Scientific Peer Review of the Scientific and Technical Basis for The San Francisco Bay Beaches Bacteria Total Maximum Daily Load Staff Report and Proposed Basin Plan Amendment

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This report has been prepared in response to a request for scientific peer review of the staff report and proposed basin plan amendment for the San Francisco Bay beaches bacteria total maximum daily load (TMDL), as outlined in the October 2, 2015, letter addressed to me from Water Resource Control Engineer Janet B. O'Hara of the San Francisco Bay Regional Water Quality Control Board. The review is based on the 4 enclosures (Attachments A to D) provided with that letter; I am not personally familiar with the beaches included. Attachment A was the original request letter from Ms. O'Hara to Dr. Gerald Bowes, Manager of the Cal/EPA Scientific Peer review Program, dated July 30, 2015, which itself includes 3 attachments (1 to 3). Among these, Attachment 2, entitled "Description of Scientific Conclusions to Be Addressed by Peer Reviewers", serves as the basis for the organization of this report.

Some general background information also influenced this review. Several of these points are summarized here because of their relevance to the issues discussed below.

Development of Total Maximum Daily Loads (TMDLs) for impaired waterbodies (those that do not meet water quality standards) is often a complex process, but this may be especially true for indicator bacteria. In part this is because the indicators themselves do not impair water quality; rather they are intended to indicate the presence of fecal contamination, which represents a potential human health risk for a variety of beneficial water uses, including contact (REC-1) and non-contact (REC-2) water recreation.

An ideal microbial indicator of fecal contamination would be present in high concentrations in feces and absent from other sources; would not grow in the environment, and would die-off there a little more slowly than pathogens and parasites of concern; would not be pathogenic itself; and would be easy and inexpensive to quantify (Vaccari et al., 2006). Of course, no such ideal indicators exist, but some groups, such as total coliforms, fecal coliforms, enterococci, and *Escherichia coli*, have been found to be useful for particular applications. Still, health risks associated with specific indicator concentrations are difficult to quantify, and might be expected to vary among waterbodies.

Total coliforms and fecal coliforms include lactose-fermenting strains of a number of different species of bacteria from genera in the family Enterobacteriaceae, such as *Escherichia*, *Enterobacter*, and *Klebsiella*. Some of these strains can survive for prolonged periods, or even grow, in the environment, and may be present in the absence of recent (or perhaps even historic) fecal contamination. Thus while the presence of total and fecal coliforms usually indicates recent fecal contamination, in some cases it may have no sanitary significance.

E. coli and enterococci, on the other hand, are less likely to be found at elevated concentrations in the absence of recent fecal contamination. However, since *E. coli* (like many of the other coliforms) and enterococci are present in the intestinal tract of many warm-blooded animals, their presence in the environment is not limited to areas with recent contamination by **human** fecal wastes. Fecal contamination from other mammals and birds does represent a potential health risk to humans, although usually a lesser one than from human feces. This further adds to the complexity of estimating the levels of indicator bacteria that might be acceptable in a particular situation for various beneficial water uses.

An additional complicating factor in the development of pathogen indicator TMDLs is that in addition to some of the factors that influence the concentrations of other pollutants (e.g., dilution, sedimentation, sorption), bacteria may die or grow in the environment. These "reaction" terms may be especially hard to capture as part of a mathematical modeling effort, and can add a high degree of uncertainty.

Further, modeling of waters within the Bay also may be more difficult than would be the case in a river. This is due to the complexity of the water movement, which is potentially in three dimensions, whereas movement in a river often can be approximated as one-dimensional and one-directional.

Nature of the Water Quality Problem

1. Pathogenic indicator bacteria concentrations exceed the Bacteria Water Quality Objectives in the water column of each the listed beaches.

Review focus: Staff Report Chapter 4: Water Quality Standards and Chapter 5: Beach Water Quality Data

REC-1 and REC-2 are designated beneficial uses of the water at the 9 studied beaches. Since the REC-1 water quality objectives are more stringent, meeting them would also meet the REC-2 objectives. The present objectives as indicated in Chapter 4 are based on three indicator groups: total coliforms, fecal coliforms, and enterococci. The numeric values include objectives for both the geometric mean or median (depending on the indicator group) and the 90th percentile or maximum count.

Thus there were 6 objectives, two for each of the 3 indicator groups. One ambiguity is whether the median (indicated in Table 4.2) or the geometric mean (indicated in tables in Chapter 5) was used for total coliforms. (This is not critical to the results of the analysis, but should be clarified.) Waters are considered impaired if more than 10% of the samples showed counts greater than one or more of the 6 objectives.

The monitoring results presented in Chapter 5 are drawn from a number of sources and in most cases represent multiple years of sampling on a regular basis (range 144-593 samples per site, with two sites at some of the beaches). Fecal coliforms are not included, but *E. coli*, which are generally considered a subgroup of the fecal coliforms that is more specific to fecal contamination, were included and compared to the fecal coliform objective. This is a reasonable and useful comparison to make, although it could in some cases underestimate the number of exceedances of the fecal coliform water quality objectives.

All 9 beaches failed to meet at least one of the bacteria water quality objectives. Thus the waters are impaired, and the nature of the problem is clearly established.

Desired Target Conditions

2. The desired numeric target represents conditions supportive of the Bacteria Water Quality Objectives and the beneficial use of water contact recreation (REC-1).

Review focus: Staff Report Chapter 6: Numeric Targets

The proposed numeric targets will be a geometric mean and a single sample maximum for enterococci, dropping the present limits for total and fecal coliforms. This is based on recommendations from the U.S. Environmental Protection Agency (USEPA). As reported in Chapter 6, it has been found that for marine waters, enterococci are a better indicator of fecal contamination for recreation uses than total or fecal coliforms. Thus USEPA now recommends using enterococci as the sole bacteria indicator for this purpose.

The numeric targets presented in Table 6.1 are based on a most probable number technique, rather than a colony forming unit method shown in Table 4.3 for the USEPA recommendation. The MPN is a valid test, and in some ways is more reliable than the methods that yield colony forming units. It is also the method presently being used, which thus adds consistency that would be lost if the method were to be changed.

Table 6.1 also differs slightly from Table 4.3 in that a single sample maximum is given, rather than a statistical threshold value. It would be helpful if the report provided the methodology used to arrive at the value in Table 6.1. Additionally, the USEPA provides two slightly different possible numeric values (geometric means of 30 vs. 35 cfu/100 mL), one providing a slightly lower human disease risk (3.2 vs. 3.6%). It is recommended that the report indicate why the slightly higher risk level was chosen for this application. This is not a criticism of this choice, which is identical to the existing enterococci objectives and may be justified on several grounds, only a request that the basis for it be explicitly stated.

To summarize, the switch to use of enterococci only, dropping the total and fecal coliform objectives, is scientifically justified, as is the use of the MPN procedure. However, it is recommended that the report comment on the choice of 35 instead of 30 MPN/100 mL for the target geometric mean, and indicate the procedure used to calculate the single sample maximum chosen.

Source Analysis

3. The analysis reasonably and accurately identifies the probable sources of pathogen indicator bacteria.

Review focus: Staff Report Chapter 7: Source Assessment

There are numerous potential sources of bacterial indicators at the beaches, as presented in detail in Chapter 7, with each beach having its own combination of major and minor contributors. Further, these sources change in relative importance based on season and environmental conditions, especially rainfall. Definitive identification of the multiple sources and their relative contributions to the total concentrations of enterococci would be prohibitively expensive, even if it were technologically feasible (which is not certain). Instead the report evaluates the data available, and uses logic to determine the most likely sources in each situation.

While it is recognized that there is uncertainty in these determinations, it appears to make sense to proceed with implementation based on this best available information, rather than expend additional resources prior to implementation. Further, this uncertainty will be addressed by evaluating progress and making changes if the need arises.

TMDL, Loading Capacity, and Allocations, and Margin of Safety

4. The concentration-based TMDLs are a reasonable loading capacity for San Francisco Bay beaches and will likely be supportive of the Bacteria Water Quality Objective.

Review focus: Staff Report Chapter 8: TMDL and Pollutant Allocations

Although water quality objectives are usually concentration based (mass or number per volume), total maximum daily loads (TMDLs) are normally load based (mass or number per day), as their name indicates. Typically a mathematical model is used to determine the concentrations that will result at specific waterbody locations from wasteloads and loads contributed by the various point and non-point sources, taking into account dilution as well as other factors that might affect water concentrations (e.g., for chemical contaminants: biotransformation, sorption, volatilization, sedimentation, photolysis; e.g., for indicator bacteria: predation, die-off, growth, sedimentation, sorption). The loads from the various sources are then reduced so that the allocations result in achieving the TMDL and meeting the standard. As indicated above in my introduction, this is particularly difficult to do for indicator organisms compared to some other contaminants, and for San Francisco Bay compared to a stream flowing in one direction.

In recognition of these difficulties, the proposed TMDL has taken a different approach. It sets certain controllable wasteload (sanitary sewer collection systems) and load (vessels) allocations to 0, as these discharges are prohibited under current regulations. Other sources (urban runoff, pets, and wildlife) are limited to the TMDL concentration itself, with no allowance for dilution or other reduction factors. Since the sources themselves will meet the TMDL, there is no need for an additional margin of safety, nor for separate consideration of critical conditions.

Overall, this argument is compelling. It reduces many of the large uncertainties that would be introduced by a modeling approach, and would seem to be highly protective of water quality and the designated beneficial uses. In fact, the only way that the water quality standard could be exceeded would be if the enterococci indicator organisms grew after entering the bay.

On the other hand, an argument might be made that the TMDL is too stringent, requiring unnecessarily low levels of enterococci in urban runoff, for example. Supporters of this viewpoint might point to dilution and die-away as mechanisms that would allow achievement of the water quality standards even at higher loadings. However, the models to support such an argument, including an appropriate margin of safety, do not appear to exist, and there can be concern that during critical periods the water at the beaches may consist almost entirely of urban runoff. Thus the proposed approach appears justified.

In Table 8.2, footnote "e" states that, "Wildlife is not believed to be a readily controllable source of bacteria …." However, geese and some other wildlife may be controllable (e.g., Section 10.1.5, and Basin Plan Amendment Table 7.2.5-3, footnote "c"), so that some expansion upon this comment may be needed.

Linkage Analysis

5. The Staff Report provides a reasonable description of the relationship between the desired target conditions and impairment to beneficial uses of water.

Review focus: Staff Report Chapter 9: Linkage between Water Quality Targets and Pollutant Sources

Chapter 9, in combination with the previous chapters, establishes the linkage between the water quality target and the indicator bacteria sources. However, the risk of illness given, based on the US EPA (1986) citation, is lower than the risks given in Table 4.3, which is based on a different USEPA (2012) citation. It would be helpful to explain the reason for this difference.

Implementation Plan

6. The implementation plan will reasonably ensure progress towards attaining water quality standards and supporting recreational beneficial uses.

Review focus: Staff Report Chapter 10: Implementation Plans and Monitoring

The implementation plan described in Chapter 10 would appear to address many of the relevant issues. It is likely that it will lead to progress in attaining the water quality standards. Further, it includes monitoring and an adaptive strategy so that changes can be made if the standards are not met according to the timetable provided.

Other Issues

A few apparent typos were noted. Copies of scanned pages with proposed edits are attached to help in eliminating these.

Summary

Development of a TMDL for indicator bacteria designed to protect San Francisco Bay beaches is a challenging task. Taken as a whole, the scientific portion of the reviewed Draft Staff Report and Basin Plan Amendment appear to be based upon sound scientific knowledge, methods, and practices, and to appropriately incorporate good professional judgment.

Additional Literature Cited

Vaccari, D.A., P.F. Strom, & J.E. Alleman. 2006. Environmental Biology for Engineers and Scientists. John Wiley & Sons, Inc., New York. 931 pp.