Evaluation of Total Maximum Daily Loads and Associated Water Quality Standards Attainment for the Las Vegas Wash, Las Vegas Bay and Lake Mead

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Bureau of Water Quality Planning
Nevada Division of Environmental Protection
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Introduction

The current total phosphorus and ammonia TMDLs on the Las Vegas Wash were established in 1989 and became fully effective in 1994 and 1995, respectively. In this report, available data from 1994 through 2001 are reviewed to assess compliance of the Total Maximum Daily Loads (TMDLs) established for the Las Vegas Wash and the associated water quality standards for Lake Mead.

Background on Existing TMDL

The Las Vegas Wash (LVW) is the major drainage of the Las Vegas Valley, transporting stormwater runoff, shallow ground water discharges, tertiary-treated sewage effluent and other point source discharges to Las Vegas Bay of Lake Mead. Figures 1, 2 and 3 provide location information on Lake Mead, Las Vegas Wash and the pertinent sampling locations. (NOTE: The monitoring station identification numbers shown on the following figures and used in this report have been replaced based upon a revised numbering system. The old ID numbers are used here for easier comparison to the stations discussed in the water quality standards regulations.)

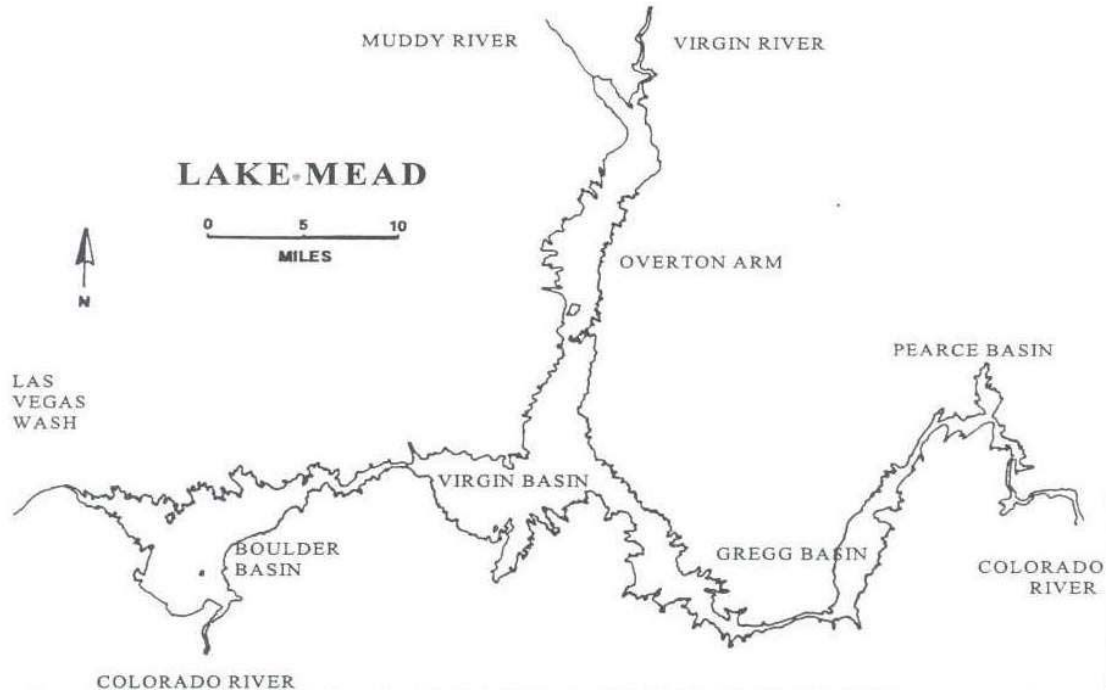


Figure 1. Lake Mead and Las Vegas Wash Location Map

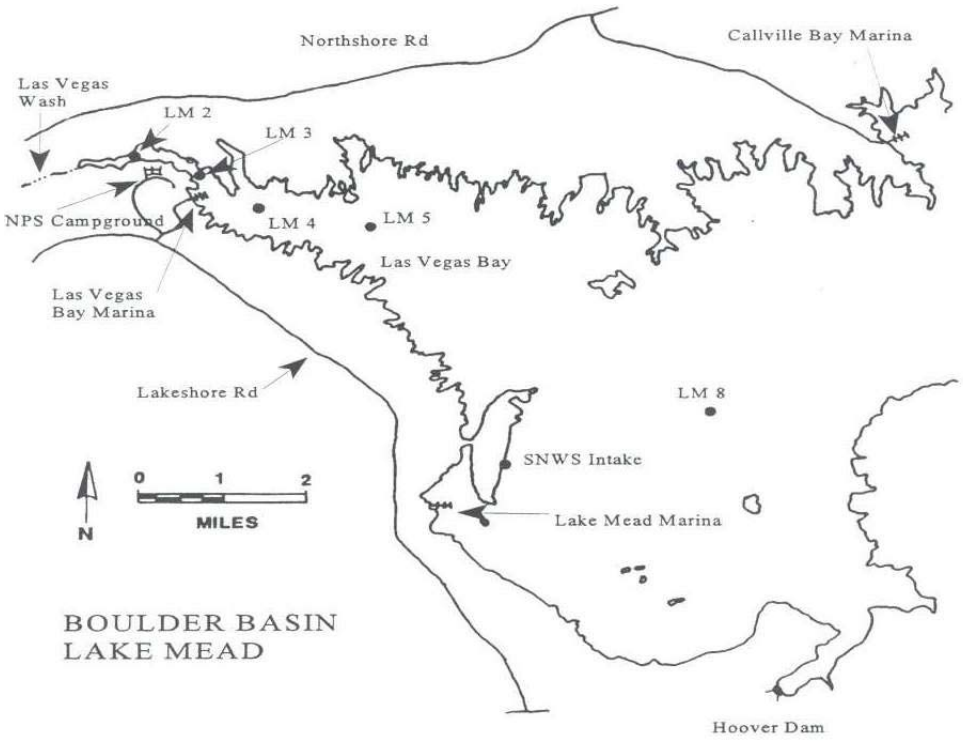


Figure 2. Lake Mead Sampling Locations

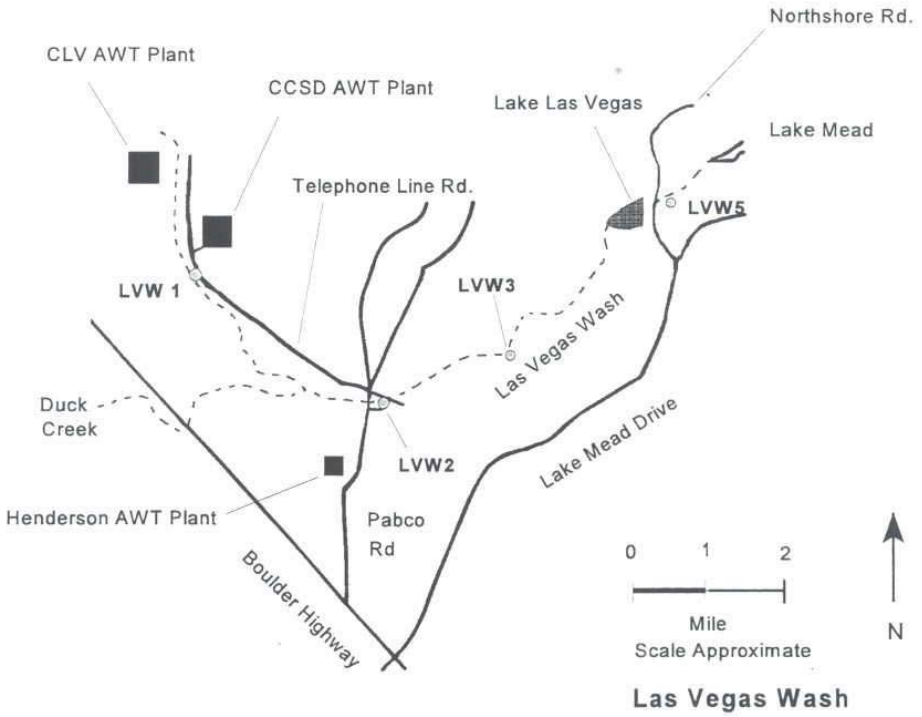


Figure 3. Las Vegas Wash Sampling Locations

In 1987, the Nevada Division of Environmental Protection (Division) established water quality standards for chlorophyll a and un-ionized ammonia for Las Vegas Bay (LVB). The resulting requirements for chlorophyll a were:

- Not more than one monthly mean in a calendar year at Station 3 (LM-3) may exceed 45 ug/l.
- The mean for chlorophyll a in summer (July 1 – September 30) must not exceed 40 ug/l) at Station 3, and the mean for 4 consecutive summer years must not exceed 30 ug/l. "Mean" indicates the average of not less than 2 samples per month. The samples must consist of the average of the data collected from not less than 3 sites within a cross section of Station 3 that are representative of the top 5 meters of the cross section. "Station 3" means the center of the channel at which the depth is 16 to 18 meters.
- The mean for chlorophyll a in the growing season (April – September) must not exceed 5 ug/l in the open water of Boulder Basin, Virgin Basin, Gregg Basin and Pierce Basin. The single value must not exceed 10 ug/l for more than 10 percent of the samples. "Mean" indicates the average of not less than 2 samples per month.

It must be noted that these chlorophyll a standards are RMHQs (Requirements to Maintain Existing Higher Quality) and not beneficial use standards. In general, RMHQs are set to control degradation of Nevada's waters while beneficial use standards are set to protect the various beneficial uses such as aquatic life, recreation, irrigation, etc.

At that time, the beneficial use criteria for un-ionized ammonia were set as:

- The 4-day average for the concentration of un-ionized ammonia must not exceed 0.04 mg/l more often than once every 3 years. The daily value for this average must consist of the average of the data collected from not less than 3 sites within a cross section of Station 2 (LM-2) that are representative of the top 2.5 meters of the cross section, and must account for diurnal fluctuations. This average is not applicable to the area between Station 2 and the confluence of Las Vegas Wash.
- The single value must not exceed 0.45 mg/l more often than once every 3 years.
- When the temperature exceeds 20 degrees C, these standards must be adjusted pursuant to methods accepted by the United States Environmental Protection Agency.
- "Station 2" means the center at which the depth is 10 meters.

The 1986 and 1987 LVB data showed non-achievement of these standards. Mean summer chlorophyll a at Station 3 (LM-3) was 53.2 ug/l, which was considerably higher than the RMHQ of 30 ug/l (4-year mean). Although the acute un-ionized ammonia standard of 0.45 mg/l was not exceeded at Station 2, the chronic un-ionized ammonia standard (0.04 mg/l) was exceeded almost 100 percent of the time during April through August. The above standards were not met during the period April through September, but were met from October through March.

To address these water quality problems, total phosphorus and total ammonia Total Maximum Daily Loads (TMDLs) for the LVW were developed, to be effective at Northshore Road as measured at monitoring site LVW-5. Utilizing a dilution ratio model with data from 1985 through 1987, French (1988) estimated that target concentrations of 0.64 mg/l (total phosphorus) and 1.43 mg/l (total

ammonia) were needed in the Wash at Northshore Road in order to meet the chlorophyll a and un-ionized ammonia water quality standards within the Las Vegas Bay. In the analysis, Northshore Road data collected during high flows (greater than 110 percent of average) were not used. While no explanation for this exclusion is offered in the report, it appears this was done to simulate the more common average conditions. It does not appear to be an attempt to account for possible lower bioavailability of wet-weather phosphorus loads[1].

It was the premise of his investigation that the Las Vegas Bay water quality is controlled by the mass loading from the Las Vegas Wash, and the amount and direction of mixing that occurs between the Wash inflow and epilimnetic waters of the Bay. The total phosphorus target was driven in part by the following relationship derived from the available Las Vegas Bay data for the period April - September:

Chlorophyll a (ug/l) = 603 x Total Phosphorus (mg/l) – 0.704

For both total phosphorus and total ammonia targets, French considered April through September to be the critical period from the viewpoint of the Las Vegas Bay water quality. This equation yields a required total phosphorus level of 0.051 mg/l to meet the long term chlorophyll a RMHQ of 30 ug/l. Using the dilution model, this target in the Bay was utilized to determine the Wash (at Northshore Road) target of 0.64 mg/l (total phosphorus).

The USGS gaging station at Northshore Road was destroyed in 1984. In order to estimate flows at Northshore Road, average flows at Station 09419700 – Las Vegas Wash at Pabco Road for 1985-87 were taken and increased by 4 cfs to 126 cfs to account for flow differences between the two locations. Using this estimated flow at Northshore Road, the TMDLs for total phosphorus and total ammonia were calculated:

TMDL (lbs/day) = target concentration (mg/l) x average flow (cfs) x 5.38

The resulting TMDLs were calculated at 434 lbs/day total phosphorus and 970 lbs/day total ammonia. Before a portion of the TMDLs could be allocated to the point source dischargers, the nonpoint source load needed to be estimated. Again using 1985-87 data, monthly average total nonpoint source loads (for April through September) were determined by subtracting the total average load discharged by the treatment plants (based upon self-monitoring reports submitted to NDEP) from the monthly average total phosphorus load at Northshore Road (based upon biweekly water quality data and USGS flow data). In an effort to eliminate some of the unpredictable variation in the nonpoint source loads, daily flows which exceeded 110 percent of the average flow were not considered in calculating the monthly average load at Northshore Road.[1] Over the 3 years (1985-87) considered, this resulted in 5 values being eliminated from the calculations. Using this

[1] It has been suggested that wet-weather phosphorus has significantly less bioavailability for algal growth than does dry-weather phosphorus loads entering Las Vegas Bay. Also, an unpublished study of a 1998 stormwater event indicated that the runoff from a particular runoff event was more dense than the Las Vegas Bay water and sank below the epilimnion, thereby not being available to algae near the surface (Bazel, 2003). While wet weather phosphorus may have a limited impact upon algal growth in the Bay, there is no evidence in the TMDL report and supporting documents that the authors intended to account for these factors by eliminating high flow loads from the load allocation calculations.

approach, the nonpoint source total phosphorus load was initially estimated at 90 lbs/day. Applying a 10 percent safety factor, the final nonpoint source load for total phosphorus was set at 100 lbs/day. Available data suggests that there were no nonpoint source loads of ammonia in the Las Vegas Wash.

With the LVW total phosphorus nonpoint source load at 100 lbs/day, the remaining 334 lbs/day total phosphorus was allocated between the point source discharges. Lacking an understanding of the kinetics of ammonia reduction in the LVW, all of the total ammonia TMDL was allocated to the point source discharges.

In the original TMDL document, the effective period for the total phosphorus and total ammonia WLAs/LAs/TMDLs was set at April 1 through September 30. During the permit renewal process for Clark County and the City of Las Vegas, the effective total phosphorus WLA period was expanded to the period March 1 through October 31. The ammonia TMDL period was unchanged by the permits. The TMDLs and wasteload allocations (WLAs) for total phosphorus and total ammonia became effective April 1, 1994 and April 1, 1995, respectively.

At the time the TMDLs were initially developed, the City of Henderson was not discharging to the Wash. Therefore, the original WLAs were divided between the City of Las Vegas and Clark County. In 1994, the City of Henderson received a discharge permit including WLAs for total phosphorus and total ammonia. Subsequent permit modifications have resulted in WLAs as shown in Table. Per language in the permits, the permittees are considered to be in compliance if either:

- The Individual WLA (or that in effect due to transfers) listed in Table 1 is not exceeded, **OR**
- The sum of the Individual WLAs listed in Table 1 is not exceeded.

Table 1. Current Las Vegas Wash Wasteload and Load Allocations

	Total Phosphorus, lbs/day Effective From March 1 - October 31	Total Ammonia, lbs/day Effective From April 1 - September 30
Clark County	173	502
City of Las Vegas	130	379
City of Henderson	30	89
Total WLA	333	970
LA	100	0
TMDL	433	970

Current Water Quality Standards

In 1998, the Lake Mead standards for chlorophyll a were revised as follows:

- Not more than one monthly mean in a calendar year at Station 3 may exceed 45 ug/l.

  Comparison to 1987 version: Same as the 1987 version.

- The mean for chlorophyll a in summer (July 1 – September 30) must not exceed 40 ug/l) at Station 3 (LM-3), and the mean for 4 consecutive summer years must not exceed 30 ug/l. The samples must be collected from the center of the channel and must be representative of the top 5 meters of the channel. "Station 3" means the center of the channel at which the depth is 16 to 18 meters.

  Comparison to 1987 version: 1) The definition of "Mean" was removed; 2) sampling point is restricted to the center of the channel rather than across the cross section.

- The mean for chlorophyll a in the growing season (April 1 – September 30) must not exceed 5 ug/l in the open water of Boulder Basin, Virgin Basin, Gregg Basin and Pierce Basin. The single value must not exceed 10 ug/l for more than 10 percent of the samples. "Mean" indicates the average of not less than 2 samples per month.

  Comparison to 1987 version: Same as the 1987 version.

- The mean for chlorophyll a in the growing season (April 1 – September 30) must not exceed 16 ug/l at LM-4 and 9 ug/l at LM-5.

  Comparison to 1987 version: New addition from the 1987 version.

The un-ionized standards were revised as follows:

- The 4-day average for the concentration of un-ionized ammonia in the vertical column and the four-sample rolling average for each interval must not exceed 0.05 mg/l more often than once every 3 years. The daily value for this average must account for diurnal fluctuation. Data must be collected at Station 2 from at least three locations between the surface and total depth. This standard is not applicable to the area between Station 2 and the confluence of Las Vegas Wash.

  Comparison to 1987 version: 1) Sampling point is restricted to the center of the channel rather than the cross section; 2) samples are to be collected throughout the water column rather than in the top 2.5 meters; 3) standard changed from 0.04 mg/l to 0.05 mg/l; 4) use of four sample rolling average added to the standards; 5) new standard does not vary with temperature.

- The single value must not exceed 0.45 mg/l more often than once every 3 years. "Station 2" means the center at which the depth is 10 meters.

  Comparison to 1987 version: Same as the 1987 version.

Compliance with Phosphorus TMDL and Chlorophyll a Standards

Estimated average monthly total phosphorus (TP) loads discharged to the Las Vegas Wash during the wasteload allocation period for 1994-2001 are shown in Table 2. The average monthly point source TP loads were obtained from the discharge monitoring reports (DMRs) submitted by the dischargers. These reported loads are calculated by multiplying the 30-day average effluent phosphorus concentration by the 30-day average effluent flow, based upon daily samples.

Loads at Northshore Road were calculated for the days monitoring data were available at LVW-5 (usually biweekly) along with the daily average flow for those days as recorded at the Northshore Road USGS gage. For consistency with the LA/TMDL calculations, samples collected during higher flows (greater than 110% of average) were excluded from the load calculations. Next, the LVW-5 biweekly loads were averaged on a monthly basis to obtain the LVW monthly average TP load. By subtracting the total point source loads from the total loads seen at LVW-5, the monthly average TP load attributed to nonpoint sources (NPS) was estimated. The NPS load includes contributions from urban runoff, ground water discharges to the LVW and discharges from numerous permitted industrial facilities and construction de-watering sites. Since total loads and nonpoint source loads at LVW-5 are calculated using biweekly data, these results must be considered as gross estimates of monthly loads.

As shown in Table 2, the WLA has always been met since the effective date of the phosphorus TMDL (April 1, 1994). However, the available data suggest that numerous exceedances of the phosphorus LA/TMDL have occurred due to nonpoint source contributions. It must be recognized that there are potentially significant errors in estimating monthly loads from biweekly data. For example, some of the monthly nonpoint source loads were calculated to be negative values as a result of this approach. Therefore, the reader is cautioned from drawing too many conclusions from Table 2. More detailed sampling is needed to accurately quantify monthly nonpoint source loads at Northshore Road[2].

The phosphorus TMDL was established to ensure attainment of the water quality standards (RMHQs) for chlorophyll a in Lake Mead. As shown in Figures 4-6, the chlorophyll a standards for Lake Mead have been met in all years since the phosphorus TMDL became effective, except for 2001. During 2001, the Bay experienced a large algae bloom with exceedances of the chlorophyll a

[2] The TMDL report fails to define any particular averaging period for compliance, such as a 30-day average. While the TMDL is silent on this issue, the discharge permits for the point sources state that the WLA is to be checked for compliance based upon a 30-day average of daily loads. One could conclude that the LA/TMDL is violated anytime the nonpoint sources for ONE day exceed 100 pounds per day (given that the flows were < 110% of the average). However, this is not deemed to be realistic and that a monthly averaging period for the nonpoints source allocation is likely more appropriate. Any future TMDL revisions need to address this issue in more detail.

Table 2. Monthly Average Total Phosphorus Loads, Las Vegas Wash

Date	Point Sources				Station LVW5 (North Shore Road) (See Note 1)	Total Nonpoint Source (See Note 1)
	City of Las Vegas	Clark Co. Sanitation District	City of Henderson	Total		
	WLA = 130 lbs/day	WLA = 173 lbs/day	WLA = 30 lbs/day	Sum of WLAs = 334 lbs/day	TMDL = 434 lbs/day	LA = 100 lbs/day
1/94	573	314	0	887	754	-133
2/94	538	342	0	880	728	-152
3/94	169	283	0	452	368	-84
4/94	**105**	**156**	**0**	**261**	**186**	**-75**
5/94	**107**	**158**	**0**	**265**	**210**	**-56**
6/94	**114**	**115**	**0**	**229**	**220**	**-9**
7/94	**106**	**180**	**0**	**286**	**277**	**-9**
8/94	**111**	**155**	**0**	**266**	**483**	**217**
9/94	**120**	**151**	**0**	**271**	**266**	**-5**
10/94	**116**	**175**	**0**	**291**	**245**	**-46**
11/94	349	201	55	605	387	-218
12/94	252	107	143	502	351	-151
1/95	341	189	163	694	Not Available	Not Available
2/95	380	177	141	698	603	-95
3/95	**71**	**156**	**0**	**227**	**261**	**34**
4/95	**105**	**104**	**0**	**209**	**259**	**51**
5/95	**91**	**111**	**0**	**202**	**219**	**18**
6/95	**72**	**158**	**0**	**230**	**188**	**-42**
7/95	**28**	**160**	**0**	**188**	**219**	**31**
8/95	**76**	**164**	**0**	**240**	**376**	**136**
9/95	**91**	**78**	**0**	**169**	**156**	**-13**
10/95	**36**	**81**	**0**	**117**	**190**	**73**
11/95	161	97	141	399	272	-127
12/95	118	652	226	995	1,096	100
1/96	49	386	258	693	572	-121
2/96	91	292	92	475	434	-41
3/96	**113**	**149**	**0**	**262**	**194**	**-69**
4/96	**100**	**162**	**0**	**262**	**296**	**34**
5/96	**118**	**120**	**0**	**238**	**215**	**-22**
6/96	**104**	**174**	**0**	**278**	**209**	**-70**
7/96	**81**	**91**	**0**	**172**	**149**	**-23**
8/96	**113**	**133**	**0**	**246**	**271**	**25**
9/96	**126**	**124**	**0**	**250**	**238**	**-12**
10/96	**108**	**170**	**4**	**282**	**245**	**-36**
11/96	192	380	107	680	147	-533
12/96	204	355	234	793	Not Available	Not Available

100 Effective period for TMDL

200 Value exceeds WLA/LA/TMDL

1. Data for sampled collected during high flow events (greater than 110% of average) were excluded from the calculations. For some months, this resulted in no available data.

2. Point source loads were calculated from 30-day average data obtained from the quarterly discharge monitoring reports

3. Total load at LVW5 calculated from biweekly sampling data and corresponding flow data

4. Total Nonpoint Source load estimated by subtracting point source loads from total load at LVW5

Table 2. Monthly Average Total Phosphorus Loads, Las Vegas Wash (cont'd)

Date	Point Sources				Station LVW5 (North Shore Road)	Total Nonpoint Source
	City of Las Vegas	Clark Co. Sanitation District	City of Henderson	Total		
	WLA = 130 lbs/day	WLA = 173 lbs/day	WLA = 30 lbs/day	Sum of WLAs = 334 lbs/day	TMDL = 434 lbs/day	LA = 100 lbs/day
1/97	110	251	273	634	486	-148
2/97	224	243	160	627	398	-229
3/97	**111**	**111**	**11**	**233**	**255**	**21**
4/97	**73**	**109**	**11**	**193**	**182**	**-10**
5/97	**97**	**121**	**9**	**227**	**211**	**-16**
6/97	**102**	**90**	**10**	**202**	**232**	**30**
7/97	**100**	**147**	**9**	**256**	**233**	**-23**
8/97	**107**	**163**	**12**	**282**	**293**	**11**
9/97	**119**	**148**	**10**	**277**	**419**	**142**
10/97	**113**	**153**	**4**	**270**	**401**	**131**
11/97	274	120	226	620	Not available	Not available
12/97	333	131	234	697	Not available	Not available
1/98	256	139	114	509	604	95
2/98	122	164	71	357	Not available	Not available
3/98	**85**	**138**	**8**	**230**	**223**	**-7**
4/98	**82**	**123**	**8**	**212**	**1585**	**1373**
5/98	**153**	**87**	**12**	**252**	**666**	**414**
6/98	**80**	**86**	**5**	**172**	**338**	**166**
7/98	**84**	**162**	**0**	**246**	**133**	**-113**
8/98	**72**	**108**	**8**	**188**	**570**	**382**
9/98	**95**	**69**	**8**	**172**	**519**	**347**
10/98	**88**	**96**	**5**	**190**	**355**	**166**
11/98	224	122	32	378	440	62
12/98	200	120	251	571	503	-68
1/99	337	301	316	954	840	-114
2/99	179	145	225	548	495	-53
3/99	**93**	**158**	**15**	**266**	**283**	**17**
4/99	**91**	**142**	**21**	**254**	**312**	**58**
5/99	**90**	**153**	**16**	**259**	**399**	**139**
6/99	**106**	**134**	**29**	**268**	**292**	**23**
7/99	**84**	**72**	**0**	**156**	**477**	**321**
8/99	**87**	**98**	**0**	**185**	**772**	**587**
9/99	**96**	**99**	**0**	**195**	**268**	**73**
10/99	**104**	**151**	**0**	**255**	**402**	**146**
11/99	296	296	309	901	681	-220
12/99	380	112	290	783	Not available	Not available

100 Effective period for TMDL

200 Value exceeds WLA/LA/TMDL

1. Data for sampled collected during high flow events (greater than 110% of average) were excluded from the calculations. For some months, this resulted in no available data.

2. Point source loads were calculated from 30-day average data obtained from the quarterly discharge monitoring reports

3. Total load at LVW5 calculated from biweekly sampling data and corresponding flow data

4. Total Nonpoint Source load estimated by subtracting point source loads from total load at LVW5

Table 2. Monthly Average Total Phosphorus Loads, Las Vegas Wash (cont'd)

Date	Point Sources				Station LVW5 (North Shore Road)	Total Nonpoint Source
	City of Las Vegas	Clark Co. Sanitation District	City of Henderson	Total		
	WLA = 130 lbs/day	WLA = 173 lbs/day	WLA = 30 lbs/day	Sum of WLAs = 334 lbs/day	TMDL = 434 lbs/day	LA = 100 lbs/day
1/00	386	97	411	894	792	-102
2/00	384	132	274	790	653	-136
3/00	**86**	**89**	**16**	**191**	**521**	**330**
4/00	**104**	**70**	**26**	**200**	**182**	**-18**
5/00	**115**	**70**	**37**	**222**	**172**	**-50**
6/00	**106**	**94**	**55**	**255**	**189**	**-66**
7/00	**93**	**127**	**0**	**220**	**165**	**-55**
8/00	**97**	**111**	**0**	**208**	**172**	**-36**
9/00	**59**	**83**	**0**	**142**	**186**	**45**
10/00	**98**	**114**	**112**	**324**	**227**	**-97**
11/00	276	125	339	740	416	-324
12/00	462	172	445	1,080	Not available	Not available
1/01	431	119	352	902	769	-133
2/01	408	84	201	693	Not available	Not available
3/01	**106**	**66**	**21**	**193**	**199**	**6**
4/01	**44**	**87**	**26**	**156**	**180**	**24**
5/01	**63**	**143**	**24**	**230**	**145**	**-85**
6/01	**82**	**131**	**42**	**255**	**168**	**-87**
7/01	**90**	**126**	**0**	**216**	**183**	**-33**
8/01	**55**	**134**	**0**	**189**	**160**	**-29**
9/01	**61**	**137**	**0**	**198**	**191**	**-7**
10/01	**128**	**51**	**0**	**179**	**127**	**-52**
11/01	411	50	13	474	311	-163
12/01	544	61	13	618	396	-222

100 Effective period for TMDL

200 Value exceeds WLA/LA/TMDL

1. Data for sampled collected during high flow events (greater than 110% of average) were excluded from the calculations. For some months, this resulted in no available data.
2. Point source loads were calculated from 30-day average data obtained from the quarterly discharge
3. Total load at LVW5 calculated from biweekly sampling data and corresponding flow data
4. Total Nonpoint Source load estimated by subtracting point source loads from total load at LVW5

RMHQs at LM-3, LM-4 and LM-5. It is interesting to note that while the data indicate there were numerous instances with elevated phosphorus loads due to nonpoint sources, in most instances elevated chlorophyll a levels did not occur. This provides support for the argument that the wet weather phosphorus loads are not available for use by the algae in the epilimnion.

Figure 4 -- Lake Mead Station LM-3, Monthly Mean Chlorophyll-a Concentrations

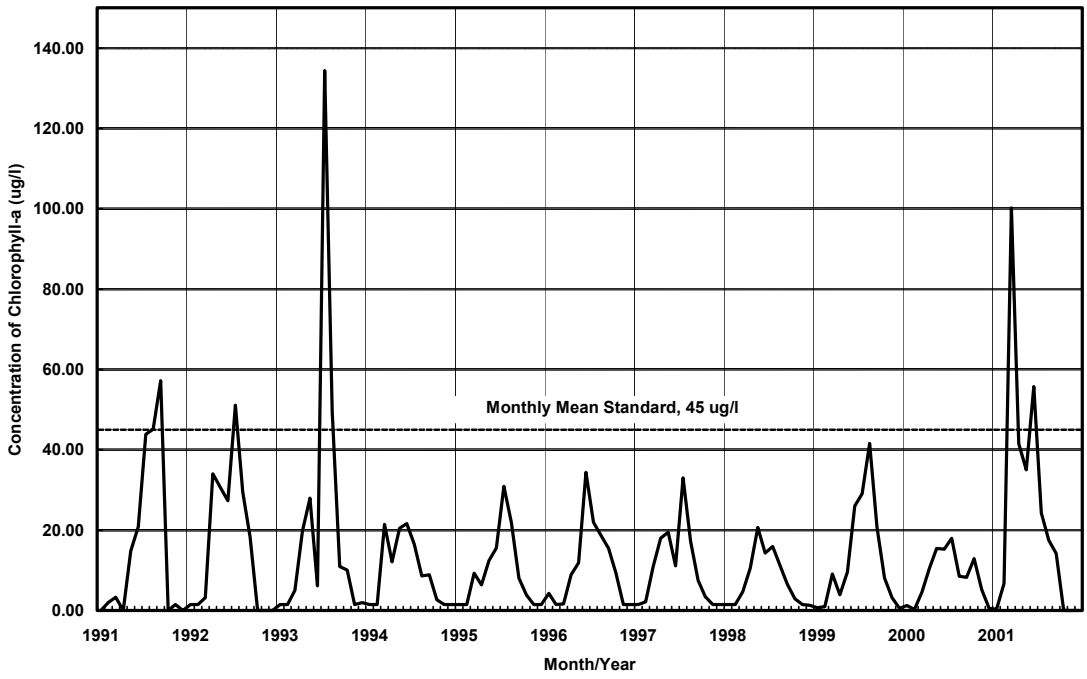


Figure 5 -- Lake Mead Station LM-3,
Annual Summer (July 1 - September 30) Mean Chlorophyll-a Concentrations

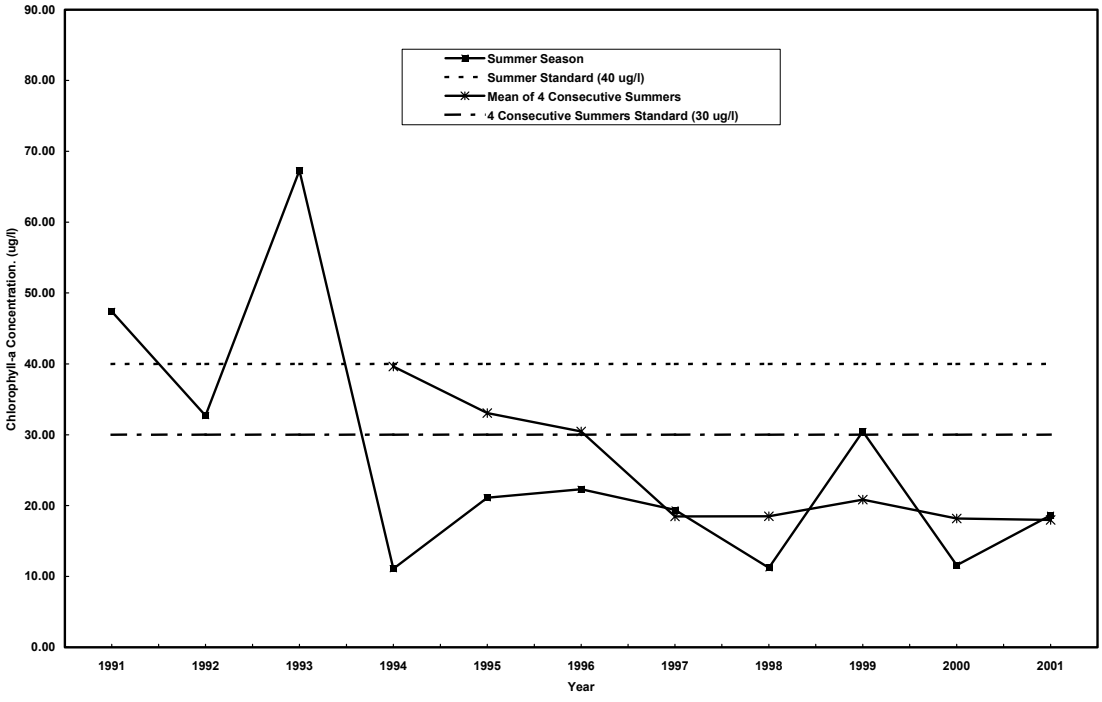
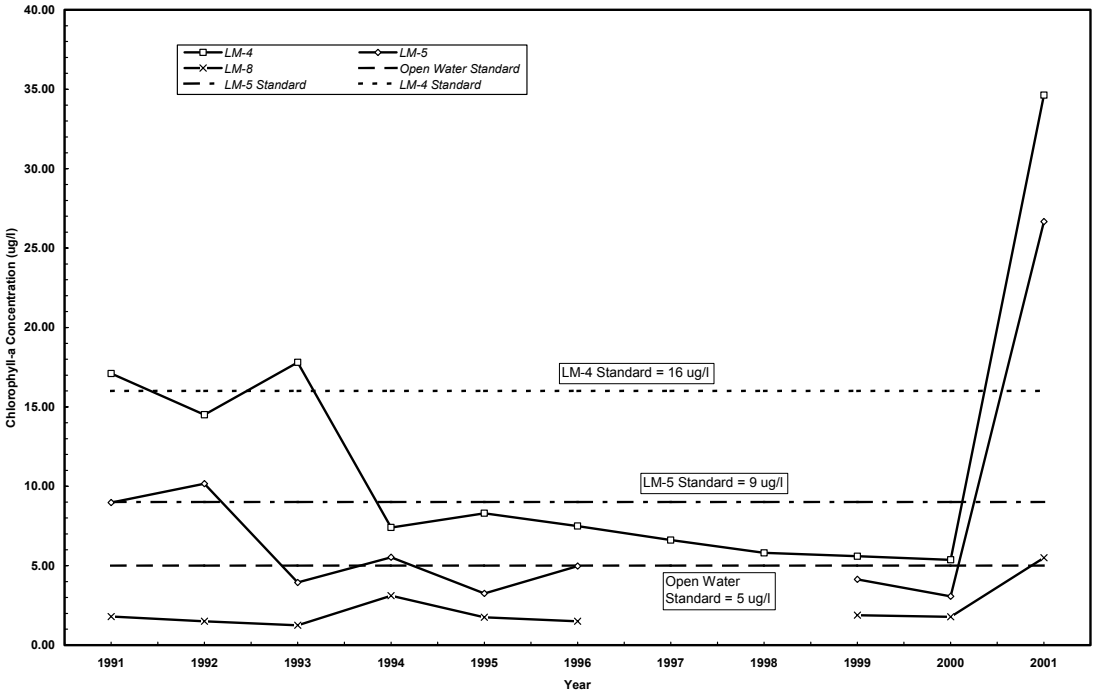


Figure 6 --Lake Mead Monitoring Stations LM-4, LM-5 and LM-8 Growing Season Mean
(April 1 - September 30)



Compliance with Total Ammonia TMDL and Un-ionized Ammonia Standards

The average monthly total ammonia loads discharged to the Las Vegas Wash during the wasteload allocation period for 1995-2001 are shown in Table 3. The average monthly point source ammonia loads were obtained from the discharge monitoring reports (DMRs) submitted by the Dischargers. These reported loads are calculated by multiplying the 30-day average effluent ammonia concentration by the 30-day average effluent flow, based upon daily samples. As shown in Table 3, the WLA has always been met since the effective date of the ammonia TMDL (April 1, 1995) except for 1995.

The total ammonia WLA/TMDL was established to ensure attainment of the un-ionized ammonia water quality standards for the Las Vegas Bay. Figure 7 presents total un-ionized ammonia concentrations based upon samples collected at LM-2 as compared to the water quality standards[3]. All samples for the period 1995-2001 met the single value standard for un-ionized ammonia of 0.45 mg/l.

It should be noted that a majority of the LM-2 samples contained ammonium levels below laboratory detection limits and that only those samples with levels above the laboratory detections limits are included on Figure 7. Samples with levels reported as "less than the detection limit" were assumed to comply with the water quality standards. This is consistent with the methodology used in

[3] Samples collected at LM-2 were analyzed for dissolved ammonium and not un-ionized ammonia. The un-ionized ammonia concentrations used in this report were calculated from these dissolved ammonium concentrations using accepted equations.

NDEP's latest development of Nevada's 2002 303(d) List of Impaired Waters.

Nevada regulations include a second un-ionized ammonia standard of 0.05 mg/l measured as a 4-day average or 4-sample rolling average. The existence of "less than detection limit" values complicate the calculation of these averages. Various approaches for handling this situation include treating these values as equal to: 1) the detection limit; 2) ½ the detection limit; or 3) zero. The worst-case scenario would be to assume these values are at the detection limit. Under this scenario, the calculations suggest that the 4-day/4-sample average standard has been continually met beginning in early 1996. Some possible "exceedances" appear during April-May 1995 and January 1996. However when the nondetect values are treated as ½ of the detection limit, these "exceedances" disappear and the standards are complied with during the entire period 1995-2001.

Discussion of Flow Data

As stated earlier, the existing TMDLs were based upon an average flow at the Northshore Road of approximately 126 cfs. Since that time, flows in the Wash have increased over time. As shown in Figure 9, LVW at Northshore Road annual average flows have increased to about 240 cfs in 2001. This increase is attributed to activities associated with rapid population growth such as increased discharges from the major wastewater treatment plants and urban and stormwater runoff. A majority of the annual flows (80 to 90 percent) are attributed to discharges from the municipal wastewater treatment plants. The remainder of flows are due to numerous industrial and construction site dewatering discharges, and dry and wet weather nonpoint discharges, with periodic spikes due to stormwater runoff events.

Table 3. Monthly Average Total Ammonia Loads, Las Vegas Wash

Date	Point Sources			
	City of Las Vegas	Clark Co. Sanitation District	City of Henderson	Total
	WLA = 379 lbs/day	WLA = 502 lbs/day	WLA = 89 lbs/day	Sum of WLAs = 970 lbs/day
1/95	103	6,174	11	6,288
2/95	110	3,285	26	3,421
3/95	300	3,566	0	3,866
4/95	**129**	**3,003**	**0**	**3,132**
5/95	**223**	**1,580**	**0**	**1,803**
6/95	**198**	**1,423**	**0**	**1,621**
7/95	**43**	**1,149**	**0**	**1,192**
8/95	**192**	**1,256**	**0**	**1,448**
9/95	**90**	**256**	**0**	**346**
10/95	330	202	0	532
11/95	455	223	6	684
12/95	684	425	15	1,124
1/96	237	724	7	968
2/96	473	405	4	882
3/96	140	43	0	183
4/96	**181**	**42**	**0**	**223**
5/96	**46**	**170**	**0**	**216**
6/96	**47**	**388**	**0**	**435**
7/96	**149**	**116**	**0**	**265**
8/96	**289**	**410**	**0**	**699**
9/96	**257**	**407**	**0**	**664**
10/96	153	270	2	425
11/96	1,882	78	4	1,964
12/96	1,752	742	6	2,500
1/97	962	497	6	1,465
2/97	686	204	6	896
3/97	574	53	3	630
4/97	**248**	**47**	**3**	**298**
5/97	**158**	**50**	**3**	**211**
6/97	**111**	**40**	**3**	**154**
7/97	**160**	**41**	**3**	**204**
8/97	**105**	**42**	**3**	**150**
9/97	**76**	**109**	**3**	**188**
10/97	146	180	3	329
11/97	1,862	69	6	1,937
12/97	1,930	54	252	2,236

100 Effective period for TMDL

200 Value exceeds WLA/LA/TMDL

1. Point source loads were calculated from 30-day average data obtained from the quarterly discharge monitoring reports

Table 3. Monthly Average Total Ammonia Loads, Las Vegas Wash (cont'd)

Date	Point Sources			
	City of Las Vegas	Clark Co. Sanitation District	City of Henderson	Total
	WLA = 379 lbs/day	WLA = 502 lbs/day	WLA = 89 lbs/day	Sum of WLAs = 970 lbs/day
1/98	405	72	839	1,316
2/98	778	68	563	1,409
3/98	1,346	80	170	1,596
4/98	**132**	**45**	**3**	**180**
5/98	**244**	**93**	**10**	**347**
6/98	**181**	**59**	**3**	**243**
7/98	**141**	**76**	**0**	**217**
8/98	**54**	**76**	**1**	**131**
9/98	**152**	**138**	**2**	**292**
10/98	54	255	3	312
11/98	468	529	7	1,004
12/98	151	406	25	582
1/99	554	491	30	1,075
2/99	188	116	40	344
3/99	203	111	8	322
4/99	**81**	**147**	**7**	**235**
5/99	**116**	**118**	**5**	**239**
6/99	**119**	**168**	**3**	**290**
7/99	**67**	**66**	**0**	**133**
8/99	**54**	**104**	**0**	**158**
9/99	**56**	**68**	**0**	**124**
10/99	103	240	0	343
11/99	310	57	13	380
12/99	451	142	37	630
1/00	622	406	34	1,062
2/00	334	446	44	824
3/00	228	121	23	372
4/00	**298**	**57**	**9**	**364**
5/00	**54**	**51**	**6**	**111**
6/00	**46**	**56**	**3**	**105**
7/00	**48**	**51**	**0**	**99**
8/00	**48**	**52**	**0**	**100**
9/00	**58**	**51**	**0**	**109**
10/00	108	76	23	207
11/00	398	88	66	552
12/00	456	74	74	604

100 Effective period for TMDL

200 Value exceeds WLA/LA/TMDL

1. Point source loads were calculated from 30-day average data obtained from the quarterly discharge monitoring reports

Table 3. Monthly Average Total Ammonia Loads, Las Vegas Wash (cont'd)

Date	Point Sources			
	City of Las Vegas	Clark Co. Sanitation District	City of Henderson	Total
	WLA = 379 lbs/day	WLA = 502 lbs/day	WLA = 89 lbs/day	Sum of WLAs = 970 lbs/day
1/01	477	75	75	627
2/01	239	116	75	430
3/01	139	66	58	263
4/01	**111**	**80**	**8**	**199**
5/01	**50**	**65**	**4**	**119**
6/01	**46**	**52**	**8**	**106**
7/01	**60**	**53**	**0**	**113**
8/01	**47**	**60**	**0**	**107**
9/01	**60**	**52**	**0**	**112**
10/01	49	51	0	100
11/01	129	56	17	202
12/01	588	86	40	714

100 Effective period for TMDL

200 Value exceeds WLA/LA/TMDL

1. Point source loads were calculated from 30-day average data obtained from the quarterly discharge monitoring reports

Figure 7. Lake Mead Station LM-2: Un-ionized Ammonia Concentrations

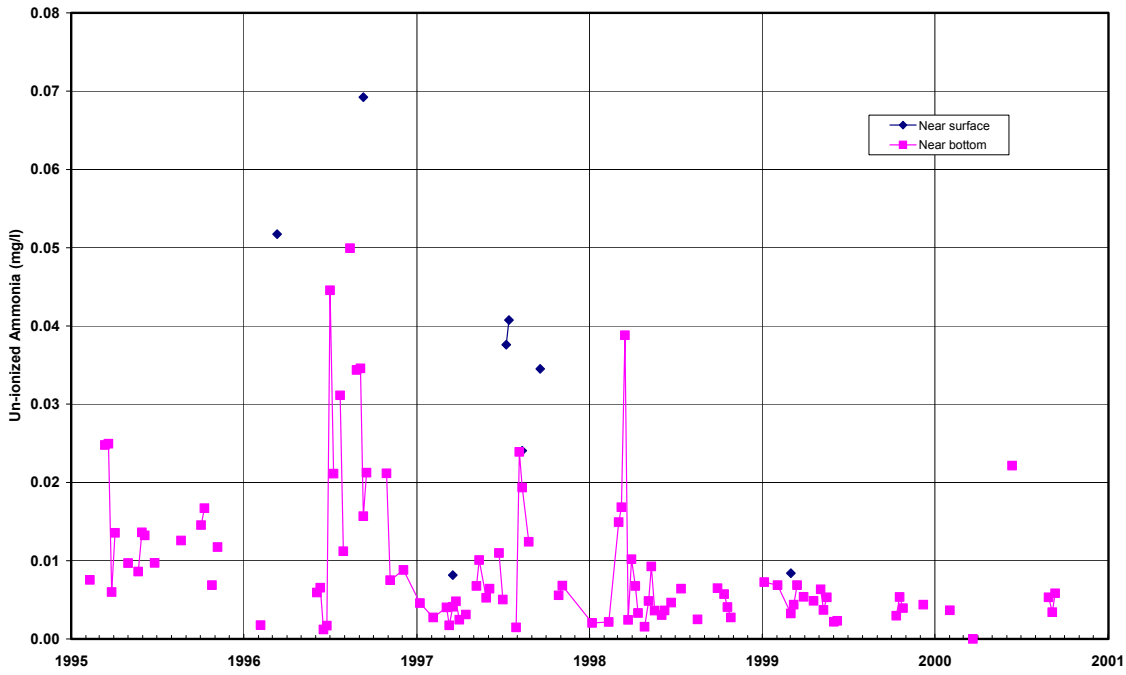
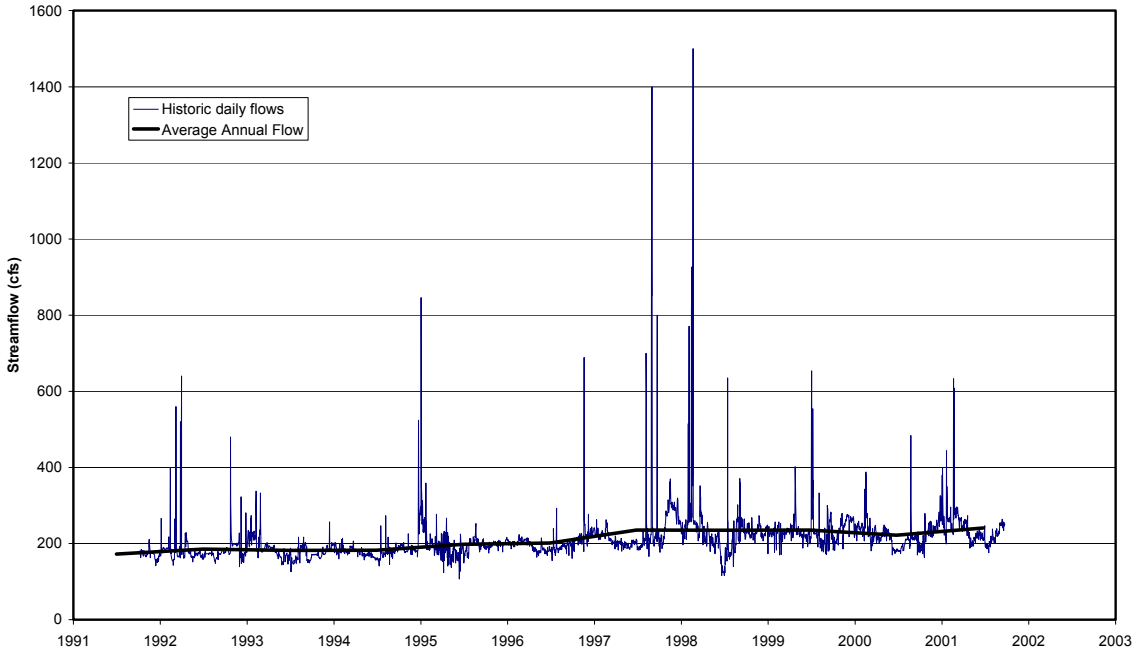


Figure 8. Streamflow at Las Vegas Wash below Lake Las Vegas (USGS Station 09419790)



1994 French study

As previously discussed, the current TMDL and Northshore Road target concentrations are based upon studies conducted by French in 1988. Since these models assumed that all conditions are stationary in time, it was deemed reasonable to revisit the analysis at a later date to evaluate these assumptions and the model. Therefore in 1994, French undertook another study to re-estimate target concentrations at Northshore Road as needed to meet Las Vegas Bay water quality standards. Also, NDEP was in the process of updating the total ammonia standard (4-day average and 4-sample average) from 0.04 mg/l to 0.05 mg/l. As part of this project, French examined the impact of this standard change upon the Northshore Road target concentration. Utilizing the dilution ratio model with more recent data (1991-1993), French (1994) estimated that target concentrations should be updated as shown in Table 4.

Table 4. Comparison of Target Concentrations at Northshore Road as Developed by French (1988 & 1994)

Parameter	1988 Value (mg/l)	1994 Value (mg/l)
Total Phosphorus	0.64	0.32
Total Ammonia	1.43	0.95

1. 1988 model inputs derived from 1985-1987 data
2. 1994 model inputs derived from 1991-1993 data
3. 1994 ammonia target based upon updated un-ionized ammonia standard of 0.05 mg/l at Station 2.

A number of conclusions were made regarding this study:

- As shown in Table 4, this study suggested that significantly lower target concentrations are needed to meet Las Vegas Bay water quality standards. The primary reason for this change in model predictions was due to a decrease in the dilutions ratios calculated from the 1985-87 dataset versus the 1991-93 dataset. These results clearly indicated that the time series involved are not stationary as assumed but continue to change.

- The total ammonia detection limits for the laboratory analysis of the Las Vegas Wash and Bay samples increased the uncertainty of the estimated total ammonia target concentration. Numerous water quality samples used in the analysis contained total ammonia levels reported as "<0.40 mg/l". For modeling purposes, it was agreed to assume that these concentrations were ½ of the detection limit. Actual levels could have been anywhere from 0 to 0.40 mg/l.

- At the time the 1994 report was completed, it was concluded that the nature of the hydrodynamic interaction between the Las Vegas Wash and Las Vegas Bay is complex and not well understood.

- The 1988 and 1994 studies both assumed that protection of the chlorophyll a standard could be achieved through phosphorus control. However, questions were raised as to whether or not the Bay is phosphorus or nitrogen limited.

Because of these uncertainties, NDEP determined that a revision of the TMDLs based upon these new targets was not appropriate until there is a better understanding of the system behavior.

2001 Algal Bloom

As previously discussed, during 2001 a significant algal bloom developed in Lake Mead. In response, the Algae Task Force was formed to address the issue. While the existing data and information did not point to a direct cause, it could be assumed that there was an adequate supply of nutrients available to prompt the bloom. Therefore the Task Force developed a list of potential contributing factors:

- In January and February 2001, the Las Vegas Valley experienced above average precipitation. Excess nutrients in the resulting runoff could have been transported into Lake Mead and contributed to the problem.

- Historically, the Wash water has entered the Bay as a negatively buoyant plume, submerging to the bottom. However, over the last few years Lake Mead water levels have dropped causing the formation of a delta at the confluence of the Wash and Bay. The shallow, braided channels in the delta could have allowed water temperatures to increase and portions of the Wash flow to enter the Bay as a buoyant plume. Nutrient-rich waters near the surface and sunlight exposure could have promoted algal growth.

- Delta sediments contain elevated phosphorus levels. Under certain conditions, phosphorus can be transferred from sediment to the water column and become available for algal uptake. It is unlikely the chemical environment necessary for this transformation existed, however, other constituents within the Bay sediments may have contributed. Further research is needed.

- The three wastewater treatment plants must meet WLA discharge limits for phosphorus from March through October. The WLA limits do not apply from November through February and phosphorus removal down to these levels is not required during this period. As previously discussed, a buoyant plume would have allowed these additional nutrients to remain at or near the surface and be available for algal growth.

Utilizing the available information, the Task Force developed the following recommendations:

Short-term recommendations

- Through the Lake Mead Water Quality Forum, request federal assistance to study the algae bloom

- Assess nonpoint source nutrient loadings entering the system. Additional dry and wet weather sampling may be required with flow data to determine actual nutrient loadings.

- Evaluate and use, if appropriate, the Las Vegas Bay model being developed under the Alternative Discharge Study to determine assimilative capacity for the lake and bay.

- Begin voluntary year-round phosphorus removal at wastewater discharge plants.

Long-term recommendations

- Conduct federally assisted study to determine the exact cause of the 2001 algal bloom and methods for preventing future outbreaks of potentially toxic algae species.

- Establish a management workgroup to ensure nutrient loadings are reduced by targeting high source areas identified in the nonpoint source assessement.

- Proceed with the Alternative Discharge Study in an expeditious manner. The potential physical and chemical changes to the Las Vegas Wash and Lake Mead must be carefully evaluated and the alternative discharge site selected must have sufficient assimilative capacity.

Since November 2001, the three treated effluent dischargers have been voluntarily implementing year-round phosphorus removal. While 2002 did not experience an algal bloom of the magnitude occurring in 2001, it is unknown what contribution the year around phosphorus removal had on this phenomenon.

UNLV Water Quality Study

In February 2002, a UNLV research team (Piechota et al.) completed an interdisciplinary study covering various aspects of water quality in storm channels, the Las Vegas Wash, the Las Vegas Bay, and Lake Mead. The main questions related to the TMDLs that the research addressed were:

- What is the impact on the algal community of changes in nitrogen species from mostly ammonia to mostly nitrate?
- What are the effects of increasing total inorganic nitrogen levels?
- Is phosphorus limitation still a valid assumption for Las Vegas Bay?
- What is the magnitude of nutrient loading from urban runoff?

Conclusions and recommendations related to the TMDLs include:

- Data indicates that the Bay and Lake Mead is still phosphorus limited.
- A more comprehensive TMDL for nutrients in Lake Mead that includes nonpoint source dry and wet weather contributions may be necessary if extensive seasonal algal blooms continue to occur. Decisionmakers should consider potential contributions from nonpoint sources and application of whole-year nutrient-loading permits instead of the current seasonally-varying permits.
- Continuous monitoring of nutrients is needed at the Las Vegas Wash outlet so that better estimates of nonpoint source loads are possible. The current biweekly sampling frequency is inadequate to accurately estimate nutrient loads at Northshore Road.
- Assumed levels of nonpoint source nutrient loads (particularly TP) for the TMDL should be reevaluated. Results from this study indicate that the TP levels during wet periods approach the point source permit levels, and exceed the 100 lbs/day assumed by NDEP in the TMDL.

Alternative Discharge Study

The three municipal wastewater agencies that treat and discharge effluent to the Las Vegas Wash have been working together in a cooperative spirit for several years to address issues related to the water quality impacts of treated wastewater being discharged into the Las Vegas Wash and Lake Mead. The Clark County Sanitation District, City of Henderson and City of Las Vegas have used the name "Clean Water Coalition" or "CWC" to represent their united efforts on the Systems Conveyance and Operations Program (SCOP). The CWC is also in partnership with the Southern Nevada Water Authority, Black & Veatch, PBS&J, Kennedy Jenks, Alpha Communications, and Converse Consultants. SCOP is needed due to 1) increasing flows transporting urban non-point pollutants into Lake Mead; 2) nutrient loading in inner Las Vegas bay; 3) regulatory requirements exceeding water reclamation process capabilities; 4) erosion in Las Vegas Wash; and 5)

management of Wetlands Park. The CWC is now embarked on a program to seek a long-term solution that will address water quality issues, environmental preservation, and continued growth in Southern Nevada through SCOP. The goal of the program is to determine the most feasible method to return wastewater effluent, not being reclaimed, to the Colorado River System. Effluent flows will double over the next 30 years, and a plan to make the best use of this valuable water resource over the next 30 to 50 years is needed. Reuse of wastewater for turf and industrial uses will be maximized, but accounts for only approximately 25% of effluent use. To make the best use of the remaining effluent, treatment technologies, alternative receiving locations in the Colorado River System, and water quality management plans must be devised and implemented (Southern Nevada Regional Planning Coalition, 2002). As part of the SCOP, a detailed model is being developed to simulate Wash and Bay hydrodynamic interactions and water quality impacts under both wet and dry weather conditions.

Summary and Recommendations

Based upon the data and information provided above, the following summaries and recommendations are offered:

- Since establishment of the total phosphorus TMDL, the WLA has not been exceeded. However the limited data suggest that the LA was exceeded at various times due to nonpoint source contributions. It is important to recognize that these LA "exceedances" were not followed by increased chlorophyll a levels (see below for more discussion). In fact, the chlorophyll a RMHQs have been met every year (except 2001) since the TMDL went into effect.

- Since establishment of the total ammonia TMDL, the un-ionized ammonia standards for Las Vegas Bay and Lake Mead have been met every year.

- The total phosphorus LA was calculated from 1985-87 with the exclusion of data collected during flows greater than 110 percent of the average. According to the TMDL report, this was done in an effort to eliminate some of the unpredictable variation in the nonpoint source loads. As a result, it appears that significant phosphorus loads from wet-weather events could have been excluded from the original analysis. It is well known that wet-weather events can introduce high phosphorus loads to the Bay over short periods of times. However, it has been suggested that wet-weather phosphorus (consisting of more particulate matter) has significantly less bioavailability for algal growth than dry-weather phosphorus loads entering Las Vegas Bay. Also, an unpublished study has shown that the storm runoff for a 1998 event was more dense than the Bay water, sank below the eplimnion, and became unavailable for algae in the epilimnion (Bazel, 2003). Additional studies are needed to improve nonpoint source load estimates and to characterize the bioavailability of the dry-weather and wet-weather phosphorus loads. If the bioavailability of the wet-weather phosphorus load is found to be significant, more frequent wet weather sampling is needed to better quantify overall loading to the Bay. The existing biweekly sampling is insufficient to accurately quantify the highly variable nonpoint source loads. At this time, the Clark County Flood Control District has installed and is operating a number of automated samplers throughout the watershed which will lead to improved wet weather load estimates.

- The language of the TMDL does not explicitly state that the LA does not apply when flows are greater than 110 percent for the average. However for consistency, this report utilized the same approach when estimating nonpoint loads. Future TMDL revisions need to address this issue.

- The existing TMDL report presents the LA/WLA/TMDL in terms of pounds of day, but does not discuss any compliance averaging period (e.g. 30 days). Future TMDL revisions need to address this issue.

- The current ammonia TMDL was established to ensure attainment of the un-ionized ammonia water quality standard for the Bay. However, this standard may no longer be appropriate. EPA has developed updated ammonia water quality criteria that are site specific values dependent upon pH and temperature. NDEP has been in the process of updating the ammonia standards for waters throughout the state. An update of the ammonia criteria for the Bay based upon current EPA guidance will be considered during the next triennial review for Las Vegas Bay and Lake Mead. It is interesting to note that a revision of the standards may not be very critical. An evaluation of the 1997-2001 data for monitoring station LM-2 (LVB1.8) shows that the current EPA guidance criteria for ammonia were never exceeded during that period. In other words, the current TMDL and ammonia WLA are providing adequate controls for meeting the existing state water quality standards AND the current EPA guidance criteria.

- Since development of the TMDLs, flows in the Wash have about doubled from the levels used in the original calculations, primarily due to increases in wastewater effluent. However, the WLAs have continued to be met even with these increased flows. It is likely that the increased flows have impacted the Wash and Bay interaction dynamics.

No changes in the current TMDLs are recommended at this time. Studies indicate that a better understanding of the Wash/Bay and nutrient/algae dynamics, and nonpoint source loading (including bioavailability issues) are needed before any changes could be considered. Also with the possibility of the discharge locations being relocated (or at least a portion of the effluent flow to be removed from the Wash), it appears to be appropriate to wait for some conclusions from the SCOP process[4] before attempting to revise the TMDL. The SCOP process is expected to address many of the issues listed above or result in tools useful for addressing these needs. NDEP will continue to monitor the SCOP process and review reports and other products as they become available and pursue TMDL revision needs as appropriate.

Under NPDES (National Pollutant Discharge Elimination System) Permit No. NV0021911, the cities of Henderson, Las Vegas and North Las Vegas, Clark County, Clark County Regional Flow Control District, and the Nevada Department of Transportation are authorized to discharge municipal stormwater runoff to the Las Vegas Wash, its tributaries and other waters of the United States. Any update of the TMDL may need to consider incorporating a WLA for the stormwater discharges regulated under this permit. In a November 22, 2002 guidance

[4] A draft modeling report is expected to be distributed this winter, followed by a draft Environmental Impact Statement by February 2004.

memorandum (regarding *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs*), EPA directs states to provide WLAs for NPDES-regulated storm water discharges as part of a TMDL. Additionally, the memorandum states that NPDES-regulated storm water discharges may not be addressed by the LA component of a TMDL.

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