San Francisco Bay Nutrient Management Strategy

FY2020 Program Plan

June 2019

SFEI Contribution #1321

SFEI San Francisco Estuary Institute

FY2020 Program Plan

This document contains the Core Program and Projects along with additional descriptions, with a focus on providing context for the major undertakings in FY2020. The presentation is organized into Core Program and Projects; within Projects, work is grouped and presented in terms of the primary Activity (Monitor, Model, Field/Lab Studies, Assessment Framework, Synthesis, Program Coordination). In addition to the brief description, priority level and cost, the tables also indicates the project Activity involved and the Focus Area (chl-DO-openBay, chl-DO-margins, Nutrients, HABs, Future Scenarios, and Coastal Exchange). In many cases, projects constitute multiple Activities and contribute to multiple Focus Areas: this alignment is depicted noted as either primary (●), moderate (◦), or none (blank). For additional context, please also see Item06a_FY2020_ProgramPlanOverview.

1. CORE PROGRAM

				Activity						Focus Area					
Proj #	**Brief Description**	**Priority**	**Cost**	Monitor	Model	Field/Lab	A_Frmwrk	Synthesis	PrgmCoord	chl-DO-open	chl-DO-mar	Nutrients	HABs	Future Scenarios	Coastal Exch
C1	**Ship-based sampling:** Assumes continuation of program with USGS, using the R/V Peterson on ~12 full-bay cruises and an additional ~12 South Bay cruises. This activity includes all field components of the study as well as sample analysis, including measurement of nutrients, phytoplankton taxonomy, phycotoxins, and continuation of pilot molecular measurements (sequencing) of phytoplankton assemblage and HAB detection, plus limited data management. The cost noted here ($401k) is based on proposed funding from RMP (240k; estimated) and NMS (161k; proposed).	4	$401,000	●	●	●				●	●	●	●		
C2	**Moored sensor** field work and data management: Servicing of the eight moored sensor stations in the South and Lower South Bay, plus the new station on South Bay shoal. Maintenance at 3 week intervals, data management. Data analysis/interpretation covered elsewhere.	4	$320,000	●	●	●				●	●	●	●		
C3	**Core Modeling:** Work includes ***Hydrodynamics:*** Running hydrodynamics for additional 1-3 years (2017, 2018, 2014), ***Biogeochemical model development:*** model validation for DO and Phosphorous (WY2013); continued work on sediment diagenesis model parameterization, model input/parameters sensitivity analysis; simulating biogeochemistry for 1-3 new year(s) (2017, 2018, 2014); reporting (reports, presentations); ***Tools/Maintenance:*** refinements to model grid aggregation scheme to allow for faster runs; Troubleshooting/refining code; Computing resources - internal or supercomputer time.	4	$349,000		●					●	◦	●	◦		
C4a	**Program/Project Management:** Financial management, project management, stakeholder engagement	4	$353,907						●						
C4b	**Science Program Coordination:** lead scientist's effort across all NMS scientific activities (50% FTE)	4	$143,966						●						

C1 Ship-based channel monitoring: sampling and analysis

FY20 Estimated Cost = $401,000 (Funding Sources: $240,000 RMP; $161,000 NMS)
Collaborators: USGS, UCSC, SFEI

Background

The core NMS ship-based observations are carried out through a collaboration with USGS, building on USGS' long-term Bay water quality program (USGS 2017). USGS has been conducting regular surveys of the Bay since the early 1970s, collecting data along its deep channel. The field program includes monthly full-Bay cruises aboard the R/V Peterson and a second biweekly cruise in South Bay. These cruises measure numerous parameters relevant to the NMS through a combination of in situ measurements and laboratory analysis of discrete samples, including: nutrients (N, P, Si), chlorophyll-a (chl-a) as a measure of phytoplankton biomass; phytoplankton community; and numerous ancillary parameters (e.g., salinity, temperature, suspended particulate matter, light penetration). Data from the ship-based program play critical roles in nearly all of NMS' activities, including condition assessment, hydrodynamic and biogeochemical model calibration and validation, and improved understanding of nutrient behavior and nutrient-related effects within SFB.

Major FY19 activities

Ship-based sampling continued throughout FY19 on 11 full-bay cruises (one was missed due to the federal furlough) and 12 South Bay cruises, with SFEI staff also participating as field technicians during cruises. CTD casts were conducted throughout the bay, and discrete samples were collected using flow through water (surface) and a niskin sampler (bottom) for total and dissolved nutrients, chlorophyll-a, algal toxins, phytoplankton microscopy, and algal pigments at a subset of stations (Figure C1.1).

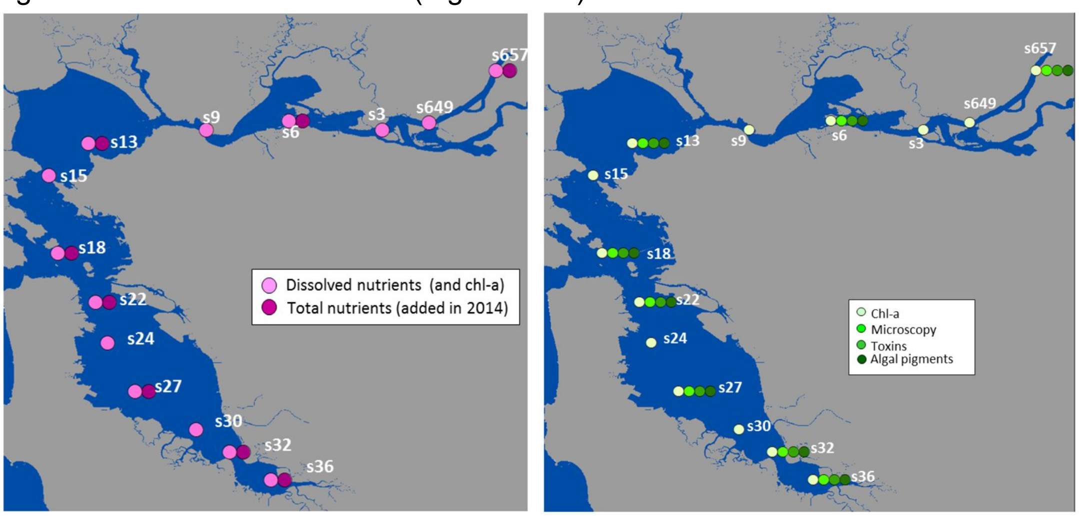

Figure C1.1 Station locations for discrete sample collection for nutrient-related parameters during biweekly and monthly USGS cruises

FY20 activities

1. Ship-based monitoring, including sample analysis (Figure C1.1): Ship-based sampling will continue aboard the R/V Peterson on ~12 full-bay cruises and an additional ~12 South Bay cruises. This activity includes all field components of the study as well as sample analysis
2. Data management: Most of the data generated from this activity is managed by USGS staff. The moderate additional investment effort for data management by NMS/SFEI staff involves incorporating the USGS data into our data management structure, and incorporating other data not managed by USGS (toxins, molecular/sequencing).

FY20 Deliverables: Nutrient and chl-a data will be made publicly available through USGS's website. Datasets for toxins, phytoplankton microscopy, and pigments will also be made publicly available through the NMS. Results will be summarized in the NMS Annual Report (funded through other projects). Similar to past years, data will be used within numerous other NMS activities (e.g., model calibration [see C.3], condition assessment, and assessment framework development).

Budget Justification: As in past years, funding from the RMP (est. $240,000) will support 1-1.5 USGS technicians, plus a portion of operating expenses. Over the course of the year, 300 station-date samples will be analyzed for a suite of nutrients (ammonium, nitrate + nitrite, reactive phosphorus, dissolved silicate; total N and total P will be measured at 75% of the sites) at the USGS national laboratory at a total cost of $40,000. A portion of FY19 nutrient analyses were covered by the FY18 NMS budget, leading to lower nutrient analysis costs in FY19 ($24,000). Phytoplankton taxonomy will be performed by microscopy on ~250 samples for phytoplankton community composition (225 grab samples, 25 net tows) and biovolume ($45k); additional phytoplankton or harmful-algae (HA) related measurements (molecular/sequencing techniques, phycotoxins, algal pigments, etc., total of $50k) for cross-validation with microscopy data and imaging flow cytobot output, and to inform monitoring program refinement and to support investigation of HA-related mechanistic science and management questions. The SFEI staff labor budget covers the following effort (0.3 FTE, $43,542): participating as field technicians on all USGS cruises; and overall project management, including coordinating laboratory analyses (with UCSC and other non-USGS labs), cruise and sample collection planning, and data management.

C2. Moored Sensor High-Frequency Observation Network: data analysis, interpretation, maintenance, new deployments

FY20 Estimated Cost = $320,000
Collaborators: SFEI, USGS-BGC, Sacramento (Stumpner, Bergamaschi, Downing, Kraus)

Background

San Francisco Bay is a dynamic and heterogeneous system. Data collected during USGS long-term monitoring cruises over the past 40 years (see C.1) have played critically-important roles in shaping both our current understanding of the major factors regulating water quality in SFB, and in documenting water quality changes over that time. We also know, from other research in SFB, including along South Bay's broad shoals, that important water quality indicators - e.g., salinity, temperature, chl-a, nutrients, dissolved oxygen, suspended sediments, etc. - have strong spatial gradients (Cloern et al., 1985; Huzzey et al., 1990; Lucas et al., 2008; Thompson et al., 2008), and can change substantially over fairly short time scales (e.g., hours to days), shaped by tidal forcings, wind, day-night variations in biological cycles, and other factors.

Over the past several years, while continuing to work collaboratively with USGS on ship-based monitoring in the SFB channel (see **C1**) the NMS has prioritized developing a moored sensor network for high-frequency in situ measurements, focused initially in South Bay and Lower South Bay (Figure C2.1). Analysis of limited existing data for sloughs and creeks, along with early mooring network data, indicated that DO levels in sloughs frequently fell below the Bay's 5 mg/L DO standard (SFEI 2015), and further highlighted the complex spatial and temporal variations in key water quality parameters (Figure 4). Two key aims for the mooring network were to allow for more comprehensive condition assessment, and to foster data collection that will allow us to better characterize and quantify ecosystem response to SFB's high nutrient loads, including by aiding the calibration of numerical models (SFEI 2014). This project description briefly highlights major moored-sensor activities during FY19, and describes the major focus of work in FY20.

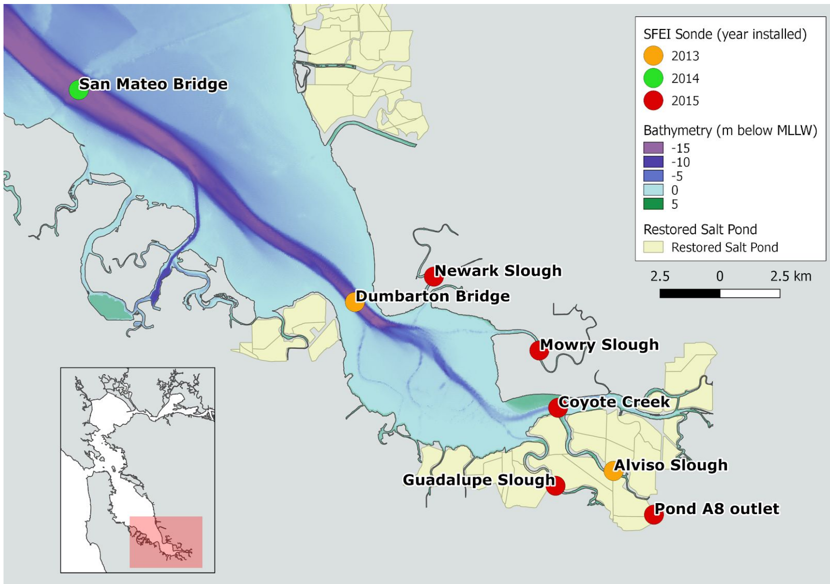

Figure C2.1. NMS-MSP site locations (as of May, 2019)

Major FY19 activities

- Sensor network maintenance (maintenance at 3 week intervals, 2 field days per interval + 1-2 days field set-up / break-down).
- Refined / cleaned dataset for additional year of data, and application of enhanced QAQC protocols to additional parameters (e.g., chl-a).
- Completed third pilot South Bay shoal deployment (10/5/2018 - 11/24/2018; same parameters as other sites, plus in situ nitrate sensor, additional chla-fluorometer, and acoustic velocity measurements). See Figure C2.2 below. Based on the three pilot shoal moorings that have been conducted, chl-a levels generally exceed those at nearby channel sites. A technical report summarizing the shoal deployments will be completed in June 2019.

Planned FY20 activities

1. Continued maintenance of current (Figure 2.1) moored sensor network, and deploying and maintaining a more permanent South Bay shoal mooring (Figure C2.2-C2.3). This involves ~50 field days (boat time, field staff, equipment)
2. Data management, including applying automated and manual data cleaning protocols as described in the mooring program 2018 update report.

FY20 Deliverables

- Refined / cleaned dataset for additional year of data, through continued use of enhanced QAQC protocols.
- Summary of major observations in the NMS FY20 Annual Report. Work related to data interpretation and synthesis is covered under other NMS tasks.

Budget Justification

Staff support for field work and data management ($143,000); field support (including boat, fuel, and field technicians; $142,000, to USGS); equipment/supplies ($30,000); analysis of discrete samples for instrument calibration ($5,000). Data interpretation included under other NMS tasks.

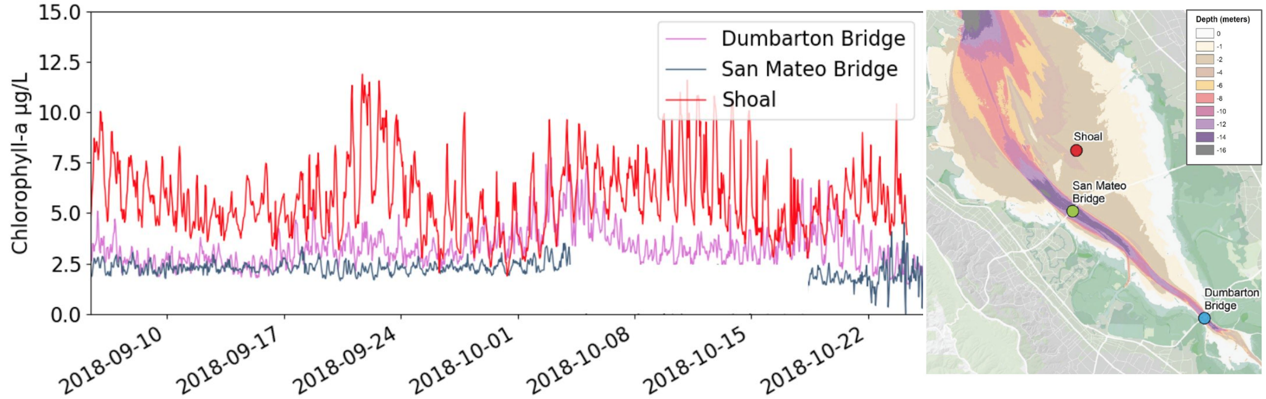

Figure C2.2 chlorophyll-a concentrations estimated from high frequency sensor readings during Fall 2018 deployments at the Shoal, Dumbarton Bridge, and San Mateo Bridge mooring sites.

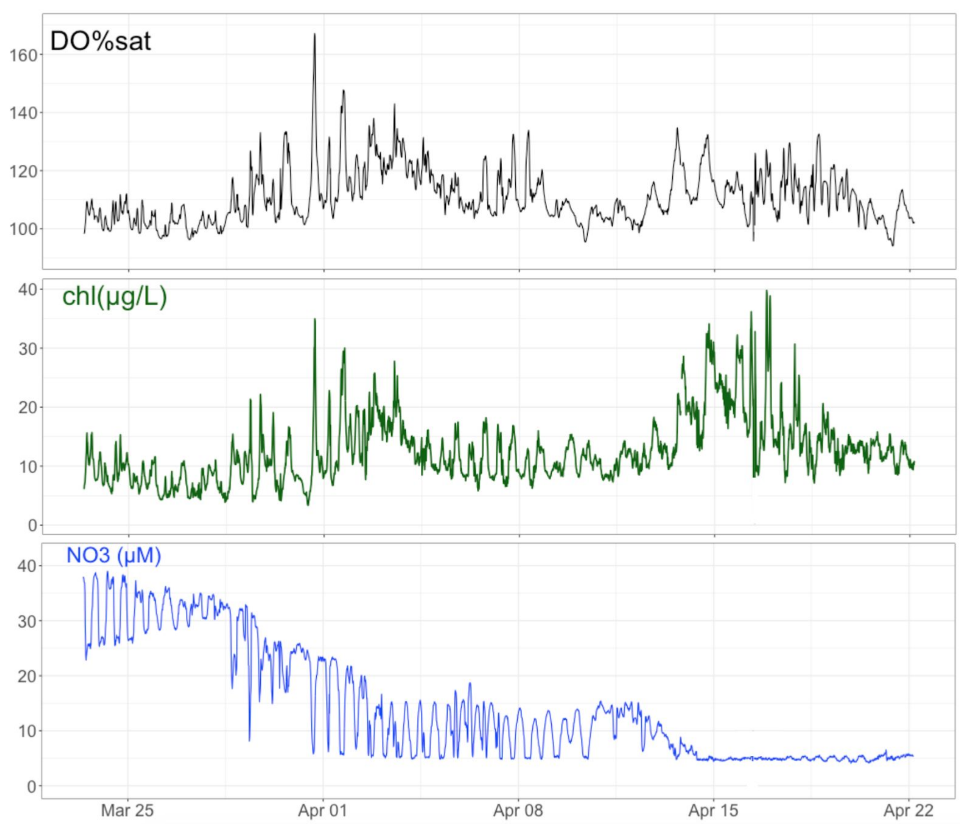

Figure C2.3 Dissolved oxygen (%saturation), chl-a, and nitrate levels estimated from in situ sensors the South Bay Shoal mooring site, Mar 23-Apr 29 2019. Supersaturated dissolved oxygen (>100%) coincided with chl-a peaks, consistent with primary production by phytoplankton. Nitrate concentration minima coincided with DO and chl-a peaks, suggesting that nitrate was being drawn down via uptake by phytoplankton. Since the detection limit for the nitrate sensor is in the range of 5-8 μM, the true concentrations during minima after April 1 and during the flat-line period between April 15-22 may have been less than 5 μM.

C.3 Core Modeling Program: development and application

FY20 Estimated NMS Cost = $349,000
Collaborators: SFEI, Deltares, UC-Davis (Holleman)

The Core Modeling tasks will focus on model development and application, including:

- *Hydrodynamics:* Running hydrodynamics for additional 1-3 years, full-Bay (core) model (2017, 2018, 2014).
- *Biogeochemical model development:* Model validation for DO and Phosphorous (WY2013); continued work on sediment diagenesis model parameterization, model input/parameters sensitivity analysis; simulating biogeochemistry for 1-3 new year(s) (2017, 2018, 2014); reporting (reports, presentations);
- *Tools/Maintenance:* refinements to model grid aggregation scheme to allow for faster runs; Troubleshooting/refining code; Computing resources - internal or supercomputer time. .

Additional modeling work will move forward through a set of Projects, P7-P13 (see Modeling work under Projects, below).

We recently developed a 5-yr draft Modeling Plan (Appendix C; NMS Updated Science Plan, 2019), which provides the necessary context for understanding the importance of the individual Core and Project work, and their sequencing.

Status of Full-Bay modeling work is well-summarized in SFEI 2018a. Suisun-Delta modeling progress reports cover the status of that work (SFEI 2018b; SFEI 2019)

Budget Justification Funding covers the cost of ~1.5 FTE modelers ($291k), funding for technical collaborators ($53k), direct costs ($5k; computing resources, travel/training at Deltares in the Netherlands)

C.4 and C.5. Program/Project Management and Science Program Coordination

FY20 Estimated NMS Cost = $354,000 (C.4) + $144,000 (C.5)

This task is broken into 2 parts: Program/Project Management and Science Program Coordination. Program/Project Management includes project management, financial management, contracting, overall program management (including stakeholder engagement, interagency coordination, fundraising) and travel ($5000). Science Program Coordination accounts for the lead scientist's effort across all NMS scientific activities (50% FTE). Program/Project Management amounts to ~13% of total NMS FY20 budget. The dollar amount represents an increase over prior years, accounting for proportional increase in program/project management effort that will be needed to support the larger program. The total effort and cost directed toward Science Program Coordination remains similar to prior years.

2. PROJECTS

MONITORING (P1-P6)

The majority of on-going NMS monitoring work occurs within Core Program (C1, C2). The projects below describe additional monitoring activities, including observational data collection that augments or complements core monitoring, and projects that may either be exploratory or pilot in nature or targeting a specific data need over relatively short period of time (as opposed to on-going).

				Activity						Focus Area					
Proj #	**Brief Description**	**Priority**	**Cost**	Monitor	Model	Field/Lab	A_Frmwrk	Synthesis	PrgrmCoord	chl-DO-open	chl-DO-mar	Nutrients	HABs	Future Scenarios	Coastal Exch
P1	**HAB-toxin monitoring in bivalves:** This project will continue work that began in FY2016, measuring phycotoxins in naturally-occurring bivalves harvested from floating docks at ~10 locations throughout the Bay. Major project goals include: quantify phycotoxin concentrations entering biota in Central and South Bay through measurements in naturally occurring mussels; collect samples with sufficient frequency that concentrations in mussels can serve as semi-quantitative bioindicators of ambient toxin concentrations in the water column as a function of space and time. To date, this work has proven to be an informative, efficient, and cost-effective approach for characterizing how phycotoxin levels vary spatially, seasonally, and interannually.	4	$104,000	●		●							●		
P2	**Additional high-frequency sensors:** Augment current HF monitoring capacity by e.g., installing e.g., nitrate sensors at existing stations (Dumbarton, San Mateo, or Coyote); or by adding chl-a sensors at sites maintained by other groups (e.g., alcatraz, Exploritorium)	4	$92,000	●		●				●		●			
P3	**Zooplankton sampling**: Zooplankton are important grazers of phytoplankton, and have the potential strongly regulate phytoplankton biomass accumulation. Despite their importance, little or no zooplankton data are available for the past 30 years for regions south of San Pablo Bay substantially influence, and these data are needed for model development and calibration. In Spring 2018, we began zooplankton sampling in priority regions of SFB, in particular those that currently have no zooplankton sampling (Central, South, Lower South). Funding to date has been used to support sampling. Funding in FY20 will support the taxonomy and counting, and continued field sampling in FY2020.	4	$87,000	●		●				●		●			
P4	**Expand mooring program:** During FY20, add new (temporary) mooring stations in diverse locations to quantify variability, to inform future monitoring program design. Note: Some of this could be accomplished by relocating equipment and maintenance effort from subset of existing sites in Lower South Bay.	3	$250,000	●		●				●		●			
P5	**IFCB data analysis** An Imaging Flow Cytobot (IFCB) is now being used on USGS cruises, and between cruises is deployed at the Exploratorium pier, collecting data every 30 minutes on phytoplankton community. Funding would support a scientist to analyze and interpret IFCB data, including refining its machine-learning image classifier and characterizing spatial (cruises) and temporal (pier and cruises) variations in phytoplankton community and abundance. (Funding will support a postdoc or researcher salary).	3	$150,000	●		●		●		●			●		
P6	**Benthos monitoring:** Grazing by benthic filter feeders can act as a major control phytoplankton biomass accumulation in regions of SFB. To quantify benthic grazer influence on phytoplankton (e.g., for model calibration), benthic surveys are needed to estimate benthos abundance and biomass (and community composition), and how they vary over space. Currently, benthos monitoring occurs monthly in Suisun and San Pablo Bays (DWR-EMP); Although South and Lower South Bays have historic benthos data, no consistent benthos monitoring occurs there currently. This project would undertake fieldwork associated with benthic surveys, sample analysis, and reporting	3	$100,000	●		●				●		●			

P1 HAB-toxin monitoring in Bivalves
FY20 Estimated NMS Cost = $104,000
Collaborators: SFSU, UCSC

Background and Goals
Mussels are filter-feeding organisms that accumulate phycotoxins in their soft tissue in proportion to its concentration in the water column (e.g., Gibble et al., 2016; Peacock et al., 2018). Mussels also gradually decrease their phycotoxin body-burden by metabolizing and excreting the toxin, allowing tthe rise and fall of tissue toxin concentrations to serve as time-integrated signals of toxin concentrations in the surrounding water (Melwani et al., 2013). Mussel toxin levels also provide information about phycotoxin exposure to higher trophic level organisms. Because some can be excreted rapidly (e.g., domoic acid excretion half-life is on the order of days), tissue toxin levels can change quickly after water column toxin concentrations decrease. Therefore, sampling frequency is an important consideration when designing and interpreting data from mussel-toxin monitoring activities.

Over the past 3.5 yrs, the NMS has been measuring toxins in naturally-occurring mussels collected biweekly from floating docks at locations around SFB. This FY20 project is a continuation of the field and lab aspects of that work (data analysis and interpretation will be funded separately), continuing the collaboration with UCSC and SFSU. Mussel toxin measurements are proving to be an efficient and cost-effective approach for obtaining valuable information about toxin levels in SFB. Sample sites are accessible by car, and sampling can be completed in 1-1.5 days. NMS-supported pilot work on bivalve phycotoxin levels began in FY2014-2015, in collaboration with UCSC. Results from that work, described in a recent publication (Peacock et al. 2018) and previewed in earlier NMS Annual Reports (2015, 2016, and 2017), show that individual mussels often contained multiple marine phycotoxins (domoic acid, saxitoxin, diarrhetic shellfish toxins). In a separate project (NOAA funded), UCSC researchers reported frequent Microcystins detections in the same tissue samples (Gibble et al. 2016). Motivated by that work, the multi-year set of observations from the SFB mussel network provide information about how three important toxins vary spatially, seasonally, and interannually (Figure P1.1). While domoic acid and saxitoxin concentrations are typically much lower than consumption guidance limits, microcystins commonly approach or exceed the human consumption threshold. In addition, in Spring 2018, we observed a 1-2 month window in which saxitoxin concentrations exceeded human consumption thresholds, results that prompted CA DPH posting a shellfish consumption advisory. Beginning in FY18 we also began collecting water quality data at each site (T, S, chl-a fluorescence, turbidity, etc.) and discrete samples for chl-a and nutrients, which will prove useful both for interpreting toxin data and as condition monitoring in very different habitats than other measurements in SFB (e.g., C1, C2).

Goals:

- Quantify phycotoxin concentrations entering biota in Central and South Bay through measurements in naturally occurring mussels.
- Collect samples with sufficient frequency that concentrations in mussels can serve as semi-quantitative bioindicators of ambient toxin concentrations in the water column as a function of space and time, to address monitoring goals and inform mechanistic understanding of where and under what conditions toxins are being produced.

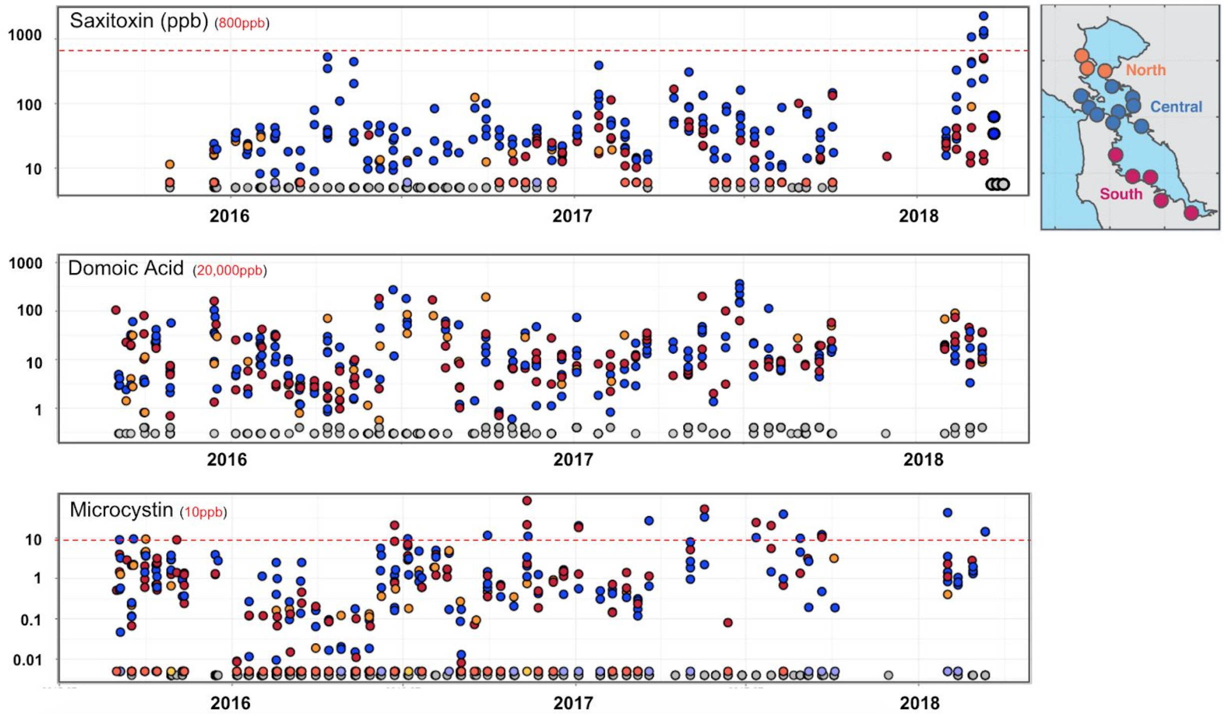

Figure P1.1 Phycotoxin concentrations in mussels collected biweekly in San Francisco Bay, showing data through April 2018. Symbol colors correspond to location (see inset map; orange=North; blue = Central; red = South). Red horizontal lines denote regulatory thresholds (off-scale for domoic acid). Top: Saxitoxin (ppb), threshold = 800 ppb; Middle: Domoic acid (ppb), threshold = 20,000 ppb. Bottom: Microcystins (ppb), threshold = 10 ppb. Samples exist for temporal gaps in these plots and have either been recently analyzed (Sep 2017-Jan 2018; May-Sep 2018) or have been prepped and are awaiting analysis. Note: Data from Peacock et al 2018 and Gibble et al 2016 are not included here. Lighter-shade symbols: < LOQ; Grey symbols: < LOD.

FY20 activities

1. Biweekly sampling of naturally occurring mussels, 8-10 stations (Figure P1.1)
2. Measure basic water quality data at sampling sites using in situ sensors, and collect and analyze discreet samples for chl-a, NO3, NH4, oPO4
3. Analyze mussels for multiple toxins: domoic acid, microcystin, saxitoxin.

FY20 Deliverables Basic data will be incorporated into the FY20 annual report. Interpretation will be undertaken through synthesis projects.

Budget Justification Field sampling and data management ($51k, including $25k to SFSU-EOS/RTC); sample preparation and analysis ($50,000k, UCSC; includes technical oversight/support from collaborator R Kudela); sampling/travel ($1000); discrete water quality measurements ($2000, SFSU-EOS/RTC; chl-a, nutrients).

P2 Install additional high-frequency sensors at select stations
FY20 Estimated NMS Cost = $92,000
Collaborators: USGS-BGC Sacramento
-- and --
P4 Expand Mooring Program
FY18 Estimated NMS Cost = $250,000 (possible to divide into 2 yrs at 125k/yr)
Collaborators:

In 2016-2017, the NMS developed a blueprint for a future monitoring program that addresses the program's observational data needs, incorporating and upon long-term monitoring activities, and adding new analytes or new approaches (including moorings with in situ sensors) as needed (SFEI 2017). Figure P2.1 depicts major features of the proposed (strawman) future NMS Observation Program, including existing and proposed moored sensor sites, as well as proposed prioritized locations for adding SUNA-NO3 sensors (P2) and augmenting existing moorings with new additional sensors or adding new mooring sites (P4). For P2, the priorities are based on

A few other relevant considerations:

- New moorings or new instrumentation can be installed for limited time windows, and then infrastructure and effort can be moved to other regions as needed. That said, even though it is possible to establish moorings sites that are more 'portable' than others, the strong tides, strong winds, heavy boat traffic throughout much of SFB still require bulky, heavy, and reliable deployments (causing mooring relocations to be nontrivial logistical undertakings). In addition, since mooring and sensor maintenance is the most costly part of the work, individual locations or distributions of sensors can substantially influence costs, as a result of different deployment requirements or differing levels of logistical efficiency (e.g., moving a single mooring to a location far from the rest of the network could add up to 1 day to each maintenance cycle).
- We anticipate that moorings will be integral components of P14 Biogeochemical Field Studies. For that reason, the planning of that work will likely influence some decisions related to P2 and P4.
- A way to more cost-effectively pursue P4 would be to relocate existing resources (and associated maintenance cost) from LSB to other locations in SFB. Based on planning discussions thus far, the best option(s), in terms of minimizing risk of missing an important event, appear to be the Mowry Slough site, the Newark Slough site, or both. This will certainly save on new instrument costs; how a move will impact maintenance costs will depend on the new location(s) (see first bullet).

Deliverables: The primary deliverable(s) will be datasets that are used to calibrate models (C3, P7-P13) and used to quantify nutrient fate and nutrient-related responses along (P14). Data interpretation will happen within, and be funded by, other projects.

Budget Justification: P2 and P4 budgets cover costs related to instrumentation, maintenance/logistics/equipment, data management/QA/QC; and support for collaborators with relevant technical expertise (USGS-BGC) to participate/advise on deployments and instrumentation.

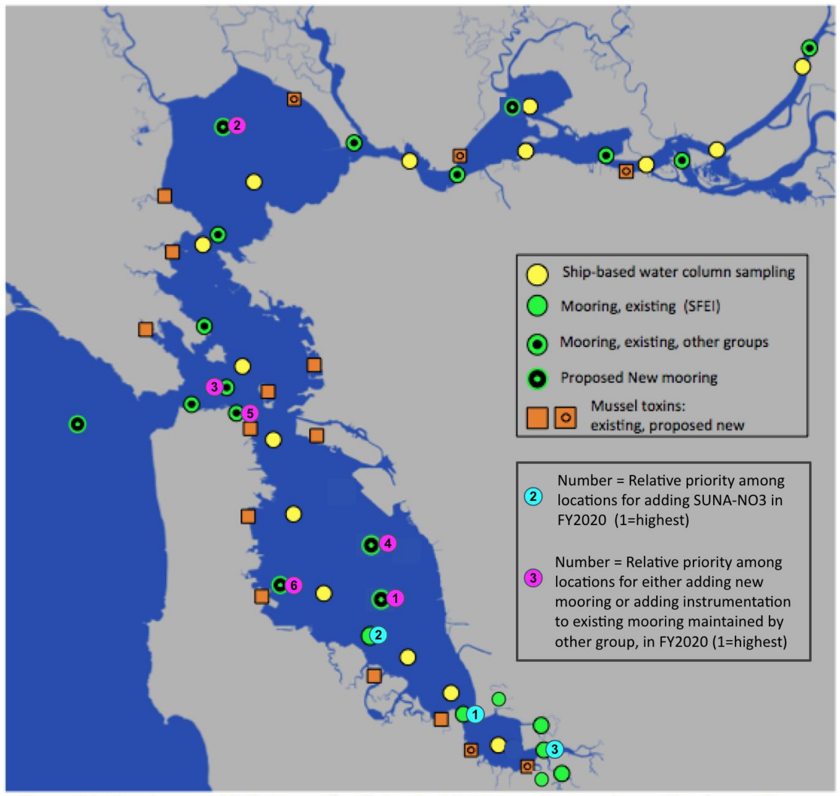

Figure P2.1 From SFEI 2017. Light blue and pink circles identify potential locations for adding SUNA-NO3 (light blue; **P2**) and new mooring site (or additional other sensors at existing site; **P4**) during FY2020. Number inside circle indicates relative priority. Note: The highest priority new mooring site (pink1) was actually recently installed (March 2019), and is included in the C2 mooring budget; so, pink2 and pink3 are actually the highest priorities for P4.

P.3 Zooplankton sampling

FY20 Estimated NMS Cost = $87,000
Collaborators: USGS, SFSU-EOS/RTC - Kimmerer Lab

Background and Goals

Microzooplankton and mesozooplankton have the potential to strongly regulate phytoplankton biomass accumulation and shape community composition by size-selective grazing. However, no data have been consistently collected to estimate zooplankton abundance or grazing rates for more than two decades in Central Bay, South Bay, and Lower South Bay. This pilot study, which started in FY18-19, has focused primarily on collecting zooplankton samples in Central, South, and Lower South Bays in conjunction with the USGS/SFEI channel monitoring program, joining approximately biweekly cruises for over the past 15. During FY20, sampling work will continue, but scaling back to monthly surveys (5-7 stations on ~12 full bay or South Bay cruises). The majority of the funding will go toward taxonomy and counting of zooplankton samples. In FY18-19 we purposefully oversampled (biweekly, in general), and plan to use information from that oversampling to help determine the frequency with which on-going zooplankton data are needed: i.e., for selected stations and time periods, count biweekly samples to determine whether monthly or biweekly data are needed in the future.

FY20 activities

1. Zooplankton will be collected on Full Bay or South Bay cruises (on average once per month) at 5-7 stations
2. Taxonomy and counting of a subset of FY18-19 samples and FY20 samples.
3. Data QA/QC and basic reporting (collaborator to be determined)

FY20 Deliverables: Dataset describing zooplankton taxonomy and abundance; Basic data report summarizing QA/QC and overview of abundances and taxonomy.

Budget Justification: Field sampling effort (labor for field sampling, sample shipping, engagement with lab, $22k; taxonomy $45k (150 samples @ $300/sample); Data QA/QC and basic reporting ($20k, collaborator to be determined).

P6 Quantify benthos/grazer abundance, estimate grazing rates
FY18 Estimated NMS Cost = $100,000 (possible to divide into 2 yrs at 50k/yr)
Collaborators: USGS Menlo Park (J Thompson)

While the Delta, Suisun Bay, and (to a lesser extent) San Pablo Bay have hard-funding for long-running benthos sampling programs, no consistently funded program exists south of San Pablo Bay. Despite the funding gap, over the past 2-3 decades USGS researchers (PI: J Thompson) have continued collecting benthos samples at 30+ locations in South and Lower South Bays 3-4 times per year (Figure P6.1), whenever possible, although the work related to sorting, counting, and estimating biomass has tapered off because of insufficient funding. However, the samples have been archived and the counting can still be done. In 2014-2015, the NMS supported USGS (SFEI 2015; Section 4) to i) Collect and summarize existing data (Figure P6.1), and ii) Catalogue the sites and dates for which samples are available but not yet counted, through 2013 (see Table 4.1 in SFEI 2015). Since 2013, USGS has continued a similar sampling regimen, and so archived, uncounted samples are available for 2014, 2015, 2016, 2017, and 2018.

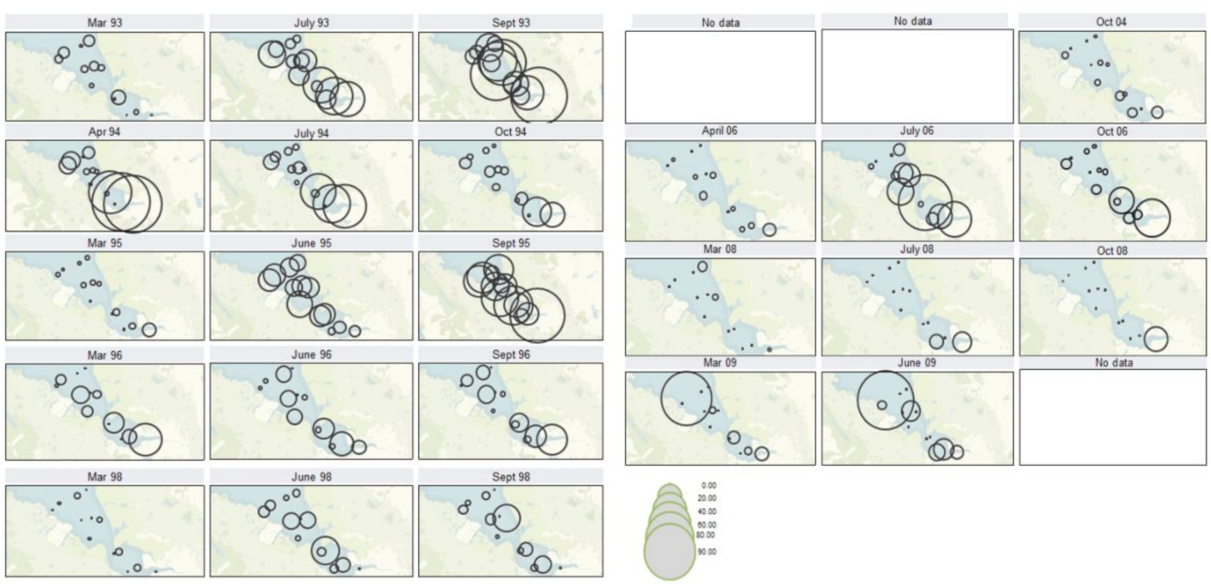

Figure P6.1 Bivalve biomass in South and Lower Bay (circle proportional to biomass; g C/m^2).

This project will support the effort related to sorting, counting, and estimating bivalve biomass. Funding of $50,000 would cover the costs of generating bivalve biomass data for 3-4 years (3-4 sampling events per year, ~30 sites per event). The exact years are still to be determined and will depend on modeling plans. Two likely time periods are WY2017 and WY2018.

FY20 Deliverables Dataset of bivalve biomass, with total number of samples or years dependent on funding level.

Budget Justification Dataset of bivalve biomass, with total number of samples or years dependent on funding level.

MODELING (P7-P13)

A major part of modeling work is being carried out with the core program (C3). The work described in the projects below are for model applications or for the development of specific tools or modeling-related datasets. Funding for P13 is covered by other funding sources, a coordinated project between NMS and Delta nutrient efforts. The 5-yr draft Modeling Plan (Appendix C; [NMS Updated Science Plan, 2019]) provides helpful context for understanding the importance of P7-P13, and why we are proposing that these begin in FY2020.

				Activity						Focus Area					
Proj #	Brief Description	Priority	Cost	Monitor	Model	Field/Lab	A_Frmwrk	Synthesis	PrgrmCoord	chl-DO-open	chl-DO-mar	Nutrients	HABs	Future Scenarios	Coastal Exch
P7	**Nutrient Dynamics** - ***Source Attribution:*** Quantify the proportional contributions of N and P from each POTW (and other sources) as a function of space and time. These will be provisional estimates based on best available simulations, and will be refined in subsequent years. ***Nutrient cycling in SFB:*** Spatial and temporal variations in N and P sources/fate/transport, at the subembayment-level, and causal factors, for informing assimilative capacity	4	$102,000		●			●				●			
P8	**Modeling Program Planning, Model Advisory Group:** Convene a group of local and national experts to serve as a Modeling Advisory Group, to review and inform modeling strategy, and provide technical review of modeling products	4	$53,000		●					●	●	●	○		
P9	**Developing Particle Tracking Capabilities NMS models:** Numerical tracers and particle tracking are important modeling tools used to help refine models and interpret model output. The transport and spreading over time of tracers or clusters of particles can be used to understand or quantify mixing rates, flushing rates, or residence times, and can also track or record conditions that a water parcel experiences during transit. The Deltares models do not currently have 3D particle tracking capabilities. However, the NMS has access to a well-tested particle-tracking code that has been used extensively in other Bay-Delta 3D-unstructured grid models. This project will focus on adapting that particle tracking model for use with Deltares hydrodynamic models. We anticipate that the first application of particles will be in P11a.	4	$20,000		●					●	●	●	●		
P10	**Lower South Bay Biogeochemical Modeling (Salt Ponds, Sloughs):** Although observations suggest that connections with restored salt ponds and sloughs have major influences on nutrient, phytoplankton, and dissolved oxygen concentrations in Lower South Bay, the NMS open-Bay biogeochemical model does not yet include those connections. This project will extend biogeochemical modeling into smallscale sloughs and ponds in the margins of Lower South Bay to quantify the effects of exchanges between open Bay ↔ sloughs/marshes ↔ salt ponds on LSB biogeochemistry, using the recently-developed LSB hydrodynamic model which does now simulate those slough/salt-pond connections. Work will move forward in two phases: i) Initial simulations with a simplified (highly-aggregated) version of the model, both to tune parameters and to obtain provisional quantitative estimates of the importance of the salt pond interactions (~30%); and ii) Simulations with higher-resolution model for refined estimates (70%).	3	$99,000		●					○	●	●			
P11	**Improving turbidity and light field estimates,** through analysis of observation data: e.g., shoal mooring turbidity data; remote sensed turbidity data; long-term DFW data. Funding would support	3	$75,000		●					●	●	●	○		
P12	**Phytoplankton Bloom Dynamics:** Spatial/temporal variation in phytoplankton production and factors regulating productivity and fate (stratification, light, grazing, nutrients, transport). Analogous to P05a, but focused on phytoplankton dynamics	3	$55,000		●					●	○	●	○		
P13	**Suisun-Delta Modeling:** Continuation of on-going work, with activitiesincluding: Suisun bay light field compilation; Suisun-Delta Hydrodynamic run for WY2016; Provisional biogeochemical model calibration for WY2016; and reporting (technical reports,	OK	$166,000		●					●	●	●	○		

Field/Lab Studies

				Activity						Focus Area					
Proj #	**Brief Description**	**Priority**	**Cost**	Monitor	Model	Field/Lab	A_Frmwrk	Synthesis	PrgrmCoord	chl-DO-open	chl-DO-mar	Nutrients	HABs	Future Scenarios	Coastal Exch
P14	**Biogeochemical Field Studies:** Launching multi-year set of field studies to quantify important biogeochemical transformation rates to inform mechanistic understanding and calibrate models (funding for Year 1+). Work will include: Literature review for SFB and comparable systems to identify data gaps and existing data that could be applied to biogeochemical models; Convene an expert working group to provide input on the design of the field program. Field work will begin in Fall 2019, and will include: ***Water column rate measurements:*** e.g., gross primary production, nitrification, and respiration or oxygen demand. When possible, sample collection and measurements will be carried out during biweekly or monthly cruises already being conducted collaboratively between USGS and the NMS, both the sake of cost-effectiveness and to take leverage ancillary data collected during those cruises. Additional cruises will likely be needed to study conditions outside the channel. ***Sediment diagenesis/fluxes***- Sediment studies will be conducted to quantify transformation rates or fluxes between the water column and sediments, related to multiple processes, including: nitrification; denitrification; N and P fluxes to/from the sediments; and sediment oxygen demand. Sediment characteristics will also be measured to establish relationships between benthic conditions and process rates which are important for model calibration. Selection of sampling locations will be informed both by biogeochemical modeling that is underway and through interpretation of existing data for SFB, and will cover a range of habitats. ~80% of funding would support external collaborators on fieldwork, analysis, interpretation; 20% SFEI staff to participate in and coordinate project(s)	4	$427,000			●				●		●			
P15	**HAB experimental study:** Factors influencing Pseudo-nitszchia growth and toxicity: This project will study growth requirements of the toxic phytoplankton Pseudo-nitszchia spp (P-N). NMS funding will be combined with other recently awarded funding (OPC) to investigators at the SFSU-RTC (now called EOS) researchers. The OPC-funded work wwill examine P-N growth and toxin production as a function of temperature and salinity, with a primary focus on conditions encountered outside the Golden Gate. The NMS funding will allow the work to pursue two or more of the following: expand the ranges of (i) temperature and/or (ii) salinity to also capture relevant conditions within SFB; or iii) investigate the effects of light (light limitation), along with temperature and salinity, on growth and toxin production. SFEI staff will join the project as co-PIs and will contribute to study design and interpretation. [Project already approved by NMS-SC, Mar 2019]	4	$55,000			●							●	●	
P17	**Salt pond / slough biogeochemical field studies:** Evidence from NMS studies suggests that salt pond <--> slough/Bay exchange has a major local, and potentially whole-subembayment, level effect on N, C and DO cycles in LSB. Observational data are needed to quantitatively characterize processes and conditions within and salt ponds and sloughs, e.g., phytoplankton biomass, nutrients, transformations, etc. Data will be used to inform model calibration.	2	$200,000			●					●	●	○		
P18	**Mechanistic HABs field study:** Undertake targeted field study to improve understanding of HAB/toxin sources, relevant mechanisms, etc.	2	$150,000			●							●		

P.14 Measuring Water Column Rates and Sediment Diagenesis/Fluxes
FY20 Estimated NMS Cost = $427,000
Collaborators: USGS-Sacramento (Bergamaschi, Downing, et al), other collaborators TBD

See also Biogeochemical Field Study Work Plan (NMS Science Plan 2.0, Appendix B).

Background and Goals Despite their importance for quantitatively understanding biogeochemical cycles and calibrating models, there have been few field studies in SFB to measure biogeochemical process rates, including nutrient transformations and oxygen demand. We plan to begin conducting rate measurements for processes that occur both in the water column and in the sediments (or across the sediment:water interface). The near term goals are to quantify rates of nutrient cycling in SF Bay and to improve our understanding of spatial and temporal patterns of biogeochemical rates. The long term goals are to compare current data to historical measurements to assess changes in the Bay over the last 40 years, and to improve the biogeochemical components of our SF Bay model and its ability to link nutrient concentrations to environmental conditions in the Bay.

FY20 activities

1. Literature review, analysis of existing data: Existing literature for SFB and comparable systems will be reviewed to identify data gaps and existing data that could be applied to biogeochemical models
2. Biogeochem expert working group: We will convene an expert working group to provide input on the design of the field program, including to help identify the most quantitatively important parameters to measure (i.e., large effects; large uncertainties) and contribute to designing a well-integrated set of studies that will cost-effectively yield the most valuable information. This expert group work will occur in Summer 2019, with the goal of identifying a plan that we can begin implementing (gradual ramp-up) in October 2019.
3. Water column rate measurements: Water column measurements may include: gross primary production, nitrification, respiration or oxygen demand, and phytoplankton growth rates or productivity. When possible, sample collection and measurements will be carried out during biweekly or monthly cruises already being conducted collaboratively between USGS and the NMS, both the sake of cost-effectiveness and to take leverage ancillary data collected during those cruises. Additional cruises will likely be needed to study conditions outside the channel, or to target specific events.
4. Sediment diagenesis/fluxes: Sediment studies will be conducted to quantify transformation rates or fluxes between the water column and sediments, related to multiple processes, including: nitrification; denitrification; N and P fluxes to/from the sediments; and sediment oxygen demand. Sediment characteristics will also be measured to establish relationships between benthic conditions and process rates which are important for model calibration. Selection of sampling locations will be informed both by biogeochemical modeling that is underway and through interpretation of existing sediment data for SFB, and will cover a range of habitats.

Deliverables: Overall project description, based on expert input: Sep/Oct 2019. Annual project updates to NMS SC; Dataset for use in model calibration (data added incrementally, complete by Jun 2021); Technical report, prepared in the form of one or more manuscripts with appendices, at project completion, estimated date Jun 2021.

Budget Justification: The intent is for this project and funding level to cover the costs associated with Year 1 field work, analysis of samples, and data interpretation. The estimates are rough, with actual costs depending on the final study design; so the funding level is essentially an upper-bound value. While it is likely that not all of the funds will be expended within Year 1, we anticipate that this funding will all go toward the Year 1 work (i.e, the Year 1 sample/data collection), and observations during subsequent years will require separate funding. The funds requested cover the costs related to designing the study and carrying out the work, and include: Staff labor to lead and participate in the project; expert advisor honoraria and travel; time and fieldwork, as well as sample processing and data analysis.

Assessment Framework

Several Projects directly focused on Assessment Framework (AF) development are planned for FY2020. In P20, we will work with regulators and stakeholders to develop an AF Work Plan. Figure P20.1 depicts, at a high-level the AF's major components, necessary work, and sequence of projects. Each of the remaining projects below are related to one of the projects illustrated in Figure P20.1

				Activity						Focus Area					
Proj #	**Brief Description**	**Priority**	**Cost**	Monitor	Model	Field/Lab	A_Frmwrk	Synthesis	PrgmCoord	chl-DO-open	chl-DO-mar	Nutrients	HABs	Future Scenarios	Coastal Exch
P19	**Trends Analysis:** GAM Evaluation for trend detection: In FY2019 the NMS began introducing a status and trends element to the Assessment Framework, using Generalized Additive Models (GAMs) for trend detection (SFEI, 2018). To date, GAMs have proven effective at trend detection for chl-a, using customized GAM structures evaluated by subembayment. This activity involves expert evaluation of additional parameters/indicators for a set of GAMs, to identify the most appropriate tools for long-term trend detection and writing up a technical report/manuscript	4	$100,000				●	●		●		●			
P20	**Assessment Framework Status and Work Plan:** This project will revisit the initial Assessment Framework efforts (AF1.0; Sutula et al., 2016, 2017), with the goal of producing three main outputs: a) Revisit and clarify the goals and intended uses of a SFB Assessment Framework, including the current status (how will AF1.0 be used?) and priorities for continued AF development; b) 'Test-drive' the numeric thresholds identified in AF1.0 by assessing condition relative to those thresholds in SFB, using long-term monitoring data; c) Develop an AF WorkPlan that reflects the major goals and timelines identified in **(a)**	4	$35,000				●			●	●	●	●		
P16	**Biota and DO monitoring** in Lower South Bay margins: An extensive fish surveying effort has been underway in Lower South Bay, funded currently by San Jose and previously by the salt pond restoration program, and conducted by UC-Davis researchers (Hobbs). This funding will combined with funding from San Jose, to allow for additional field work relevant to NMS goals - e.g., extending the overall study duration; targeted surveys specific to DO management questions (e.g., locations, tidal phases/stages); or supporting ancillary data collection (e.g., continuous DO in currently unmeasured locations). Specific activities / study design will be identified through discussions with UC-Davis and San Jose.	4	$25,000			●	●				●				
P21	**Fish/DO/habitat Data Analysis:** This funding will support continued analysis of data collected by the UC-Davis Lower South Bay fish surveys. This work will build upon the analyses included in the 2018 DO habitat quality report, including pursue some of the recommendations/next-steps identified in that report. In addition, since that report only included data through 2016, new work will include 2+ additional years of data	4	$25,000				●	●			●				
P22	**DO-levels, condition in LSB:** Further data analysis to identify options for determining protective DO conditions in Lower South Bay sloughs/margins; utilize available fisheries data, coupled with high frequency DO data, to inform relationships and assessment criteria (e.g. Virginia Province approach and others). This would be one step, requiring on-going work in subsequent years.	3	$50,000				●	●			●				
P23	**Potential for low DO conditions in SFB (South Bay focus):** Over the 25+ year record when DO data were consistently measured Bay-wide, near-surface and near-bottom DO levels almost always exceeded the 5 mg/L Basin Plan standard. Under what conditions could unacceptable DO conditions develop? To explore this question, we will use hydrodynamic+biogeochemical models to identify conditions under which low DO could develop in deep subtidal habitats. For a first phase of this work, we will 'force' the biogeochemical model by adding varying magnitude blooms to simulations (concentration*area*depth), and assess the effects on DO levels. Through this approach we can identify the organic matter loading rate required (as a function of space and time) to draw down DO levels low enough to have a pronounced impact.	3	$31,000		●		●	●		●		●		●	

Proj #	Brief Description	Priority	Cost	Activity						Focus Area					
				Monitor	Model	Field/Lab	A_Frmwrk	Synthesis	PrgmCoord	chl-DO-open	chl-DO-mar	Nutrients	HABs	Future Scenarios	Coastal Exch
P24	**Expert working group on HAB impacts:** Convene an expert panel to inform an approach to incorporating available HAB data into an Assessment Framework and review available data collected to date	2	$25,000				●	●					●		
P25	**Expert working group on DO influence on habitat:** Convene an expert panel of wildlife biologists and others to inform the degree to which DO may impair resident wildlife, within the context of local and national assessment criteria (e.g. Virginia Province)	2	$25,000				●	●			●				
P26	**Fish/DO/habitat** Explore additional approaches for DO-related habitat condition in LSB: This project will explore DO-related habitat from a complementary angle to prior work (2018 DO habitat report), using an emerging approach that considers both DO, T, and metabolic DO requirements (animals' DO requirements vary as a function of T and species, with DO needs increasing with increasing T).	2	$25,000				●	●			●				

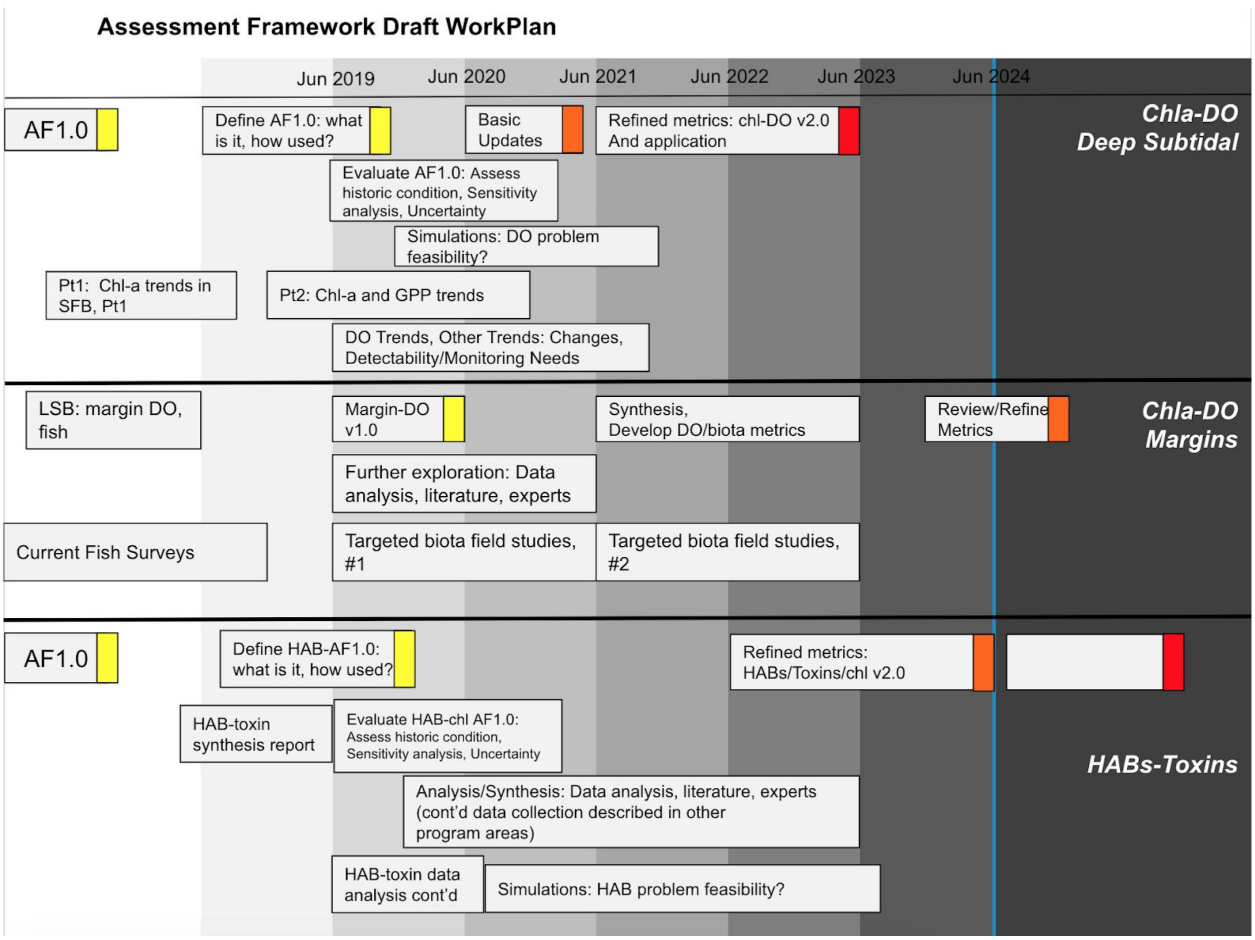

Figure P20.1 High-level Assessment Framework Draft WorkPlan.

Synthesis

Synthesis work is being carried within multiple other projects. These projects are primarily synthesis work. In other program areas or projects, we have made the clear a distinction between the work (and cost) of collecting the data (or developing the model) and the work related to interpreting the data, to help track the amount of effort going toward each. Therefore, in some cases, targeted synthesis projects are a primary avenue for interpretation that data (e.g., P27, P28, P29, P31)

				Activity						Focus Area					
Proj #	**Brief Description**	**Priority**	**Cost**	Monitor	Model	Field/Lab	A_Frmwrk	Synthesis	PrgmCoord	chl-DO-open	chl-DO-mar	Nutrients	HABs	Future Scenarios	Coastal Exch
P27	**Analysis of high-frequency DO data in sloughs/creeks of Lower South Bay:** Complete on-going work related to interpreting DO concentrations in sloughs/creeks in LSB, to identify causal factors and estimate rates	4	$60,000					●		●	●	●			
P28	**On-going analysis of moored sensor data:** e.g., GPP spatial variations; factors contributing to variations in biomass	4	$84,000					●		●		●			
P29	**Analysis/interpretation of ship-based monitoring data:** Continue and write-up analysis/interpretations from long-term monitoring data, e.g., related to phytoplankton community, gross primary production, nutrients, etc.	4	$48,000					●		●		●	●		
P30	**Annual Report, status and trends report**	4	$40,000					●		●	●	●	●		
P31	**HAB synthesis:** complete current HAB long-term data report, expand toxin data analysis, including by providing some support for expert reviewer	4	$22,000				●	●					●		
P33	**Deeper dive into HAB data analysis/interpretation**: Continuation of the report in P31	2	$49,000				●	●					●		

Coastal Exchange

For more information see original project description, approved Sep 2018

P34	**Coastal Exchange:** A sizable proportion (e.g. 50% or more, depending on season) of the nutrients that enter SFB exit via the Golden Gate to the coast ocean. The fate of those nutrients, and their effects on the GoF and coastal habitats are poorly known. Through this project, we will begin a 3-year study, teaming up with an on-going study (collaborators SCCWRP/UCLA/UCSC) to explore fate of nutrients leaving SFB and obtaining refined boundary condition estimates for nutrients entering SFB. [Project already approved by NMS-SC, Mar 2019]	4	$200,000	●											●

Future Scenarios

P32	**Future Risks/Future Scenarios:** Develop a Work Plan for exploring Future Risks/Scenarios: workshop/goal setting; stakeholder input; expert input; planning	3	$50,000					●						●	