State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #3:
Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

By

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Memorandum

5 October 2009

To: Ms. Wendy Phillips; Chief, Groundwater Cleanup and Permitting Section, CA Regional Water Quality Control Board

From: Bob Arnold

Subject: Review of Regional Board Staff Technical Memorandum #3: *Pathogens in wastewaters that are in hydraulic connection with beaches represent a source of impairment for water contact recreation.*

I will first cover the technical issues delineated for review in an attachment to your email dated 19 September.

1. The interpretation of four technical documents selected to support Technical Memorandum #3—emphasis on the Haile documents (1996, 1999) and the 1983 EPA criteria for recreational risk in marine water.

- **An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay**—Haile et al., 1996. This is a detailed and convincing piece of research that illustrates the type of health effects and relative risk associated with bathing on Santa Monica beach sites that are proximate to discharge points for overland runoff. Although the document does not bear directly on situations in which the presumed source of contamination is the proximate groundwater, the study shows very clearly that runoff containing contaminants of fecal origin produces both elevated concentrations of fecal indicators and higher incidence of waterborne disease among those bathing in impacted waters. The study also establishes the relevance of enterococcus concentration as a useful indicator and the usefulness of the disease parameters (symptoms such as gastrointestinal and respiratory problems, rash and so forth) eventually selected for use in Technical Memorandum #3.
- **Haile, R.W., Witte, J.S., Gold, M. *et al.* 1999. The health effects of swimming in ocean water contaminated by storm drain runoff.** ***Epidemiology 10*****: 355-363.** This is apparently the peer reviewed form of the same study in Santa Monica Bay. The fact that the work withstood peer review for archival publication is noteworthy and adds to the credibility of the study and interpretation of findings. The authors note that their findings may have widespread relevance since the indicators of fecal contamination are similar to those at a great number of other

beaches. They also indicate that incremental risk upon exposure to waters containing those levels of the indicator organisms is probably significant based on the results of their work (incremental risk on the order of >1 per 100 exposed). Finally, they make the point that the standards for fecal indicators in marine recreational areas appear to be relevant since exposure at lower levels had no statistically significant health outcome. The article did not stress use of enterococcus results in predicting incidence of disease, but relied on coliform measurements and direct measurement of virus.

- **Gold, M. 1994. What are the health risks of swimming in Santa Monica Bay: an examination of the issues surrounding the public health debate. Ph.D. dissertation, UCLA.** The dissertation largely set the stage for the subsequent epidemiological study (above). The major finding related to high concentrations of fecal indicators including enteric viruses across the bay. There was comment about higher than acceptable levels of indicator organisms in Malibu Bay, but that was not the primary focus of the work. The importance of the work was that it was done competently and that it provoked the subsequent study.
- **Cabelli, V.J. 1983. Health effects criterin for marine recreational waters. EPA-600/1-80-031.** This is an exceptional piece of work, as evidenced in part by the fact that we are still reading it. The document uses data from a variety of studies in the United States and Egypt to establish the methodologies for epidemiological work of this kind, selection of disease indicators, and justification for use of specific indicator organisms. The fact that findings are appropriate to several locations attests to their utility. Interestingly, the response of Egyptians to enterococci-indicated exposure was reduced, but that of visitors was not, in the Alexandria study. The current standards for enterococci in seawater can be justified on the basis of the study results, since significant swimming-related disease incidence was provided by exposure to waters containing 10-100 enterococci per 100 mL. In fact, the swimming related incidence of HCGI illness was about double that of the endemic rate among non swimmers when waters contained ~50 enterococci per 100 mL. The author concluded that enterococci have a survival behavior more similar to the infectious agents that do other indicator organisms tested. The linear relationship suggested between swimming related incidence and log transformed enterococci data seems justified based on the studies reviewed.

2. Discussion of correlation coefficients among annual frequency distributions for enterococcus MPN data at Malibu beaches.

The contention here is that the correlations among annual frequency distributions provides evidence of annual similarities at each beach for which data are provided and thus an indication that fluctuation in enterococcus numbers is probably the

result of some regular pattern of events as opposed to random odd events like direct contamination by bathers, etc.

I am unable to provide a convincing statistical analysis as part of this review. Nevertheless, I feel that this is a weak argument, primarily because the statement does not seem to rest on statistically valid hypothesis testing. That is, do the calculated correlation coefficients in fact justify the conclusion that the distribution of values observed is derived from the same population of actual values each year—that the distribution of enterococcus MPNs does not change from year to year. Even if that distribution of concentrations is time invariant (as suggested) it seems that the population of enterococcus concentrations in the waters tested may take on a distribution of this sort for any number of reasons, including a somewhat randomly generated source of contamination due to bathing and so forth. It seems difficult to justify the elimination of such an explanation based on the data provided.

As a minor point, the text on p. T3-15 indicates that correlation coefficients for MPN-dependent frequencies at the Surfrider Beach ranged from 0.82-0.98. The values provided in the Appendix T3-B table indicate that the correlation coefficient varies from 0.72-0.98. For those not statistically well informed (including me), the method of calculation of the correlation coefficient might be provided.

3. Validity of conclusion that water quality during dry weather at Surfrider Beach, Malibu Colony Beach, Malibu Pier Beach, Carbon Beach and Marie Canyon persistently fails to meet water quality objectives. This statement is well supported by the enterococcus data provided.

4. Conclusions regarding the groundwater origin of microbial contamination at Malibu Lagoon and beaches. Since this is the crux of the technical paper, it is well to consider the evidence presented in total. The staff report and references therein establish the validity of enterococcus measurements as an indicator of fecal contamination that provides a potential source of health risk. There is no reason to question the validity of the enterococcus standards for protection of public health. That is, consistent violations of the marine standard for recreational use will likely produce a significant disease increase among bathers. Consequently, the waters off Malibu, which do not meet standards, probably present a health-related problem. There are high concentrations of bacterial indicators of fecal contamination in the ground waters of heavily populated and commercial sections of the Malibu community. Furthermore, groundwater contaminants appear to add contamination to the enterococcus levels in the Malibu Lagoon at the MCW-1 sampling station, downstream from the Malibu Civic Center area. Finally, there are somewhat speculative, but increasingly accepted, mechanisms for the transport of bacteria and viruses from proximate ground waters, through near-surface beach sands and into the surf zone. Observations regarding transport through the beach front were derived from

studies outside the Malibu area, but in southern California, from multiple lines of experimentation. These have been described in peer-reviewed archival journals, adding to their credibility.

No other credible sources of near-shore marine pollution are described in the technical report. If land surface runoff is a possibility, it seems unlikely that the effects would be so general or unmanageable during summer months, particularly since the period 2005-2008—the period of record for the measurements provided—was apparently an unusually dry period for the region. In any case, rainfall would likely increase the efflux of groundwater bacteria into the surf zone as well as increasing the rate of surface runoff.

Considering the entire argument presented and supporting information provided, the staff has made an adequate case for improving the microbial quality (indicators of fecal contamination) in Malibu ground water in order to improve the water quality in the nearshore marine area off the Malibu coastline in order to reduce associated threats to human health.

Additional comments. On page T3-2, it is indicated that several changes were made to the technical memorandum based on an Early Technical Review. These changes include generation of statistical support for conclusions, recommendations regarding additional supporting studies, emphasis on the hydrological and microbiological complexity of the subsurface intertidal region and verification of the relationship between human illness due to marine recreational activities and coastal OWDSs. In my opinion, statistically based inference remains largely missing from the document. The treatment of incremental risk at Surfrider Beach (Table 6) is apparently based on results reported in the 1983 EPA report and published information regarding bathing near stormwater discharge point in Santa Monica Bay. However, the connection here is not well developed and results of those studies that contribute to the staff position should be clearly laid out.

At this point, I feel that the case is well made for construction of sewerage in the Malibu area, but I was convinced in part by information from the supporting documents that might be included directly in the technical memorandum. The epidemiological case in particular requires supporting information. In my opinion, further studies are not required to justify Board action, so that recommendations specific to such studies are unnecessary. The complexity of the hydrological conditions, microbiological transport mechanism and so forth are sufficiently plain.

The technical memorandum (#3) is clearly written and easy to understand. The staff has done its work very well.

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #4:
Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life

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Memorandum

5 September 2009

To: Ms. Wendy Phillips; Chief, Groundwater Cleanup and Permitting Section, CA Regional Water Quality Control Board

From: Bob Arnold

Subject: Review of Regional Board Staff Technical Memorandum #4. Nitrogen loads from wastewater flowing into Malibu Lagoon.

I will first address the technical issues that were identified for peer review in attachments to your email note dated 28 August. Issues are taken in the order that you suggested.

1. The approach used to inventory wastewater discharges in the Malibu Civic Area (255,000 gallons per day). The flows inventoried fell into the following four classes:

(i) Large, permitted commercial enterprises with Waste Discharge Requirements (WDRs). A subset of these sources provide advanced wastewater treatment (undefined in the report) prior to effluent discharge. The other subset provides only septic treatment prior to discharge. For these sources there is a record of both wastewater volume generated and total nitrogen concentration (Kjeldahl, nitrate, nitrite) discharged to the environment.

(ii) Smaller permitted commercial sources, which also produced a record of wastewater volumes, but were not required to analyze for nitrogen forms in treated effluent. These sources seldom if ever provided advanced treatment prior to discharge.

(iii) Small businesses that were not regulated by the state and for which there was no official record of wastewater volume generated or probable total nitrogen concentration in treated waste.

(iv) Private residences, for which there was no record of wastewater flow or effluent quality.

Thus a complete inventory of the required wastewater volume generated required the authors to find or otherwise estimate the following information, generally from the tertiary sanitary engineering literature and/or the assumptions noted below:

- For dischargers in class (i) the volume flows and nitrogen levels provided all information necessary to calculate flows and respective nitrogen loads at points of discharge.
- For smaller, permitted commercial sources (class (ii), above) flow data were available, but nitrogen levels would depend on an assumption (see below) regarding total nitrogen level.
- Small business flows were estimated using information derived by staff regarding on-site population and business activity. Detailed information/methods for these steps are not described in Technical Memorandum No. 4.

- Flows from residences were estimated based on 100 gallons per day per residence bathroom.

There is very little to criticize in this approach to volume estimation. A few details or perhaps examples of the process by which flows were assigned to small, unpermitted businesses might provide a feel for this work. However, the magnitude of flow generated by this class of dischargers must have been fairly small and probably insignificant ---- making the quality of assumptions used or accuracy of related estimates almost irrelevant within the context of the overall exercise. To make this plain, it would be useful to organize the eventual flow information by class of discharger within each of the geographical sectors within the study area. It also seems possible that water use data, if uniformly available for small businesses could have been used to generate estimates of wastewater flows. It seems very unlikely that such an alternative approach, however, would have led to materially different results at the conclusion of the nitrogen analysis. In a sense, assumptions regarding domestic flows are the most critical, inasmuch as treated domestic wastewater is a major contributor to the eventual calculation of the nitrogen load to Malibu Lagoon. Again, water demand data might have been used to generate wastewater flow estimates.

In general, I am satisfied that no set of alternative (rational) assumptions would have materially improved the quality of the analysis to this point.

2. **Methods for calculating nitrogen load** contributions from individual OWDSs. Again relying on the four classes of dischargers within the Malibu Civic Area:

(i) Total nitrogen data were available for large, permitted commercial sources with WDRs. Again, there is no clear indication of which specific sources fell within this category in any of the summary tables, so that the efficiency of advanced wastewater treatment processes (unspecified) for nitrogen management cannot be determined from the Table 3 data.

(ii) It was assumed that the smaller, permitted, commercial sources produced an effluent that was similar to domestic effluent quality following septic treatment. The report indicates that some effort was undertaken to express effluent strength, including total nitrogen concentration as a function of the type of business practiced on site. Details and intermediate results from that work are not provided, however.

(iii) Site-specific information was used to anticipate total nitrogen concentration at unpermitted commercial facilities. Again, essentially no information is provided with which to illustrate the type of information collected, methodology for its conversion to nitrogen concentration or nitrogen load, and so forth.

(iv) The total nitrogen concentration in residential wastewater was estimated by assuming that the concentration of total nitrogen (as N) was a constant fraction (0.21) of the five-day biochemical oxygen demand. The correlation was taken from an exceptionally important sanitary engineering text and should be at least approximately correct.

I have the following reservations regarding the approach taken to estimation of nitrogen concentrations for the purpose of nitrogen load allocation at respective discharge points:

- Although the correlation between total nitrogen concentration and BOD_5 (0.21 mg/L as N per mg/L BOD_5 as O_2) may be accurate for domestic wastes, the justification for its use in this context is misleading. The authors contend that nitrogenous oxygen demand is a consistent contributor to BOD_5 (p. T4-4). In fact, the kinetics of biochemical oxygen demand may be dominated by carbonaceous oxygen demand over the first five days of the BOD measurement. This does not invalidate the approach taken, inasmuch as both total nitrogen and BOD_5 are useful indicators of the strength of a waste and are likely correlates in domestic wastewater. Since BOD_5 data were more broadly available than total nitrogen data, the method of estimation probably has merit. For those cases in which both BOD_5 and total nitrogen data are available, however, the authors should provide them --- to demonstrate the strength of the correlation.

- No attempt is made in the report to define "advanced" OWTS treatments. In the interest of defining the most significant sources of nitrogen load, the facilities that provide advanced treatment, the nature of the treatment provided and typical BOD_5 and total nitrogen removal efficiencies might be added to the report.

- The choice of BOD concentrations , absent data, and thus total nitrogen concentrations (21% of BOD_5) seems arbitrary:

Facility Type	BOD_5 (mg/L)	TN (mg/L as N)
Shopping centers with restaurants	800	160*
Small Offices	220	40
Schools		45-75**

* reduced to 80 mg/L to reflect frequent pumping of septic tanks at Malibu Country Mart.

** dependent on soil type and groundwater separation.

Nevertheless, any other assignment of values would be equally arbitrary and probably no more reasonable than the values chosen for the nitrogen loading models. At the end of the exercise, however, it isn't possible to determine which facilities were included in each class (large commercial, small commercial without water quality data, etc.) so it is not possible to reproduce the spreadsheet calculations from the data provided. Given that reviewers will be incapable of performing independent calculations, the authors might carry out their own sensitivity analysis------to determine which parameters are the primary determinants of the eventual nitrogen load estimates. A good candidate for sensitivity analysis, for example, is the 80 mg/L (as N) total nitrogen concentration that is assumed for some of the commercial sources. Were this value actually 40 mg/L, would the outcome of the analysis change dramatically? The spreadsheet approach is well suited to make such repetitive calculations, and the results could be illuminating. This comment applies to several of the assumed parametric values.

- Various data elements are missing from table 1, page T4-20. Is there a reason for this?

- The apparent importance of residential contributions to regional nitrogen loading suggests that it may be important to distinguish between reported literature values (20, 45, 85 mg/L as N)---to make a selection that is appropriate for Malibu. If local data exist with which to make this distinction, they should be cited in the text. I failed to find data related to nitrogen levels in septic tank effluents, although staff suggested that measurements in septic tank effluent had been made. Absent data, the sensitivity of spreadsheet results to the assumed value should be determined.

- Finally, is it possible that seasonal effects are of importance to average nitrogen load estimation in the study area? No mention was made of variation in population or commercial activity in the Malibu study area. However, since estimated groundwater travel times to Malibu were sometimes on the order of decades, it is conceivable that winter occupancy rates and seasonal commerce might lower annual average nitrogen loading rates in a way that also lowers the average nitrogen load at the Malibu Lagoon. Since neither this study nor previous studies seem to have considered seasonal effects, it seems likely that they are unimportant in this context.

3. Division of the Malibu Civic Center area in hydrologic zones. There is clear justification for division of the study area into hydrologic zones. This seems like a very good way to account for substantial differences in fractional contributions of wastewaters to the Malibu Lagoon that arise from consideration of topography, water table contours and groundwater travel times to the lagoon. The breadth of both fractional contributions and estimates of groundwater travel times is a little unnerving. That is, travel times are held to vary from up to 50 years, for at least a portion of the wastewater discharged in sector I to less than one year for a portion of the flow that originates in sector II. The estimated fractions of discharged wastewater that reach the Malibu Lagoon range from 1% (Winter Canyon, main area sector IV, Sector V) to 95% (sector II much of sector III). The approach is sound, in my opinion, and potentially allows planners and engineers to discriminate geographically in making decisions regarding the importance of new sewerage to the quality of water in the Malibu Lagoon. That is, based on nitrogen considerations alone, it seems probable that new construction would be best deployed in sectors II, III and part of IV. The effects of that construction on lagoon water quality should be relatively rapid due to the short, estimated travel times. The staff's own spreadsheet model can be used to estimate fractional reductions in annual nitrogen load to Malibu Lagoon as consequence of several possible sewerage configurations. Staged construction and water quality response in the lagoon could then be used to avoid unnecessary extension of the sewage system.

I offer just a few comments in this area--- use of hydrological sectors, etc:

- Since water table contours are not provided in the report, readers are obliged to accept staff's opinion on gradients and groundwater flow directions. A contour map would undoubtedly lead those reviewing the document to the same conclusion that was reached by staff and would better ground the very significant assumptions about flow routing and

contribution to Malibu Lagoon that are presented in the document. Such a contour map should be developed and included in the report if it is practical to do so.

- Where the selection of flow contribution by sector or sub-sector has an element of uncertainty, staff should examine the sensitivity of their general findings to the fraction adopted. The spreadsheet solution should make such an exercise accessible, and the results would likely show that staff findings are robust with respect to selection of sector-dependent factors governing respective fractions of on-site discharges that reach the lagoon.

- Judgment regarding the fate of nitrogen during on-site treatment and subsequent transport seems arbitrary. While estimated nitrogen losses may have been conservatively high, contributing to the strength of the staff's eventual findings and recommendations, it would be preferable to cite local data for the loss of total nitrogen during on-site treatment, and the discussion of nitrogen fate and transport following discharge is inadequate. That discussion makes no distinction between ammonium ion absorption, which is both efficient and fast on soil particles, and nitrification/de-nitrification reactions, which can lower the concentrations of available nitrogen forms and dramatically affect nitrogen transport in the subsurface. Furthermore, the availability of molecular oxygen in groundwaters affected by on-site discharges deserves attention since oxygen is required for nitrification. Finally, staff might comment on the form in which nitrogen is present in the Malibu Lagoon since this bears on the forms in which nitrogen is transferred from on-site disposal locations.

4. Model adjustment using new nitrogen load factors. I have nothing to say about the use of updated nitrogen load factors to adjust model results. This activity seems well justified and takes advantage of previous modeling work.

5. Other comments. I could make about a dozen grammatical suggestions but have not since this lies outside the scope of my review. I can send a marked up electronic version of the draft technical memorandum if you like.

In the end, I think that none of the comments offered here will materially alter the results of staff's analysis. Sensitivity analysis can be better used to show that analytical results are in fact robust with respect to tributary assumptions. Staff is well positioned to use their spreadsheet model for that purpose.

Although it goes beyond the limits of my review, I would like to know how much 6 lbs/day of nitrogen addition to the lagoon is likely to increase available nitrogen levels in Malibu Lagoon. To that end, what would be the incremental change in total nitrogen concentration in effluent from the Malibu Creek due to 6 lbs/day (as N) of supplemental nitrogen under some sort of critical flow condition?

Staff's analysis suggests that parts of the study area might be excluded from a sewer construction program since their collective on-site discharge contributes little or nothing to nitrogen levels in Malibu Lagoon. Staged construction would allow regulators to determine the effects of

sewerage in areas that are the likeliest source of anthropogenic nitrogen in the lagoon, before extending sewer construction into the other geographic sectors of the study area.

In summary, staff's work is very well done. No set of alternative assumptions is likely to affect the general findings of the report. Sensitivity analysis could be used to demonstrate that point.