Total Maximum Daily Loads for Walker Lake

- Pollutant: Total Dissolved Solids

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Photograph provided by John Walker

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Bureau of Water Quality Planning
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Executive Summary

Background

Section 303(d) of the Clean Water Act requires each state to develop a list of water bodies that need additional work beyond existing controls to achieve or maintain water quality standards, and submit an updated list to the Environmental Protection Agency (EPA) every two years. The Section 303(d) List provides a comprehensive inventory of water bodies impaired by all sources. This inventory is the basis for targeting water bodies for watershed-based solutions, and the TMDL (Total Maximum Daily Load) process provides an organized framework to develop these solutions. CFR (Code of Federal Regulations) 40 Part 130.7 require states to develop TMDLs for the waterbody/pollutant combinations appearing in the 303(d) List.

On October 16, 2001, Mineral County and the Walker Lake Working Group filed a civil action in federal district court against EPA under the Clean Water Act alleging that the EPA had failed to take necessary steps to save Walker Lake. On November 22, 2002, the parties entered into a Consent Decree agreeing to the following actions:

1. If Nevada fails to include Walker Lake on the 2002 303(d) List for total dissolved solids (TDS), EPA will either:
    a. Determine that Walker Lake needs to be listed for TDS and amend Nevada's 303(d) List; or
    b. Determine that Walker Lake need not be listed for TDS and provide a copy of its decision to the Plaintiffs.
2. If Walker Lake is placed on Nevada's 2002 303(d) List for TDS, EPA agrees to establish a Walker Lake TDS TMDL by March 15, 2005, unless Nevada establishes and EPA approves a TMDL prior to March 15, 2005.

Prior to the issuance of the Consent Decree, the Nevada Division of Environmental Protection (NDEP) had already included Walker Lake on its 2002 303(d) List (dated October 2002). After discussions with EPA, NDEP agreed to develop the following Walker Lake TDS TMDL in accordance with the Consent Decree. In the event that the NDEP TMDL is not approved, EPA will establish the Walker Lake TMDL.

Problem Statement

Walker Lake water levels have dropped over 140 feet since 1882 with a volume decrease from about 9.0 million acre-feet to a present level of about 1.76 million acre-feet. The TDS levels have increased from about 2,500 mg/l in 1882 to about 15,900 mg/l in December 2004 (Figure 3). This increase in TDS has been primarily due to the volume reduction, however TDS loads from the Walker River and local sources have also contributed.

The ever-increasing TDS levels along with other physical, biological and chemical conditions in the watershed and lake have stressed the fishery and other aquatic life in the Lake and changed the resident fish population. Historically, Walker Lake supported a number of native and introduced fish species. Today, only the Lahontan cutthroat trout (LCT), Lahontan tui chub, and the Tahoe sucker are found in Walker Lake. The LCT are maintained in the lake solely through the Nevada Department of Wildlife and the U.S. Fish and Wildlife Service stocking program. However, this program is in jeopardy with ever-increasing mortality rates of the stocked fish as the TDS continues to rise.

TMDL TDS Target

The purpose of the target analysis is to identify and quantify those future conditions needed for the support of the beneficial use. In this case, the beneficial use of concern is the propagation of aquatic life including tui chub, Tahoe sucker and adult and juvenile Lahontan cutthroat trout (NAC 445A.1693). For this TMDL, a long-term average TDS target of 12,000 mg/l has been selected to provide a sufficient level of support for the beneficial use as practiced through the current stocking program methods.

TMDL and Load Allocations

Load allocations have been assigned to four TDS loading sources (Walker River, groundwater, lake bed sediments, and TDS mass accumulation in the lake).

> **Walker River:** Traditionally, TMDLs are defined in units of mass per time (pounds per day, tons per year, etc.). However, according to federal regulations (40 CFR 130.2(i)), TMDLs need not be expressed in pounds per day (or tons per year) when alternative means are better suited for the problem. Setting a load allocation at current or below current river loading levels could be contrary to other potential solutions for the lake. For example, additional river inflow is under discussion as a possible element of a restoration strategy for Walker Lake. Increases in river inflow could result in additional TDS loading to the lake. With this in mind, the Walker River load allocation is set as a maximum TDS concentration of 500 mg/l, consistent with the State of Nevada's TDS water quality standard for the river (Nevada Administrative Code 445A.167).
>
> **Groundwater and Lake Bed Sediment:** The total load allocations for groundwater (29,000 tons/year) and lake bed sediment (18,000 tons/year) sources were set equal to estimated average annual historic loads (Thomas, 2004).
>
> **TDS Mass in Lake:** At the current lake level and TDS concentration (December 2004: 1,760,000 acre-feet, 15,900 mg/l TDS) it is estimated that the current total TDS mass in the lake is approximately 38.0 million tons. At the current lake level, the TDS mass in the lake would need to be lowered to 28.7 million tons (a reduction of 9.3 million tons) to achieve the target concentration of 12,000 mg/l. Applying a 10% margin of safety to this reduction, the total load allocation for the TDS mass in the lake becomes –10.23 million tons.

Table ES-1 summarizes these four load allocations along with margin of safety considerations. The TMDL is expressed as the total amount of TDS (28.7 million tons) that can be present in Walker Lake that would result in attainment of the TMDL numeric target. If each of the four allocations were achieved, the TMDL would also be achieved.

These allocations focus on TDS loads and mass at the current lake level and current flow regime. It must be kept in mind that federal regulations require TMDLs be established for pollutants (such as TDS) preventing attainment of water quality standards (which includes support of beneficial uses). By definition, flow or flow alteration are not considered to be pollutants (per Clean Water Act, Section 502). Therefore, the TMDL analysis is based on existing lake levels.

Table ES-1. TDS Load Allocations

Source	Load Allocation	Margin of Safety	Total Load Allocation
Walker River	Maximum TDS concentration of 500 mg/l *	[redacted]	Maximum TDS concentration of 500 mg/l *
Groundwater	29,000 tons/year	[redacted]	29,000 tons/year
Lake Bed Sediments	18,000 tons/year	[redacted]	18,000 tons/year
TDS mass in Lake**	-9,300,000 tons	-930,000 tons	-10,230,000 tons

*This load allocation is to be applied as an annual average
**Based upon TDS levels in lake on December 2004

Implementation

Neither the Clean Water Act nor Nevada laws and regulations require a separate TMDL implementation plan. In Nevada, a collection of activities (NPDES permits for point sources; Nevada's Nonpoint Source activities and projects) and documents (Continuing Planning Process (NDEP, 2004); Nonpoint Source Management Program (NDEP, 1999)) serve as Nevada's "implementation plan" for all TMDLs, with the nonpoint source program being voluntary having no regulatory requirements for participants or participation.

Total Maximum Daily Load for
Walker Lake

1.0 Introduction

Section 303(d) of the Clean Water Act requires each state to develop a list of water bodies that need additional work beyond existing controls to achieve or maintain water quality standards, and submit an updated list to the Environmental Protection Agency (EPA) every two years. The Section 303(d) List provides a comprehensive inventory of water bodies impaired by all sources. This inventory is the basis for targeting water bodies for watershed-based solutions, and the TMDL (Total Maximum Daily Load) process provides an organized framework to develop these solutions. CFR (Code of Federal Regulations) 40 Part 130.7 require states to develop TMDLs for the waterbody/pollutant combinations appearing in the 303(d) List.

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1.1 Total Maximum Daily Load (TMDL) Defined

TMDLs are an assessment of the amount of pollutant a water body can receive and not violate water quality standards. Typically, TMDLs provide a means to integrate the management of both point and nonpoint sources of pollution through the establishment of waste load allocations for point source discharges and load allocations for nonpoint sources. TMDLs are to be established at levels necessary to achieve and maintain the applicable narrative and numerical water quality standards with consideration given to seasonal variations and a margin of safety.

Once approved by the U.S. Environmental Protection Agency, TMDLs are implemented through existing National Pollutant Discharge Elimination System (NPDES) permits for point source discharges to achieve the necessary pollutant reductions. Depending upon the state and its regulations, nonpoint source TMDLs can be implemented through voluntary or regulatory nonpoint source control programs. In Nevada, the nonpoint source program is voluntary having not regulatory requirements for participants or participation.

While each TMDL report is unique, many contain similar elements. Following is a discussion of the typical components that appear in TMDLs based upon EPA guidance (EPA, August 1999).

1.1.1 Problem Statement: The objective of the problem statement is to describe the key factors and background information that describes the nature of the impairment, such as chemical water quality, biological integrity, physical condition, etc.

1.1.2 Source Analysis: As part of a source analysis, the known loading sources (both point and nonpoint sources) are characterized by location, type, frequency, and magnitude to the extent possible. In the case of nonpoint sources, characterization activities can require significant financial resources.

1.1.3 Numeric Target Analysis: Section 303(d) (1) of the Clean Water Act states that TMDLs "shall be established at a level necessary to implement the applicable water quality standards." A purpose of the target analysis is to quantify those future conditions needed for compliance with the water quality standards and for support of the beneficial use. According to the U.S. EPA (1999), one of the primary goals of target analyses are to clarify whether the ultimate goal of the TMDL is to comply with a numeric water quality criterion, comply with an interpretation of a narrative water quality criterion, or achieve a desired condition that supports meeting a specified designated use.

1.1.4 Pollutant Load Capacity, TMDL, and Allocations: Another component is the identification of the waterbody loading capacity. The loading capacity is the maximum amount of pollutant loading a waterbody can assimilate without violating the numeric target. TMDLs are set equal to or lower than the loading capacity. The allowable loadings identified in the TMDL are then distributed or "allocated" among the significant sources of the pollutant.

A margin of safety is included in the analysis to account for uncertainty in the relationship between pollutant loads and the water quality of the receiving water. It can also be stated that the margin of safety is to account for uncertainties in meeting the water quality standards when the target and TMDL are met. Additionally, consideration needs to be given to seasonal variations and critical conditions. The margin of safety may be provided implicitly through conservative analytical assumptions in the TMDL calculation or explicitly through a decision to reserve (not allocate) a portion of the loading capacity. The general equation describing the TMDL with the allocation and margin of safety components is given below:

$$TMDL = \text{Sum of } WLA + \text{Sum } LA + \text{Margin of Safety} \quad (Eq.\ 1)$$

Where:

Sum of WLA = sum of wasteload allocations given to point sources
Sum of LA = sum of load allocations given to nonpoint sources

According to 40 CFR 130.2(i), TMDLs need not be expressed in pounds per day when alternative means are better suited for the waterbody problem. As discussed below, the Walker Lake TMDL and allocations are expressed through alternative means that better reflect the characteristics of the TDS problem in Walker Lake and of the loading sources.

1.1.5 Other Components: Although federal regulations do not require it, TMDL submittals sometimes include a plan for TMDL implementation and for monitoring TMDL effectiveness. In Nevada, TMDLs are implemented through NPDES permits for point sources and through Nevada's voluntary Nonpoint Source Program for nonpoint sources of impairment.

2.0 Background

2.1 Study Area

Walker Lake is a terminal lake located in west central Nevada at the mouth of the Walker River in the east side of the Walker River basin (Figure 1). The Walker basin is part of the Great Basin and includes approximately 4,000 square miles of land within Nevada, California and the Walker River Indian Reservation (Rush, 1974). Primary water sources for the lake include Walker River, local runoff, local groundwater inflow and precipitation on the lake surface. As a terminal lake, Walker Lake has no outflow as surface water or groundwater with water lost primarily through evaporation. Walker Lake has experienced significant reductions in water levels and increases in total dissolved solids concentrations over the last 122 years. Since 1882, Walker Lake levels have dropped about 144 feet (from about 4083 feet to 3939 feet) with a reduction in volume from about 9,000,000 acre-feet to 1,760,000 acre-feet (December 2004). The reduction in volume led to an increase of TDS levels from 2,500 (in 1882) to 15,900 mg/l (in December 2004) (Rush, 1974; USGS and NDEP data).

Walker Lake is a monomictic[1] lake with a current (December 2004) volume of 1,760,000 acre-feet, elevation of 3934.5 feet, surface area of about 31,800 acres, and a maximum depth of about 82 feet. Thermal stratification typically develops in May and June with turnover beginning in October/November concluding with complete destratification by December/January. The climate in the study area is generally semiarid with temperatures ranging from –10 to 12 ° C in January to 10 to 38 ° C in July (NDEP, September 2000; Copper and Koch, 1984). Average annual precipitation on the lake is estimated at 4.9 inches per year (Thomas, 1995) and average annual evaporation is approximately 4.1 feet per year (Everett and Rush, 1967).

2.2 Key Water Quality and Quantity Monitoring Stations

Key water quality and quantity monitoring stations at Walker Lake are shown on Table 1 and Figure 2. Since 1990, Site WL – Walker Lake at Sportsmen's Beach has been part of NDEP's statewide monitoring network which involved grab samples from the dock and analysis for various constituents, including TDS. Beginning in 1999, NDEP and Nevada Department of Wildlife (NDOW) began collecting more intensive data including: 1) samples collected at various depths for chemical analysis including TDS; and 2) dissolved oxygen and temperature profiles.

Table 1. List of Selected Water Quality and Quantity Monitoring Sites as Walker Lake

ID	Description	Agency	Period of Record
Water Quality Stations			
WL	Walker Lake at Sportsmen's Beach	NDEP/NDOW	1990-Current
WL2	Walker Lake South		1999-Current
WL3	Walker Lake Center		
WL4	Walker Lake North		
Water Quantity Stations			
10288500	Walker Lake near Hawthorne, Nevada	USGS	1928-Current

[1] Monomictic lake: Lakes which are relatively deep, do not freeze over during the winter, and undergo a single stratification and mixing cycle during the year (usually in the fall).

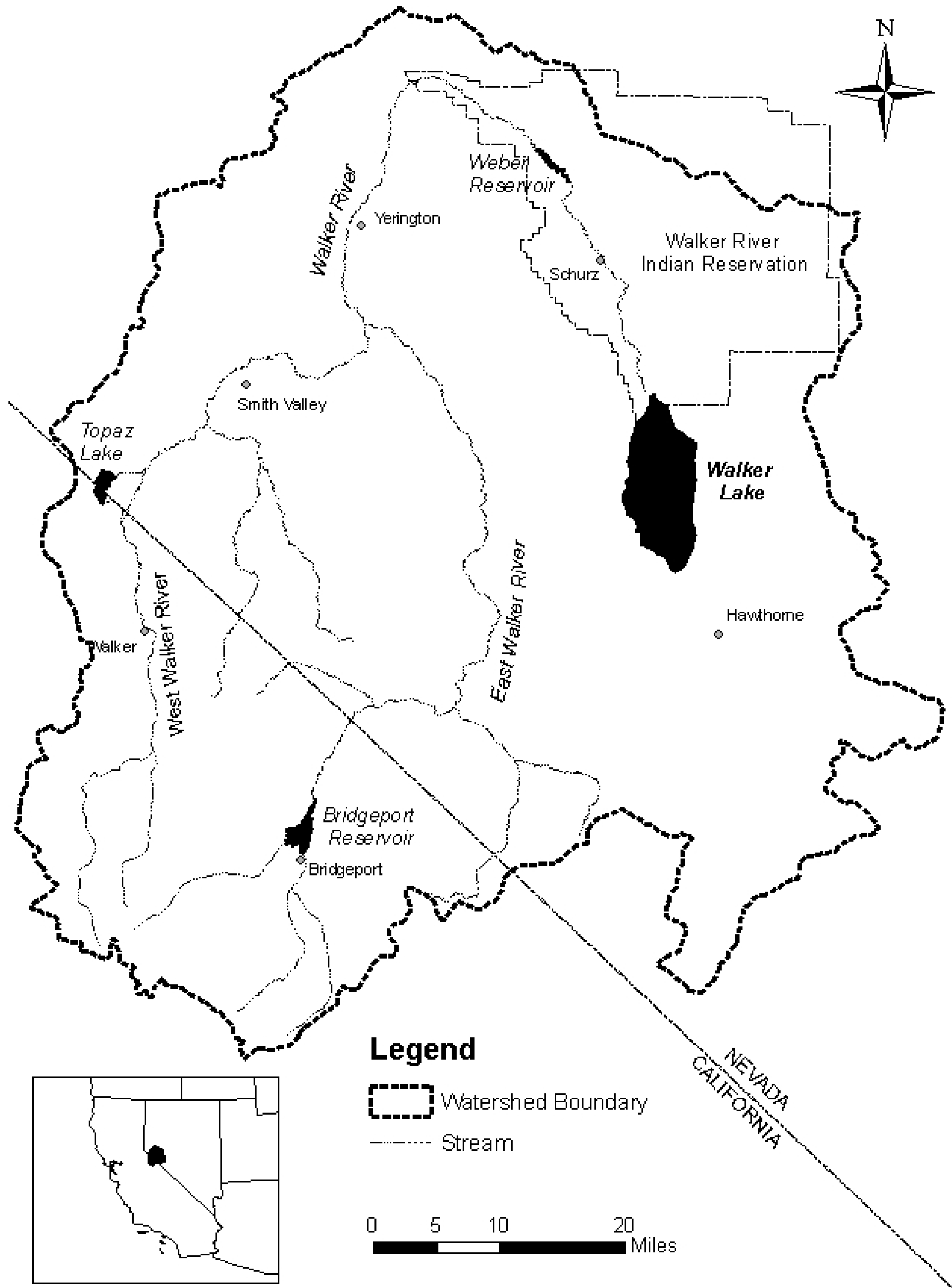


Figure 1. Walker Lake and Walker River Basin Location Map

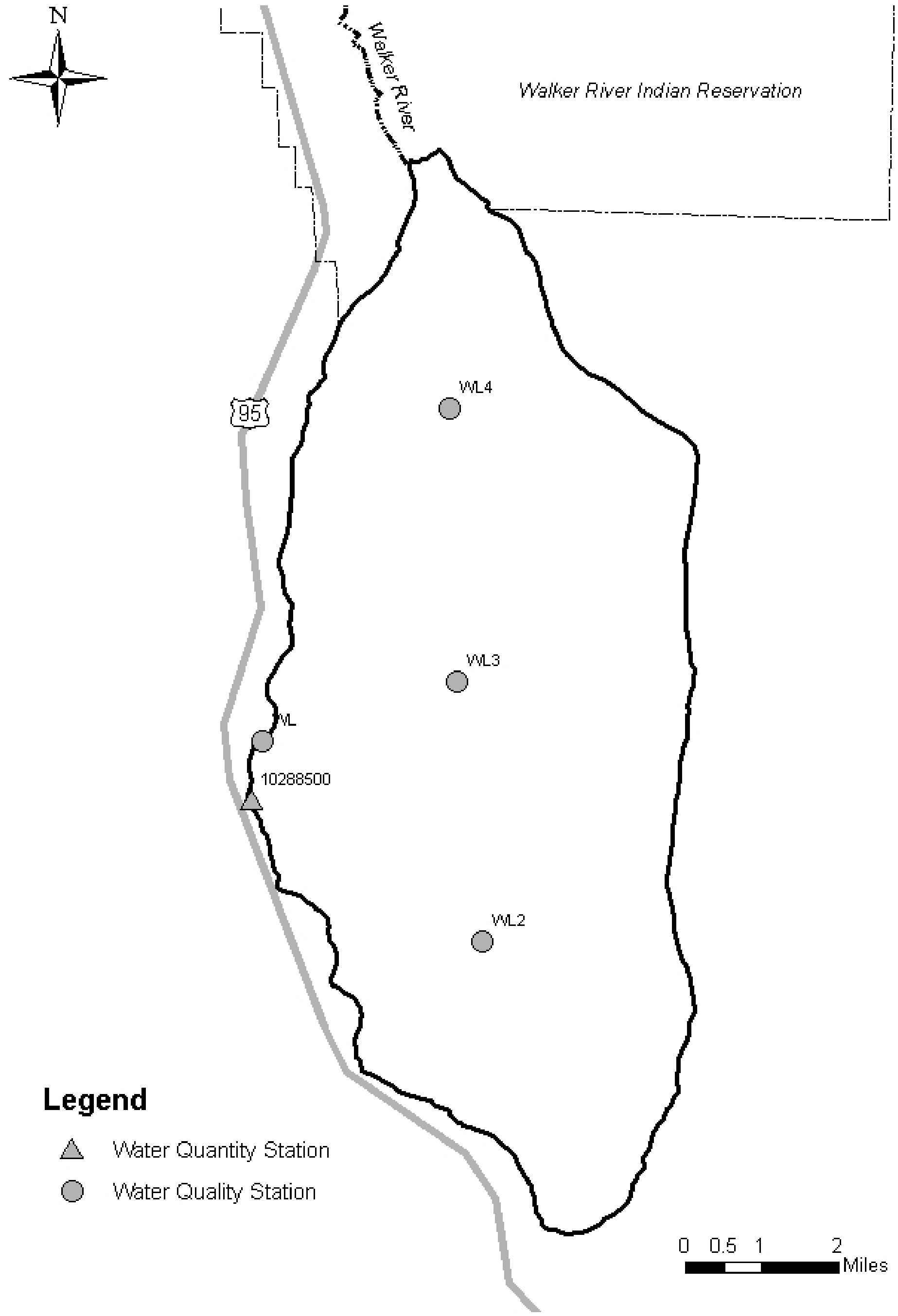


Figure 2. Walker Lake and Key Water Quality/Quantity Monitoring Sites

2.3 *Walker Lake Water Quality Standards*

2.3.1 Background: Until recently, no specific water quality standards had been set for Walker Lake. In the fall of 1998 the Nevada Division of Environmental Protection (NDEP) began reviewing water quality standards for Walker River and Walker Lake. NDEP reviewed the existing standards, and developed proposed revisions and additional standards. After receiving and considering public comments, NDEP presented the proposed water quality standards revisions for the Walker River and new water quality standards for Walker Lake to the Nevada State Environmental Commission (SEC) on December 5, 2000 for their consideration. NDEP's petition included a proposed TDS standard of 10,000 mg/l. With some modifications (narrative changes and higher TDS standard of 12,000 mg/l), the SEC adopted the new standards and standards revisions during the February 15, 2001, hearing. Of particular interest and the most controversial were the inclusion of numeric standards for total dissolved solids, arsenic (1,050 mg/l) and chloride (3,200 mg/l).

The Nevada Legislative Commission on April 17, 2001, objected to the regulation proposing water quality standards revisions for the Walker River and new water quality standards for Walker Lake and remanded it back to the SEC for further consideration. The Nevada Legislature followed this action with a Senate Concurrent Resolution denying the standards. Nevada Legislative Commission objected to the proposed regulations on the basis that it does not conform to the statutory authority pursuant to which it was adopted and does not carry out the intent of the legislature in granting that authority. The major concern expressed at the April 17^{th} Legislative Commission hearing was that the regulation contains standards that may not be reasonably attainable without significant increases in the volume of water flowing into Walker Lake.

Subsequent to the action by the Nevada Legislature, NDEP began work on an alternative standards petition for Walker Lake. On December 11, 2001, NDEP presented a new petition to the SEC which included beneficial uses for Walker Lake and some numeric criteria to support these uses. However, the more controversial numeric criteria (TDS, arsenic and chloride) were not included in the new petition. At the December meeting, the petition was approved by the SEC and later approved by EPA.

2.3.2 Current Water Quality Standards: Nevada's water quality standards, contained in the Nevada Administrative Code (NAC) 445A.118 – 445A.225, define the water quality goals for a waterbody by: 1) designating beneficial uses of the water; and 2) setting criteria necessary to protect the beneficial uses. Beneficial uses consist of such things as irrigation, recreation, aquatic life, fisheries, and drinking water. Per NAC 445A.1693, the designated beneficial uses for Walker Lake consist of:

- Recreation involving contact with the water
- Recreation not involving contact with water
- Propagation of wildlife
- Propagation of aquatic life and, more specifically, the species of major concern are the tui chub, Tahoe sucker, and adult and juvenile Lahontan cutthroat trout.

Applicable numeric standards for Walker Lake can be found in NAC 445A.1696 of the Nevada regulations. As discussed above, the regulations do not include numeric criteria for TDS, arsenic and chloride.

Nevada also has water quality standards for the Walker River and its main tributaries. The applicable water quality standards for TDS in these waters are 500 mg/l (NAC 445A.160 through 445A.169). While the NAC includes standards for the Walker River (and its main forks) from its mouth at Walker Lake up through and beyond the Walker River Indian Reservation to the California-Nevada stateline, Nevada has no authority to set and enforce water quality standards for the Walker River Indian Reservation.

2.4 303(d) Listing

In 2002, EPA approved the beneficial uses and criteria promulgated by the State of Nevada for Walker Lake. The propagation of aquatic life was included as one of the beneficial uses. While the standards do not include numeric criteria for TDS, NDOW has shown that TDS levels have impaired the aquatic life beneficial use. NDOW found that hatchery LCT (Lahontan cutthroat trout) experienced high death rates upon release into the high TDS waters of Walker Lake. In the mid-1990s, NDOW began acclimating the hatchery trout in high TDS water prior to releasing into Walker Lake. While this acclimation process has improved initial survival of the juvenile fish, the health and lifespan of the LCT and its food sources are impaired due to the elevated TDS levels. Increasing TDS concentrations have caused significant biological changes in Walker Lake, including a reduction in biological diversity and the extinction of at least one zooplankton species. The declining water quality is also directly related to the loss of native species of fish (Tahoe sucker, Lahontan redside shiner, Lahontan speckled dace) (Horne and Beutel, 1997; Sevon, 2002; Williams, 2001). Based upon these various sources, Walker Lake was included on the 2002 and proposed 2004 303(d) List for TDS.

2.5 Walker River Mediation

In 2002, mediation began with representatives of the United States, the states of Nevada and California, the Walker River Paiute Tribe, the Walker River Irrigation District, the Counties of Lyon and Mineral in Nevada and Mono County in California, and the Walker Lake Working Group. Initial meetings were to focus on short-term measures that could begin addressing the immediate confronted by Walker Lake concerning a continued increase of TDS levels.

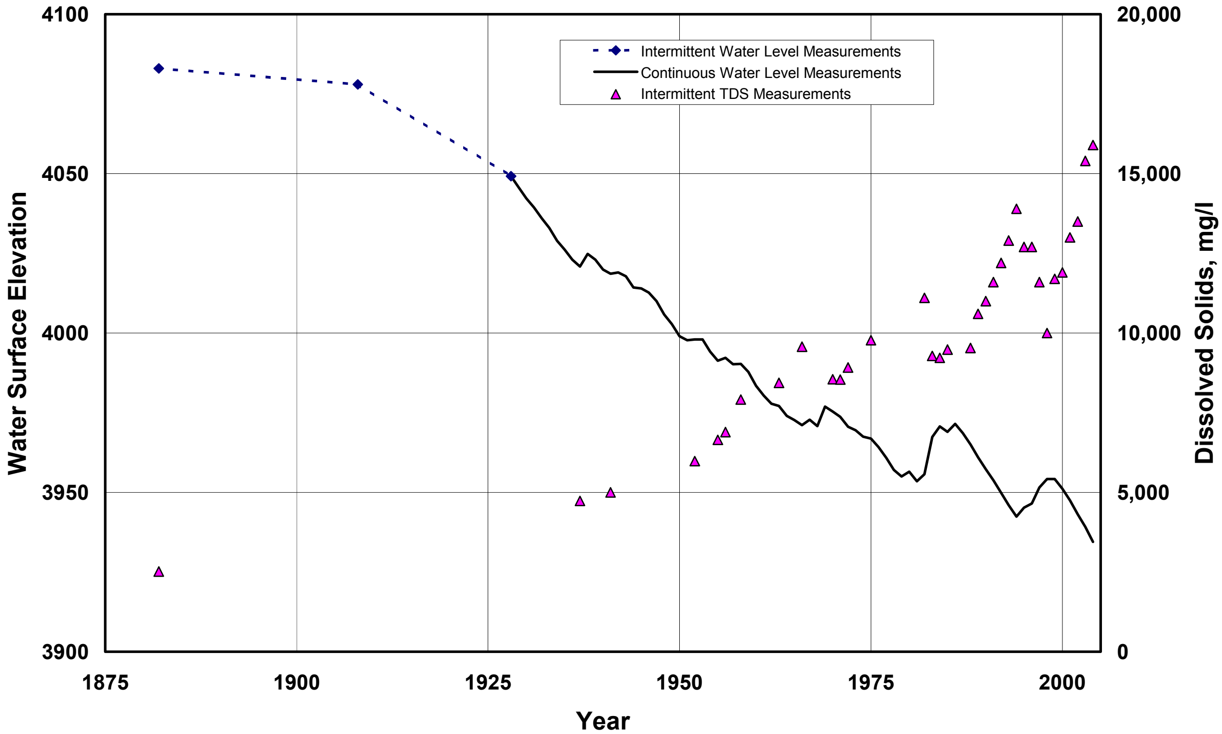
3.0 Walker Lake TDS TMDL

3.1 Problem Statement and Source Analysis: Walker Lake water levels have dropped over 140 feet since 1882 with a volume decrease from about 9.0 million acre-feet to a present level of about 1.76 million acre-feet. The TDS levels have increased from about 2,500 mg/l in 1882 to about 15,900 mg/l in December 2004 (Figure 3). This increase in TDS has been primarily due to the volume reduction, however TDS loads[2] from the Walker River and local sources have also contributed. Due to these continued loads, the total TDS mass in the lake increased from about 31 million tons in 1882 to about 38 million tons in 2004. This accounts for about 3,000 mg/l of the TDS concentration increase experienced during this 122-year period.

The decline over the last century can be attributed largely to upstream diversions for agriculture and other uses. In a published thesis, Milne (1987) estimated that 1987 Walker Lake water level would have actually been higher than the 1908 level [4,078 feet] if water development projects had not occurred in the basin. Irrigation is the largest water user in the basin with an estimated surface water righted acreage exceeding 120,000 acres in Nevada and California (Calif. Dept. of Water Resources, 1992). As a result of significant upstream water use, lake evaporation losses have exceeded remaining inflows resulting in the

[2] According to Thomas (1995), an estimated average 66,000 tons of dissolved solids were added to Walker Lake annually between 1882 and 1994. Since that study, Thomas (2004) has revised the estimated annual salt loading (1903 to 1994) to 86,000 tons/year. However due to salt removal in the lake by mineral precipitation, biological uptake and downward diffusion into the lake bed, the annual net increase of salt in the lake is 56,000 tons/year.

Figure 3. Walker Lake - Water Surface Elevations and TDS



water level decline. At the current water level (3934.5 feet, surface area = 31,800 acres – December 2004), net evaporation losses (evaporation minus precipitation on lake surface) are estimated at about 120,000 acre-feet/year. Pahl (1999) presented estimates of Walker Lake inflow from Walker River and local surface water and groundwater which ranged from 89,000 to 106,000 acre-feet per year depending upon the period of record being considered[3]. In other words, an additional 14,000 acre-feet to 31,000 acre-feet of inflow is needed to balance the net evaporative losses and maintain the existing lake level [approximately 3934.5 feet].

If the conditions experienced over the last 100 years persist, the lake level will continue to drop until net evaporation losses are balanced by river and local inflows. Assuming average annual inflows (from all sources) of about 95,000 acre-feet per year, this "equilibrium" point would be reached when the water elevation is at 3903 feet, with a surface area of 25,700 acres, and a volume of 825,000 acre-feet. At this point, the lake TDS will be significantly higher than seawater with the freshwater ecosystem long since dead.

Even if the lake were to maintain its present level, TDS levels would continue to increase due to loading from the Walker River and local sources. In 1995, Thomas had estimated that about 66,000 tons of dissolved solids entered Walker Lake on an annual average basis between 1882 and 1994. Since that study, Thomas (2004) has revised the estimated annual salt loading at 86,000 tons/year between 1903 and 1994. However due to salt removal in the lake by mineral precipitation, biological uptake and downward

[3] It is estimated that pre-1900 inflows were approximately 250,000 acre-feet/year as needed to balance the net evaporation losses likely experienced at the time. Rush (1974) estimated the 1882 surface area to be 68,600 acres. Using an average annual precipitation amount of 4.9 inches (Thomas, 1995) and an average annual evaporation rate of 4.1 feet (Everett and Rush, 1967), an average annual net evaporation rate of 250,000 acre-feet/year can be calculated.

diffusion into the lake bed, the annual net increase of salt in the lake is 56,000 tons/year (Table 2). At the 2004 lake volume, this loading would result in an annual increase in the TDS concentration of about 20 mg/l. In other words, if the lake holds at its current water level (December 2004: Elevation = 3934.5 feet, Volume = 1,760,000 acre-feet, TDS = 15,900 mg/l), its TDS level of 15,900 mg/l would increase to about 17,000 mg/l in 50 years and to about 18,000 mg/l in 100 years.

Table 2. Average Annual Salt Fluxes (1903-94) to Walker Lake (Thomas, 2004)

Source	Average Annual Salt Flux (tons/year)	Percent of Salt Flux
Walker River	21,000	31%
Groundwater	29,000	43%
From Lake Bed Sediments	18,000	26%
Total Flux to Lake	68,000	100%
To Lake Bed Sediments	-12,000	
Net Flux to Lake	56,000	

Note: Fluxes have been adjusted for removal due to mineral precipitation and biological uptake

The ever-increasing TDS levels along with other physical, biological and chemical conditions in the watershed and lake have stressed the fishery and other aquatic life in the Lake and changed the resident fish population. Historically, Walker Lake supported a number of native and introduced fish species (Table 3). Today, only the Lahontan cutthroat trout (LCT), Lahontan tui chub, and the Tahoe sucker are found in Walker Lake.

Historically, LCT occurred throughout the Walker basin from the headwaters in California to and including Walker Lake. Lacustrine (lake-dwelling) LCT would migrate from Walker Lake into Walker River tributaries and spawn in riffles. It is thought that the lower Walker River may not have been used as the primary spawning and rearing habitat, but was more likely a migratory corridor to reach the upper river and tributaries (Walker River Basin Recovery Implementation Team, 2003). With the construction of reservoir and numerous diversion structures over the years, the migration path for the lacustrine LCT was blocked. By the 1940s, these infrastructure caused the extirpation of the LCT from the lower Walker basin[4] (Beutel and Horne, 1997). In 1953, annual stocking of hatchery-reared LCT began (Horton, 1996). Since that time, NDOW creel census records have shown a decline in the LCT trophy population in Walker Lake (NDOW records, various years).

Beginning in 1973, both NDOW and the U.S. Fish and Wildlife Service (USFWS) have provided about 100,000 LCT each for the annual fish stocking program in Walker Lake. Ten years later, NDOW began an in-lake bioassay program in which samples of fish to be stocked were placed in live cages for 7 to 10 days to document survival. During the early years of this program, TDS levels were in the 9,000 to 10,000 mg/l with survival rates ranging from about 80% to 100%. By 1994, the TDS level reached 13,500 mg/l and survival rates in the live cages had dropped to about 7% (NDOW records, various years). In an attempt to increase survival, NDOW and USFWS began acclimation procedures in 1994 using

[4] By 1970, LCT were listed as an endangered species and later reclassified as threatened in 1975 (Walker River Basin Recovery Implementation Team, 2003).

Table 3. Native and Introduced Fish Species in Walker Lake (Koch et al. 1977)

Native Species	
Lahontan cutthroat trout	*Salmo clarki henshawi*
Lahontan tui chub	*Gila bicolor obesa*
Tahoe sucker	*Catostomus tahoensis*
Lahontan redside[1]	*Richardsonius egregious*
Lahontan speckled dace[1]	*Rhinichthys osculus robustus*
Introduced Species	
Sacramento perch[1,2]	*Archoplites interruptus*
Carp[1]	*Cyprinus carpio*
Yellowstone cutthroat trout[1,2]	*Salmo clarki lewisi*
Largemouth bass[1]	*Micropterus salmoides*
Bluegill[1]	*Lepomis macorchirus*
Brown bullhead[1]	*Ictalurus mebulosus*
Black bullhead[1]	*Ictalurus melas*
Brown trout[1,2]	*Salmo trutta fario*
Rainbow trout[1,2]	*Salmo gairdneri*
Eastern brook trout[1,2]	*Salvelinus fontinalis*
Lake trout[1,2]	*Salvelinus namaycush*
Kokanee salmon[1,2]	*Oncorhynchus nerka kennerlyi*

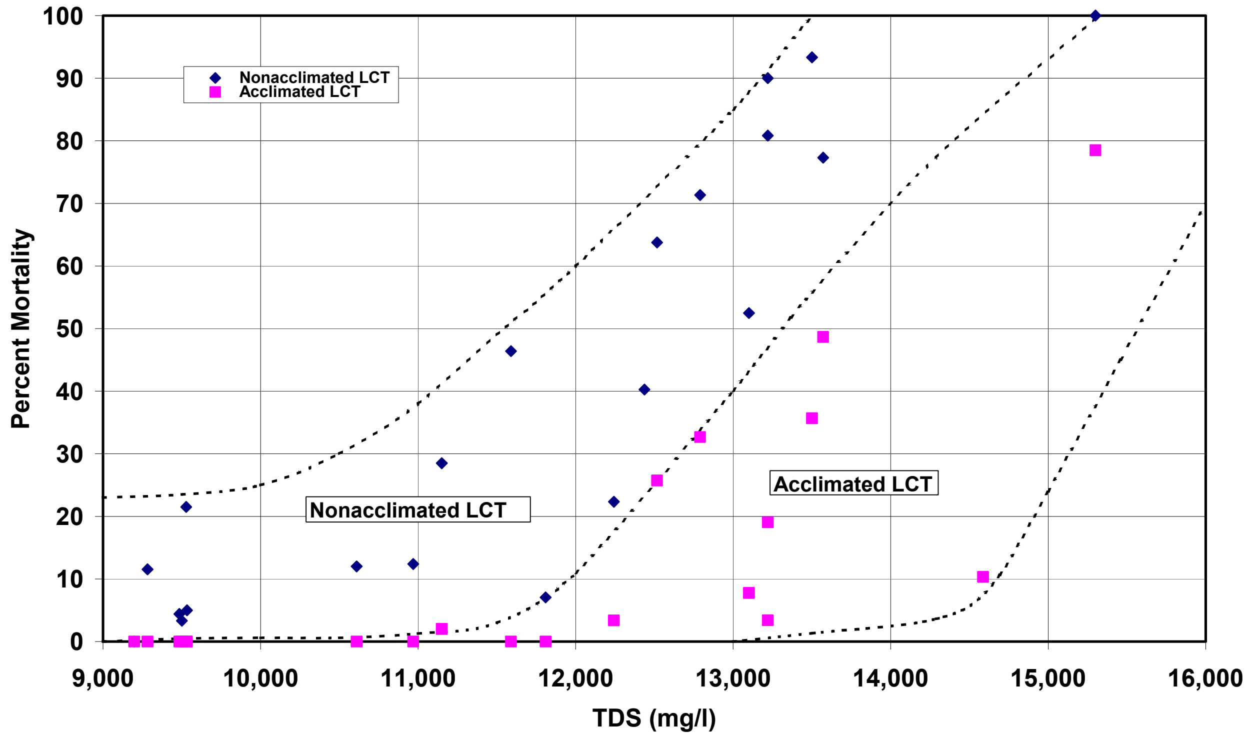
[1] Extirpated from Walker Lake today
[2] Species that were exotic to Walker drainage

various procedures. USFWS has acclimated its LCT (raised in the Lahontan National Fish Hatchery (LNFH)) by placing them in Pyramid Lake water for 2.5 to 7 days[5]. Up until 2002, NDOW acclimated LCT (from the Mason Valley Hatchery) in a mix of Walker Lake and hatchery water just overnight. In subsequent years, all LCT have been acclimated at Pyramid Lake for 2.5 to 7 days. The acclimation program was successful in improving survival of the stocked LCT. However, as TDS continued to increase, so did the mortality of the acclimated and unacclimated LCT. The latest LCT stocking efforts (2004) have yielded the worst survival results of the 11-year acclimation program with 100% mortality of the nonacclimated LCT and about 80% mortality of the acclimated LCT (NDOW records, various years).

Figure 3 summarizes the mortality data for the nonacclimated and acclimated LCT for varying TDS levels. This figure graphically shows how the acclimation process has improved survival of the LCT being stocked; however at levels above 12,000-13,000 mg/l, even the acclimated LCT experienced 3 to 33% mortality levels during the stocking process. Following planting, the higher TDS levels continue to impact the juvenile and adult LCT in the lake. Galat et al. (1983) found kidney degeneration more prevalent in lakes with TDS of 5,000 mg/l or more. However Galat et al. did not relate kidney degeneration to life span impacts. According to Beutel and Horne (1997), poor habitat conditions, including elevated TDS, have decreased the average life span of LCT in Walker Lake from about 8 years down to only 2 to 3 years.

[5] The TDS of Pyramid Lake is about 5,200 mg/l.

Figure 4. Mortality of LCT Stocked in Walker Lake



A variety of laboratory studies have been undertaken to characterize TDS stress impacts on LCT. A study by Lockheed Ocean Science Laboratories (LOSL, 1982) examined the effects of varying TDS on various age LCT (2-month old versus 10-month old acclimated to Pyramid Lake water). When exposed to a TDS level of 14,305 mg/l, 50% of the 2-month old LCT died in 96 hours. At a TDS level of 15,532 mg/l, 33% of the 2-month old LCT died after 48 hours. For the 10-month old LCT, no mortalities occurred at a TDS of 19,152 mg/l. Using Walker Lake water manipulated to create varying TDS levels, Dickerson and Vinyard (1999) found 25 to 75% mortality within 7 days for unacclimated fish at a TDS level of 13,180 mg/l. LCT acclimated for 3 days at 3,600 mg/l TDS showed a 24% mortality within 7 days at a TDS level of 13,180 mg/l. Unacclimated fish experienced 100% mortality within 4 days at a TDS level of 15,467 mg/l. These laboratory study results compare well with NDOW's field investigations during stocking.

Unlike the LCT, the tui chub are naturally propagating in Walker Lake using the shallower near-shore waters for spawning (Koch et al., 1979). The tui chub are the most abundant fish and comprise about 99% of the Walker Lake fish population (Cooper and Koch, 1984). As a key component of the LCT diet, the Tui chub and their health directly impact the LCT. While juvenile and adult tui chub are relatively tolerant of high TDS, tui chub eggs are less tolerant. In a study by Lockheed Ocean Science Laboratories (LOSL, 1982), tui chub eggs experienced 80% and 100% mortality in 12,379 mg/l TDS and 15,532 mg/l TDS, respectively. This study also showed that embryonic development of the tui chub was affected with TDS levels ranging from 8,759 to 9,342 mg/l. These findings suggest that the tui chub may be currently having little success in reproducing in Walker Lake. However more studies are needed to ascertain the reproductive status of the tui chub in Walker Lake.

Another native fish in Walker Lake is the Tahoe sucker. However, the Tahoe sucker is now relatively rare in Walker Lake (Koch et al. 1979) and Stockwell (1994) has suggested that this is due to the loss of river access for spawning purposes rather than high TDS levels.
In addition to direct impacts to the fish, the elevated TDS has also impacted other components of the ecosystem and food web. According to Koch et al. (1979), the abundance and diversity of benthic organisms is low compared with other large lakes. Koch concluded that this is likely due to high TDS levels and low dissolved oxygen in the hypolimnion. Zooplankton (small, semitransparent animal which live in the open water of lakes) are the predominant food source for small fish and Horne (1994) reported a reduction in abundance and diversity due to elevated TDS levels.

According to Beutel and Horne (1997), the LCT and other aquatic life are exposed to other stresses in addition to the elevated TDS levels, such as an "oxygen-temperature squeeze". During lake stratification, the LCT are squeezed between the bottom layer of low oxygen water (the hypolimnion) and the upper layer of warm water (the epilimnion). The LCT prefer water cooler than 20 °C and dissolved oxygen levels above 5 mg/l (Koch et al. 1979) and will seek refuge to satisfy these needs. However, as the lake level has declined the amount of refuge between the high temperature and low dissolved oxygen layers has decreased. While stressors other than TDS are impacting the LCT and other aquatic life, this TMDL document is focusing on TDS as required by the Consent Decree.

Other beneficial uses (NAC 445A.1693 – wildlife, recreation) are impacted by the health of Walker Lake's aquatic life and overall ecosystem. Walker Lake provides habitat for a variety of wildlife and is a critical stopover point for migratory birds which rely on the aquatic life for their food supply. The decline of Walker Lake system also impact recreational uses which provide income for the region. The loss of support for the aquatic life beneficial use would have significant impacts upon these other beneficial uses.

3.2 Numeric Target Analysis: The purpose of the target analysis is to identify and quantify those future conditions needed for the support of the beneficial use. In this case, the beneficial use of concern is the propagation of aquatic life including tui chub, Tahoe sucker and adult and juvenile Lahontan cutthroat trout (NAC 445A.1693).

Selecting a single TDS target needed to support the designated beneficial use of concern is challeging. First, while the data indicate TDS levels affect the health of the lake and its aquatic ecosystem, it is also clear that other factors (such as the dissolved oxygen-temperature squeeze) are affecting the system. Depending on the level of aquatic health desired (fair, good, excellent, etc.), one could select any number of TDS targets. Second, the relationship between TDS and the aquatic health is complex and not easily defined. While data indicate there is a relationship, there is a level of uncertainty associated with any TDS target that is selected. Third, the natural variability of inflows to the Lake in response to dry year/wet year cycles leads to variations in TDS. A single TDS target could rarely be met from month to month and year to year.

For this TMDL, a long-term average TDS target of 12,000 mg/l has been selected to provide a moderate level of support for the beneficial use. It is believed that this annual average TDS target will allow for some natural fluctuations in TDS from year to year while maintaining the TDS levels below 14,000 mg/l in most years. Once levels rise above 14,000 mg/l, the LCT stocking program becomes much less viable. Actual future TDS fluctuations will depend upon climatic conditions, water use patterns and options implemented to maintain TDS levels in an acceptable range. It must be noted that this target could be updated in the future as additional research is completed.

3.3 Pollutant Load Capacity, TMDLs, and Allocations: The following presents the TMDL and load allocations established for the various TDS sources as needed to meet the average annual target TDS level of 12,000 mg/l. These allocations are based on an analysis of loading capacity at the current lake level. It must be kept in mind that federal regulations require TMDLs be established for pollutants (such as TDS) preventing attainment of water quality standards (which includes support of beneficial uses). By definition, flow or flow alteration are not considered to be pollutants (per Clean Water Act, Section 502).

As discussed below, an explicit margin of safety is included in part to account for the possibility that the lake level (and associated TDS loading capacity) may fall in the future.

<u>TMDL Calculation</u>

The total existing and total allowable TDS loads can be calculated using the following equation:

$$TDS\, mass\ in\ lake(tons) = \frac{TDS\ concentration\ (mg/l) \times current\ lake\ volume\ (AF)}{735.56} \quad \text{[Eq. 1]}$$

At the current lake level and TDS concentration (December 2004: 1,760,000 acre-feet, 15,900 mg/l TDS) it is estimated that the current total TDS mass in the lake is approximately 38.0 million tons. At the current lake level and the target TDS concentration of 12,000 mg/l, the TDS mass in the lake would need to be lowered to 28.7 million tons. The TMDL is therefore 28.7 million tons of TDS in Walker Lake.

<u>Load Allocations</u>

Load allocations have been assigned to the 3 main TDS loads (as identified by Thomas (2004)) to the lake and the TDS mass accumulation in the lake:

<u>Walker River Load Allocation</u>

According to Thomas (2004), the average annual TDS loading to the lake from Walker River is approximately 21,000 tons/year. Setting a load allocation in terms of tons/year could be contrary to other potential solutions for the lake. For example, additional river inflow is under discussion as a possible element of a restoration strategy for Walker Lake. Increases in river inflow could result in additional TDS loading (beyond the 21,000 tons/year) to the lake. However, because the TDS concentrations in Walker River are likely to remain far below the numeric target identified for the Lake, increased river flows would have the effect of diluting TDS concentrations in the Lake. In order to provide for the possibility of increased Walker River flows and associated TDS dilution effects, it was determined that the Walker River load allocation should be set on a concentration basis.

Traditionally, TMDLs are defined in units of mass per time (pounds per day, tons per year, etc.). However according to federal regulations (40 CFR 130.2(i)), TMDLs need not be expressed in pounds per day (or tons per year) when alternative means are better suited for the problem. With this in mind, the Walker River load allocation is set as a maximum TDS concentration of 500 mg/l, consistent with the State of Nevada's TDS water quality standard for the river.

Groundwater and Lake Bed Sediment Allocation

Thomas (1994) estimated groundwater and lake-bed sediment loads at 29,000 and 18,000 tons/year, respectively. For purposes of this TMDL, allocations for these sources are set at the existing loading levels because these sources are not believed to be controllable.

TDS Mass in Lake Allocation

Unlike most water bodies, from which pollutants may be discharged to downstream waters, Walker Lake is a terminal lake in which pollutants accumulate over time. Moreover, TDS is an accumulating conservative pollutant that is not removed from the system over time through chemical or biological transformations. For these reasons, the largest "source" of TDS in the Walker Lake system is the TDS load already present in the Lake. In order to attain the applicable water quality standard and associated numeric target, it would be necessary to remove large amounts of TDS from the Lake over time.

The load allocation for TDS already in Walker Lake is therefore expressed as a negative number to reflect the amount of TDS that would have to be removed to bring about attainment of the numeric target (even if all other TDS loading sources were reduced to zero). Table 4 summarizes the load allocations.

As discussed above, the TMDL is set at 28.7 million tons of TDS in Walker Lake based upon attainment of a 12,000 mg/l average annual concentration. This would require a reduction of approximately 9.3 million tons from the existing Lake TDS load of 38.0 million tons. As discussed in the next section, an explicit 10% margin of safety is being included in this load allocation to account for analytical uncertainties. The load allocation for in-lake TDS is equal to the estimated load reduction needed in the Lake (9.3 million tons) plus the 10% margin of safety (0.93 million tons), resulting in a negative total load allocation of -10.23 million tons of TDS in the Lake.

Margin of Safety, Seasonal Variations and Critical Conditions

The Clean Water Act requires that TMDLs include a margin of safety (MOS), either explicitly or implicitly. The purpose of the MOS is to account for uncertainties in the relationship between pollutant loads and the water quality of the waterbody. The TMDL provides an implicit MOS by setting the numeric target at 12,000 mg/l—less than the 14,000 mg/l level above which the LCT stocking program becomes less viable. Moreover, to account for uncertainty in determining the total TDS load in the lake and the possibility that loading capacity may decrease in response to future reductions in lake volume, an explicit 10% MOS of safety was used to set the total load allocation for the TDS mass in the lake. Since no change in existing loads from the river, groundwater and lake bed sources are being called for in the load allocation (and these loads are much less significant than the existing TDS load in the lake), no MOS was necessary for these allocations. The resulting load allocations are presented in Table 4.

Table 4. TDS Load Allocations

Source	Load Allocation	Margin of Safety	Total Load Allocation
Walker River	Maximum TDS concentration of 500 mg/l *	[redacted]	Maximum TDS concentration of 500 mg/l *
Groundwater	29,000 tons/year	[redacted]	29,000 tons/year
Lake Bed Sediments	18,000 tons/year	[redacted]	18,000 tons/year
TDS mass in Lake**	-9,300,000 tons	-930,000 tons	-10,230,000 tons

*This load allocation is to be applied as an annual average
**Based upon TDS levels in lake on December 2004

In a TMDL, consideration needs to be given to seasonal variations and critical conditions. In general, TDS loadings to the Lake are a long term concern and are less sensitive to short term variability in pollutant levels than would be the case for many other pollutants. Therfore, the TMDL appropriately focuses on long term TDS loading levels and concentrations. However, the TMDL is designed to provide TDS levels below critical concentration levels, taking into account interannual variability in flows and TDS loads. These factors are accounted for by setting the target as an average TDS concentration at a level lower than the level above which LCT stocking becomes less viable. This approach recognizes that the Lake TDS will continue to fluctuate seasonally and with the ever-changing drought and flood cycles experienced in Nevada.

3.4 Implementation: Neither the Clean Water Act nor Nevada laws and regulations require a separate TMDL implementation plan. In Nevada, a collection of activities (NPDES permits for point sources; Nevada's Nonpoint Source activities and projects) and documents (Continuing Planning Process (NDEP, 2004); Nonpoint Source Management Program (NDEP, 1999)) serve as Nevada's "implementation plan" for all TMDLs, with the nonpoint source program being voluntary having no regulatory requirements for participants or participation.

It is recognized that the proposed TMDL and allocations may not provide for the long term protection of Walker Lake if TDS concentrations continue to increase in response to reduced lake volume. Additional flows could partially address this concern by reducing the rate of lake volume reduction or possibly increasing lake volume. We recommend continued monitoring of river and lake TDS levels and flows, and ecosystem health. It is also recommended that the TMDL be reviewed as necessary to account for any changes in TDS controls or river flows to the lake.

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