Proposed Approaches for Quantitative Analyses to Support Decisions on San Francisco Bay Nutrient Assessment Framework Classification
May 19, 2014 Draft

Context: The February 2014 Technical Team workshop summary proposes several types of indicators that may be included in the first phase of the SF Bay Nutrient Assessment Framework (AF) development. As assessment framework is intended to be iterative, these analyses consist of what can be conducted over the course of several months to inform the draft assessment framework, to be produced in fall 2014. One of these indicators, chlorophyll a (a measure of phytoplankton biomass), requires additional quantitative analyses to support decision-making on boundaries in the AF classification[1] scheme. The purpose of this document is to provide an overview of the proposed approach for conducting these analyses.

The approach to identifying classification boundaries for chlorophyll a is two-fold:

1) Calculations of projected increases in harmful algal blooms based on total phytoplankton biomass
2) Calculations of projected sub-optimal dissolved oxygen concentrations based on total phytoplankton biomass

1. Projected Increases in Harmful Algal Blooms (HAB) Based on Total Biomass (R. Kudela, UC Santa Cruz)

Overview: HAB occurrence is driven by a number of factors and may not be linked to only nutrient inputs per se. However, elevated nutrient inputs are associated with increased chlorophyll a biomass; increasing chlorophyll a is linked to increased frequency and duration of harmful algal blooms. As part of the SF Bay assessment, there are enough data for both total biomass (chlorophyll) and individual HAB species to begin exploring the relationship between HAB-forming organisms' abundances and total biomass and to project thresholds for HAB issues based total biomass. This analysis will also inform next steps in terms of additional data collection/monitoring, targeted studies, and data analysis geared to further exploring and refining those thresholds over time.

Specific approach is as follows:

1) For each HAB species that has been identified in SFB (at minimum, Pseudo-nitzschia, Alexandrium, Dinophysis, Microcystis) identify seasonal and interannual patterns from historical data
2) Identify the relationship (if any) between means/patterns from #1 and seasonal/interannual patterns of total chlorophyll
3) From the literature or similar datasets (i.e. Santa Cruz Wharf) create cell density thresholds where impacts would be of concern (i.e. cell density at which a potential HAB issue exists). This may include quantifying the probability when cell density exceeds toxin concentrations of concern.

[1] Classification here refers to the binning of SF Bay segments into categories from high to low ecological condition with respect to the indicator of interest. Segmentation refers to the identification of how these "classes" would differ with respect to the various sub-basins of the Bay.

4) Set total biomass thresholds at which HAB impacts (by species) may become apparent
5) Conduct the analysis based on the Jassby et al. (1997) spatial segmentation of the Bay, and for the temporal elements (90th percentile of spring and fall blooms, and mean conditions from April-November) for the USGS dataset. If necessary, treat the period after the opening of the South Bay Salt Ponds separately.

Outcomes: The goal is to identify biomass thresholds at which HAB issues may become apparent and also to put some confidence intervals on this assessment. For most species there is no consensus cell density threshold, so a range of values will likely be identified. Focus will be primarily on the high-biomass periods (spring, autumn), and will focus initially on known toxin producers (Pseudo-nitzschia, Alexandrium, Microcystis).

2. Projected Changes in Dissolved Oxygen in deep subtidal areas of San Francisco Bay Based on Total Phytoplankton Biomass (SFEI staff; J Cloern, USGS; M Stacey, UC Berkeley)

Overview: One potential pathway of impairment is the linkage of elevated phytoplankton biomass to sub-optimal dissolved oxygen concentrations (Senn et al. 2014). The purpose of this analysis is to quantify the chlorophyll a concentrations that could result in sub-optimal dissolved concentrations in SF Bay segments. Because this calculation is extremely complex, the Technical Team agreed to approach the analysis in a step-wise fashion. The first step would be to use a simplified approach with conservative assumptions. Additional steps would be added to make the calculations more realistic or representative of existing or future conditions if the preliminary results warranted further exploration. Two elements of this analysis include: 1) DO stoichiometric calculations, assuming no mixing (no exchange between subembayments, stratification for a sufficient period of time for the bloom to develop and for DO to be consumed), and 2) analyses of the frequency and duration of stratification that could occur and scenarios that could result in a change in that frequency or duration into the future. During the first phase, stratification analyses will focus on South Bay in the summer, since this is the location that would most likely result in a problem.

Specific Approach for Stoichiometric Calculations:
Based only on stoichiometry (no time/kinetics, no mixing), for a given bloom volume and biomass concentration, what would the final dissolved oxygen concentration be in the bottom layer if all organic carbon produced during the bloom was degraded? Assume basic stoichiometry:

$CH_2O + O_2 \rightarrow CO_2 + H_2O$,

with CH_2O serving as simplified algal biomass and C:chl ~ 35 (based on Cloern et al. 1995)

1) Consider a range of bloom Volumes (production volume, V_p) based on bathymetry data for each subembayment (plots in Figure 1) and different scenarios for how the bloom covers different areas of the subembayment (e.g., as a percentage of the surface layer, as per example diagrams in Figure 1).
2) Consider a range of chl-a concentrations

3) Calculate the Mass of organic matter produced = V_p * [chl-a]
4) Consider an appropriate bottom volume (Figure 1) within which to assume the biomass will be respired (assume bottom layer is well-mixed)
5) Calculate final DO concentration in bottom layer, assuming a starting concentration of 7.5 mg/L, assuming after all new OM has been degraded.
6) Conduct the analysis for each Bay segment.
7) Consider initial realistic constraints on bloom production, including total nutrient pool, and consider estimates in terms of historically observed chl-a.
8) In a separate exercise for LSB, consider the period of low DO in the 1960s, convert the BOD loads (carbonaceous and nitrogenous) to phytoplankton biomass equivalents, and based on that value estimate gross primary production rates that could cause low DO.

Specific Approach for Stratification Analyses (M Stacey, UC Berkeley):
The purpose of this element is to use an empirical approach to understand the stratification dynamics in South Bay, with an emphasis on the Lower South Bay. Using available data from the USGS and our own data collection, tidal and buoyancy dynamics will be examined to understand how they interact in South Bay to define the strength, frequency and duration of stratification events. By connecting these events to forcing under current conditions, we will then be able to consider scenarios for future forcing and evaluate the likelihood of significant changes in the stratification of South Bay due to climate change.

Data to be used:
1. Dumbarton Narrows, February 12 – March 10, 2008: Comprehensive data set just north of The Narrows that includes multiple velocity profilers and several top-bottom sensor (salinity and temperature) pairs. The data extends across the entire cross-section, including both the channel and the shallows.
2. San Mateo Channel, February 24 – March 16, 2009; September 9-30, 2009: Comprehensive data sets from south of the San Mateo Bridge that includes multiple velocity profilers and several top-bottom sensor (salinity and temperature) pairs, both in the channel and on the adjacent shoals.
3. USGS Monitoring at San Mateo Bridge: October 1, 1990-September 30, 2012. 15 minute resolution of top-bottom salinity and temperature
4. USGS Monitoring at Channel Marker 17: December 2, 2003 – March 30, 2005. 15 minute resolution, top-bottom salinity and temperature

Goals of Analysis:
1. Establish variability of stratification in South Bay, with an emphasis on Lower South Bay, under current conditions.
2. Connect observed (or inferred) persistence of stratification in South Bay to tidal and buoyancy forcing. The short-term comprehensive data sets will be used to examine how stratification is tied to tidal dynamics; tidal predictions will then be used to evaluate the longer-term variability contained in the USGS monitoring data.
3. Consider implications of scenarios of climate change for future stratification conditions. This analysis will be based on the use of a stratification parameter (summarized in May 19, 2014 presentation to SF Bay Assessment Framework Technical Team, see attached

Appendix A), which combines the destratifying influence of tidal or wind mixing and the stratifying effects of forcing by salinity gradients are atmospheric heating.

Overarching Outcome of Component: The goal is to identify biomass thresholds at which DO may become apparent, using conservative assumptions. This information would get paired with an understanding of stratification frequency and duration in South Bay—the segment where it is most likely that a problem would occur. If even under conservative assumptions, the chlorophyll a doesn't appear likely to cause a problem for Bay segments, then additional refined analyses may not be necessary. Refined analyses can be undertaken overtime, with additional monitoring or modeling.

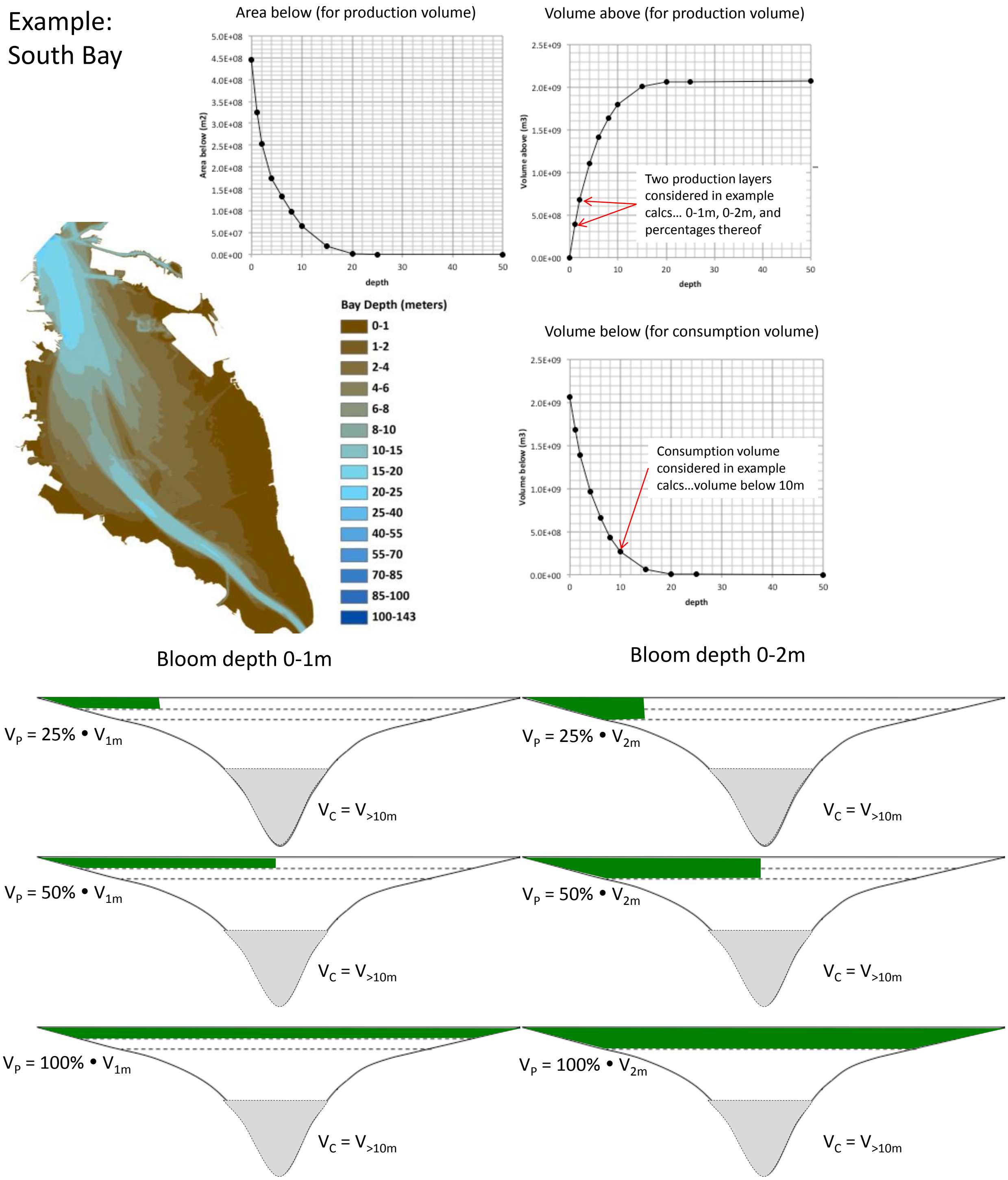

Figure 1. Example for South Bay of relationship between depth and total volume and the volume above and below production volume (top panel) and different scenarios in which 25%, 50% and 100% bloom in top 0-1 m and 0-2 m of surface waters gets transferred to bottom waters (bottom panel).

Appendix A: Conceptual Approach to Stratification Analysis

Parameterizing Stratifying Processes

$$St = \frac{\text{Stratifying Processes}}{\text{Destratifying Processes}}$$

If St exceeds a threshold, stratification builds

Need to evaluate frequency and duration of exceedence, and how that will change with climate

Destratifying Processes: Tidal or wind-driven shear production: $P \approx \frac{u_*^3}{\kappa H}$

H is local depth

u_* is "mixing" velocity: bed stress or wind stress (changes with climate?)

Stratifying Processes: Buoyancy Fluxes: B

Straining of salinity field, Atmospheric Heating

$$St = \frac{BH}{u_*^3}$$

Parameterizing Stratifying Processes

$$St = \frac{BH}{u_*^3}$$

Definition of B

Tidal Straining: $B \approx -\frac{g}{\rho}\frac{\partial \rho}{\partial x} u_* H^2$ Climate influence through changes in Q

Surface Heating: $B = \frac{\alpha g \tilde{h}}{\rho c_p}$ Climate influence through changes in $\tilde{h}$

Evaluation of future stratification scenarios

Evaluation of threshold: historical data or water column model or both

Future scenarios: Specify scenarios of B, H, u_*