 µg/l. As previously stated, the June-September period has been selected as this is the time of highest recreation use and highest algae levels.

With this proposed standard, Lahontan Reservoir is expected to remain on the 303(d) list of impaired waters with average June-September total phosphorus levels in the three basins ranging from 0.13 to 0.41 mg/l during 2003-05 and 2012-13. The ability to meet this proposed standard will remain limited. The combined flow-weighted phosphorus concentration from the Carson River and Truckee Canal is estimated at about 0.17 mg/l. On top of that, internal phosphorus loads alone adds another 30 tons/year of phosphorus increasing average reservoir levels to near 0.30 mg/l.

Given that there is significant uncertainty in any relationship between TP and chlorophyll-a, sole reliance on the TP standard (derived from that relationship) to determine the beneficial use support status of Lahontan Reservoir could lead to false conclusions. As a response variable, chlorophyll-a levels are a more direct measure of use support/impairment than are total phosphorus levels. Therefore, NDEP is recommending the incorporation of decision framework based upon both TP and chlorophyll-a, with an emphasis on chlorophyll-a conditions (Figure 11. Under this framework, Lahontan Reservoir would be considered in attainment of the nutrient criteria if the chlorophyll-a criterion was met, regardless of total phosphorus levels. If chlorophyll-a data are not available, the assessment is made solely on total phosphorus levels.

Figure 11. Decision Framework for Attainment of Nutrient Criteria

	Jun-Sep Mean TP ≤ 0.14 mg/l	**Jun-Sep Mean TP > 0.14 mg/l**
Jun-Sep Mean Chl-a ≤ 15 µg/l	Criteria met	Criteria met
Jun-Sep Mean Chl-a > 15 µg/l	Criteria NOT met	Criteria NOT met
Chl-a level is unknown	Criteria met	Criteria NOT met

This decision framework would be incorporated in the NAC by including the following footnote for the total phosphorus and chlorophyll-a criteria:

The nutrient criteria are considered attained if:

1. *The chlorophyll-a criterion is met regardless of the level of total phosphorus; or*
2. *If chlorophyll-a data are not available, the total phosphorus criterion is met*

Total Nitrogen: NDEP is proposing to not add a total nitrogen beneficial use standard for the control of algae. Because of the nitrogen-fixing ability of the cyanobacteria that common grows in the reservoir, setting a maximum nitrogen standard and maintaining that level would do little to limit cyanobacteria growth. In 1983, Cooper et al., concluded that the control of nitrogen levels beyond existing levels was not thought to impact algae levels and no nitrogen standards were set (Cooper et al., 1983). However, EPA (2012) recently produced a fact sheet in support of the development of both phosphorus and nitrogen water quality criteria. Several points are made in this fact sheet:

1. Because of the highly variable nature of nutrient limitation in aquatic systems, numeric criteria for both N and P provided the greatest likelihood of protecting aquatic systems.
2. Because of the diversity of the nutritional needs amongst organisms, numeric criteria for both N and P area more likely to protect aquatic systems.
3. Because N fixation is highly variable across waterbody types, numeric criteria for both N and P are likely to be more effective in protecting aquatic systems.
4. Both N and P criteria are important to consider when assessing downstream impacts.

NDEP concludes similarly and proposes to not establish a beneficial use nitrogen standard, but rely on the existing RMHQs for the maintenance of existing quality. A detailed discussion of our rationale is provided in Appendix A.

Nitrate: The current nitrate beneficial use standard of 10 mg/l is based upon EPA criteria for protection of municipal or domestic supplies. Nitrate creates problems in humans when it is reduced to nitrite, as may occur in the gastrointestinal tract. In infants less than 6 months old, nitrite can then reach the bloodstream and react with hemoglobin to produce methemoglobin, which impairs oxygen exchange. The current EPA recommendation for nitrate remains at 10 mg/l so NDEP is not proposing any regulatory changes.

Nitrite: The current nitrite beneficial use standard of 1.0 mg/l is based upon EPA criteria for the protection of municipal or domestic supplies. Because of the potential risk of metheglobinemia, EPA recommends that waters with nitrite concentrations over 1.0 mg/l not be used for infant feeding. EPA has not updated its recommendation so NDEP is not proposing any regulatory change to the nitrite standard.

Total Ammonia: The current total ammonia criteria were set in 2002 for the protection of aquatic life and are based upon 1999 EPA guidance. The criteria are based upon rather complicated calculations based upon water temperature and pH. In 2013, EPA released revised guidance which recommends calculations different from the 1999 guidance and Nevada's current regulations. NDEP will be re-evaluating the current total ammonia standards as part of a statewide activity.

Dissolved Oxygen: The amount of oxygen dissolved in a body of water serves as an indication of the health of the water and its ability to support a balanced aquatic ecosystem. Dissolved oxygen (DO) is essential for the survival of all aquatic organisms.

The existing DO standard of 5.0 mg/l was established in 1984 based upon EPA's Red Book recommendation (1976) for maintenance of healthy fishery. Current EPA guidance recommends the same value (5.0 mg/l) for the protection of warmwater fish.

DO levels in Lahontan Reservoir vary throughout the year and with depth. Natural stratification can have a significant impact upon DO levels on all lakes and reservoirs, including Lahontan Reservoir. During the summer when stratification is common, organic material (algae) that is produced in the epilimnion settles into the hypolimnion where it decomposes. The dissolved oxygen consumed in the process is not replaced as stratification prevents mixing of the hypolimnion with the higher DO water in the epilimnion. As a result, DO levels below 5 mg/l can be common in the hypolimnion in a productive lake such as Lahontan Reservoir. Figure 12 depicts dissolved oxygen levels at LR5 in 2003.

It is proposed that the current DO standard of 5.0 mg/l be retained in the regulations, with the criterion applying to the entire water column, except during times of stratification when the criterion apply only in the epilimnion. Lahontan Reservoir is currently meeting the proposed DO water quality standard in over 95% of the measurements.

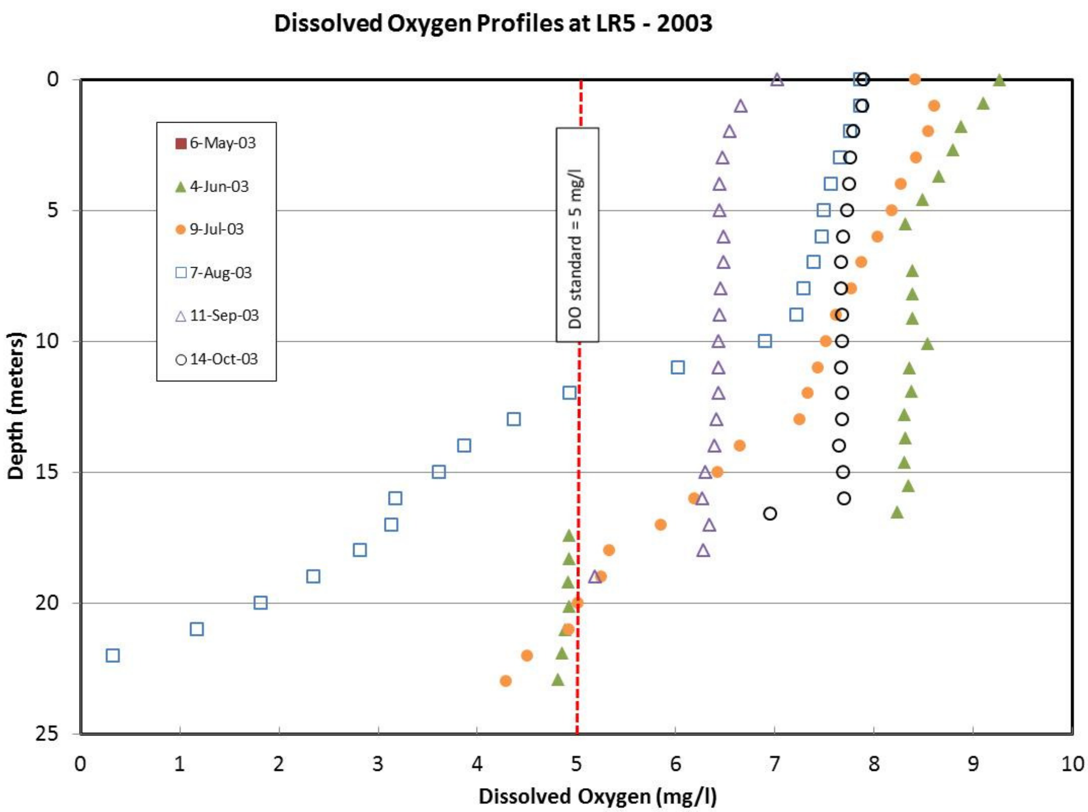

Figure 12. Dissolved Oxygen Profile at LR5, 2003

Total Suspended Solids: Total Suspended Solids (TSS) are solid materials, including organic and inorganic, that are suspended in the water. Suspended solids affect aquatic life in a variety of ways. Excess TSS levels can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. Particles that settle out can smother fish eggs and those of aquatic insects, as well as suffocate newly-hatched larvae.

EPA's "Blue Book" (1972) recommended TSS levels of 25 mg/l for a high level of protection of aquatic communities and 80 mg/l for a moderate level of protection. In 1984, the Carson River reaches upstream of Highway 95A were assigned TSS standards of 80 mg/l due to the "excessively high" values that occurred. Lower TSS levels were expected in Lahontan Reservoir due to settling. Therefore, a TSS standard of 25 mg/l (Single Value) was selected for Lahontan Reservoir in 1984.

Subsequent criteria guidance documents (Red Book, 1976; Gold Book, 1986) did not provide suspended solids standards as measured as TSS. In 2003, EPA recognized the need for updated TSS and turbidity criteria recommendations and established a strategic action to "produce and implement a strategy for the development of suspended and bedded sediment criteria (EPA, 2003). While some draft documents have been produced as a result, it is unknown when any final guidance will be available. Until any final guidance is issued, NDEP has decided to incorporate the older guidance values as appropriate.

A summary of TSS conditions in the reservoir is provided in Table 5. Lahontan Reservoir is currently on NDEP's 2008-10 impaired waters list due to exceedances of the TSS standard.

Table 5. Summary of TSS Conditions (in mg/L)

	2003	**2004**	**2005**	**2012**	**2013**
No. of Samples	71	78	67	50	43
Minimum	<10	<10	10	4	<10
Maximum	160	100	170	192	116
Average	27	19	20	36	36
% Exceedance	35.2%	15.4%	13.4%	48.0%	48.8%

Turbidity: Turbidity is a measure of how particles suspended in water affect water clarity. Elevated turbidity can affect the productivity of a lake thereby reducing food availability for aquatic life, and can impair the ability of fish to feed. In general, warmwater fish are more tolerant of turbid conditions than are coldwater fish.

The existing Single Value turbidity standard of 50 NTU (nephlometric turbidity units) was set in 1984 for the protection of warmwater fish based upon EPA's "Water Quality Criteria (Green Book)" (1968) recommendations for warmwater streams. According to the Green Book, the turbidity levels for a warmwater lake should be less than 25 NTU. Subsequent EPA guidance (Blue Book, 1972; Red Book, 1976; Gold Book, 1986) no longer provided a recommendation for turbidity in streams or lakes. Until any final guidance is issued, NDEP has decided to incorporate the older guidance values as appropriate.

A summary of turbidity conditions in the reservoir is provided in Table 6. Lahontan Reservoir is currently on NDEP's 2008-10 impaired waters list due to exceedances of the TSS standard.

Table 6. Summary of Turbidity Conditions (in NTU)

	2003	**2004**	**2005**	**2012**	**2013**
No. of Samples	71	78	67	50	43
Minimum	7	8	5	19	10
Maximum	130	130	200	180	130
Average	33	36	28	61	57
% Exceedance	11.3%	24.4%	9.0%	42.0%	51.1%

Color: The most common cause of color in water is from the decomposition of naturally occurring organic matter. Of the beneficial uses, drinking water is considered to have the most restrictive color requirements.

Based upon 1976 EPA (Red Book), the current standard of 75 PCU (platinum-cobalt color units) was established in 1984 to protect municipal or domestic supply. According to the Red Book, water can consistently be treated using standard coagulation, sedimentation and filtration processes to reduce color to < 15 color units (Safe Drinking Water Act limits) when the source water is at 75 color units.

No revised color criteria recommendations have been developed at this time. Therefore, no changes are proposed for the existing color beneficial use criteria. A summary of color conditions in the reservoir is provided in Table 7. Over 98% of the samples in 2003-05, 2012-13 meet the current color standard

Table 7. Summary of Color Conditions (in pcu)

	2003	**2004**	**2005**	**2012**	**2013**
No. of Samples	71	78	67	50	43
Minimum	10	10	20	25	25
Maximum	75	60	80	120	80
Average	30	26	29	53	46
% Exceedance	0.0%	0.0%	1.5%	8.0%	2.3%

Total Dissolved Solids: Total dissolved solids (TDS) consist of inorganic salts, small amounts of organic matter and dissolved materials. While the term salinity (used in oceanography) and TDS are not precisely equivalent, for most purposes the terms are generally the same. The principal inorganic anions and cations dissolved in water include the carbonates, chlorides, sulfates, sodium, potassium, calcium and magnesium. Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and higher costs for treatment systems because of corrosion or the necessity for additional treatment.

The current TDS criterion of 500 mg/l (annual average) was established in 1984 based upon 1977 Water Supply Regulations established by the Nevada Division of Health. This criterion is consistent with current EPA guidance and no revisions are proposed.

A summary of TDS conditions in the reservoir is provided in Table 8. All of the samples in 2003-05, 2012 meet the current TDS standard. In 2013, one sample exceeded the standard.

Table 8. Summary of TDS Conditions (in mg/L)

	2003	**2004**	**2005**	**2012**	**2013**
No. of Samples	71	78	67	50	43
Minimum	98	137	95	171	162
Maximum	238	316	241	342	667
Average	188	208	160	220	242
% Exceedance	0.0%	0.0%	0.0%	0.0%	2.3%

Chloride: As described above, chloride is one of the anions that make up TDS in waters. Chloride ions have been found to cause mineral tastes in drinking water at lower concentrations than other constituents. Also, chlorides can potentially be toxic to aquatic life.

The current chloride beneficial use criterion of 250 mg/l (single value) was established in 1984 for the protection of municipal or drinking water uses. As with TDS, the chloride criterion was based upon 1977 Nevada Division of Health drinking water standards that existed at the time. Currently, EPA has recommended chloride criteria for the protection of aquatic life as follows: chronic - 230 mg/L (96-hour); acute - 860 mg/L (1-hour) (not to be exceeded more than once in any three year period). According to the guidance, these criteria are not to be exceeded more than once during a three year period. It is proposed that the chloride beneficial use criteria be changed in accordance with the current guidance.

A summary of chloride conditions in the reservoir is provided in Table 9. All of the samples in 2003-05, 2012-13 meet the proposed chloride standard.

Table 9. Summary of Chloride Conditions (in mg/L)

	2003	2004	2005	2012	2013
No. of Samples	71	78	67	50	43
Minimum	<5	<5	<5	5	5
Maximum	16	20	19	14	60
Average	10	12	9	7.4	13

Sulfate: Sulfates are one of the anions that contribute to TDS concentrations. Elevated sulfate levels may have a laxative effect of drinking water users. The current sulfate beneficial use criterion of 250 mg/l (single value) was established in 1984 for the protection of municipal or drinking water uses. As with TDS and chloride, the sulfate criterion was based upon 1977 Nevada Division of Health drinking water standards that existed at the time. This criterion is consistent with current EPA guidance and no revisions are proposed.

A summary of sulfate conditions in the reservoir is provided in Table 10. All of the samples in 2003-05, 2012-13 met the current sulfate standard.

Table 10. Summary of Sulfate Conditions (in mg/L)

	2003	2004	2005	2012	2013
No. of Samples	71	78	67	50	43
Minimum	12	19	12	23	22
Maximum	55	69	75	66	240
Average	32	35	28	35	40

Sodium – SAR (Sodium Adsorption Ratio): Irrigating with water high in sodium relative to the calcium and magnesium contents can result in excessive soil accumulation of sodium, leading to reductions in water infiltration. The most common measure to assess for this potential problem is called the Sodium Adsorption Ratio (SAR). SAR is calculated value which relates relative concentrations of sodium (Na) to the sum of calcium (Ca) and magnesium (Mg) ions in a sample.

The current annual average SAR standard of 8 was established in 1984 for the protection of irrigation uses. According to the 1984 Rationale document, this criterion was based upon guidance provided in EPA's "Quality Criteria for Water (Red Book)" (1976). Actually, both the Red Book and the more recent (1986) Gold Book provide a SAR range of 8 to 18 that are generally considered useable for general crops and forages. In addition, the Red and Gold books state that SAR values of 4 may be more appropriate for sensitive fruits.

No change to the current SAR standard is proposed. All samples collected in 2003-04 and 2012-13 meet the current standard (Table 11).

Table 11. Summary of SAR Conditions

	2003	2004	2005	2012	2013
No. of Samples	26	18	No data	50	21
Minimum	1	1.3	No data	0.7	0.9
Maximum	1.5	1.6	No data	1.34	2.9
Average	1.3	1.4	No data	0.82	1.1

Alkalinity: Alkalinity, often referred to as hardness, is the sum total of components in the water that tend to elevate the pH above a value of about 4.5. Alkalinity is important for aquatic life because it buffers pH changes, including those that occur naturally as a result of algal photosynthetic activity. Also, the main components of alkalinity will complex with some toxic heavy metals and reduce their toxicity.

The current alkalinity standard of "<25% change from natural conditions" was based upon EPA's recommendations in Water Quality Criteria (1972) also known as the "Blue Book". Current EPA guidance recommends an alkalinity criterion of $\geq$20 mg/l as $CaCO_3$ except where natural conditions are less. Because of the buffering capability of alkalinity, a minimum limit was recommended.

For Lahontan Reservoir, it is recommended that the alkalinity standard be revised to "$\geq$20 mg/l" in accordance with current EPA recommendations. Alkalinity levels in Lahontan Reservoir average around 75 mg/l as $CaCO_3$. No exceedances of the proposed beneficial use criterion have been identified in the entire period of record.

A summary of alkalinity conditions in the reservoir is provided in Table 12. All of the samples in 2003-05, 2012-13 met the proposed sulfate standard.

Table 12. Summary of Alkalinity Conditions (in mg/L)

	2003	2004	2005	2012	2013
No. of Samples	71	78	67	50	43
Minimum	42	56	49	77	75
Maximum	94	117	100	130	152
Average	77	84	72	91	88

E. Coli: *E. coli* (*Escherichia coli)* is a bacteria that occurs in water and has been used as an indicator of fecal contamination. *E. coli* criteria are set to protect primary contact recreation, including swimming, bathing, water skiing, etc., where a high degree of body contact with the water, immersion and ingestion are likely.

Water quality criteria for bacteria are concentrations of indicator organisms that should not be exceeded in order to protect human health from pathogen-caused illness. Waterbodies may contain many different pathogens that cannot be measured directly; therefore, indicator organism are used to predict the health risks from pathogens in water. EPA has recommended that *E coli* be used to predict the presence of gastrointestinal illness-causing pathogens in freshwaters.

The current *E. coli* criteria were set in 2002 and were based upon EPA's "Ambient Water Quality Criteria for Bacteria" (1986):

Annual Geometric Mean < 126 No./100 mL
Single Value < 235 No./100 mL

All of the samples collected in 2003-05, and 2012-13 met these standards (Table 13).

Table 13. Summary of E Coli Conditions (in No./100 mL)

	2003	2004	2005	2012	2013
No. of Samples	38	37	30	23	18
Minimum	<10	<10	<10	<10	<10
Maximum	20	<10	42	20	20

In 2012, EPA issued revised contact recreation criteria for *E. coli* that vary from the previous guidance. NDEP is in the process of working with EPA to resolve some issues associated with the revised guidance. Once these issues are resolved, NDEP anticipates reviewing all *E. coli* standards for all waters in the NAC, including Lahontan Reservoir.

Fecal coliform: Fecal coliform is another bacteria that has been used as an indicator of fecal contamination of water. However since 1986, EPA has recommended *E. coli* as it has been found to be a better indicator. In 2012, NDEP revised the fecal coliform criterion to 1,000 No./100 ml for the protection of irrigation uses based upon EPA's Blue Book (1972). No additional changes are proposed at this time. All of the samples collected in 2003-05, and 2012-13 met the current standards (Table 14).

Table 14. Summary of Fecal Coliform Conditions (in No./100 mL)

	2003	2004	2005	2012	2013
No. of Samples	38	37	30	23	18
Minimum	<10	<10	<10	<10	<10
Maximum	30	20	80	10	20

Summary of Proposed Revisions

Following is a summary of the proposed revisions for NAC 445A.1822 and 445A.1824 which covers the Carson River section from Dayton Bridge to Lahontan Dam, and water quality criteria.

Reach Description: Currently, the Carson River section from US Highway 95A at Weeks to Lahontan Dam is defined as a single reach in NAC 445A.1824. As a result, the reach includes both a free-flowing river section and a reservoir section (Lahontan Reservoir). However since streams and reservoirs have different water quality dynamics, they typically have a different set of water quality standards. Therefore, it proposed that the river reach be separated from the Lahontan Reservoir segment and added to upstream Carson River reach with no changes to the water quality criteria. NAC 445A.1822 describes water quality standards for the Carson River from Dayton Bridge to US Highway 95A at Weeks. NDEP proposes to revise NAC 445A.1822 so as to be applicable from Dayton Bridge to Lahontan Reservoir. No water quality criteria revisions are planned at this time for this reach. Following is a summary of the proposed reach description revisions:

- Revise limits of NAC 445A.1822 from “Dayton Bridge to US Highway 95A at Weeks” to “Dayton Bridge to Lahontan Reservoir”

- Revise limits of NAC 445A.1824 from “US Highway 95A at Weeks to Lahontan Dam” to “Lahontan Reservoir: entire reservoir”

- Revise parameter name “Total Phosphates” to “Total Phosphorus”

- Revise Total Phosphorus criteria from “S.V. $\leq$ 0.06 mg/l” to “S.V. $\leq$ 0.14 mg/l”. Add chlorophyll-a standard of “S.V. $\leq$ 15 µg/l”. Both criteria will be based upon a June-September average within each basin as measured in the <u>upper 1 meter</u> of the water column. Additionally, the following footnote will be included:

  The nutrient criteria are considered attained if:

  1. *The chlorophyll-a criterion is met regardless of the level of total phosphorus; or*
  2. *If chlorophyll-a data are not available, the total phosphorus criterion is met*

- Revise Dissolved Oxygen criterion to include following footnote – “*When lake is stratified, the dissolved oxygen standard applies only to the epilimnion*.”

- Revise Chlorides criterion from “S.V. ≤ 250 mg/l” to “1-hour avg. ≤ 230 mg/l; 96-hour avg. ≤ 860 mg/l”.

- Revise Alkalinity criterion from “<25% change from natural conditions” to “S.V. ≥ 20 mg/l”.

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APPENDIX A

RECOMMENDED BENEFICIAL USE CRITERIA FOR NUTRIENTS

Review of Beneficial Use Criteria for Nutrients

Nutrients, such as phosphorus and nitrogen, are essential for the health and diversity of our surface waters. However excessive levels can lead to overgrowth of algae, with an associated impact to aquatic life and recreational uses. Typical nutrient levels do not directly impair uses. It is through the responses (algae growth, depressed dissolved oxygen, reduced clarity) that the beneficial uses are generally impaired.

Background on Current Standards

The current phosphorus and nitrogen criteria were set in 1984 as follows in Table A-1:

Parameter	Criteria	Most Restrictive Beneficial Use
Total phosphates (aka total phosphorus	Single value ≤ 0.06 mg/l	Aquatic life; contact recreation
Nitrate	Single value ≤ 10.0 mg/l	Municipal or domestic supply
Nitrite	Single value ≤ 0.1 mg/l	Aquatic life

While the nitrate and nitrite criteria were set based upon EPA guidance, the total phosphorus criteria were set based upon studies performed by the Desert Research Institute (DRI) in the 1980s. DRI evaluated relations between nitrogen, phosphorus and algae and concluded that phosphorus loading was the major contributor to the eutrophic (highly productive, high algae levels) conditions in the reservoir. In other words, the control of nitrogen levels beyond existing levels was not thought to impact algae levels (Cooper et al., 1983). Therefore, only total phosphorus standards were set for the control of algae (with the intent of protecting aquatic life and contact recreation uses).

The total phosphorus standard was based upon an assumed algae level in the reservoir that was deemed to be acceptable. One of the first steps in developing the total phosphorus standard was to establish a desired maximum algae level. High algae levels decrease the aesthetic value of the reservoir for swimming, boating, and water skiing. While some algae is needed to provide food for aquatic life including fish, too much can be detrimental and can lead to depressed dissolved oxygen levels in the lower depths of the reservoir. Based upon DRI recommendations, NDEP selected the chlorophyll-a target of 10 µg/l. Chlorophyll-a is a pigment that exists in algae and other plants, and is a common surrogate for algal biomass. From the NDEP Water Quality Standards Rationale (1984):

> "*Eutrophic conditions are generally associated with waterbodies having mean summer chlorophyll-a values exceeding 10 ug/l."* (Jones and Lee, 1979). *Lakes and reservoirs that fall into this category usually have excessive growths of algae that significantly impair beneficial uses* (Archibald and Lee, 1981). *The goal at Lahontan Reservoir will be to achieve a meso-eutrophic level of productivity that would be characterized by a summer mean chlorophyll-a value of less than 10 ug/l.*

Cooper and Vigg (1984) found the lower basin near the dam to be more productive with summer chlorophyll-a levels about 4 to 5 time higher than in the upper basin of the reservoir. Therefore, conditions in the lower basin were used to derive the phosphorus standard. To achieve the chlorophyll-a goal of 10 µg/l in the lower basin, it was estimated that the total phosphorus levels needed to be at or below 0.06 mg/l (60 µg/l) based upon the following equation presented by Grieb et al. (1983):

Mean Summer Chlorophyll-a (μg/l) = 0.9(P)*$^{0.6}$ [Eq. 1]

$$\text{Mean Summer Chlorophyll-a } (\mu g/l) = 0.9 \cdot (P)^{0.6} \quad \text{[Eq. 1]}$$

Where:

P = mean summer in-lake total phosphorus concentration (μg/l)

While Grieb et al. developed 7 equations for various light and nutrient limiting conditions, the above equation produced the best predictions for the more productive lower basin. Empirical equations by other authors were evaluated but the above-Grieb et al. equation provided estimates that best approximated actual chlorophyll-a measurements. As a result of this work, the Lahontan Reservoir total phosphorus standard was set as a single value of 0.06 mg/l.

Problems with Development of the Current TP Standard

A review of the methods used to develop the current Lahontan Reservoir TP standard suggested there are a number of significant short comings in the approach (Pahl, 2012). Some key issues are as follows:

- The chlorophyll-a target of 10 μg/l used in the analysis may not be appropriate for Lahontan Reservoir. According to the standards rationale, Jones and others (1979) stated that eutrophic conditions are generally associated with waterbodies having mean summer chlorophyll-a values exceeding 10 μg/l. In reality, Jones and others never identified 10 ug/l chlorophyll-a as the threshold above which waterbodies could be considered as eutrophic. They did however summarize a range of chlorophyll-a thresholds suggested by five different publications to be indicative of oligotrophic, mesotrophic and eutrophic. The use of trophic thresholds for setting chlorophyll-a goals are discussed in more detail later in this document.

  The standards rationale also references Archibald and Lee (1981) to justify use of the 10 μg/l target for chlorophyll-a. However, Archibald and Lee provide no citation or support for their use of this threshold.

- In developing their equations, Grieb et al. used nutrient, chlorophyll-a and Secchi depth data for 34 manmade lakes in south eastern U.S. While the Grieb et al. equation seems to fit the 1980-81 dataset, the climate, geography and hydrology of the southeastern region of the U.S. is considerably different from that of the Carson River basin and Lahontan Reservoir. This raises significant concerns about the use of this equation from a regulatory standpoint. According to Grieb et al., *"[c]are should be taken in applying the model in dissimilar regions other than as a first approximation of the expected conditions in a warm water fishery."*

- The uncertainty in any prediction derived from the Grieb et al. equation is large. In order to meet the chlorophyll-a target of 10 ug/l (mean summer level in epilimnion), the Grieb et al. equation predicts that a mean summer total phosphorus level of 60 ug/l (0.06 mg/l) would be acceptable. However when uncertainty in the equation is accounted for, there is 95% confidence that the acceptable phosphorus levels for a given summer could be anywhere between 10 ug/l (0.01 mg/l) and 350 ug/l (0.35 mg/l).

- The Grieb et al. equation was based upon June-August mean total phosphorus and chlorophyll-a levels. However, the current total phosphorus standard of 0.06 mg/l was set as a single value criterion. Based upon the Grieb methodology, some sort of average total phosphorus standard may have been more appropriate than a single value criterion.

- According to Nevada state law and the Clean Water Act, water quality standards are to be reasonably achievable. Given that the average total phosphorus levels (0.20 mg/l) in the Carson River (at Lahontan Reservoir) are significantly higher than 0.06 mg/l, an unrealistically large reduction in nonpoint sources in the watershed would be needed to achieve the necessary TP levels in the reservoir. Additionally, Richard-Haggard (1983) estimated that an average of 30 tons/year of phosphorus are released from the sediment into the water column. This loading is sufficient to result in a water column TP concentration (0.13 mg/l) much higher than the standard. Significant reductions in these loads would be extremely challenging and expensive.

Selecting an Appropriate Chlorophyll-a Target

The common approach for establishing nutrient criteria for a reservoir is to first develop desired endpoints for the response variables, such as chlorophyll-a, as needed to maintain a certain trophic condition (oligotrophic, mesotrophic, eutrophic) or to support beneficial uses. Once these criteria are identified, phosphorus and nitrogen can be derived based upon nutrient-chlorophyll-a relationships: 1) derived from data specific to the reservoir, and 2) from the literature.

The current Lahontan Reservoir standard is based upon a desired trophic condition at the boundary between mesotrophic and eutrophic conditions. There are a couple key issues with basing a chlorophyll-a threshold upon a desired trophic condition. The trophic state of a reservoir is a general concept with no precise definition and no single set of agreed upon thresholds for classification. As a result, several different classification schemes have been developed over the years with different averaging periods (annual, growing season, summer). Setting the algae goal for a reservoir at a somewhat arbitrary mesotrophic-eutrophic boundary may or may not be protective of a particular use.

Another problem is in relating a trophic classification to the beneficial use. One main tenet of water quality standards is that criteria are set to protect the beneficial uses. Basing a water quality standard on trophic classification with no consideration as to how this may relate to beneficial uses is a flawed approach.

As EPA has not recommended any particular chlorophyll-a values as needed to protect beneficial uses, selection of an appropriate chlorophyll-a threshold becomes complicated. To aid in the selection of an appropriate algae threshold, NDEP performed a thorough review of the literature and other states' regulations to identify potential candidate values for Lahontan Reservoir (Appendices B-E). The key beneficial uses for which chlorophyll-a thresholds are usually set to protect are as follows:

- Contact and non-contact recreation
- Aquatic life
- Municipal and drinking waters

The following sections present a review of the potential chlorophyll-a thresholds for these beneficial uses. One complicating factor in the selection of a chlorophyll-a threshold is that desired goals for one beneficial use may conflict with that for another use. For example, a number of studies have shown that fish productivity can increase with increases in algae levels (Figure A-1), while recreational uses may be adversely impacted by these higher algae levels.

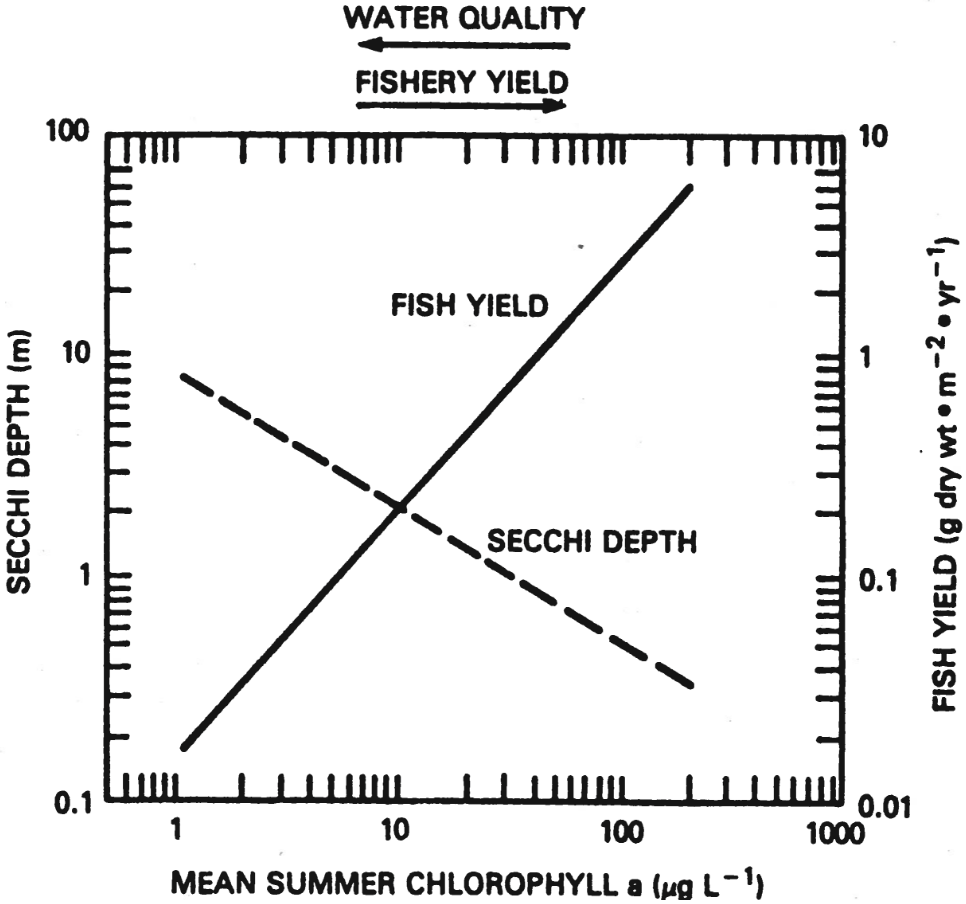

Figure A-1. Relationship between lake characteristics (e.g. Secchi depth, chlorophyll-a) and management objectives (e.g. water quality, fishery yield). Modified from Wagner and Oglesby (1984).

Recreation Use Considerations: Attainment of the contact and noncontact beneficial uses is largely subjective and dependent upon waterbody location, user familiarity with the waterbody and their expectations for the waterbody. As a result, identified chlorophyll-a thresholds vary widely throughout the country, with users having expectations of lower chlorophyll-a levels for the higher elevation, more northern latitude lakes. Appendix B summarizes the key literature (Table B-1) and state standards (Table B-2) that were reviewed to identify appropriate chlorophyll-a criteria that would be protective of recreation uses.

In some instances, states have successfully relied on user perception survey results in setting nutrient and clarity water quality standards. Extensive user perception surveys have been performed in Minnesota by Heiskary and Walker (1988). Heiskary and Walker (1988) reported that users considered swimming impaired when chlorophyll-a levels were above 15 µg/l. Based upon this study and other work, the State of Minnesota established chlorophyll-a standards for five different waterbody classifications. Chlorophyll-a critieria range from 3-6 µg/l for trout waters to 22 µg/l for southern Minnesota waters. In general, the lower chlorophyll-a criteria to those waters in the central/northern forested areas of Minnesota.

Vermont users appear to have similar expectation to that of the northern Minnesotans. Smeltzer and Heiskary (1990) identified chlorophyll-a levels >6 µg/l. Following that study, the State of Vermont established criteria similar to the Minnesota criteria. Vermont's chlorophyll-a criteria range from 5 µg/l for Class A1 (highest quality) waters to 16 µg/l for Class B (good to very good quality) waters.

A number of professional papers have provided potential chlorophyll-a thresholds not based upon user perception surveys like in Minnesota and Vermont, but based upon a classification system deemed appropriate by the investigators. For example, Dillon and Rigler (1975) et al. used a chlorophyll-a threshold of 5 µg/l for "lakes to be used for water recreation but preservation of coldwater fishery is not imperative. For "lakes where body contact recreation is of little importance with emphasis on cool water and warm water fishery", Dillon and Rigler used a chlorophyll-a threshold or 10 µg/l. For Wisconsin lakes, Lillie and Mason (1983) considered "good" waters to have chlorophyll-a levels of 5-10 µg/l. However in Louisiana, Burden et al. (1985) considered "excellent to good waters" to have higher chlorophyll-a levels up to 14 µg/l Raschke (1995) identified a chlorophyll-a threshold of 25 µg/l to maintain minimal aesthetic environment for viewing, safe swimming, good fishing and boating.

In the western U.S., some states/tribes have established (or are under review) chlorophyll-a standards. The Pyramid Lake Paiute Tribe established a chlorophyll-a standard of 5 µg/l for recreation uses. In the upper Carson River watershed in California, Indian Creek Reservoir was assigned a chlorophyll-a standard of 10 ug/l. The State of Arizona has developed criteria which have yet to be approved by EPA. Arizona has proposed chlorophyll-a criteria of 10-15 µg/l for deep (mean depth > 18 m) and shallow (mean depth < 4 m) lakes, and chlorophyll-a criteria of 20-30 µg/l for other lakes.

Overall, the literature and other information suggest that chlorophyll-a levels of to 15 to 20 µg/l are common thresholds beyond which recreation use could be considered impaired for waters such as Lahontan Reservoir.

Aquatic Life Use Considerations: According to NDOW, Lahontan Reservoir is managed for a variety of warmwater fish, such as walleye and bass. The success of these different fish is dependent upon the productivity of the water, with algae making up a part of the food chain. Appendix C summarizes the key literature (Table C-1) and state standards (Table C-2) that were reviewed to identify appropriate chlorophyll-a criteria that would be protective of recreation uses.

The optimal chlorophyll-a concentrations for coolwater and warmwater fisheries can be higher than desired for other beneficial uses such as contact and noncontact recreation, and coldwater fisheries (Malcolm Pirnie, Inc., 2005). In a study of 30 large Alabama reservoirs, Maceina et al. (1996) found that the growth of largemouth bass increased with chlorophyll-a levels up to 20 µg/l. Bachmann et al. (1996) identified an even higher thresholds for natural Florida lakes where largemouth bass were more abundant in lakes with chlorophyll-a levels >40 µg/l.

Several states have set chlorophyll-a water quality standards for the protection of coolwater and warmwater fish. Chlorophyll-a standards for coolwater lakes range from 9 µg/l (Minnesota) to 25 µg/l (Virginia). For warmwater lakes, chlorophyll-a standards range from 20 µg/l (Colorado, W. Virginia) to 35 µg/l (Virginia).

The literature and other information suggest that chlorophyll-a levels of 20 to 25 µg/l maybe an appropriate threshold for the protection of the Lahontan Reservoir warmwater fishery.

Drinking Water Considerations: Excess algae in a reservoir can affect drinking water supplies by creating taste and odor problems and introducing algal toxins into the water (Malcolm Pirnie, Inc., 2005). Excessive algae levels are also linked the creation of carcinogenic trihalomethanes (THMs) during a drinking water system's disinfection process. Many of these problems can be caused by cyanobacteria (often referred to as blue-green algae) (Welch and Jacoby, 2004). Unfortunately, there is minimal literature available to characterize correlations between chlorophyll-a thresholds with taste/odor or toxic problems in public water supplies. Appendix D summarizes the key literature (Table D-1) and state standards (Table D-2) that were reviewed to identify appropriate chlorophyll-a criteria that would be protective of recreation uses.

Heath et al. (1988) found that algal-related health problems were more likely to occur when chlorophyll-a levels in a South African reservoir exceeded 30 µg/l. Raschke (1995) identified a chlorophyll-a threshold of 15 µg/l for water supply impoundments of the Piedmont region of southeastern U.S. In a study of Cheney Reservoir which supplies drinking water to Witchita, Kansas, Smith et al. (2002) recommended that chlorophyll-a levels be reduced to 10 µg/l to reduce taste and odor problems that were being caused by cyanobacteria. Cheney Reservoir water is piped directly from the reservoir to the Witchita water treatment plant.

Few examples of drinking water chlorophyll-a were found in our research of state regulations. Arizona has proposed chlorophyll-a criteria of 10-20 µg/l. Oklahoma has a number of lakes and reservoirs that are assigned the beneficial use of "Public and Private Water Supply (PPWS)." A subset of these waters has been provided additional protection by being identified as "Sensitive Public and Private Water Supply" waters. These are waters that are currently being used as a drinking water supply, and where additional protection from new point sources and additional loading from existing point sources is desired (OWRB, 2005). Oklahoma has adopted a chlorophyll-a criterion of 10 µg/l (long term average) for these sensitive waters. For the other PPWS waters, no chlorophyll-a criterion has been assigned.

Colorado has the most restrictive chlorophyll-a criterion (5 µg/l) of the values found in our research. However, this criterion was set for "Direct Use Water Supplies", waterbodies from which water is directly piped to a plant for treatment and subsequent distribution to customers. This criterion would not apply to reservoirs which release water into a stream for later diversion to a water treatment plant. Colorado recognizes that less restrictive chlorophyll-a criterion would be appropriate for these situations, but has yet to establish any regulatory values.

It should be noted that when Nevada assigns municipal and domestic supply as a use to a waterbody, it does not require that the must meet drinking water standards. The goal is that the water be treatable with conventional methods to meet the drinking water standards. Other states have taken a similar approach.

Overall, the literature suggests that a chlorophyll-a threshold of 5-10 µg/l may be an appropriate threshold where water is piped/pumped directly from a lake/reservoir (or from a nearby downstream location) to a water treatment plant. In the case where drinking water supplies are not directly removed from a waterbody, less restrictive criteria are appropriate. As far as Lahontan Reservoir is concerned, water is not directly removed for any drinking water supply. However, reservoir water does recharge regional groundwater systems that are used for municipal or domestic supply. Given that any reservoir water would be naturally filtered through the area geology with algal matter being removed, it is deemed unnecessary to assign a chlorophyll-a criterion for the protection of the municipal or domestic supply beneficial use. Criteria to protect recreation and aquatic life should provide adequate protection for drinking water uses.

Other Considerations: Some states have identified lake chlorophyll-a criteria that are not tied to any particular beneficial use. Maine has set chlorophyll-a criteria ranging from 5 – 10 µg/l, while Oregon has set slightly higher criteria ranging from 10 – 15 µg/l. Nevada has established antidegradation criteria for Lake Mead ranging from 40 µg/l near the mouth of Las Vegas Wash to 5 µg/l for the open waters. These criteria are set to protect water quality that is deemed higher than needed to support the beneficial uses.

Recommended Chlorophyll-a Target for Lahontan Reservoir: Based upon a review of literature and other states' regulations, the following chlorophyll-a targets are suggested for the protection of the main beneficial uses. It is recommended that a chlorophyll-a target of 15 µg/l be used for Lahontan Reservoir.

Table A-2. Summary of Chlorophyll-a Thresholds by Beneficial Use

Beneficial Use	**Chlorophyll-a (µg/l)**
Contact and Noncontact Recreation	15 – 20
Aquatic Life	20 - 25
Municipal or Domestic Supply	None needed
Recommended Threshold	15

Research of other states' regulations show a multitude of approaches in how chlorophyll-a (and associated phosphorus) standards are applied to a lake or reservoir from depth, spatial and temporal perspectives. Some states have established chlorophyll-a standards for a variety of depths, such as:

- Mean of levels in the entire water column
- Mean of levels in the epilimnion
- Mean of levels in the upper meter
- Mean in the euphotic zone

To deal with spatial considerations, states may evaluate:

- chlorophyll-a levels based upon the mean of all sites for the entire lake/reservoir
- chlorophyll-a levels based upon the mean for a segment of the lake/reservoir (such as a distinct bays, or zones)

States use a variety of time periods upon which mean chlorophyll-a levels are calculated:

- Annual mean
- Summer mean
- July 1 – September 30 mean
- May – October mean

It is recommended that a chlorophyll-a target of 15 µg/l be applied as a June-September average in the upper 1 meter of the water column. June-September is recommended as the averaging period as this the time during which most of the recreation occurs and the highest algae levels are observed. The upper 1 meter is recommended as this is the zone in which most of the recreation occurs. Given the distinct configuration of Lahontan Reservoir, it is recommended that each of the basins be evaluated separately.

Phosphorus and Nitrogen Criteria

EPA encourages the adoption of standards for both causal (both nitrogen and phosphorus) and response (chlorophyll-a and clarity) variables. As described earlier, a common approach for establishing nutrient criteria for a reservoir is to first develop a desired endpoint for a response variables, such as chlorophyll-a, and then identify phosphorus and nitrogen criteria based upon nutrient-chlorophyll-a relationships.

<u>Phosphorus Criteria</u>

Based upon Lahontan Reservoir data collected by NDEP, average June-September phosphorus and chlorophyll-a levels were calculated for each of the 3 basins (Table A-3). For further comparison, data collected by DRI in 1980-81 and 1983 have also been included. While nutrient loads to Lahontan Reservoir have changed significantly since the 1980s, it was deemed useful to show how these older data compare to the more recent data. The resulting plot (Figure A-2) of these data show significant scatter with no particular relationship between phosphorus and chlorophyll-a levels. This lack of one well-defined relationship is believed to be the result of several factors. A significant factor is the high variability in water levels from year to year and throughout the year due to fluctuating water inflows and releases for downstream irrigation. Over the last 47 years (1967-2013), annual maximum water levels have varied from about 90,000 to 325,000 acre-feet, and annual minimum water levels have varied from about 4,000 to 175,000 acre-feet. For an average year, reservoir levels have varied from about 75,000 to 250,000 acre-feet. Such large fluctuations in water levels have significant impacts on water quality conditions thereby affecting the complex relationship between algae and nutrients.

Table A-3. Average June-September Total Phosphorus (mg/l) and Chlorophyll-a Levels (µg/l) in the Upper Meter by Basin

Year	Upper Basin		Middle Basin		Lower Basin	
	TP	Chl-a	TP	Chl-a	TP	Chl-a
1980[1]	0.18	6.5	0.18	7.0	0.18	18.5
1981[1]	0.34	5.5	0.34	10.3	0.34	15.8
1983	---	---	---	---	0.12	8.1
2003	0.29	8.2	0.21	2.0	0.13	2.1
2004	0.32	12.2	0.28	7.4	0.16	3.3
2005	0.28	29.6	0.22	20.7	0.14	10.8
2012	0.33	7.8	0.41	9.4	0.21	4.1
2013	See note				0.22	18.6

[1]TP averages are for all sites combined. Data were not available for individual monitoring sites.
Note: Insufficient data were available for the upper and middle basins due to low water levels.

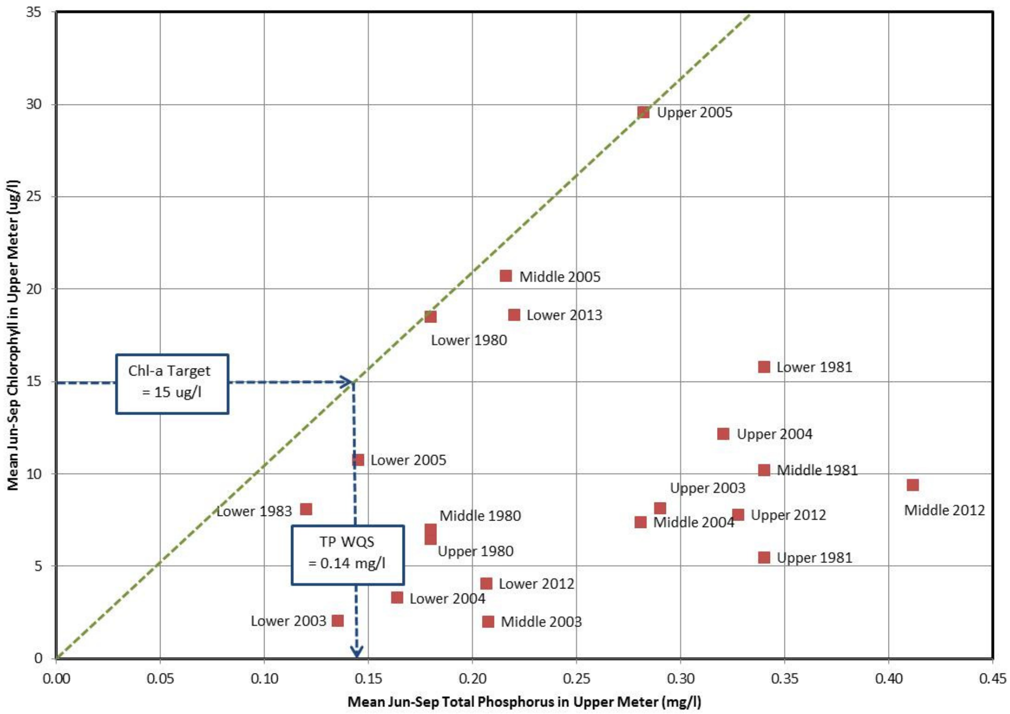

Figure A-2. Mean June-September Total Phosphorus and Chlorophyll-a Relationship

While there appears to be no well-defined relationship between phosphorus and chlorophyll-a data when considering all the data, a much different picture is seen when each of the years are examined separately (Figure A-3). This seems to demonstrate that the phosphorus:algae relationship is often fairly well defined for a given year, but can vary dramatically from year to year. Given the lack of one distinct nutrient-chlorophyll-a relationship that could apply to any year, a conservative approach is to plot a line which envelopes all of the data, bordering the most restrictive data points (Figure A-2). This plot essentially captures the maximum chlorophyll-a levels that were observed for given phosphorus levels.

This line has been forced to pass through the origin (0.0 µg/l chlorophyll-a at 0.0 mg/l total phosphorus) as typically done by others. Numerous researchers have developed a variety of nutrient-chlorophyll-a relationships either for groups of lakes or for specific waterbodies. In all cases, the resulting equations pass through the origin.

As discussed earlier, a chlorophyll-a target of 15µg/l is recommended for Lahontan Reservoir. Based upon the envelope plot on Figure A-2, it is estimated that total phosphorus levels as low as 0.14 mg/l could potentially lead to chlorophyll-a levels of 15µg/l. Therefore, NDEP is proposing to establish a total phosphorus standard of 0.14 mg/l as a June-September average in the upper 1 meter of the water column. For the sake of comparison, the Grieb et al. equation used in the 1980s standards setting action yields a slightly lower TP value of 0.11 mg/l.

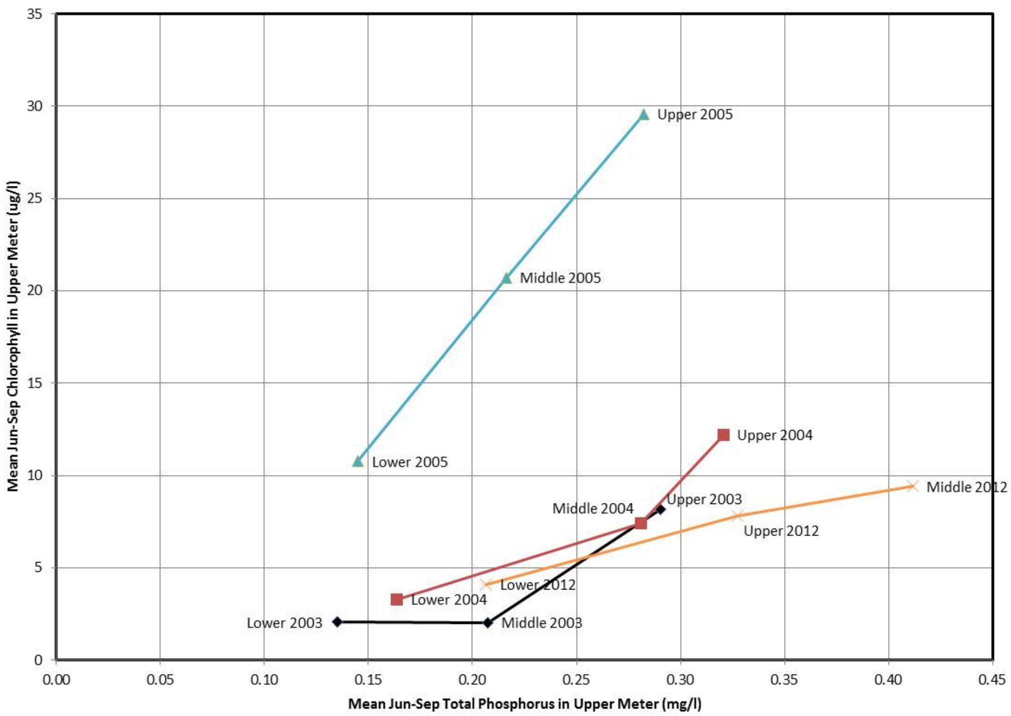

Figure A-3. Mean June-September Total Phosphorus and Chlorophyll-a Relationships for Each Separate Year

Nitrogen Criteria

Based upon NDEP water quality data, average June-September total nitrogen and chlorophyll-a levels were calculated for each of the 3 basins (Table A-4). As with the phosphorus analyses, nitrogen and algae data collected by DRI in the 1980s was included in the analyses. While nutrient loads to Lahontan Reservoir have changed significantly since the 1980s, it was deemed useful to show how these older data compare to the more recent data.

The resulting plot (Figure A-4) of these data shows a similar scatter in the data as with the phosphorus-chlorophyll-a plot. When examined by each separate year, the relationships appear to be a bit more well-defined for a given year but vary across the years (Figure A-5). High variability in reservoir water levels conditions are believed to be a significant factor leading to variability in these relationships. Perhaps a more influential factor is the ability of cyanobacteria to extract nitrogen from the atmosphere. While the relationship between TN and chl-a suggest that higher TN levels (in 2005) are a cause of algae growth, this increase in TN may be in part due to nitrogen fixation. During 2005, significant blooms of nitrogen-fixing cyanobacteria occurred. As a result of the July 2005 bloom, LR1 and LR2 total nitrogen levels increased from about 0.5 to 2.15 mg/l at LR1 and 1.75 mg/l at LR2 (Figure A-6). Less dramatic increases in TN were observed at LR3, LR4 and LR5 during the July 2005 bloom. This behavior flips the cause and response variables, with the algal levels causing the nitrogen increase. However, a similar behavior was not observed during the June 2013 bloom. No significant increases in nitrogen levels were measured concurrently with the increase in chlorophyll-a.

Table A-4. Average June-September Total Nitrogen(mg/l) and Chlorophyll-a Levels (µg/l) in the Upper Meter by Basin

Year	Upper Basin		Middle Basin		Lower Basin	
	TN	Chl-a	TN	Chl-a	TN	Chl-a
1980[1]	0.78	6.5	0.78	7.0	0.78	18.5
1981[1]	1.01	5.5	1.01	10.3	1.01	15.8
1983	---	---	---		0.48	8.1
2003	0.83	8.2	0.55	2.0	0.42	2.1
2004	1.06	12.2	0.84	7.4	0.69	3.3
2005	1.32	29.6	1.02	20.7	0.95	10.8
2012	1.20	7.8	1.13	9.4	0.80	4.1
2013	See note				0.88	18.6

[1]TP averages are for all sites combined. Data were not available for individual monitoring sites.
Note: Insufficient data were available for the upper and middle basins due to low water levels.

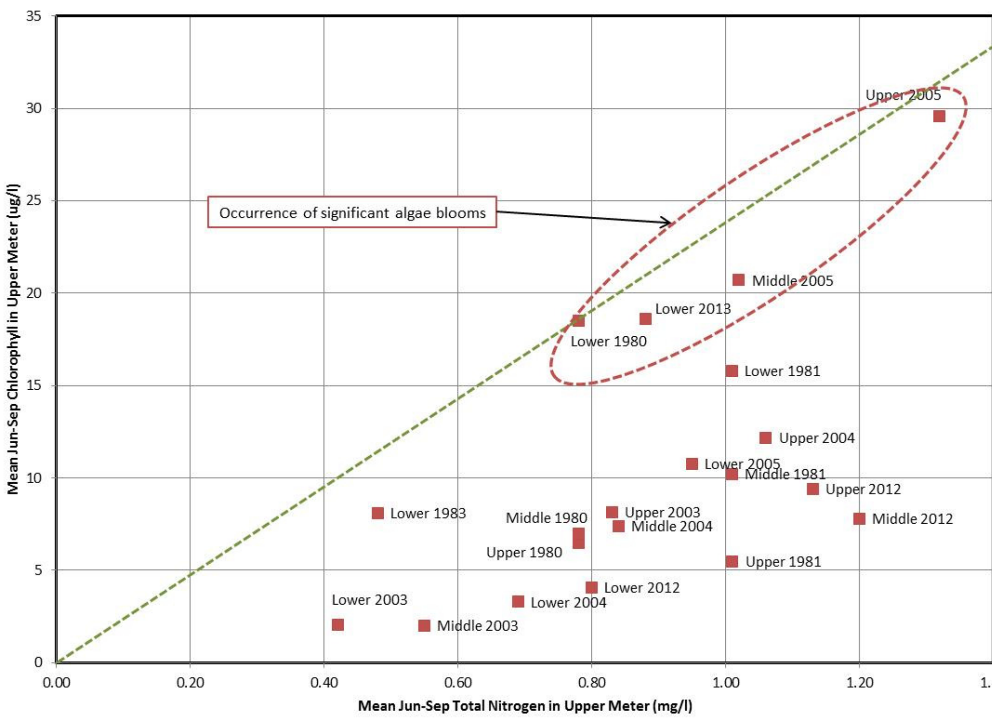

Figure A-4. Mean June-September Total Nitrogen and Chlorophyll-a Relationship

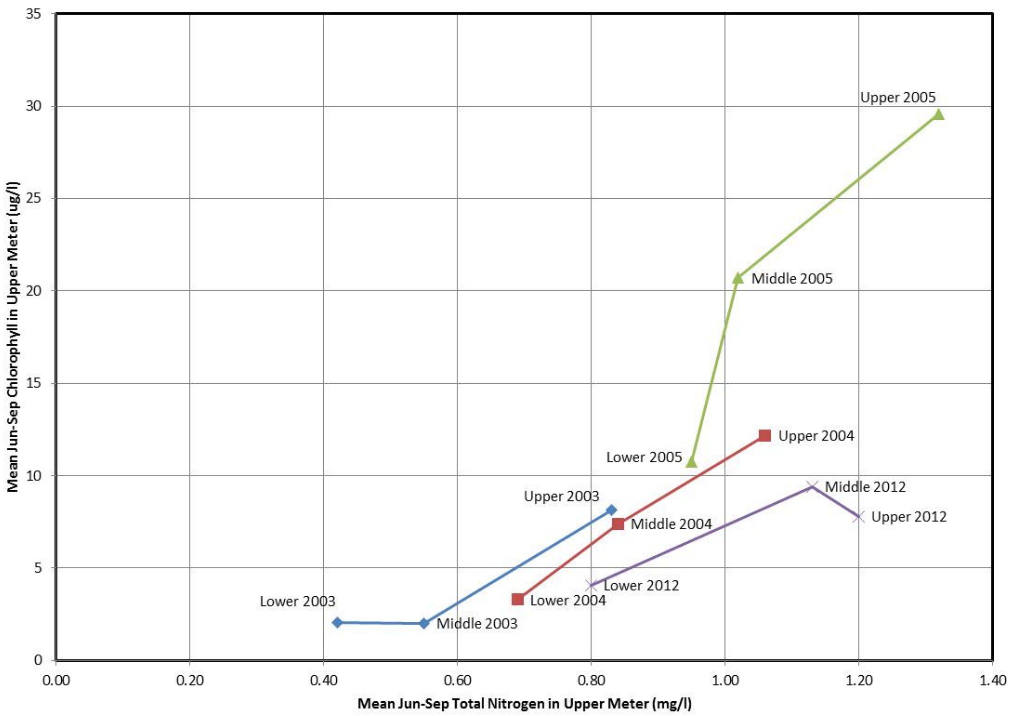

Figure A-5. Mean June-September Total Nitrogen and Chlorophyll-a Relationship for each Separate Year

While this possible increase in TN (~2 mg/l) due to nitrogen fixation may appear to be large, it is not uncommon in productive waterbodies. The best example is Upper Klamath Lake which experiences frequent blooms of *Aphanizomenon* (the same cyanobacteria that typically appears in Lahontan Reservoir). According to the Upper Klamath Lake TMDL (Oregon DEQ, 2002), algal nitrogen fixation increased TN loads by a factor of 3.5. In a dissertation by Kann (1997), TN increases of about 1.0 to 4.0 mg/l were identified for the Upper Klamath Lake. In a recent USGS study (Hoilman et al., 2008), 2006 Upper Klamath Lake data showed TN increased by about 12 mg/l during a cyanobacteria bloom with chl-a levels very high (9,000 ug/l).

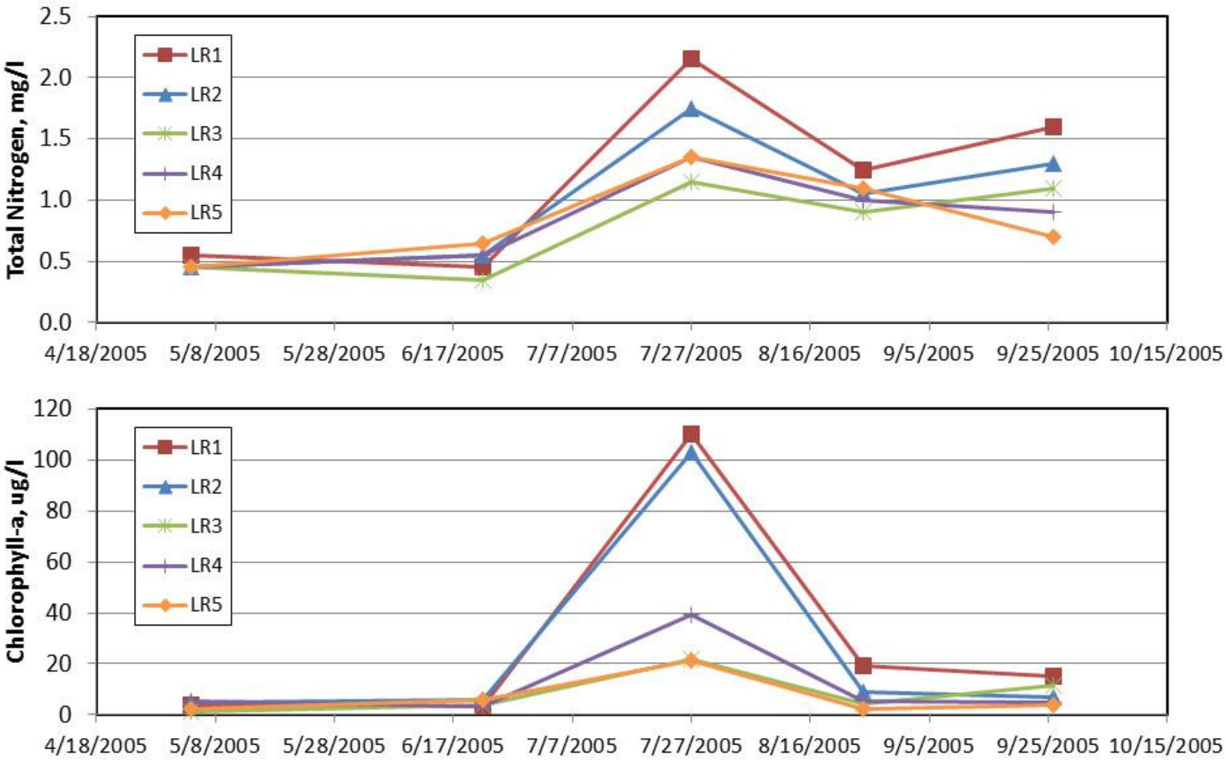

Figure A-6. Total Nitrogen and Chlorophyll-a Levels, 2005

The nitrogen-fixing behavior makes it problematic to use a nitrogen-chlorophyll-a plot for developing a nitrogen standard. It is likely that the nitrogen levels associated with most of the plotted points (not just the significant bloom points called out on the plot) have been affected by nitrogen fixation. Again, this makes it difficult to identify which is the cause and which is the response and calls into question the utility of a nitrogen water quality standard. Because of the nitrogen fixing ability of cyanobacteria, setting a maximum nitrogen standard and maintaining that level may do little to limit cyanobacteria growth. In 1983, Cooper et al. (1983) concluded that the control of nitrogen levels beyond existing levels was not thought to impact algae levels and no nitrogen standards were set. In recent work, Schindler et al. (2008) reached a similar conclusion. Schindler et al. concluded that eutrophication of freshwater lakes cannot be controlled by reducing nitrogen inputs. Based upon a 37-year whole ecosystem experiment, the authors concluded that reducing nitrogen inputs increasingly favored nitrogen-fixing cyanobacteria with no reduction of algal biomass. The findings of Schindler et al. are in line with the commonly held belief that algae production in freshwater lakes is controlled by phosphorus availability. However, significant controversy over this paradigm has arisen in recent years. Other investigators have concluded that the control of both phosphorus and nitrogen are needed to control eutrophication and cyanobacteria growth. In lines with these findings, EPA (2012) recently produced a fact sheet summarizing the scientific evidence in support of the development of both phosphorus and nitrogen water quality criteria. Several points are made in this fact sheet:

5. Because of the highly variable nature of nutrient limitation in aquatic systems, numeric criteria for both N and P provided the greatest likelihood of protecting aquatic systems.

6. Because of the diversity of the nutritional needs amongst organisms, numeric criteria for both N and P area more likely to protect aquatic systems.
7. Because N fixation is highly variable across waterbody types, numeric criteria for both N and P are likely to be more effective in protecting aquatic systems.
8. Both N and P criteria are important to consider when assessing downstream impacts.

NDEP recognizes the need to control both nitrogen and phosphorus. However, the inability to separate the cause and response variables limits the utility of the nitrogen-chlorophyll-a relationship shown in Figure A-4. Therefore, NDEP is proposing to rely on the existing RMHQs for the maintenance of existing quality. In 1984, total nitrogen RMHQs of 1.3 mg/l (Annual Average) and 1.7 mg/l (Single Value) were established to maintain existing higher quality in Lahontan Reservoir. Though not clear from the documentation, these RMHQs appear to have been generally calculated based upon water quality conditions in the reservoir near the dam. Limited data exist upon which the 1984 RMHQs can be evaluated. Most recently, NDEP has sampled Lahontan Reservoir in 2003-05, and 2012-13 with a focus on the summer conditions. These data are not deemed adequate upon which to base a review of the RMHQs. The focus on summer sampling does not provide an adequate characterization of conditions throughout the year. Also, conditions during 2012-13 were poor due to low water levels and would not be indicative of higher quality water. Therefore, no changes to the existing RMHQs or additions of new RMHQs are recommended under this proposal.

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APPENDIX B

SUMMARY OF RECREATION THRESHOLD VALUES FOR CHLOROPHYLL-A

Table B-1. Recreation Use Threshold Values from Literature

Source	Location	Chl-a (µg/l)	Notes
Burden et al. (1985)	Louisiana	14	Excellent to good
		30	Good to acceptable
		32	Acceptable to marginal
Dillon and Rigler (1975)		2	Lake will be clear but will not support a highly productive fishery
		5	Lake to be used for water recreation but preservation of coldwater fishery is not imperative
		10	Lake where body contact recreation is of little importance with emphasis on cool water and warm water fishery
		25	Lake suitable only for warm water fishery
Heiskary and Walker (1988)	Minnesota Lakes	<2	Beautiful
		5 - 14	Minor aesthetic
		15 - 58	Swimming impaired
		39 – 71	No swimming
Heiskary and Walker (1995)	Lake Pepin (Minnesota)	30	Based upon user perception surveys
Lillie and Mason (1983)	Wisconsin	<1	Excellent
		1 – 5	Very good
		5 – 10	Good
		10 – 15	Fair
		15 – 30	Poor
		>30	Very poor
Raschke (1995)	Piedmont impoundments in southeastern U.S.	<25 (a)	Maintain minimal aesthetic environment for viewing, safe swimming, good fishing and boating
Smeltzer and Heiskary (1990)	Vermont	>6	Frequently produces perceptions of use impairment

(a) Growing season mean

Table B-2. Recreation Use Threshold Values from State Regulations

State/Waterbody/Region	Chl-a (µg/l)	Key Protected Uses	Notes
Arizona			
Deep Lakes – mean depth >18 m	10-15 (a)	Full Body Contact	Under EPA review
Shallow Lakes – mean depth <4 m			
Igneous Lakes	20-30 (a)		
Sedimentary Lakes			
Urban Lakes			
California			
Indian Creek Reservoir	10 (b)	**Recreation**, cold water fishery	Targets for TMDL
Kansas			
Eutrophication TMDLs	12	primary contact recreation (i.e., **swimming** and domestic water supply)	
	20	secondary contact recreation (i.e., fishing)	
Minnesota			
Lake Trout waters in all ecoregions	3 (c)	Class 2A – Coldwater fishery, **recreation**, drinking water supply	
Other trout waters in all ecoregions	6 (c)		
N. Lakes and Forest Ecoregion	9 (c)	Class 2B - Cool and warm water fishery, **recreation**; Class 2Bd – Cool and warm water fishery, **recreation**, drinking water supply	
Central Hardwood Forest Ecoregion	14 (c)		
W. Cornbelt Plains and N. Glaciated Plains Ecoregions	22 (c)		
Nevada			
Pyramid Lake	5 (d)	Primarily aquatic and **recreation** uses	Pyramid Lake Paiute Tribe standards
Vermont			
Class A1 – waters are to be maintained in their natural condition	5 (e)	Aesthetics	Criteria primarily based upon user perception surveys
Class A2, B1 – excellent aesthetics	9 (e)	Aesthetics	
Class B, B2, B3 – good to very good aesthetics	16 (e)	Aesthetics	

(a) Growing season mean
(b) Summer mean in epilimnion
(c) Summer (July 1 – September 30) mean in water column
(d) Depth average in the upper 20 meters
(e) May-October mean in the euphotic zone

APPENDIX C

SUMMARY OF AQUATIC LIFE THRESHOLD VALUES FOR CHLOROPHYLL-A

Table C-1. Aquatic Life Use Threshold Values from Literature

Source	Location	Chl-a (µg/l)	Notes
Coldwater			
Dillon and Rigler. (1975)		2	Lake will be clear and hypolimnetic oxygen levels will be adequate for coldwater fishery
		5	Lake to be used for water recreation but preservation of coldwater fishery is not imperative
		10	Lake where body contact recreation is of little importance with emphasis on cool water and warm water fishery
		25	Lake suitable only for warm water fishery
Elliott et al. (1996)	United Kingdom	14	Brown trout abundance much higher
Johnston et al. (1999)		6	Increased trout growth and survival
McGhee (1983)	N. Carolina	15	Trout waters
Warmwater			
Bachmann et al. (1996)	Florida	40	Largemouth bass more abundant
Maceina et al. (1996)		20	Growth of largemouth bass increased
Raschke (1995)	Piedmont impoundments in southeastern U.S.	<25 (a)	Maintain minimal aesthetic environment for viewing, safe swimming, good fishing and boating

(a) Growing season mean

Table C-2. Aquatic Life Use Threshold Values from State Regulations

State/Waterbody/Region	Chl-a (µg/l)	Key Protected Uses	Notes
Arizona			
All Lakes	5-15 (a)	Coldwater aquatic life	Under EPA review
All Lakes (except urban)	25-40 (a)	Warmwater aquatic life	
Urban Lakes	30-50 (a)		
Effluent Dominated Waters	30-50 (a)	Effluent dominated warmwater	
California			
Indian Creek Reservoir	10 (c)	Recreation, cold water fishery	Targets for TMDL
Colorado			
Lakes and reservoirs > 25 acres surface area	8 (d)	Coldwater fishery	
	20 (d)	Warmwater fishery (while being respectful of recreation uses)	
Minnesota			

State/Waterbody/Region	Chl-a (µg/l)	Key Protected Uses	Notes
Lake Trout waters in all ecoregions	3 (d)	Class 2A – **Coldwater fishery**, recreation, drinking water supply	
Other trout waters in all ecoregions	6 (d)		
N. Lakes and Forest Ecoregion	9 (d)	Class 2B - **Cool and warm water fishery**, recreation; Class 2Bd – **Cool and warm water fishery**, recreation, drinking water supply	
Central Hardwood Forest Ecoregion	14 (d)		
W. Cornbelt Plains and N. Glaciated Plains Ecoregions	22 (d)		
Nevada			
Pyramid Lake	5 (e)	Primarily **aquatic** and recreation uses	Pyramid Lake Paiute Tribe standards
Virginia			
Virginia	10 (g)	Cold water	Protect fishery recreation and aquatic life
	25 (g)	Cool water	
	35 (g)	Warm water	
W. Virginia			
W. Virginia	10 (h)	Cool water	
	20 (h)	Warm water	

(a) Growing season mean
(b) Annual mean in water column
(c) Summer mean in epilimnion
(d) Summer (July 1 – September 30) mean in water column
(e) Depth average in the upper 20 meters
(f) April-October median at one meter or less
(g) April-October 90th percentile at one meter or less
(h) Average of four or more samples collected May-October

APPENDIX D

SUMMARY OF DRINKING WATER THRESHOLD VALUES FOR CHLOROPHYLL-A

Table D-1. Drinking Water Use Threshold Values from Literature

Source	Location	Chl-a ((µg/l)	Notes
Heath et al. (1988)	South Africa	30	Levels should be below 30 µg/l to be to efficiently treat the raw water for drinking; Algal related health problems more likely to occur at levels above 30 µg/l
Raschke (1995)	Piedmont impoundments in southeastern U.S.	<15 (a)	Maintain minimal aesthetic environment for viewing, safe swimming, good fishing and boating
Smith et al. (2002)	Cheney Reservoir, Kansas, USA	10	Recommended level to control taste and odor problems for Witchita water system customers

(a) Growing season mean

Table D-2. Drinking Water Use Threshold Values from State Regulations

State/Waterbody/Region	Chl-a (µg/l)	Key Protected Uses	Notes
Arizona			
All Lakes	10-20 (a)	Drinking water supply	Under EPA review
Colorado			
Lakes and reservoirs > 25 acres surface area	5 (b)	Direct use drinking water	Drinking water intake located in the lake or reservoir
Oklahoma			
Lakes designated as SWS	10 (c)	Sensitive public and private water supply (SWS)	

(a) Growing season mean
(b) Summer (July 1 – September 30) mean in water column
(c) Long term average at 0.5 meters below the surface

APPENDIX E

SUMMARY OF THRESHOLD VALUES FOR CHLOROPHYLL-A NOT ASSOCIATED WITH SPECIFIC BENEFICIAL USE

Table E-1. Other State Regulatory Values Not Specific to a Beneficial Use

State/Waterbody /Region	Chl-a (µg/l)	Key Protected Uses	Notes
Maine			
All Lakes	8 (a)	No specific beneficial uses identified	
Impounded Class A	5 (a)		
Impounded Class B and C	8 (b), 10 (c)		
Nevada			
Lahontan Reservoir	10 (see note)		While not identified in the regulations, this value was used to derive the TP standard
Lake Mead	40 (d)	Antidegradation criteria	At 1.85 miles from mouth of Las Vegas Wash
	16 (d)		At 2.7 miles from mouth of Las Vegas Wash
	5 (d)		In open water
Oregon			
Natural lakes that thermally stratify	10 (e)	No specific beneficial uses are identified as being protected under these criteria	
Natural lakes that do not thermally stratify, reservoirs, rivers and estuaries	15 (e)		

(a) Depth integrated sample from epilimnion
(b) Spatial mean of depth integrated samples from epilimnion
(c) Maximum of all depth integrated samples from epilimnion
(d) Growing season average
(e) Mean of a minimum of three samples collected over any three consecutive months at a minimum of one representative location (e.g., above the deepest point of a lake or reservoir) from samples integrated from the surface to a depth equal to twice the secchi depth or the bottom (the lesser of the two depths)