Stormwater Runoff Water Quality Newsletter
Devoted to Urban/Rural Stormwater Runoff
Water Quality Management Issues
* * * * *

Volume 11 Number 1 Editor: Anne Jones-Lee, PhD
January 14, 2008 Contributor to this Issue:
G. Fred Lee, PhD, PE, DEE
* * * * *

This issue of the Newsletter is devoted to selected sections of Dr. G. Fred Lee and Dr. Anne Jones-Lee's comments on the California State Water Resources Control Board's (SWRCB) staff's proposed approach for developing **sediment quality objectives** (SQOs) for Enclosed Bays and Estuaries of California. The complete comments (29 pages) are available as,

> Lee, G. F., and Jones-Lee, A., "Comments on the SWRCB Staff's Proposed Approach for Developing Sediment Quality Objectives for Enclosed Bays and Estuaries of California," Submitted to State Water Resources Control Board, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, November 30 (2007). http://www. members.aol.com/GFLEnviroQual/SedQualObj11-07.pdf

Those comments include a discussion of Lee and Jones-Lee's qualifications to undertake this review, which include more than 40 years' experience in evaluating the water quality significance of chemical contaminants in aquatic sediments.

SQOs are to be used to evaluate sediment quality as part of a regulatory program for controlling the adverse impacts of chemical contaminants in aquatic sediments that affect the beneficial uses of a waterbody. Ultimately, sediment remediation programs and source control for those sources that lead to impairment of sediment quality could evolve from the SQOs. The proposed approach for SQO development is set forth at http://www.swrcb.ca.gov/bptcp/sediment.html.

Overall Assessment

As discussed herein, there are significant technical deficiencies in the staff's proposed approach that preclude it from being a reliable component of a regulatory program to manage the water quality impacts of sediment-associated contaminants in a technically valid, cost-effective manner. The major technical deficiency is that the role of aquatic chemistry in affecting how chemical contaminants in aquatic sediments impact beneficial uses of waterbodies has not been inadequately considered or incorporated. The lack of a proposed implementation approach in the staff report is another major deficiency.

In developing its proposed approach, the SWRCB staff faced a monumental task of trying to address the highly complex issues of how chemical contaminants associated with sediments affect beneficial uses of waterbodies. The staff was not provided with adequate financial resources, or sufficient time or expertise to develop implementable SQOs. The staff's report that is under review by the SWRCB should be considered a "work in progress" to be followed by a more adequately developed, technically sound regulatory program for managing contaminated sediments. Only after the technical and implementation deficiencies in the proposed approach have been corrected should the SWRCB consider its adoption as fulfilling the legislature's requirement for the Bay Protection and Toxic Cleanup Program.

Background to Developing SQOs

In 1989 the California State Legislature adopted the Bay Protection and Toxic Clean Up Program (BPTCP), which mandated that sediment quality objectives be developed as part of the regulatory program for managing chemical contaminants in aquatic sediments. The SWRCB website at, http://www.swrcb.ca.gov/bptcp/docs/cwc13390.html presents the background to the development of SQOs, including the following sections:

"CHAPTER 5.6 BAY PROTECTION AND TOXIC CLEANUP

§ 13390. Legislative intent.

It is the intent of the Legislature that the state board and the regional boards establish programs that provide maximum protection for existing beneficial uses of bay and estuarine waters, and that these programs include a plan for remedial action at toxic hot spots. It is also the intent of the Legislature that these programs further compliance with federal law pertaining to the identification of waters where the protection and propagation of shellfish, fish, and wildlife are threatened by toxic pollutants and contribute to the development of effective strategies to control these pollutants. It is also the intent of the Legislature that these programs be structured and maintained in a manner which allows the state board and the regional boards to make maximum use of any federal funds which may be available for any of the purposes specified in this chapter.

§ 13391. California Enclosed Bays and Estuaries Plan.

(a) The state board shall formulate and adopt a water quality control plan for enclosed bays and estuaries, which shall be known as the California Enclosed Bays and Estuaries Plan, in accordance with the procedures established by this division for adopting water quality control plans.

§ 13393. Sediment policy objectives.

(a) The state board shall adopt sediment quality objectives pursuant to the workplan submitted pursuant to Section 13392.6.

(b) The state board shall adopt the sediment quality objectives pursuant to the procedures established by this division for adopting or amending water quality control plans. The sediment quality objectives shall be based on scientific information, including, but not limited to, chemical monitoring, bioassays, or established modeling procedures, and shall provide adequate protection for the most sensitive aquatic organisms. The state board shall base the sediment quality objectives on a health risk assessment if there is a potential for exposure of humans to pollutants through the food chain to edible fish, shellfish, or wildlife."

SWRCB Staff's Approach for SQO Development

According to the SWRCB announcement on its website of the availability of the draft staff report (http://www.waterboards.ca.gov/bptcp/sediment.html),

"SEDIMENT QUALITY OBJECTIVES

Sediments in bays and estuaries are often contaminated with a variety of pollutants stemming from sources including industrial and agricultural discharges, municipal wastewater treatment plants and stormwater. Exposure to contaminated sediments can have a significant effect on the health, diversity and abundance of invertebrates such as clams and worms. Foraging fish and birds may also be exposed by ingesting contaminated invertebrates or sediments. In turn, those organisms consuming contaminated fish may be exposed to toxic pollutants. These effects underscore the need to develop sediment quality objectives that protect aquatic ecosystems and human health."

The SWRCB staff proposed an integrated approach to developing an evaluation of sediment quality through SQO development involving multiple lines of evidence. Page 8 of Appendix A of the staff report states,

"Section V. Benthic Community Protections

A. Multiple Lines of Evidence Approach

The methods and procedures described below shall be used to implement the Narrative Objective described in Section IV.A. These tools are intended to assess the condition of benthic communities relative to potential for exposure to toxic pollutants in sediments. Exposure to toxic pollutants at harmful levels will result in some combination of a degraded benthic community, presence of toxicity, and or elevated concentrations of pollutants in sediment. The assessment of sediment quality shall consist of the measurement and integration of three lines of evidence (LOE). The LOE are:

***Sediment Toxicity**: Sediment toxicity is a measure of the response of invertebrates exposed to surficial sediments under controlled laboratory conditions. The sediment toxicity LOE is used to assess both pollutant related biological effects and exposure. Sediment toxicity tests are of short durations and may not duplicate exposure conditions in natural systems. This LOE provides a measure of exposure to all pollutants present, including non-traditional or unmeasured chemicals.*

***Benthic Community Condition**: Benthic community condition is a measure of the species composition, abundance and diversity of the sediment-dwelling invertebrates inhabiting surficial sediments. The benthic community LOE is used to assess impacts to the primary receptors targeted for protection under Section IV.A. Benthic community composition is a measure of the biological effects of both natural and anthropogenic stressors.*

***Sediment Chemistry**: Sediment chemistry is the measurement of the concentration of chemicals of concern* in surficial sediments. The chemistry LOE is used to assess the potential risk to benthic organisms from toxic pollutants in surficial sediments. The sediment chemistry LOE is intended only to evaluate overall exposure risk from chemical pollutants. This LOE does not establish causality associated with specific chemicals."*

As discussed in these comments, as proposed the so-called "sediment chemistry" component of the triad is not technically valid for assessing the potential impacts of a chemical(s) on sediment quality or benthic organisms, or for assessing the impairment of beneficial uses of a waterbody.

> *"Each LOE produces specific information that, when integrated with the other LOEs, provides a more confident assessment of sediment quality relative to the narrative objective. When the exposure and effects tools are integrated, the approach can quantify protection through effects measures and also provide predictive capability through the exposure assessment.*
>
> ***Table 12 Tools for Use in Evaluation of LOEs***
>
> *LOE TOOLS METRICS*
>
> ***Chemistry***
>
> > *Bulk sediment chemistry to include existing list plus other chemicals of concern CA LRM Pmax*
> >
> > *Concentration on a dry weight basis*
>
> ***Sediment Toxicity***
>
> > *10-Day amphipod survival using a species tolerant of the sample salinity and grain size characteristics. E.g., Hyalella azteca or Eohaustorius estuarius Percent of control survival*
>
> ***Benthic Community Condition***
>
> > *Invertebrate species identification and abundance*
> >
> > *Species richness Presence of sensitive indicator taxa Dominance by tolerant indicator taxa Presence of diverse functional and feeding groups Total abundance"*

The statement about including "*other chemicals of concern*" in the CA LRM Pmax co-occurrence-based approach for the "chemistry" (more properly, chemical concentration) is a superficial attempt to try to make this technically invalid approach appear more reliable. Repeatedly at staff-organized meetings to discuss SQO development, and in his writings Lee has pointed out that there is a vast array of chemicals that could be causing toxicity in a sediment but that are not considered in the Long and Morgan, MacDonald, or Field et al., co-occurrence-based approaches. Misguided focus on a chemical based on its total concentration can result in failure to address the primary cause of the sediment toxicity. This issue is discussed further below.

Appendix A of the staff report presents "Staff Proposal Draft Water Quality Control Plan for Enclosed Bays and Estuaries of California Part 1 Sediment Quality." This section states in the "Intent and Summary,"
"*It is the goal of the State Water Board to comply with the legislative directive in Water Code §13393 to adopt sediment quality objectives (SQOs). Part 1 integrates chemical and biological measures to determine if the sediment dependent biota are protected or degraded as a result of exposure to toxic pollutants* in sediment and to protect human health.* ***This plan is not intended to address low dissolved oxygen, pathogens or nutrients including ammonia."*** [Bold added for emphasis – see discussion below.]

Appendix C states,

> "***Direct Effects Station Assessment Example Calculation***

This document describes the calculations needed to evaluate sediment with respect to the sediment quality objective for aquatic life-benthic community protection. The evaluation process consists of 5 steps, as shown in Figure 1. Step 1 consists of sediment sampling and laboratory measurement of three Lines of Evidence (LOE): chemistry, toxicity, and abundance of benthic infauna. The data from each LOE are then summarized, interpreted using multiple indices, and integrated in Steps 2-4 in order to determine a LOE condition category. The final step of the evaluation process is to combine the three LOE category classifications to determine the station assessment category.

The data used in the example are typical of those likely to be encountered in California embayments. Steps 2-4 are described separately for each LOE. The thresholds used to evaluate the data were obtained from Appendix A (Draft Enclosed Bays and Estuaries Sediment Quality Plan). The data analyses described in this example have been broken down into a number of intermediate steps to allow the reader who is unfamiliar with these analyses to follow the calculations. In practice, many of these steps are accomplished with a single calculation and the calculations are easily automated using readily available computer software.

Figure 1. Steps in the sediment evaluation process.
Step 1 Collect and analyze samples Chemistry, Toxicity, Benthos
Step 2 Compile and summarize data QA review, means, sums
Step 3 Apply Indicators for each LOE Indices and thresholds
Step 4 Determine LOE Category Integrate indicators
Step 5 Station impact assessment Integrate LOEs

The steps involved in analysis of the chemistry LOE are gathering the data and getting them into the appropriate units, calculating the Logistic Regression Model values, calculating the Chemical Score Index values, and integrating these values to determine the chemistry LOE category. All of the calculations can be done with a standard desk calculator, but can be more easily accomplished using a spreadsheet program, such as Excel.

Data preparation
The first step in the process is to gather the appropriate sediment chemistry data and put it into the proper units for analysis. The chemical constituents needed for the chemistry [so-called] *LOE analysis and the sample data are listed in Table 1. Note that all constituents are expressed on a dry weight basis, metals in mg/dry kg and organic constituents in mg/dry kg. For any chemicals that were measured but not detected, an estimated concentration (e.g., ½ of the detection limit) should be used for calculation purposes.*

California Logistic Regression Model Calculation
The California Logistic Regression Model (CA LRM) uses logistic regression models to predict the probability of sediment toxicity based on chemical

concentration. The concentration data for each chemical, along with chemical-specific regression slope and intercept are used in the following equation to predict the probability of toxicity (p).”

According to the staff report, on page 77,

“Logistic Regression Model (National LRM)

The Logistic Regression Model (LRM) approach was based on the statistical analysis of paired chemistry and amphipod toxicity data from studies throughout the U.S. (Field et al. 1999, 2002). A logistic regression model is developed for each chemical to estimate the probability of toxicity at a given concentration. LRM models for 18 chemicals having low rates of false positives were selected for use in this study. The LRM method does not establish specific concentration values for each chemical, but rather describes the relationship between contaminant concentrations and the probability of toxicity. The maximum probability of effects obtained from the individual chemical models (Pmax) was selected to represent the chemical mixture present in a sample (Field et al. 2002).”

Overall Evaluation of Proposed SQO Development Approach

Inappropriateness of Inclusion of “Co-Occurrence” Information. The SWRCB staff’s proposed approach for evaluating the water quality significance of chemical constituents in aquatic sediments is to combine multiple “lines of evidence” (often referred to as a “triad” approach): sediment toxicity, benthic organism assemblages, and the total concentrations of selected chemicals in the sediments. While the sediment toxicity and benthic organism assemblage information are technically valid components of a biological effects-based sediment quality evaluation, the total concentration of a chemical or chemicals in a sediment, either directly, or through a co-occurrence assessment or index, is not. It has been known for more than 30 years that the total concentrations of sediment-associated chemicals, individually or collectively, do not have a cause-and-effect relationship to the impact that that sediment has on benthic organisms, aquatic life, or sediment/water quality. (The unique exception to this truth, for some situations, is ammonia, which, as discussed subsequently, is not included in the parameters considered in the proposed SQO development approach.) The fact that an elevated concentration of a chemical may occur in a sediment that has exhibited some impact (“co-occurrence”) is not evidence of a cause-and-effect relationship. This lack of a cause-and-effect relationship was explicitly recognized in the staff report. However, the staff went on to use the “co-occurrence” approach as though it had sufficient validity to serve as a key component of the foundation for SQO development. Regulators need to get beyond the simplicity of the co-occurrence approaches, and realize the technical invalidity of the approaches for regulatory purposes.

Incorporating the total concentrations of sediment-associated chemicals in an SQO, while simple and straight-forward, is not technically sound and can be expected to lead to inappropriate sediment quality evaluations. Inclusion of such concentrations, or indices developed based on those concentrations, cannot be presumed to be an appropriate “safety net” or “best guess” for situations in which reliable data are lacking; it is simply not valid. Admixing an invalid or extraneous parameter with other, reliable parameters, does not make the invalid parameter valid or useful; it only serves to render the overall conclusions obtained through the triad untrustworthy, and hence useless. The same is true for the use of concentration-based elements in "screening" exercises; unreliable sediment screening approaches mislead the direction and focus of further evaluation and remediation. Sediments with higher concentrations of certain chemicals can be of less environmental quality significance than sediments having a lower concentration because the potential impact cannot be reliably keyed to the total concentration. Use of unreliable evaluations can be expected to cause dischargers, including the public, to spend large amounts of money for sediment quality "remediation" and source control without reliable justification that is based on the actual role of the chemical(s) in causing the sediment toxicity, altered benthic organism assemblages, or other adverse condition.

Excluded Contaminants Need Consideration. Another significant deficiency with the SWRCB staff's recommended approach is the imprudently narrow focus of the list of chemicals considered in the SQO development. While many of the chemicals included are suspected of potentially causing impacts at some undefined level and in some undefined way, notably absent from that list are numerous chemicals that are, in fact, known to cause sediment quality impairment. For example, low-dissolved-oxygen (DO), ammonia, and hydrogen sulfide can be responsible for sediment toxicity but are not given consideration. They can, in fact, be largely responsible for toxicity erroneously attributed, through "co-occurrence" evaluation, to other chemicals that also occur in the sediment. Further, there is a vast array of potentially toxic chemicals, such as some of the widely-used pesticides, that are not being adequately considered in the staff's proposed list of chemicals that serves as the basis for SQO development.

The inclusion of total chemical concentrations in the evaluation of the role of a sediment-associated chemical in causing sediment toxicity skews the results of the entire triad, and clouds the results and insight provided by the technically valid portions of the assessment. Inclusion of total concentration can certainly be simple, straight-forward, and provide a seemingly meaningful catch-all for the evaluation. In reality, it is simply a "wild card" that is not reliably related to potential impact. Inclusion of this parameter, as is being proposed, reflects an insufficient and mistaken understanding of basic principles of aquatic chemistry and how chemicals in sediment can impact aquatic life in sediment.

In short, because the inclusion of chemical concentrations in the "triad" evaluation renders its results unreliable, the proposed approach for SQO development is not technically valid. The sediment quality evaluation should be a truly biological effects-based approach that incorporates sediment toxicity and benthic organism assemblage information, without any incorporation of "pseudo-effects" "co-occurrence" approaches. The chemical concentration component of the proposed triad should be replaced with a reliable Toxicity Identification Evaluation ("TIE") of the chemical(s) in sediment in which toxicity and/or altered benthic organism assemblages are manifested.

The Overlooked/Postponed Issues of Implementation. One of the most important elements of any environmental quality objective is the delineation of how it can and will be used to manage water quality, i.e., its implementation. One of the most significant deficiencies in the proposed approach for developing the SQOs is its lack of detailed information on how the results of the SQO triad, even if reliable, would be implemented to reliably direct and regulate the identification and cleanup of contaminated sediment, and institute appropriate source identification and control to prevent future sediment contamination. As documented herein, because the chemical component of the SQO triad is fundamentally flawed, the outcome of the SQO is unreliable for assessing the role of a chemical(s) in impacting sediment quality and, therefore, the impact of the sediment and the suspected source of the chemical on beneficial uses of a waterbody.

The staff has asserted that the unreliability of co-occurrence can be addressed in the implementation phase of sediment quality management. First, it is not technically valid or cost-effective policy to develop a fundamentally flawed evaluation approach and then try to rectify the inherent deficiencies by manipulating its implementation. Second, even if the SQO triad evaluation approach were reliable, the proposed implementation discussion provided in the report is insufficient, at best, to enable proper review to ensure that the approach and implementation correctly identify sediment quality problems, the chemical(s) and/or conditions responsible for biological impacts, and sources of the chemical(s). These issues are discussed further in a subsequent section of these comments.

Comments on SQO Development Approach

The SWRCB staff's effort to develop sediment quality objectives that can be used in sediment quality evaluation has made significant advances in documenting the complexity of aquatic sediments, especially in the relationship (more appropriately lack of relationship) between the bulk chemical composition of sediments and sediment toxicity and benthic organism assemblages. The incorporation of sediment toxicity and benthic organism assemblage information in an evaluation of the *impact* of chemicals on sediment quality is normally appropriate. Finding sediment toxicity and altered benthic organism assemblages compared to the population that should be present based on habitat characteristics should trigger further investigation to evaluate the cause of the toxicity and/or altered benthic organism populations. Of particular concern is whether the toxicity is causing the altered benthic organism assemblages. However, the staff's proposed incorporation of the California Logistic Regression Model, a **co-occurrence**-based component, with those otherwise valid effects-based parameters, invalidates the proposed evaluation scheme.

The principles of aqueous environmental chemistry, as well as the extensive empirical evidence from site-specific research, attest irrefutably to the fact that the bulk sediment chemical composition is not relatable to the potential or actual impact of that sediment. A detailed discussion of this issue has been presented by Lee and Jones-Lee (2002, 2004) in their reviews,

> Lee, G. F. and Jones-Lee, A., "Appropriate Incorporation of Chemical Information in a Best Professional Judgment 'Triad' Weight of Evidence Evaluation of Sediment Quality," Presented at the 2002 Fifth International

Conference on Sediment Quality Assessment (SQA5), In: Munawar, M. (Ed.), *Aquatic Ecosystem Health and Management* 7(3):351-356 (2004). http://www.gfredlee.com/BPJWOEpaper-pdf

Lee, G. F., Jones-Lee, A., "Appropriate Incorporation of Chemical Information in a Best Professional Judgment 'Triad' Weight of Evidence Evaluation of Sediment Quality" poster at the 5th International Conference on Sediment Quality Assessment, Aquatic Ecosystem Health and Management Society Chicago, IL, October (2002). http://www.gfredlee.com/BPJ_Poster.pdf

as well as in

Jones-Lee, A. and Lee, G. F., "Unreliability of Co-Occurrence-Based Sediment Quality Guidelines for Contaminated Sediment Quality Evaluation at Superfund/Hazardous Chemical Sites," J. *Remediation*, 15(2):19-33, Spring (2005). http://www.members.aol.com/annejlee/SQGSuperfund2.pdf

and other papers and reports provided on Lee and Jones-Lee's website, http://www.gfredlee.com/psedqual2.htm. Their papers and reports also contain numerous references to the wider professional literature which further documents the unreliability of co-occurrence-based approaches for evaluation of sediment quality and the potential for a chemical(s) to cause sediment toxicity.

The first of the papers listed above was presented at the Fifth International Conference on Sediment Quality Assessment. That conference included a series of papers by internationally recognized authorities on sediment quality evaluation. As would be expected from principles of aqueous environmental chemistry, there was agreement by the presenters and many of the conference participants that co-occurrence-based sediment quality evaluation is technically invalid since the total concentration of a chemical or group of chemicals is not evidence of the impact of the chemicals on aquatic life or the potential for excessive bioaccumulation of a chemical in aquatic organism tissue.

Review of the list of references provided by the staff in its report discussing the proposed SQO approach reveals that the staff has relied exclusively upon authors who advocate for co-occurrence-based approaches, to the exclusion of the vast technical literature that substantiates the technical unreliability of the approach. Notably absent is reference to the presentations at the 2002 Fifth International Conference on Sediment Quality Assessment, as well as countless papers in the literature that address why co-occurrence-based approaches should not be used in sediment quality evaluation. Such unbalance in a review, especially in advocacy of a technically unreliable position, is not serving the SWRCB or the public interest well.

The inclusion of chemical concentrations in the proposed SQO methodology in the manner advocated by the staff, is a contrivance to incorporate what the staff mistakenly calls "chemistry" into a triad approach for sediment quality evaluation. As discussed by Lee and Jones-Lee (2002, 2004) and Jones-Lee and Lee (2005) referenced above, aquatic sediment chemistry involves the evaluation of the chemical reactions – their kinetics and thermodynamics – that control whether a chemical exists in forms that affect aquatic life in a sediment. Jones-Lee and Lee (2007) recently discussed the assessment of sediment chemistry (chemical reactions that influence the impact of chemicals on aquatic life and other beneficial uses of waterbodies) in the modeling of water quality impacts of chemicals in stormwater runoff.

> Jones-Lee, A. and Lee, G. F., "Modeling Water Quality Impacts of Stormwater Runoff-Associated Pollutants," Report of G. Fred Lee & Associates, El Macero, CA, September (2007).
> http://www.members.aol.com/GFLEnviroQual/StormwaterWQModeling.pdf

Lee and Jones-Lee (2002, 2004) and Jones-Lee and Lee (2005) discussed how sediment chemistry can be reliably incorporated into sediment quality evaluation. This is done through a toxicity identification evaluation framework to determine whether and which chemicals present in a sediment are causing sediment toxicity (stressor identification). It is this type of evaluation that should serve as the "chemical" component of a triad approach for sediment quality evaluation.

The staff report indicates that the proposed SQO development approach is restricted to a limited number of classical potential pollutants that are considered in developing California Logistic Regression Model Calculations, and does not include the wide variety of other sediment-associated chemicals that can cause toxicity to aquatic life. The staff stated explicitly, as quoted above in bold typeface, that this SQO development approach does not consider the impact of low-DO or ammonia as causes of sediment toxicity. While not specifically mentioned by the staff, it also does not consider the impacts of hydrogen sulfide as a toxicant in sediments. As discussed by Lee and Jones-Lee (2007a,b,c) and as has been known for more than three decades, low-DO, ammonia, and hydrogen sulfide are the most common causes of sediment toxicity. While those chemicals are well-known toxicants in aquatic systems, their full potential impact on aquatic resources is often not understood. If those issues are not addressed, it makes little sense to pursue contrivances to address chemicals that are of comparatively less significance to sediment quality. The failure of the SQO staff report to even discuss the significance of not including the potential toxicity associated with low-DO, ammonia, and hydrogen sulfide derived from aquatic sediments as part of the cause of sediment toxicity is a major, fundamental flaw with the proposed approach.

In an effort to address this issue, Lee and Jones-Lee published three Newsletters that discussed various aspects of this issue, and developed the information into the following reports.

> Lee, G. F., and Jones-Lee, A., "Role of Aquatic Plant Nutrients in Causing Sediment Oxygen Demand Part I – Origin of Rapid Sediment Oxygen Demand," Report of G. Fred Lee & Associates, El Macero, CA, May (2007a). http://www.members.aol.com/LFandWQ/NutrientSOD1RapidOD.pdf

Lee, G. F., and Jones-Lee, A., "Role of Aquatic Plant Nutrients in Causing Sediment Oxygen Demand Part II – Sediment Oxygen Demand," Report of G. Fred Lee & Associates, El Macero, CA, June (2007b).
http://www.members.aol.com/LFandWQ/NutrientSOD2SOD.pdf

Lee, G. F., and Jones-Lee, A., "Role of Aquatic Plant Nutrients in Causing Sediment Oxygen Demand Part III – Sediment Toxicity," Report of G. Fred Lee & Associates, El Macero, CA, June (2007c).
http://www.members.aol.com/LFandWQ/NutrientSOD3Tox.pdf

Those three reports discuss the potential role of aquatic plant nutrients (nitrogen and phosphorus compounds) derived from natural, as well as anthropogenic, sources in contributing to, or being the underlying cause of, aquatic sediment toxicity. Aquatic plant nutrients stimulate the growth of algae in a water column. The algae die, settle, and are decomposed in sediments. This anoxic environment leads to the sediments' containing significant concentrations of chemicals that exert an oxygen demand. Of particular importance are ferrous iron and sulfide species. Both of those chemical species, when stirred or suspended in a water column, can cause a very rapid depletion of DO that is well-documented to have caused fish kills.

By ignoring low-DO, ammonia, and hydrogen sulfide in the protocols for assessing the causes of adverse impacts on aquatic life in sediments, major adverse impacts on benthic organism assemblages could go unaddressed. Further, the public and other dischargers could find themselves chasing "ghosts" of alleged sediment quality problems and stressors so-identified based on technically unreliable and invalid approaches. Failure to address these issues in a technically valid manner can be expected to result in large amounts of public and private expenditures for sediment "remediation" and "source control" without alleviating the real sediment quality problems.

Other Chemicals of Concern

In addition to the staff's approach being significantly deficient in providing guidance on evaluating the role of chemicals in sediments in causing toxicity to benthic organisms due to low-DO, ammonia, and hydrogen sulfide, there is a vast array of other chemicals that need to be considered in identifying the causes of sediment toxicity. One such group of chemicals is the pyrethroid-based pesticides. In the mid- to late 1990s, G. F. Lee and S. Taylor of RBF Consulting, Irvine, CA, conducted a comprehensive study of aquatic life toxicity in Upper Newport Bay (Orange County, California) on behalf of the Santa Ana Regional Water Quality Control Board. They sampled urban, highway, agricultural, and open-space stormwater runoff from 10 different subwatersheds in the Upper Newport Bay watershed. As discussed by Lee and Taylor (2001a,b,c) and as summarized in several Stormwater Runoff Water Quality Newsletters (www.gfredlee.com/newsindex.htm), they found that the stormwater runoff from all of the watersheds investigated was toxic to the standard test organism *Ceriodaphnia*. The toxicity was not due to heavy metals as had previously been hypothesized based on total concentrations, but rather was due to the organophosphate-based pesticides diazinon and chlorpyrifos. Through directed TIE investigations with the assistance of the University of California, Davis, Aquatic Toxicology Laboratory staff and Dr. Jeff Miller of AquaScience in Davis, CA, they tentatively identified part of this toxicity as also being due to pyrethroid-based pesticides.

> Lee, G. F., Taylor, S., and County of Orange Public Facilities and Resources Department, "Upper Newport Bay Water Quality Enhancement Project, Final Report," Agreement Nos. 8-023-258-0 and 8-174-250-0, submitted to State Water Resources Control Board, Santa Ana Regional Water Quality Control Board and Orange County Public Facilities and Resources Department to meet the requirements of the US EPA 319(h) Project, G. Fred Lee & Associates, El Macero, CA and RBF Consulting, Irvine, CA, May (2001a).
>
> Lee, G. F. and Taylor, S., "Results of Heavy Metal Analysis Conducted During 2000 in the Upper Newport Bay Orange County, CA Watershed," Report of G. Fred Lee & Associates, El Macero, CA (2001b).
> http://www.members.aol.com/apple27298/Heavy-metals-319h.pdf
>
> Lee, G. F. and Taylor, S., "Results of Aquatic Toxicity Testing Conducted During 1997-2000 within the Upper Newport Bay Orange County, CA Watershed," Report of G. Fred Lee & Associates, El Macero, CA (2001c).
> http://www.members.aol.com/apple27298/295-319-tox-paper.pdf

At the time of the studies a decade ago, the manufacturers of pyrethroid-based pesticides and the USEPA Office of Pesticide Programs believed that the pyrethroid-based pesticides were bound so tightly to soils that they would not be toxic to aquatic life. The pyrethroid-based pesticides were not on the list of chemicals of potential concern in water quality investigations even though more than 25,000 pounds (ai) of pyrethroid-based pesticides were being used in the Upper Newport Bay watershed each year. Now, some 10 years later, through studies such as those of Weston and his associates at the University of California Berkeley, it is beginning to be realized that pyrethroid-based pesticides are a common cause of aquatic life toxicity in urban and some agricultural stormwater runoff. As mentioned above, these issues have been discussed in several issues of Lee's Stormwater Newsletters including NL 8-1/2, 8-6, 9-3, 9-4, 9-6, 9-7, 9-8, 10-3, and 10-8. Those studies brought to light the fact that pyrethroid-based pesticides, which have been widely used in agriculture and more recently in urban areas, should be recognized as a cause of sediment toxicity by inclusion in the SWRCB staff's list of chemicals of concern.

The pyrethroid-based pesticides are just one type of unregulated or inadequately regulated chemical that can cause water quality impacts. As discussed in NL 7-3, 8-5, 9-3, and 10-7 under "unrecognized pollutants," of the millions of chemicals in commerce today only a very small number of chemicals of potential concern are regulated. These issues are discussed further in,

> Lee, G. F. and Jones-Lee, A., "Unrecognized Environmental Pollutants," In: Water Encyclopedia: Surface and Agricultural Water, Wiley, Hoboken, NJ, pp 371-373 (2005).
> http://www.members.aol.com/annejlee/WileyUnrecognizedPollutants.pdf

This situation highlights the need for water quality, and especially sediment quality, evaluations to be truly effects-based. The evaluations should not be distorted by incorporating the notoriously unreliable co-occurrence-based approaches as is now proposed by the SWRCB staff for developing SQOs.

Elevating Stature of Unreliable, Invalid Approaches

One of the insidious aspects of the use of the co-occurrence-based California Logistic Regression Model in the proposed SQO development is that this use, to some, gives the appearance of credibility to a demonstrably invalid methodology for evaluating sediment quality. Although it has been known since the Long and Morgan co-occurrence approach was developed in the early 1990s that it was technically invalid for application in sediment quality guidelines, it has been widely used by federal and state regulatory agencies and others because it provides a mechanical, low-effort use for readily measurable total chemical concentrations, and existing data. Others then blindly cite prior use as justification for continued use without facing the reality that it is not reliable.

In the July 2006 Scientific Steering Committee meeting, Ed Long (one of the originators of the co-occurrence-based approach for sediment quality evaluation) stated,

> *"My lingering concern is that, based on my experience with the values that I published, that despite any large-font, bold-print warnings against doing so, people will tend to use your single chemical values in a regulatory framework. I was aghast to find after I retired from NOAA and got into the reality of working with industrial clients, that there are state and federal judges in this country that are using my values as regulatory values on a single chemical basis."*
>
> *"In the publication I put out in 1995 I stated it very clearly in bold, … and it was summarily ignored."*

Despite such admonitions, some of the California Regional Water Boards and the SWRCB are using co-occurrence-based approaches/values to classify sediment quality and to designate impaired waterbodies, thereby ignoring the literature, basic principles of aquatic chemistry/toxicology, as well as Long's own statements of not using this approach in a regulatory program. An example is the SWRCB's 2006 Clean Water Act Section 305b report, "Water Quality Assessment of the Condition of California Coastal Waters and Wadeable Streams," October 2006 (available at, http://www.swrcb.ca.gov/swamp/docs/factsheets/305breport2006.pdf).

This issue is discussed in the complete comments on the deficiencies in the SQO development approach as presented by Lee and Jones-Lee (2007).

Stressor Identification

The staff report provided a section devoted to stressor identification in its report. That section is evidently part of the staff's guidance on SQO implementation; the stressor identification results are to be used to correct the errors associated with use of total concentration co-occurrence-based chemical information. While the staff report mentions that the co-occurrence-based approach (*California Logistic Regression Model Calculation)* should not be used to try to identify the cause of sediment toxicity or altered benthic organism assemblages, the staff's recommended approaches for identification of the stressor(s) states,

> *"F. Stressor Identification*
>
> *If sediments fail to meet the narrative SQOs in accordance with Section V and VI, a sequential approach is necessary to manage the sediment appropriately. The sequential approach consists of development and implementation of a work plan to seek confirmation and characterization of pollutant-related impacts, pollutant identification and source identification. The workplan shall be submitted to the Regional Board for approval. Stressor identification consists of the following studies:*
>
> *1. Confirmation and Characterization of Pollutant Related Impacts.*
>
> *Exceedance of the direct effects SQO at a site indicates that pollutants in the sediment are the cause but does not identify the specific pollutant responsible. The MLOE assessment establishes linkage to sediment pollutants; however, the lack of confounding factors (e.g., physical disturbance, non-pollutant constituents) should be confirmed. There are two generic stressors that are not related to toxic pollutants that may cause the narrative to be exceeded:*
>
> *2. Pollutant Identification*
>
> *Methods to help determine cause may be statistical, biological, chemical or a combination. Pollutant identification studies should be structured to address site specific conditions, and may be based upon the following:*
>
> *a. Statistical methods: Correlations between individual chemicals and biological endpoints (toxicity and benthic community)."*

This statistical approach is not valid for identification of the pollutant responsible for a biological effect such as sediment toxicity and/or altered benthic organism assemblages compared to the assemblages that should be present based on habitat characteristics. It is another manifestation of the invalid co-occurrence-based approaches in that it contrives to relate total concentrations of a chemical(s) to a biological response. As with sediment concentration/impact co-occurrence, it has long been well-established that the total concentration of a chemical cannot be relied upon for inferring or predicting impacts. A variety of factors influence a chemical's availability to, and hence impact on, organisms.

The statistical approach described in the staff report assumes that the concentration of a bioavailable form of a chemical is constant in a sediment; i.e., that the detoxifying chemicals that cause part (and possibly all) of a chemical to be non-toxic occur at constant composition in all samples of the sediment. This is highly unlikely. This approach contradicts the basic principles of aquatic chemistry. (See the discussion of basic aquatic chemistry in Jones-Lee and Lee's (2007) discussion of modeling of chemicals as pollutants that impair water quality.)

> Jones-Lee, A. and Lee, G. F., "Modeling Water Quality Impacts of Stormwater Runoff-Associated Pollutants," Report of G. Fred Lee & Associates, El Macero, CA, September (2007).
> http://www.members.aol.com/GFLEnviroQual/StormwaterWQModeling.pdf

Several of the university graduate-level aquatic chemistry texts such as Stumm and Morgan (latest edition) discuss the issues that need to be considered in reviewing the aquatic chemistry of chemicals in aquatic systems that influence the species composition of a chemical and therefore the relationship between the total concentration and the toxic forms. Dr. G. F. Lee taught graduate-level aquatic chemistry courses for more than 30 years at several major US universities. He has conducted several million dollars in research which has been published in several hundred professional papers and reports devoted to aquatic chemistry water quality issues. Dr. Lee had approximately 100 graduate students conduct their MS theses and PhD dissertations under his supervision. He pioneered in developing approaches that reveal and demonstrate the importance of incorporating aquatic chemistry into water quality evaluations through considering the thermodynamics and kinetics of the reactions that influence the chemical species composition and therefore its impact on aquatic life. In the early 1980s he developed the "Aquatic Chemistry Wheel" which diagrammatically represents the types of reactions that should be considered in determining the role of a chemical(s) in a water quality/sediment quality evaluation. This is discussed in Jones-Lee and Lee (2007) referenced above, and in a recent Newsletter. Lee and Jones-Lee (2002, 2004) discussed how chemical information should be used in a best professional judgment (BPJ) triad weight-of-evidence approach for sediment quality evaluation.

As discussed by Lee and Jones-Lee (2007) the other staff proposed approaches for stressor identification including *Gradient Analysis, Bioavailability, Spiking of Sediments for "Verification*" can also provide unreliable stressor identification.

Overall, except for the appropriate use of TIEs, the staff-recommended stressor identification presented in the staff report is flawed and can readily lead to incorrect assessments of the chemical(s) responsible for sediment quality impairment. Unreliable stressor identification can lead to large expenditures for misdirected and hence ineffective sediment "remediation" and source control.

The inadequate and unreliable incorporation of aquatic chemistry and aquatic toxicology into the SQO development and implementation approach seriously damages the credibility of the high-quality work that was done in developing SQOs based on biological effects (sediment toxicity and altered benthic organism assemblages).

Sediment Cleanup Objectives

The staff report contains a section providing guidance for establishing sediment cleanup objectives. As discussed by Lee and Jones-Lee (2007) the staff's suggested approaches for establishing sediment cleanup objectives *Correspondence with sediment chemistry. Correspondence with bioavailable pollutant concentration. Correspondence with tissue residue. and Literature review* are not reliable.

Inadequate Consideration of Implementation

Dr. Gary Wolff, chairperson and vice-chair of the SWRCB at the SWRCB hearing asked Shelia Vassey of the SWRCB Office of Chief Counsel responsible for working with

SWRCB staff in SQO development, whether information on implementation of the SQO into a regulatory program was a necessary component of the SQO development. Attorney Vassey confirmed that information on implementation of the SQO into a regulatory program is required. This means that the current SQO staff report should be considered to be a "work in progress" and should not be adopted by the SWRCB without detailed, properly reviewed, information on how the SQOs will be used in a regulatory program. This, coupled with the fact that the staff's proposed implementation section on Stressor Identification and Sediment Cleanup Objective is largely technically invalid, makes the current SQOs inadequate for adoption by the SWRCB.

Fundamental to the development of technically valid regulations is that they be based on a scientifically sound foundation, and that a clear and reliable path for implementation be provided. Regulatory programs that are based on pseudoscience approaches such as that proposed to the SWRCB for SQO development, can only led to technically invalid assessments of the approach that should be followed to manage water quality problems (see discussion by Lee and Jones-Lee, 2002).

There are numerous examples of the problems caused by basing the initial phase of a regulatory program on technically invalid approaches. For example, the Los Angeles Regional Water Quality Control Board, with the concurrence of the SWRCB and the USEPA Region 9, adopted a $42-million Santa Monica Bay Restoration Program to control lead in urban stormwater runoff to the Bay because of the finding that the lead concentration in Bay sediment exceeded a co-occurrence-based so-called "sediment quality guideline." Lee and Jones-Lee (2004), and Lee (1998, 2005) pointed out that the Santa Monica Bay Restoration Plan corrective action program is based on a technically invalid approach, and that detailed studies should be conducted to determine if the lead that exceeds the co-occurrence-based guideline is, in fact, toxic or if it is inert as would be expected based on its aqueous environmental chemistry. The regulatory agencies at the regional, state, and federal levels all decided, without further study, that the lead must be toxic because it exceeded sediment quality guidelines (co-occurrence-based). Studies conducted after the regulatory program was adopted, however, showed that the lead in the Santa Monica Bay sediments was, as expected based on its aquatic chemistry, not toxic. Nonetheless, even with that new site-specific information documenting the lack of toxicity of the lead that exceeded the co-occurrence-based guideline, the regulatory agencies have not changed the Bay's restoration program. The public in the Santa Monica Bay watershed are trapped into a technically invalid Bay "restoration" program to correct a "problem" that does not exist. Clearly the "implementation phase" does not correct for faulty SQOs.

Such misdirection of the limited resources available can be expected to continue if the SWRCB adopts the staff's recommended SQO development approach. Any identification of a water quality or sediment quality "problem," especially one based in any way on total concentrations or co-occurrence-based approaches, should be followed by properly conducted, true chemistry and toxicity studies to reliably determine if a real water quality impairment such as toxicity exists, the cause of the impairment (not simply what "co-occurs" with measured concentrations) as well as the role of aquatic nutrient-caused sediment toxicity (such as episodic low-DO) in affecting the aquatic life resources of the waterbody. Based on past experience, the statements in the staff report regarding the need to do follow-up stressor identification studies can be expected to be ignored, as long as the regional boards continue to follow technically invalid approaches for developing and using sediment quality evaluation and remediation approaches.

Having unreliable scientific foundation for the SQOs can lead to endless controversy between regional boards' staff members and the regulated community over the chemical(s) responsible for the toxicity, etc. This can lead to the regional board staff members' becoming disillusioned with the attempts to regulate sediment quality using the approach currently recommended. Inappropriate regulatory approaches can ultimately result in the regulated community's having to take the issues to the court to find remedy from implementation of their unreliable results. Using the SWRCB database used to develop the SQOs, it can be demonstrated that the chemical concentration component of the SQO can be in error and mislead the identification of chemicals as causing impaired sediment quality.

One of the most vulnerable groups that will be subject to inappropriate application of the SWRCB staff's proposed SQO-based sediment quality evaluation is the urban stormwater runoff water quality managers and the public they represent. Urban stormwater runoff from streets and highways has long been known to contain a variety of particulate heavy metals and other chemicals that will accumulate in receiving water sediments. While it has been well-established that such metals are largely non-toxic and do not convert to toxic forms under most receiving water conditions, the total concentrations of the metals will likely continue to exceed co-occurrence-based sediment quality guidelines, including those proposed for the SQO development approach. (These issues have been extensively discussed in Stormwater Newsletters available on the Lee and Jones-Lee website.)

This situation illustrates the fallacy and misleading quality of the co-occurrence-based approach; while the heavy metals commonly considered in stormwater runoff are largely in non-toxic forms, the sediments in their receiving waters will likely exhibit toxicity due to chemicals (such as pesticides, ammonia, etc.) that are not included in the SWRCB staff's list of chemicals that they propose to consider in evaluating sediment toxicity. Further, the aquatic organism assemblages in areas where the runoff-derived heavy metals and other particulate potential pollutants settle can be found to be altered due to physical disturbance of the sediments that causes rapid-acting oxygen-demanding substances (derived from processes influenced by nutrient inputs) to periodically disrupt the normal benthic organism assemblages. Under the proposed, technically invalid approach for incorporating chemical concentration information in sediment quality evaluation, the sediments impacted by urban stormwater runoff would be classified, albeit incorrectly, as highly impacted by heavy metals. While the staff proposed that such errors in sediment classification could be corrected though the use of one or more of the proposed approaches for stressor identification, such as statistical correlation, as discussed above, those approaches would not likely correctly evaluate that situation or correct the misdiagnosis.

Overall, the staff's proposed approach for SQO development can trap the public and private entities into spending large amounts of money only to find they are chasing phantom sediment quality "problems." Members of the Scientific Advisory Panel repeatedly stated that the total chemical concentration co-occurrence-based SQOs should not be used in a regulatory program. Yet clearly the co-occurrence-based SQO is a key component of the proposed sediment quality evaluation approach and, therefore, likely a component of the regulatory program that will evolve from the staff's proposed approach for sediment quality evaluation.

One of key implementation issues is the need to incorporate a reliable TIE procedure to identify the cause of true sediment toxicity. As discussed by Jones-Lee and Lee (2007), while there may be no "cookbook" TIEs that can be reliably used by those with limited understanding and experience in the aquatic chemistry of sediments as it relates to sediment toxicity, it is possible for those with this knowledge to conduct TIEs to potentially identify causes of sediment toxicity. This situation points to the need to focus the initial sediment quality evaluation on biological effects (toxicity and benthic organism assemblages) without trying to force-fit total chemical concentration information into the evaluation.

Repeatedly during the course of SQO development, G. F. Lee and others urged the SWRCB staff to fully develop the implementation approach for the use of the SQO-based sediment quality evaluation. Without development and reliable evaluation of the implementation approach, the full significance of the fundamental technical deficiencies with the staff's recommended approach cannot be appreciated.

In order to understand the implementation problems with the staff's proposed SQO develop approach, G. F. Lee suggested to staff members that they needed to develop several example situations, and step through the implementation approach through to making decisions on the need for sediment remediation/source control. While the staff did not conduct this type of evaluation, it would be prudent for the SWRCB to require that this type of exercise be conducted. Even if the staff's proposed SQO development approach were free (or becomes free) of inappropriate chemical components, the SWRCB should not adopt it until a detailed, technically valid, implementation approach has been developed and demonstrated. Involving the regional board staff that will have to try to implement this approach is key to evaluating the implementability of the proposed SQO-based sediment quality evaluation.

Additional References

Jones-Lee, A. and Lee, G. F., "Modeling Water Quality Impacts of Stormwater Runoff-Associated Pollutants," Report of G. Fred Lee & Associates, El Macero, CA, September (2007). http://www.members.aol.com/GFLEnviroQual/StormwaterWQModeling.pdf

Lee, G. F., "Comments on 'The Santa Monica Bay Restoration Plan, September 1994' for Stormwater Runoff Water Quality Management," Submitted to Santa Monica Bay Restoration Project, Report of G. Fred Lee & Associates, El Macero, CA, February (1995).

Lee, G. F., "Santa Monica Bay Stormwater Runoff Water Quality Impact Research Needs," Comments submitted to J. Dorsey, Chair, Santa Monica Bay Restoration Project Technical Advisory Committee, G. Fred Lee & Associates, El Macero, CA, June (1998).

Lee, G. F. and Jones-Lee, A., "Comments on The Santa Monica Bay Restoration Plan, April 1994," Submitted to Santa Monica Bay Restoration Project by G. Fred Lee & Associates, El Macero, CA, June (1994).

Lee, G. F. and Jones-Lee, A., "Organochlorine Pesticide, PCB and Dioxin/Furan Excessive Bioaccumulation Management Guidance," California Water Institute Report TP 02-06 to the California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 170 pp, California State University Fresno, Fresno, CA, December (2002). http://www.gfredlee.com/OClTMDLRpt12-11-02.pdf

Lee, G. F. and Jones-Lee, A., "Appropriate Incorporation of Chemical Information in a Best Professional Judgment 'Triad' Weight of Evidence Evaluation of Sediment Quality," Presented at the 2002 Fifth International Conference on Sediment Quality Assessment (SQA5), In: Munawar, M. (Ed.), *Aquatic Ecosystem Health and Management* 7(3):351-356 (2004). http://www.gfredlee.com/BPJWOEpaper-pdf

Lee, G. F., and Jones-Lee, A., "Comments on the SWRCB Staff's Proposed Approach for Developing Sediment Quality Objectives for Enclosed Bays and Estuaries of California," Submitted to State Water Resources Control Board, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, November 30 (2007).
http://www. members.aol.com/GFLEnviroQual/SedQualObj11-07.pdf