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Subject: Microbiological, Limnological, and Nutrient Evaluations of the Las Vegas Wash/Bay System

Dear Mr. Pahl:

This letter provides comments on a portion of the report entitled "Microbiological, Limnological, and Nutrient Evaluations of the Las Vegas Wash/Bay System", which was prepared by Professors Thomas Piechota, David James, Jacimaria Batista, and Penny Amy of the University of Nevada, Las Vegas ("UNLV"). These comments have been reviewed with the Clark County Sanitation District, City of Henderson, and City of Las Vegas, who concur with them. We support the decision by DEP to retain UNLV to conduct studies related to water quality in Lake Mead. As the authors note in the acknowledgments section, the City of Las Vegas contributed to the cost of these studies, and all three entities contributed by providing data. We believe that most of the report advances the state of the science on the wash and lake, and would support additional work by UNLV. This letter should not be taken as criticism of most of the work covered by the report.

However, the report includes an unfortunate digression, characterized as a "background" introduction to section 3 of the report, with which we disagree. Rather than being an introduction, this section expresses conclusions and recommendations unrelated to the work performed. We write here to bring the issues in dispute to your attention, and to provide additional perspective, so that DEP may have a fuller understanding when considering regulatory decisions.

Oregon
Washington
California
Utah
Idaho
Washington D.C.

1. The plants already provide filtration and tertiary treatment.

In a subsection entitled "Upgrade of All Local WWTPs to Tertiary Treatment", the report asserts that "the addition of filtration units to treatment trains to remove solids, in all the local WWTPs, would have a positive effect on the removal of P from the wastewater effluent" (page 3-7). The report also identifies "Upgrade of all local WWTPs to tertiary treatment level for nutrient removal" as a factor "that would contribute to the decrease of nutrient loadings" to Las Vegas Bay" (page 3-4).

In fact, the local treatment plants already provide tertiary treatment, and have for years. All the treatment plants now have filters, and consistently produce an effluent containing remarkably low concentrations of phosphorus. There is no need to add filters, except as part of an increase in capacity.

2. The phosphorus load to Lake Mead has been decreasing, not increasing.

The report implies that the phosphorus load to Lake Mead has been steadily increasing, and will continue to increase in the future. It asserts that there has been "increased nutrient loading discharged to the Las Vegas Bay" (page 3-3). The increase is attributed to "the rapid development of the Las Vegas Valley" (page 3-4).

In fact, the phosphorus load to Lake Mead has decreased, not increased, over the last 25 years. Exhibit 1, attached, shows phosphorus loadings during the 1970s and 1980s, as calculated by DEP (stormwater loadings appear to have been excluded from these calculations). Exhibit 2 also shows phosphorus loadings during the 1970s and 1980s, this time as calculated by the City of Las Vegas. Exhibit 3 shows phosphorus loadings in the 1990s, as calculated by UNLV and Las Vegas. A visual review of these exhibits suggests the following rough summary. Excluding spike loadings associated with stormwater, summer phosphorus loading to the lake was typically in the range of 1000-2000 pounds per day from the mid-1970s until 1981. Following 1981, when the plants began removing phosphorus, and before 1994, when filters were installed, the loading was often in the range of 500-1000 pounds per day—in other words, the loading dropped by about half from pre-1981 levels. Since 1994, the loading has usually been less than 500 pounds per day, and was often about 250 pounds per day, during the phosphorus-removal season—once again, the loading dropped by about half. Although a much better summary could be obtained from an analysis of the data themselves, these figures suggest that the dry-weather phosphorus loading has decreased by roughly 75% during the last 25 years. The loadings have certainly not been increasing, despite the increase in population during this time.

Nor do these figures give us any reason to believe that stormwater loadings are increasing. During 1976-86, there were four months with loading of more than 4000 pounds per day, which must have been influenced by stormwater loadings (see Exhibit 2); during 1991-2000, there were only three months with loading of this magnitude (see Exhibit 3). As for months above 2000 pounds, which may have been associated with stormwater loadings, there were about twelve during 1976-1986, but only five during 1991-2001. Although we do not mean to suggest that these data are definitive, they do not show an increasing trend, and there is nothing in the report that shows an increasing trend.

In short, dry-weather phosphorus loadings have been decreasing, not increasing, despite the rapid development of the area during the last 25 years.

3. Wintertime phosphorus removal is not likely to lower chlorophyll concentrations in the *winter*.

The report suggests that the seasonal phosphorus limits—which are not in effect during the months of November through February—should be extended so that they become "whole-year discharge" limits (page 3-5). The main argument is that wintertime discharges cause summertime blooms, an issue covered in the next section. However, the report also asserts that "there is a high chance for algal blooms to occur" in the winter[1], particularly in November and December, which may have "warm winter weather conditions with high nutrient loadings" (page 3-5).

In fact, wintertime concentrations of chlorophyll have consistently been low. Exhibit 4 shows chlorophyll data collected by the entities at the inner-bay station identified in the water-quality standards. Each winter, chlorophyll a drops to near-zero levels.[2]

The report also asserts, in support of wintertime phosphorus removal, that "Algal blooms in the Bay *or even the entire Lake* have occurred almost every recent year (1996, 1997, 1998, and 2001) (LVRJ, 2001)" (pages 3-5 to 3-6, emphasis added). This citation seems to be to the Las Vegas Review-Journal, and it is not clear to what the newspaper is referring. Certainly there cannot have been problematically large algal blooms *throughout the lake* during these years, because most of the lake is oligotrophic, and

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[1] "Winter" is sometimes used to refer to the months in which phosphorus removal is not required (November through February), and "summer" to the rest of the year.

[2] During the winter of 2001-2002, chlorophyll did not drop to near-zero levels until January.

never has large algal blooms. Even the unusually extensive bloom of 2001 seems to have been limited to a few areas within the lake.

In short, there is no reason to believe that limiting phosphorus during November through February will produce lower chlorophyll levels, or any other benefit, during these winter months.

4. Wintertime phosphorus removal is not likely to lower chlorophyll concentrations in the *summer*.

The report asserts that wintertime discharges of "phosphorus may not cause algae blooms instantly due to the lower temperatures or light intensities during the winter", but "the discharged phosphorus is stored in the lake as different forms and returned to the water column as available P under suitable conditions". The report provides no data or analysis to back up this bare assertion. We nevertheless have considered the issue, and conclude that wintertime discharges are unlikely to have a substantial effect on algal growth in the spring and summer. Here is our reasoning.

Phosphorus from the treatment plants can be categorized as either dissolved or particulate. Turning first to the dissolved phosphorus, there should be little doubt that the dissolved phosphorus quickly passes through the inner bay.[3] During the wintertime, water from Las Vegas Wash is typically denser than lake water when it enters the bay. Wintertime conductivity profiles (which can be obtained from the City of Las Vegas) routinely show a substantial conductivity increase at the bottom of station 1.85, and little conductivity increase above the bottom. These data suggest that the interflow is relatively self-contained in the winter, and that there is little mixing between the interflow and the lake in the area near Las Vegas Wash.

[3] The "inner bay" is not a formally defined area. Since the mouth of the bay is 7 miles from the zero point that once differentiated the lake from Las Vegas Wash, it might seem convenient to divide the bay roughly in half, and define everything to mile 3.5 as being part of the inner bay. However, the report assumes that mile 3.5 is the center of the outer bay (page 3-2). For this discussion, we need not specify an exact boundary. It is sufficient to note that the chlorophyll criteria apply at the sampling station formerly known as station 3 or station LM3, and now as station LVB1.85. This station is clearly in the inner bay, and it is the focus of our discussion about the inner bay. The phrase "outer bay" seems best suited to the part of Las Vegas Bay out beyond station LM3.5, where water quality typically is more like Boulder Basin than like the inner bay.

There seems to be widespread agreement that the interflow from Las Vegas Wash moves through the inner bay very quickly—on the order of hours, or perhaps a few days. As a result, the residence time of dissolved wintertime phosphorus in the inner bay is too short to affect algae in the spring and summer growing seasons. Wintertime phosphorus quickly moves through in the inner bay, and is long gone by the time algae growth picks up in the spring.

These concepts were well understood when DEP established seasonal limits. Its rationale for seasonal limits was that the higher wintertime discharge of phosphorus would quickly pass through the inner bay but remain in the outer bay and Boulder Basin, where they might encourage a spring algal bloom. This spring bloom, it was hoped, would be transformed into an increase in fish, and thereby abate the "skinny fish" problem caused by a lack of nutrients in the oligotrophic parts of the lake.

Turning to particulate phosphorus, it too may pass through the inner bay in the same way that the dissolved phosphorus does. After all, the particulate phosphorus discharged by the treatment plants cannot be readily settleable, since the effluent has passed through settling basins, and has often been filtered. The few hours of residence time in the inner bay seems unlikely to produce much additional settling. Once again, there is little reason to believe that wintertime discharges of phosphorus remain in the inner bay.

Even if we assume that some of the particulate phosphorus settles to the bottom of the inner bay, it by no means follows that the settled phosphorus affects algal growth in the spring or summer. If sedimented phosphorus is a significant contributor to algal growth, it must first be released from the sediments, and then travel up to the euphotic zone.

Although there is no doubt that phosphorus is released from the sediments when the bottom waters are *anaerobic*, it is also true that phosphorus tends *not* to be released when the bottom water are *aerobic*: "Under aerobic conditions, the exchange equilibria are largely unidirectional toward the sediments." (Robert G. Wetzel, Limnology, p. 264 (2d ed. 1983).)

Even during the peak chlorophyll concentrations during the spring of 2001, the bottom waters at station 1.85 were always aerobic. According to the quarterly reports provided by the City of Las Vegas, dissolved oxygen never dropped below 1 mg/L during March through June 2001; other than the last week of June, it never dropped below 2.5 mg/L. Therefore, even if some wintertime phosphorus had accumulated in the sediments, it should not have been released, and unless released could not have contributed to the peak chlorophyll levels in the spring of 2001.

During July through September 2001, however, dissolved oxygen in the bottom waters at station 1.85 stayed consistently below 1 mg/L, and dropped as low as 0.1 mg/L. Although these conditions are still aerobic, there may have been other nearby areas that were anaerobic and released phosphorus. Any released phosphorus, however, would have been of little use to the algae unless it made its way up from the bottom waters to the euphotic zone where the algae grow. At least three processes inhibited the movement of phosphorus up to the euphotic zone.

The first is lake stratification. Just as stratification prevents the oxygenated surface waters from mixing down to the hypolimnion, it prevents the mixing of de-oxygenated bottom waters up to the surface.

The second is re-sedimentation. When the released phosphorus comes into contact with oxygenated waters, it generally is precipitated:

> "Ferrous iron released from the sediments is always in excess of phosphate, and when oxidized, it precipitates much of the phosphate. Some of the ferric phosphate in particulate form may slowly hydrolyze and restore some phosphate to the upper waters and littoral areas. However most phosphate is returned eventually to the sediments." (Wetzel, p. 263 (citation omitted).)

The third is the interflow from Las Vegas Wash. Phosphorus moving up from the bottom waters would move up into the interflow, which would carry it out towards the outer bay and Boulder Basin. Unless the phosphorus was rising rather quickly, it would have been carried out the inner bay before it could make its way up to the euphotic zone.

Because of these three processes, it appears that most phosphorus released from the sediments in the inner bay is not very likely to make its way to the euphotic zone, and therefore is not likely to have much effect on chlorophyll concentrations.

Chlorophyll concentrations during 2001 are consistent with these concepts. If there had been a substantial release of sedimented phosphorus during July through September 2001, and the phosphorus made its way to the euphotic zone, we would have expected a substantial *increase* in chlorophyll concentrations. Instead, during these months the chlorophyll concentrations at station 1.85 *decreased* dramatically from their high spring peaks to typical levels. Therefore, any release of sedimented phosphorus in 2001—whether from stored wintertime discharges or another source—seems not to have increased chlorophyll concentrations in the inner bay.

In short, wintertime phosphorus removal is not likely to lower chlorophyll levels, either during the winter or during the summer. Nevertheless, the entities have agreed to work cooperatively with DEP to investigate whether there might indeed be some benefits. Last winter the entities agreed—without formal permit limits—to remove additional phosphorus. When the data from last winter are fully explored we may be in a better position to make an informed decision.

5. During dry-weather conditions, the nonpoint phosphorus load appears to be nearly zero.

The report suggests that DEP assumed, rather than measured or calculated, the nonpoint source contribution of phosphorus to Lake Mead (page 3-9). Actually, DEP did perform a calculation, one that seems quite similar to the calculation offered in the report. However, neither the report nor DEP has considered the more important issue of whether stormwater loadings substantially affect chlorophyll levels in the lake.

Here is the calculation performed by DEP:

> "Monthly average total phosphorus nonpoint source loads were determined by subtracting the total average load discharged by the two[4] treatment plants from the monthly average total phosphorus load at North Shore Rd. These monthly average differences were then averaged over the growing season (April – September) to obtain a yearly average nonpoint source load. . . . Using this approach, the nonpoint source load at North Shore Road was estimated to be 90 lbs/day.
>
> A 10 percent safety factor was assumed. Therefore a nonpoint source load of 100 lbs/day total phosphorus is assumed." (DEP, Total Maximum Daily Loads at North Shore Road and Waste Load Allocations, pages 3, 7 (May 1989).)

DEP recognized that the nonpoint-source loadings were variable. As shown in Exhibit 5, nonpoint-source loadings usually hovered around zero, with occasional peaks in the range of 200-500 pounds per day. DEP concluded that the peaks were "likely due to the sporadic nature of stormwater flows", and discussed eliminating flows greater than 110% of average from the calculation. (DEP 1989, pages 4-5, 7.)

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[4] At the time, the City of Henderson was not discharging to Las Vegas Wash.

Although the UNLV report used data from a different decade, it found a remarkably similar pattern to the one described by DEP. In four of the six years covered by the report, the nonpoint-source loading hovered around zero (17, minus 13, 41, and 8 pounds per day); in two years, it was substantially higher (268 and 577 pounds per day). Therefore, although neither the report nor DEP commented on the point, both sets of data seem to show that nonpoint-source loading is almost zero except when it rains.

Both the report and DEP seem to have assumed that , when assessing effects on chlorophyll, a pound of phosphorus in stormwater is equal to a pound of phosphorus in dry-weather flow. This assumption may be incorrect.

6. Do stormwater loadings have a substantial effect on chlorophyll concentrations in Las Vegas Bay?

There is no doubt that phosphorus loadings can increase exponentially during storms. For example, if the flow in Las Vegas Wash increases to 1,000 cfs, and the phosphorus concentration increases to 1 mg/L, the loading rate to Lake Mead increases to more than 5,000 pounds per day—more than ten times higher than the TMDL of 434 pounds per day. Monthly average loadings of more than 5,000 pounds per day, as shown in Exhibit 2, suggest that loadings during individual storms can be substantially higher.

Nevertheless, it is not clear whether the stormwater loads have any effect on chlorophyll levels in the lake. Certainly, the increased phosphorus loading does not produce a concomitant increase in chlorophyll; after all, chlorophyll concentrations in the inner bay simply do not increase from, say, 30 µg/L to 300 µg/L after a storm. Because no one has ever analyzed the data, no one knows how much chlorophyll concentrations increase after a storm, or whether they increase at all. We suggest some additional studies, below, that could be used to evaluate these issues.

There are several reasons why nonpoint phosphorus might have little or no effect on chlorophyll in the lake. The first is that much of the phosphorus does not stay around for long. Stormwater moves quickly through the inner bay, probably in a few hours. As the stormwater passes through the inner bay, it takes with it the dissolved portion of the phosphorus load, along with a portion of the particulate load. Of course, the phosphorus moving through the inner bay could conceivably encourage algal growth in the outer bay and Boulder Basin, but chlorophyll levels in these areas have been so low that past efforts have been aimed at increasing them, not decreasing them.

The remainder of the particulate phosphorus is likely to settle to the bottom, as the mud and other suspended solids settle. Sedimented phosphorus may be released and returned to the water column, as discussed in section 4 above. However, the development of anaerobic conditions might take some time, and the movement of sedimented phosphorus up to the euphotic zone would be inhibited by the same processes discussed in section 4.

Stormwater could actually lower the chlorophyll levels, rather than raising them. If the storm fills the inner bay with mud, which then settles, the mud may drag down some of the algal cells or clumps, and thereby remove phosphorus from the system. Also, if the mud-laden water is dense enough, it will descend to below the thermocline, thereby bringing oxygenated water into the hypolimnion and counteracting the anaerobic conditions that release phosphorus from the sediments. Settling mud may bury decomposing organic material on the bottom, thereby abating the deoxygenation process until new organic material accumulates.

If past storms have been followed by sudden increases in chlorophyll levels, the increases have not been obvious. Nor does the data provided by the report suggest an association. The year with the highest nonpoint loading (1997, with 577 pounds per day) produced chlorophyll concentrations not noticeably different from the previous year, which had the lowest nonpoint loading (1996, with minus 13 pounds per day) (see page 3-10 and Exhibit 4).

Nevertheless, since the bloom of 2001 has rekindled interest in nonpoint sources of phosphorus, it may now be time for a more rigorous consideration of whether there is a relationship between stormwater loadings and chlorophyll levels in the lake.

7. It may be helpful to review existing data.

The U.S. Geological Survey collects and reports daily streamflow data for Las Vegas Wash. From these data it should be possible to identify storm flows. The entities routinely sample the inner bay and analyze for phosphorus (total and dissolved) and chlorophyll; during most of the year, they sample and analyze weekly. As a result, storms can be identified, along with the phosphorus and chlorophyll concentrations in the lake during the week of the storm, the week after, the second week after, and so forth. It may be useful to look at the phosphorus and chlorophyll data within specified intervals before and after storms, to see whether they increase (or decrease) within consistent intervals following a storm. If there is a response, it may be useful to see whether the response increases as storm flows increase, or as phosphorus loadings increase. The hypothesis here is that storm loadings cause higher phosphorus and chlorophyll levels in the inner bay; comparing storms with phosphorus and chlorophyll levels seems to be the most direct way to evaluate the hypothesis.

This type of study, which makes use of existing data, seems an appropriate and inexpensive followup to the work presented in the UNLV report.

8. Dates, data points, and calculations should be carefully checked.

Finally, there are many statements within the report—meaning, as it has throughout this letter, the digression at the beginning of chapter 3—that appear to be incorrect. For example, in a subsection entitled "Nutrient Removal History of Wastewater Treatment Plants", the report says that CCSD began removing phosphorus in 1984 (page 3-2). The correct date is 1981, three years earlier. The report says that the 1 mg/L phosphorus limit went into effect in 1985 (page 3-3). Once again, the correct date is 1981. The report says that the current seasonal phosphorus limit went into effect in 1995. The correct date is 1994. The report says the seasonal phosphorus limit extends through September (page 3-5). In fact, it extends through October of each year.

Several calculations may also need correcting. For example, the report asserts that a load of 577 pounds per day is "ten . . . fold higher" than a load of 100 pounds per day, and that 268 pounds per day is "five fold higher" than 100 pounds per day (page 3-10). Table 3-4 refers to a "total ratio" that seems to be intended as an average of the other data on the table; if so, the average (or flow-weighted average, if that was intended) appears not to have been calculated correctly. The reported data may also needed to be checked. Table 3-2 includes a dissolved orthophosphorus concentration of 2.935 mg/L, which is much higher than the total-phosphorus concentration of only 0.019 mg/L, and seems questionable.

Thank you for considering these comments, which we hope will lead to discussions and research to resolve uncertainties and expand our collective scientific knowledge.

Sincerely,

Lawrence S. Bazel

cc: T. Piechota
D. James
J. Batista
P. Amy

List Of Exhibits

1. Total phosphorus loading at North Shore Road from 1972 through 1985, from Nevada Division of Environmental Protection (May 1987), Las Vegas Wash and Lake Mead Proposed Water Quality Standards Revisions and Rationale.

2. Total phosphorus loads at Northshore Road, from City of Las Vegas (August 1987), Analysis of the Water-Quality Standards Proposed by the Nevada Division of Environmental Protection.

3. LW0.55 Total Phosphorus Loading, from Hadland et al. (March 21-23, 2001), Update on Long-term Trends in Water Quality in Las Vegas Wash and Las Vegas Bay, Lake Mead (presentation at NWEA conference).

4. LM3 Chlorophyll-a Monthly Mean, from City of Las Vegas (undated).

5. Total Phosphorus Nonpoint Source Load, from Nevada Division of Environmental Protection (May 1989), Total Maximum Daily Loads at North Shore Road and Waste Load Allocations (lines connecting points redrawn where not clear on original).

NORTH SHORE ROAD

TOTAL PHOSPHORUS

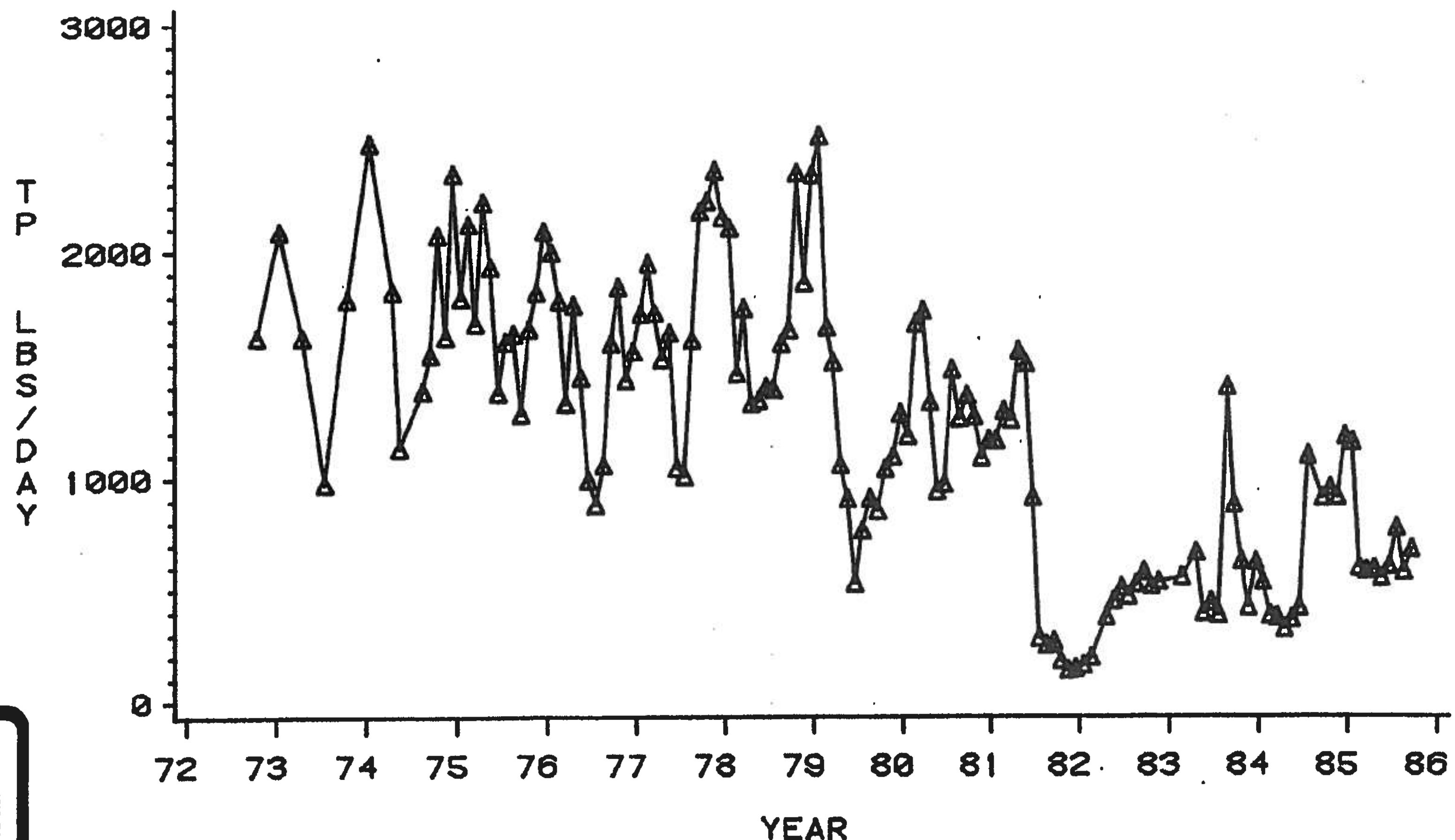
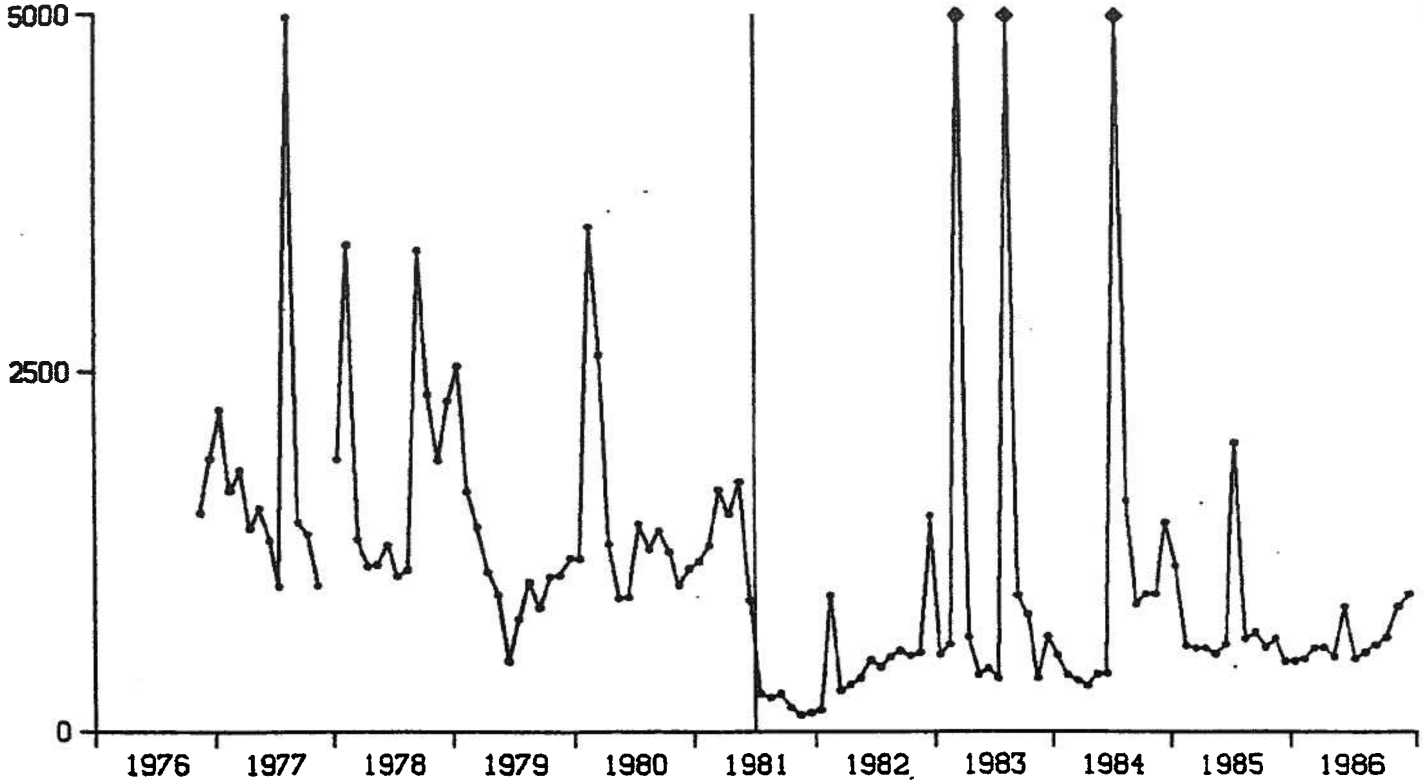


Figure 6. Total phosphorus loading at North Shore Road from 1972 through 1985.

FIGURE 7

Total Phosphorus Loads at Northshore Road

monthly arithmetic averages, lbs/day as P
diamond is off-scale, vertical line is July 1, 1981



CONCLUSION: Loads went down after the wastewater-treatment plants began removing phosphorus.

EXHIBIT
2

LW0.55 -Total Phosphorus Loading

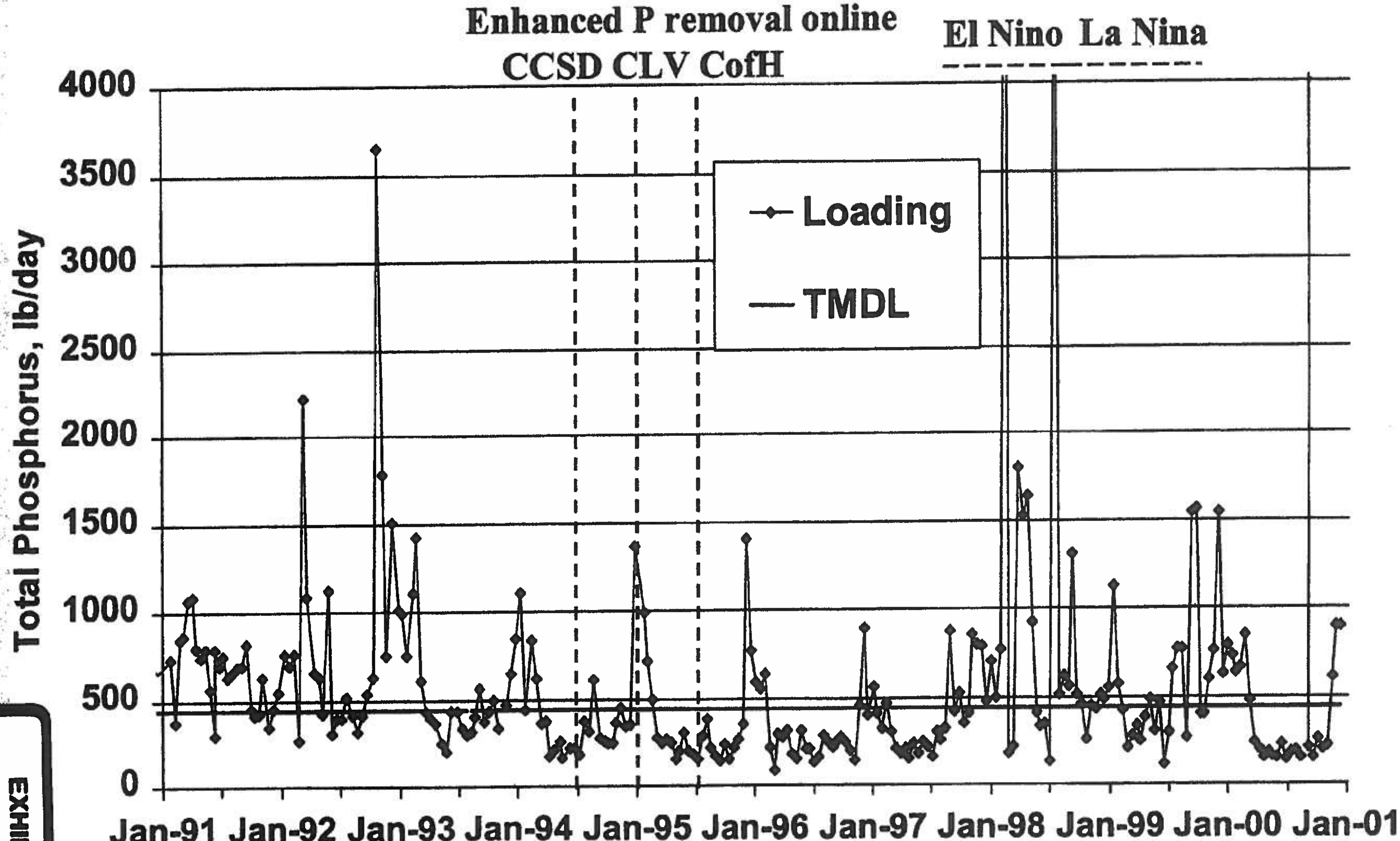


EXHIBIT
3

LM3 Chlorophyll-a Monthly Mean

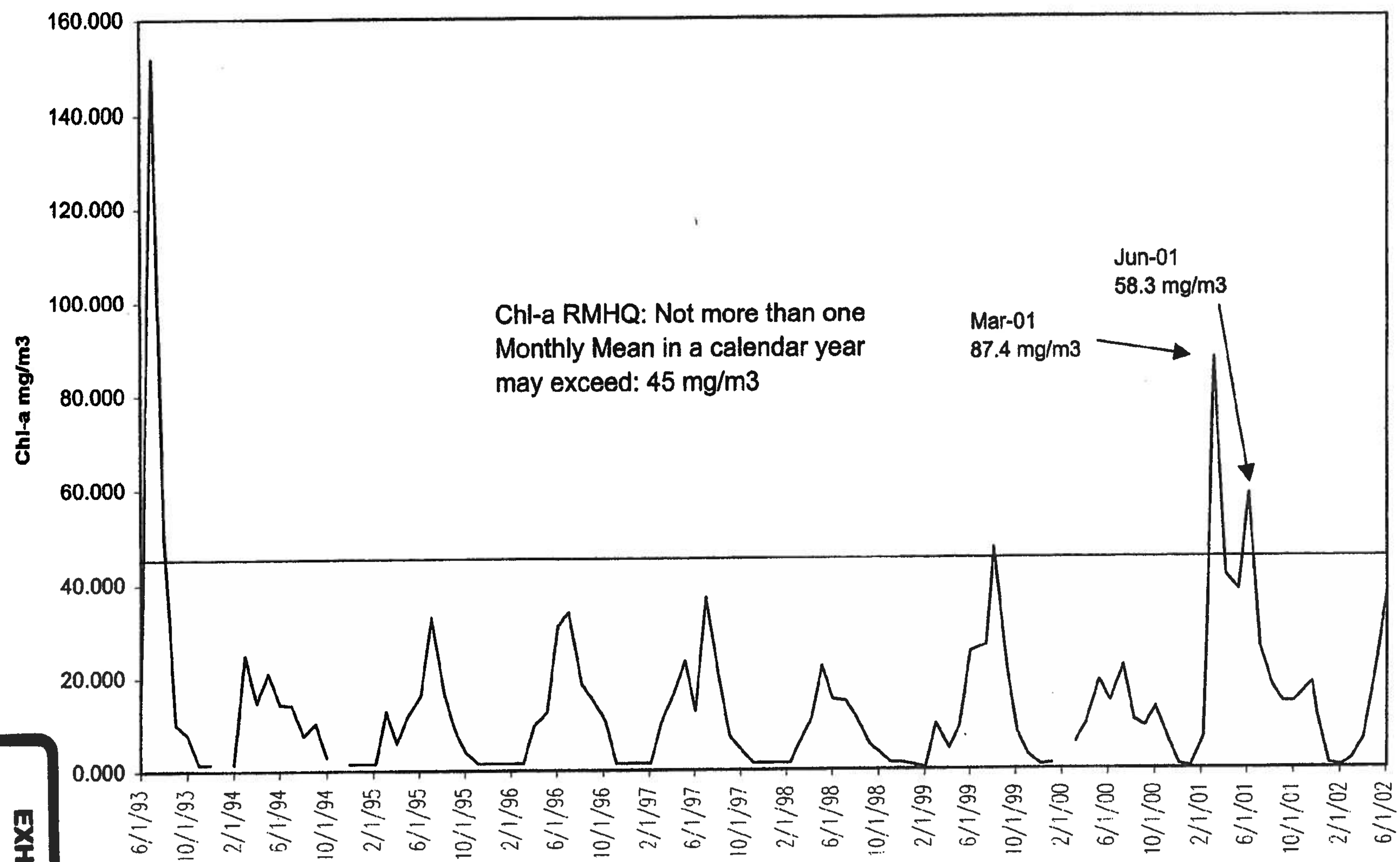


EXHIBIT 4

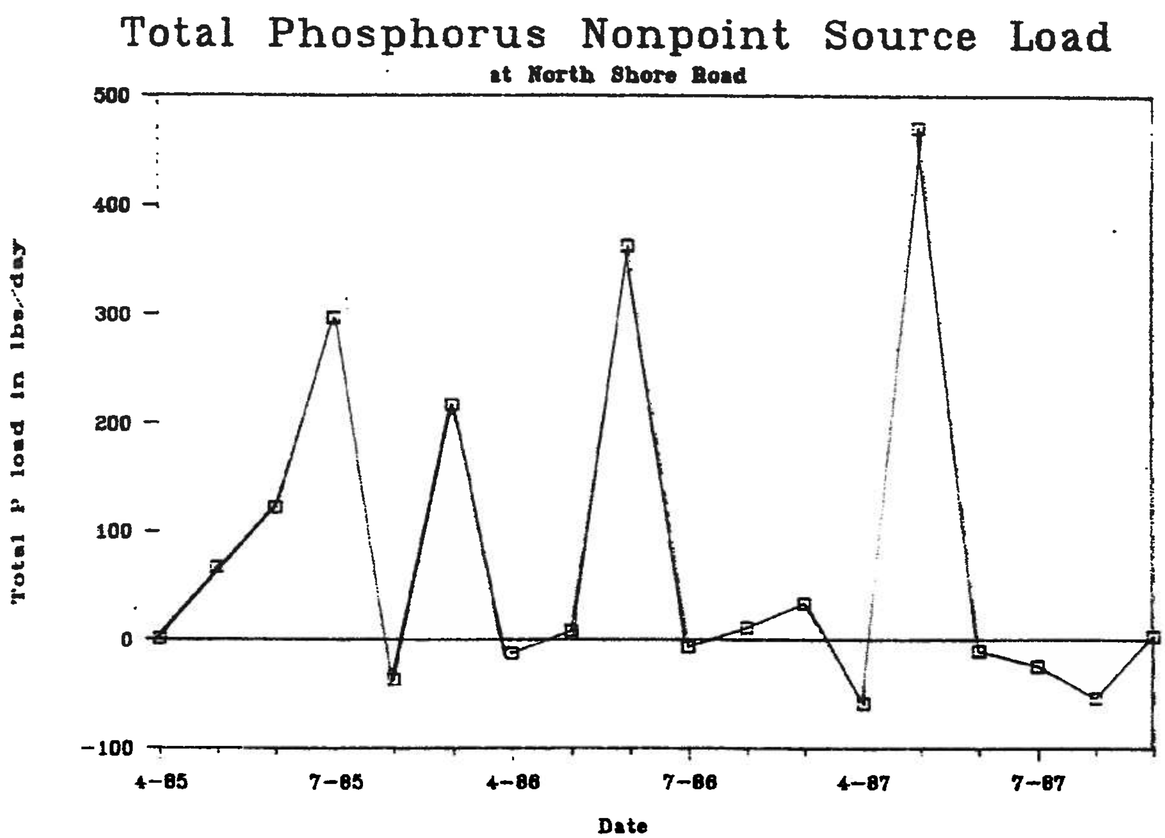


Figure 1: Monthly Total Phosphorus Nonpoint Source Loads at North Shore Rd.