File: Los Osos CSD WW project


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**MEMORANDUM**

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| **To:** | Michael Thomas | **Date:** ~~April 12, 2006~~ June 2002 ← Auto-Date – MBT |
| **From:** | Jon Butcher and Ron Rimelman | **Project:** Morro Bay |
| **Subject:** | Scoping Air Deposition of Nitrogen to Morro Bay | **Pjn:** Q500-63-03 |

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## Purpose

Provide a scoping analysis to determine if nitrogen emissions from the Duke Energy Morro Bay Power Plant constitute a significant source of nitrogen loading to Morro Bay, as requested by Michael Thomas of Regional Board 3. This initial analysis is conducted at a scoping level only, with the intention of providing an order-of-magnitude estimate of the load potentially associated with the power plant. If the load is determined to be a significant part of the overall nitrogen mass balance of the estuary more detailed analyses will be warranted.

## Setting

### *Morro Bay*

Morro Bay estuary supports the most significant wetland system on California's central coast, and is part of the National Estuary Program (MBNEP, 2000). The estuary is located in San Luis Obispo County, CA, and has a surface area of 2300 acres. The Morro Bay watershed covers approximately 48,000 acres and reaches an elevation of 2,763 feet.

MBNEP (2000) identifies nutrient over-enrichment, primarily nitrogen enrichment, as one of seven priority problems facing the Morro Bay estuary. This enrichment leads to nuisance algal blooms, and may be implicated in the decline of critical eelgrass habitat. Studies to date have assessed nitrogen loads from watershed runoff, urban storm runoff, and ground water, but have not evaluated the contribution of atmospheric deposition.

### *Morro Bay Power Plant*

The Morro Bay Power Plant occupies 140 acres between the city of Morro Bay and Morro Rock, at the north end of the estuary. The power plant consists of four generation units with a combined electrical production capacity of 1,002 net megawatts. The plant was designed to utilize both fuel oil and natural gas for power production, but since 1995 has used only natural gas. To date, the major water quality concern relative to the Morro Bay Power Plant has been its use of cooling water from the bay, and little attention appears to have been given to its potential impacts on local nitrogen deposition.

Natural gas contains only low levels of nitrogen compounds. However, significant amounts of nitrogen oxides (NOx) are produced in gas combustion process, primarily through the oxidation of atmospheric nitrogen. Emissions occur primarily as nitrogen oxide (NO), but this compound is rapidly oxidized (time scale of minutes to hours) to $NO_2$. $NO_2$ in turn reacts to form a variety of compounds, including $HNO_3$ and $NH_4NO_3$ that exhibit significant dry deposition to the land and water surface and can contribute to excess nitrogen loading. These latter reactions occur more slowly, making it difficult to gauge the localized deposition impact of a source. In addition, significant amounts of $NO_3$ and $NH_4$ may be dissolved into raindrops and removed from the atmosphere as wet deposition.

Pacific Gas and Electric sold the Morro Bay Power Plant to Duke Energy in July 1998. Subsequently, Duke proposed a plan to retire the existing power plant and update the units with smaller, more efficient gas turbines. In addition to replacing the existing turbines, the project would result in an increase in net capacity to 1200 megawatts and a reconfiguration from three 450-foot tall stacks to two 145-foot tall stacks. The proposed new units will use selective catalytic reduction (SCR) for control of NOx emissions, which involves injection of an aqueous ammonia solution to convert NOx back to nitrogen gas. Use of the new turbines with NOx control is projected to reduce total NOx emissions from 855.4 to 292.3 tons per year (Duke Energy, 2000, Table 6.2-4); however, some new ammonia nitrogen emissions will occur due to "ammonia slip" in the SCR process. In addition, the conversion to shorter stacks has the potential to increase the localized impact of emissions. Modeling conducted for the AFC (Table 6.2.-35) indicates that the maximum hourly ground-level concentration of $NO_2$ will decrease slightly relative to the existing plant, but the maximum annual average concentration will increase from 2.0 to 2.6 $\mu g/m^3$.

Duke Power filed an Application for Certification (AFC) for the plant modifications with the California Energy Commission (Duke Energy, 2000). The resulting certification process has generated an enormous volume of studies and documents, some, but not all, of which are available on the CalEnergy web site. Of particular relevance is the Final Staff Assessment of the AFC (CalEnergy, 2001). These two documents provided much of the input for this memorandum.

As part of the AFC, Duke Energy conducted dispersion modeling using the ISC model in both short-term and long-term format. This exercise generated 1-hour and annual exposure concentrations at several receptor points in the watershed. The modeling assumes that all NO emissions are rapidly converted to $NO_2$; however, no more sophisticated simulations of nitrogen atmospheric chemistry have been attempted, nor are any estimates of deposition rates provided in the AFC.

It should be noted that certain potentially important information was not available on the web site and efforts to obtain this information from CalEnergy have thus far not been successful. These missing documents included the detailed air dispersion modeling study conducted for Duke Energy submitted as Appendix 6.2-2 of the AFC as well as subsequent pollutant isopleth maps submitted by Sierra Research for Duke Energy in November 2000.

## Technical Approach

Estimating nitrogen deposition is a complex problem for several reasons. Both wet and dry deposition components are significant and dependent on meteorologic conditions. Deposition rates depend on transformations among nitrogen species, which are rate-limited processes involving complex atmospheric chemistry. An accurate, quantitative estimate of power plant nitrogen contributions to

Morro Bay is not possible at this time. However, it is possible to develop a bounding calculation by using the data provided in the AFC and making a series of reasonable upper-bound assumptions. Estimation can be broken down into a series of components, as follows:

1) Direct Deposition to Estuary: Deposition rate times surface area
   a) Dry Deposition: Use information in the AFC on concentrations. Estimate deposition rate as surface-layer concentration times a deposition velocity, consistent with U.S. EPA (1995) guidance.
      i) NOx: Assume 40 percent of NOx emissions are converted locally to $HNO_3$ and use $HNO_3$ deposition velocities. This will provide an upper bound on total deposition because the 40 percent conversion will actually take place over a much greater spatial scale (see discussion below).
      ii) $NH_3$: Assume all $NH_3$ dry deposition occurs as $NH_3$. This is again a conservative assumption because $NH_3$ deposition velocities are greater than deposition velocities of the common recombinant species $NH_4NO_3$ (Tarnay et al., 2001).
   b) Wet Deposition: Wet deposition has not been monitored at Morro Bay and has also not been modeled. Therefore the wet deposition component is estimated in relation to the dry deposition estimate by use of the observed wet to dry deposition ratio at the nearest National Acid Deposition Program (NADP) station.
2) Loading due to Deposition on Watershed: The influence on water quality of deposition to the watershed is difficult to assess, because much of the nitrogen may be retained by plants and soils. Therefore, the influence of loading onto the watershed is assessed qualitatively through consideration of stream monitoring data and studies of other watersheds.

## Direct Deposition to Estuary

### *Dry Deposition of NOx*

As noted above, it is assumed that all NOx originating from the power plant is rapidly converted to $NO_2$ and a portion is then converted to $HNO_3$. The first assumption is consistent with the assumptions in the AFC modeling, in which NOx and $NO_2$ concentrations are presented interchangeably. Only a fraction of the $NO_2$ will be converted locally to $HNO_3$ (or other depositional forms, such as $NH_4NO_3$) prior to being transported out of the watershed. The AFC (p. 6.2-70) estimates 40 percent conversion by the time the plume reaches the San Rafael Wilderness Area; therefore, conversion over the bay is likely to be less than 40 percent, which provides an upper bound estimate.

Ground-level NOx concentrations will vary with distance from the plant as the plume disperses. Because complete ISC model output and isopleth maps have not been obtained, this information is incomplete. However, the AFC (Table 6.2-39) does provide maximum annual average $NO_2$ concentrations of 2.6 $\mu g/m^3$ at the city of Morro Bay (north end of the estuary, near the plant) and 0.08 $\mu g/m^3$ at Los Osos (south end of the estuary, far from the plant). The distribution between these points is not known, so a value of 1.97 $\mu g/m^3$ (75 percent of the range) was picked as a conservative upper bound estimate of the areal average concentration over the bay. This is equivalent to 0.600 $\mu g/m^3$ as nitrogen (as nitrogen is 14/46 of the weight of $NO_2$). As noted above, 40 percent of this amount (0.240 $\mu g/m^3$) is assumed to be converted to $HNO_3$ and available for deposition to the estuary.

Deposition velocity for $HNO_3$ to water is cited as 6.4 mm/s (Tarnay et al., 2001; Hertel et al., 1995; Lee et al., 1998). This yields a total deposition rate for $HNO_3$ of 0.001536 $\mu g$-N/$m^2$/s, or 0.4839 kg-N/ha/yr.

### *Dry Deposition of $NH_3$*

The AFC does not report ground-level concentrations of $NH_3$ associated with the power plant. The ratio of maximum daily emissions of NOx to $NH_3$ is, however, reported as 0.5382 (CalEnergy, 2001, p. 3.1-39). Ground-level concentrations are assumed to follow this ratio relative to NOx, so the area-weighted average concentration is estimated at 1.060 $\mu$g-$NH_3$/m$^3$, equivalent to 0.873 $\mu$g-N/m$^3$. Tarnay et al. (2001) report a range of deposition velocities for $NH_3$ to water of 1.5 to 7.6 mm/s. The median of this range is 4.55 mm/s. Using this value, the estimated total deposition rate for $NH_3$ associated with the power plant is 0.003972 $\mu$g-N/m$^2$/s, or 1.2526 kg/ha/yr.

It is interesting to note that $NH_3$ deposition appears to be a potentially greater load source than NOx deposition. The $NH_3$ emissions from the plant are a by-product of the NOx control system, and are given little attention in the AFC and Staff Review.

### *Total Dry Deposition from Power Plant*

The sum of the estimated NOx and $NH_3$ annual deposition from the power plant is 1.737 kg-N/ha/yr. The estuary surface area is 2300 acres (MBNEP, 2000), or 930.7778 ha. Therefore, the total estimated upper-bound on dry deposition to the surface of the estuary is 1617 kg-N/yr.

## Wet Deposition to the Estuary

Wet deposition of nitrogen includes primarily those nitrogen species that dissolve in water droplets, of which $NH_4$ and $NO_3$ are the main forms. No monitoring or modeling of wet deposition of nitrogen appears to have been undertaken at Morro Bay. Therefore, an approximate estimate of wet deposition was made by reference to the wet:dry deposition ratio at the nearest monitoring site. This is a fairly weak assumption, as it does not take into account local conditions at Morro Bay. However, it should provide a reasonable order-of-magnitude estimate.

Wet and dry deposition of nitrogen is measured simultaneously at EPA CASTNET sites. These sites are fairly sparse on the west coast. The nearest site to Morro Bay is the CASTNET site at Pinnacles National Monument (PIN414), which is located in San Benito County at an elevation of 335 meters. The inland location significantly above sea level introduces additional uncertainty into the estimate.

Over the period 1997-2000, the ratio of wet to dry nitrogen deposition at Pinnacles was 56.47/43.53 = 1.3 (http://www.epa.gov/castnet/sites/pin414.html, accessed 5/25/02). Based on this information, wet deposition from the power plant to Morro Bay is estimated at 2.258 kg-N/ha/yr, or, over the whole estuary, 2102 kg-N/yr.

## Total Nitrogen Deposition to the Estuary

The sum of the estimated wet and dry deposition of N to the estuary associated with the power plant emissions is 4.0 kg-N/ha/yr, or 3719 kg-N/yr. Note that this is an upper-bound estimate on the potential nitrogen deposition from the proposed future plant configuration.

Estimates of existing plant-related deposition are difficult to ascertain, as the modeling in the AFC focused on the future plant configuration. Further, the existing configuration does not have NOx controls, but has much higher stacks. The AFC does report a maximum annual concentration at the city of Morro Bay of 2.0 $\mu$g/m$^3$ from the existing plant, which is 69 percent of the estimated future maximum annual concentration of NOx. The existing plant also does not use ammonia NOx controls, so plant-related ammonia deposition should be minimal. Assuming that the ratio at the city applies across the bay, this would suggest that existing N deposition from the plant to the estuary surface is on the order of $0.4839 * 0.69 * (1 + 1.3) = 0.77$ kg-N/ha/yr, or a total of 715 kg-N/yr over the estuary.

Background rates of nitrogen deposition in this area are not well known, as no deposition monitoring sites are present. (The AFC does report a "background" $NO_2$ concentration at the city of Morro Bay of 25 $\mu g/m^3$, but this appears to include existing plant emissions, and is also likely elevated by local mobile sources. No estimates of "background" at other sites in the watershed are given.) The isopleth maps developed by EPA's National Acid Deposition Program suggest that the background wet deposition rate for this portion of the California coast is slightly less than 1 kg-N/ha/yr, implying that the total background N deposition rate is on the order of 2-3 kg/ha/yr. The total N deposition observed at Pinnacles ranged from 1.6 to 5.1 kg-N/ha/yr over the period 1996-2000. Therefore, it appears that the existing power plant emissions represent an increase over natural background of 50 percent or less, while the future power plant configuration may approximately double the natural background nitrogen deposition rate to Morro Bay.

## Nitrogen Deposition to the Watershed

Nitrogen associated with the power plant will also deposit into the watershed. Some of this nitrogen may eventually reach the bay. However, much of the nitrogen that deposits into the watershed will be taken up by plants and soils. Significant N export from upland forests due to atmospheric deposition is only observed when the soil becomes saturated by N (Bytnerowicz and Fenn, 1996). Otherwise, most of the atmospheric N is retained in the biosphere.

It appears unlikely that the soils in the Morro Bay watershed are saturated with N. The evidence for this is seen in the monitoring data from Morro Bay tributaries forwarded by Regional Board 3. Some stations in the watershed have relatively high average concentrations of nitrate nitrogen, with averages approaching 4 mg/L. However, all those stations with average nitrate concentrations greater than 1 mg/L are downstream of cropland and/or urban areas (Figure 2). Nine stations that are upstream of cropland and urban areas have average nitrate concentrations that range from 0.2 to 0.4 mg/L. These low levels are indicative of regional background, according to data collected by Tetra Tech in support of regional nutrient criteria determination for Regional Board 3 (personal communication from Gary Wortham, Tetra Tech, 5/29/02). Therefore, it appears that past emissions from the plant have not resulted in nitrogen saturation in watershed soils. Therefore, it appears unlikely that nitrogen deposition from the power plant to the watershed will result in significant nitrogen loading to Morro Bay. Elevated nitrate loads observed in tributaries entering Morro Bay are most likely attributable to loading from agricultural and residential land uses, particularly septic systems.

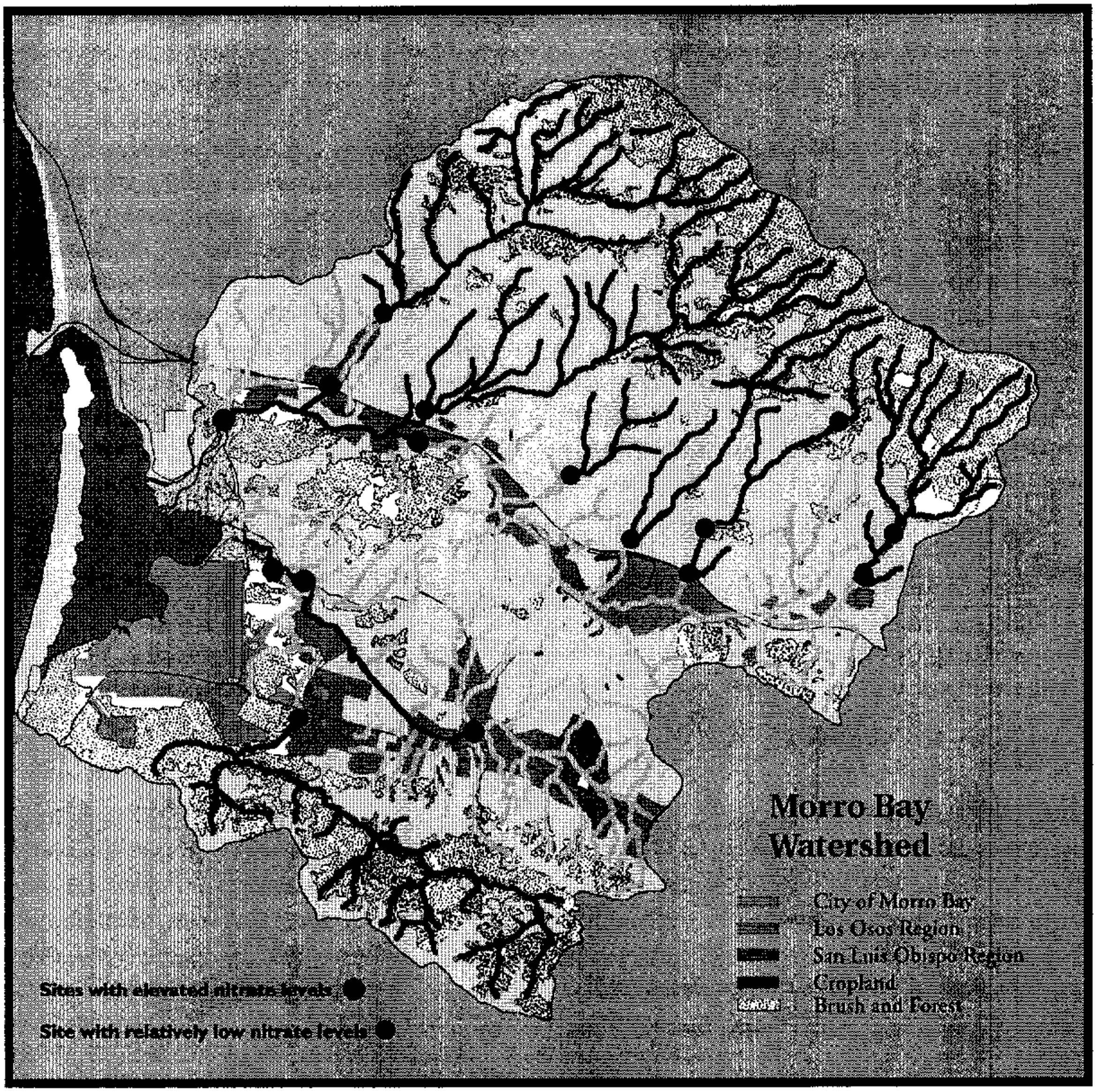


**Figure 2. Summary of Nitrate Sampling Undertaken for MBNEP.**

## Watershed Loading of Nitrogen

Is direct deposition of nitrogen to the estuary a significant part of the overall nitrogen balance? Answering this question requires a comparison of the atmospheric deposition to watershed loading. Unfortunately, no nutrient loading mass balances have been completed for Morro Bay, according to MBNEP. To provide an order-of-magnitude estimate for comparison, some quick calculations were made, based on monitored stream concentrations and estimated flows.

Very little flow gaging is available for this area, although a USGS monitoring station was maintained on Morro Creek at Morro Bay from Oct. 1970 through September 1978 (USGS gage 11142080). Annual flows for this gage (converted to inches of depth) are plotted against annual rainfall totals reported at the Morro Bay Fire Department Cooperative Summary of the Day weather station (COOP 045866) in Figure 3. The long term average precipitation reported at this station is reported as 17.7 inches/yr, which would correspond to approximately 8 inches of runoff.

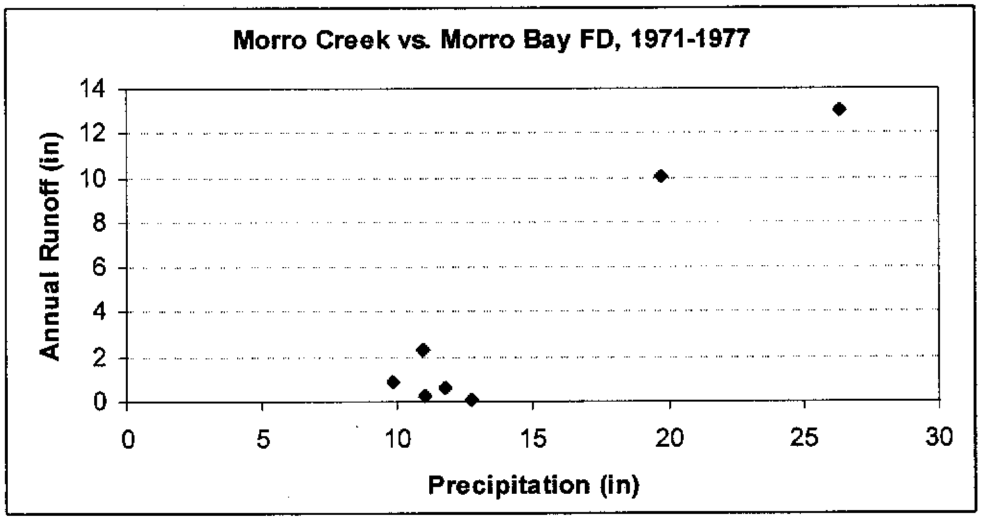


**Figure 3. Annual Runoff in Morro Creek versus Annual Precipitation at Morro Bay F.D.**

Biweekly monitoring of nitrate concentrations at numerous stations in the watershed for 1993-2001 was provided by the RWQCB (see station locations in Figure 2). The average concentration of nitrate in lower Chorro Creek was 1.77 mg/L. Average concentrations of nitrate at several of the stations on downstream Los Osos Creek are considerably higher (3- 5 mg/L). Unfortunately, no monitoring data was provided for total nitrogen. There are also significant direct ground water loads to the bay from the Los Osos area, where all residential development is on septic tanks.

If we assume conservatively that the average concentration of total nitrogen in water discharged from the watershed to Morro Bay is 3 mg/L, this is equivalent to a total annual average load of 118,000 kg/yr. Given this number, it appears that the current contribution of nitrogen from the power plant is less than 1 percent of the total nitrogen load to the estuary. The proposed reconfiguration of the plant could, however, increase the contribution from power plant emissions to around 3 percent of the watershed load.

## Summary

This scoping analysis presents rough, order-of-magnitude estimates of the potential contributions from the Morro Bay Power Plant to the nitrogen balance in Morro Bay. Based on this analysis, it appears likely that the existing power plant deposition to the watershed is insignificant in the overall nitrogen balance of the bay (less than 1 percent). The proposed reconfiguration of the power plant appears to have the potential to increase the atmospheric deposition load to a level around 3 percent of the watershed load. (This estimate is based on an upper bound estimate of ammonia deposition and what is likely a lower bound estimate of watershed loading.) Ironically, this increase is predicted to be due almost entirely to the proposed use of aqueous ammonia for NOx emission controls. The Morro Bay AFC, however, gives little attention to ammonia emissions. If possible, a further clarification of the potential for ammonia deposition to the estuary should be requested from the applicant. A final determination of the significance of atmospheric nitrogen deposition would require a complete nitrogen mass balance for the estuary.

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