Application of Vollenweider-OECD Modeling:
Limiting Nutrient Issues

G. Fred Lee, PhD, PE, BCEE and Anne Jones-Lee PhD
G. Fred Lee & Associates
El Macero, California
gfredlee@aol.com www.gfredlee.com

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In previous writings [see papers at http://www.gfredlee.com/pexfert2.htm] the authors have discussed the development, application, and utility of the Vollenweider–OECD eutrophication modeling approach for evaluating the impacts of phosphorus load reduction on eutrophication-related water quality of lakes, reservoirs, and estuarine waters. Conditions described for its optimal use included planktonic algal biomass that was, or could be made to be, limited by available phosphorus. While that was intuitively the case and was generally characteristic of the waterbodies to which the approach was being applied in the early days of its use, with continued use and evaluation of modeling approach it has been found that P-limitation is not a necessary condition for use of the model. Planktonic algal biomass in waterbodies containing concentrations of available phosphorus considerably above growth-limiting levels has been found to be affected by P load reductions, in keeping with the Vollenweider-OECD load-response models. This evolution in understanding has important implications for the broader utility of this well-vetted modeling approach, including in the establishment of nutrient criteria and TMDLs (total maximum daily loads) for water quality evaluation and management.

While P-limitation is not essential to effect reduction in planktonic algal biomass by P load reduction, it is important to understand that the commonly used approach of trying to estimate nutrient limitation based on Redfield ratios is not technically valid. The limiting nutrient in a waterbody or an area of a waterbody is most reliably determined by measuring the concentrations of available N (NO_3^- plus NH_3) and available P (soluble ortho P) during the period of maximum phytoplankton biomass. In general, if, at that time, the available P concentration is a few µg P/1, the peak phytoplankton biomass is likely limited by P. If the available N concentration is on the order of 30 to 50 µg/1, N is likely limiting phytoplankton production. If the concentrations of both nutrients are greater than those levels, some factor other than N or P is likely limiting maximum planktonic algal biomass.

The ratio of available N to available P concentration is also used to indicate which nutrient would be expected to be depleted first (i.e., potentially limiting) in a water, based on the theoretical uptake ratio of these nutrients by algae of 7.5 N to 1 P on a mass/L basis. Algal assays can be used to estimate the limiting nutrient by identifying which nutrient, if added to a sample of the water, would enable increased algal growth. Caution must be exercised in using the latter two approaches to estimate the limiting nutrient during periods of water quality concern. Both must be performed near the time of maximum algal production; the results of such assessments conducted at other times of the year will not necessarily give an accurate representation of the limiting nutrient during the period of water quality concern. Further, analyses for available N and P during peak biomass production should be conducted in conjunction with those procedures to verify that one of these nutrients is actually limiting the growth. While an N-to-P ratio may indicate a lesser relative abundance of one nutrient, growth-limiting levels of nutrients may not be reached; some other factor such as light may, in reality, be limiting algal growth during the period of concern. Thus, when the information sought is what is limiting planktonic algal growth at a particular time, the most cost-effective

approach is analysis at peak biomass for available N and P.

Lee and Jones-Lee discussed N and P limitation in the use of the Vollenweider-OECD eutrophication modeling approach in the following two documents:
Lee, G. F. and Jones-Lee, A., "Developing Nutrient Criteria/TMDLs to Manage Excessive Fertilization of Waterbodies," Proceedings Water Environment Federation, TMDL 2002 Conference, Phoenix, AZ, November (2002).
http://www.gfredlee.com/Nutrients/WEFN-Criteria.pdf

Lee, G. F., and Jones-Lee, A., "Synopsis of CWEMF Delta Nutrient Water Quality Modeling Workshop – March 25, 2008, Sacramento, CA," Report of G. Fred Lee & Associates, El Macero, CA, May 15 (2008).
http://www.gfredlee.com/SJR-Delta/CWEMF_WS_synopsis.pdf

Excerpts from Lee and Jones-Lee's CWEMF Presentation:
"Impact of Altering the Phosphorus Loads to the Delta on Delta Algal Concentrations"
At the CWEMF Delta Nutrient Water Quality Modeling Workshop, Dr. Erwin Van Nieuwenhuyse, Fishery Biologist with the US Bureau of Reclamation Division of Environmental Affairs, Sacramento, CA (evannieuwenhuyse@mp.usbr.gov) made a presentation, "Impact of Sacramento River Input of Phosphate to the Delta on Algal Growth" that discussed the impact of altering phosphorus loads to the Delta phytoplankton biomass. His presentation is available at CWEMF website, http://cwemf.org/Calendar/index.htm.

Van Nieuwenhuyse presented data describing the impact of reducing the phosphorus concentrations in the Rhine River in Europe on phytoplankton chlorophyll. He reported that there was a significant decrease in planktonic algal chlorophyll there associated with decreased phosphorus concentrations. He also pointed out that those data suggest that phosphorus concentrations of about 400 ng/L appear to be an upper limit of the concentration range in which decreasing the P concentration effects a reduction in planktonic algal biomass.

At the CWEMF workshop, Dr. Lee mentioned that Rast et al. conducted a review of the literature to assess and quantify the impacts of altering the phosphorus loads to waterbodies (and hence, in-waterbody concentrations) on phytoplankton concentrations. The results of their investigations are presented in:

> Rast, W., Jones, A., and Lee, G. F., "Predictive Capability of US OECD Phosphorus Loading-Eutrophication Response Models," *Journ. Water Pollut. Control Fed.* **55(7)**:990-1003 (1983).
> http://www.gfredlee.com/Nutrients/PredictiveCapabilityOECD.pdf

Rast et al.'s findings also support the position that for waterbodies with apparently surplus phosphorus compared to the typically reported phosphorus half-saturation-constant of a few nanograms per liter, phosphorus reduction can be expected to result in reduction of planktonic algal chlorophyll levels, up to a limit of a few hundred nanograms P per liter.