SAN FRANCISCO BAY
NUTRIENT MANAGEMENT STRATEGY

FY2021 Annual Report & Overview of FY2021-2022 Work Activities

September 2021

SFEI Contribution #1318

1. INTRODUCTION

This report presents an overview of the Nutrient Management Strategy's (NMS's) FY2021 Program Plan, including the suite of projects pursued, and major FY2021 work activities.

Section 2 summarizes the process for developing NMS Program Plans, including considerations specific to the FY2021 Program Plan's development and approval; and provides an overview of funding and approved projects. *Section 3* provides an at-a-glance overview of FY2021 projects' scientific and regional focuses; a compilation of and links to recent work products; and summaries of FY2021 major work activities.

2. OVERVIEW: FY2021 PROGRAM PLAN and FUNDING

2.1 Process for Developing NMS Program Plans

The NMS annual calendar (Jul-Jun) is organized such that options for specific work priorities for the upcoming year are initially laid out at the NMS Steering Committee's December meeting, and then explored again in more detail at the March meeting. Further input is gathered on a draft Program Plan from the NMS Nutrient Technical Workgroup during an April/May meeting. The proposed Program Plan is then discussed and voted on at the NMS-SC's June meeting

The specific projects pursued in each year's annual Program Plan are based on science priorities and related work activities mapped out in the NMS SciencePlan2.0. NMS SciencePlan2.0 is a multi-year workplan (FY2020-FY2024), developed through a series of priority-setting discussions with the NMS Steering Committee during 2018-2019, as part of planning for the second NMS 5-year permit. The goal of that planning process was to identify a multi-year set of projects that targeted the highest priority management questions, science needs, and updated goals for Permit #2. Background is summarized here (program structure, management questions, program areas and science focus areas), including guidance for navigating an electronic version of NMS SciencePlan2.0 and the FY2021 Program Plan.

2.2 Approved FY2021 Program Plan

An ambitious FY2021 work plan started taking shape during early discussions and planning (Sep 2019 - Feb 2020) for the FY2021 Program Plan, including launching some multi-year projects, and front-loading a portion of permit funds to support that work. However, during the final stages of planning for FY2021 work (March-June 2020), there was considerable uncertainty about the trajectory of the covid-19 pandemic, and how the pandemic might impact potential NMS projects. At its March 13 2020 meeting, the NMS-SC directed SFEI staff to continue planning for an ambitious FY2021, but to build in contingencies that provided flexibility for the final project decisions and workflow to adapt to evolving possibilities and constraints.

In June 2020, the NMS-SC approved a program plan that included a diverse range of projects and contingencies/flexibility, with options to pursue either a fieldwork-heavy set of projects or a set of projects that primarily involved data analysis/synthesis, depending on what became feasible (see Table 1 for the full set of approved projects; FY2021 Program Plan: link). The decision also recognized that pursuing all the approved FY2021 projects in parallel was not realistic, and some work would necessarily move to the following year. In the end, work was able to proceed on multiple field projects and special studies (C1, C2, P1a, P1c, P2, P5a, P5b, P6, P13, P16, P18, P19, P20). Work also moved forward substantially on a number of modeling, data-analysis, and synthesis projects (C3, P3, P8a, P8b, P11a, P12a, P13, P18). After re-assessing capacity early in FY2021, it was decided that the bulk of the work and funding for the remaining projects would be moved to FY2022 (P4, P8b, P8c, P8d, P9, P10a-b, P11b, P12b, P14, P15).

FY2021 revenue came from multiple sources (Table 1; details in footnotes). Funding from BACWA (R.1 Nutrient Permit FY2021) was $2.6mill, which is larger than the annual average for Permit #2. Given the contingencies and lower anticipated spending for FY2021, reducing the requested amount was discussed; however, by the time it became clear what work would be feasible, that amount had already been approved by BACWA. There was also substantial funding from the RMP, with some being essentially a pass-through (R.3), and other funds used to support core program (R.2) and projects (R.4). The approved FY2021 Program Plan also includes a set of continuation projects from FY2020 or other years (Tables 1, P15-P20). Three of those projects were approved in FY2020 with the recognition that funds from FY2021 would be used to round out the support. Others are not supported by new FY2021 funds, but were incorporated into the FY2021 Program Plan to provide a more holistic picture of the NMS-related work that was underway. Although the carry-forward funds supporting these projects are not strictly speaking new revenue, they are included in Table 1 as revenue to more easily summarize total available funding in FY2021.

3. SUMMARY of FY2021 TECHNICAL WORK

3.1 FY2021 Science Focus and Recent Work Products

Table 2 presents the FY2021 projects, along with high-level context about the science/management issues (Science Focus Area) that each project is targeting, and the type of project (Program Area) (see background p. 6-7,9 for definitions). Most FY2021 projects targeted more than one focus area, and many are hybrids in terms of Program Area (e.g., both Monitoring and informing Assessment Framework Development). Table 2 also highlights the SFB subembayments where each projects' results are anticipated to be highly relevant.

Recent NMS Work Products (Jun 2020-Sep 2021) are compiled in Table 3, along with links to report PDFs. An expanded version of the Work Product table is also included as Table A.1, which, similar to Table 2, identifies the targeted Science Focus Areas and subembayments for which the project's results are anticipated to be highly relevant.

3.3 Major FY2021 Work Activities

The summary of FY2021 work activities below is organized by Program Area (Monitoring and Special Studies; Modeling; Synthesis; Assessment Framework), with related project numbers and work products indicated with [C# or P#] and [wp#].

Modeling

During the first two months of FY2021, the NMS modeling team focused on final analyses stemming from FY2020's major model development campaign, and finalizing the write-up of results and recommendations [wp15]. In addition, building on FY2020 work, the model was applied in conjunction with a mass balance approach for analyzing model results to quantitatively characterize space-time-variability and key drivers of nutrient and phytoplankton transformations [P18; wp16 Section 5]. Mass-balance-application work was continued in a limited way during FY2021, including extending the analyses to Central and San Pablo Bays and to a second water year (WY2017). However, a decision was made to pause further work, and resume it again as part of interpreting simulations run with the updated model (below). Over the remainder of FY2021, one major focus of C3 work was on testing and incorporating another round of model improvements, targeting a subset of the priorities identified during recent sensitivity analyses work [wp15 Section 4], including:

- Refining/improving the sediment diagenesis module, which influences processes such as denitrification, sediment O_2 demand, and nutrient fluxes, sediment→ water-column.
- Developing light attenuation coefficient (K_D) data for use within model.
- As part of FY2021 work in the Delta-Suisun region [P20, along with C3], refining zooplankton grazing and clam grazing, taking advantage of the grazer datasets that exist in that region; and early tests incorporating clam grazing into simulations focusing more on Central/South/Lower South Bays.
- Beginning to incorporate the above improvements into the SFB model, and testing/re-tuning the model across diverse conditions using 6-year continuous simulations (wy2013-wy2018; made possible by 4 new years of hydrodynamic predictions that were calibrated/validated through FY2020 projects).

Other focuses of core modeling work and related projects during FY2021 included:

- Evaluating options for generating sufficiently-accurate K_D values, for use as biogeochemical model input [P3, C3] (balancing reliability/accuracy; turnaround time; and cost). Work moved forward on a few fronts, including: as an interim step, generating a space-time varying K_D field (daily), through improving the semi-empirical approach used thus far; working with a regional consulting firm to cost-effectively obtain a one-year K_D dataset from sediment transport simulations [wp13], and evaluating, including comparisons with NMS shoal mooring data; launching a collaborative pilot project with Deltares to further test the potential for the SFEI-NMS model to produce reliable K_D data.
- Major investment in model development and application in the Delta-Suisun region, supported by both non-NMS [P21] and NMS funds [C3]. NMS funds were strategically invested, for example, to jointly pursue testing and improvements to processes that are critical to both efforts (e.g., clam grazing, sediment diagenesis). The work yielded three work products over the past year [wp14, wp5, wp1]. The work also produced valuable information related to the potential influence of Regional San's upgrade on Delta nutrient loads SFB and nitrogen source apportionment in Suisun, San Pablo, and Central Bays.
- Nutrient source apportionment: developing and testing analytical approaches for tracking contributions of individual point sources to nutrient concentrations throughout SFB; and, through exploratory analyses, characterize the influence of potentially-important factors

(system dynamics, analytical considerations) on predicting sources' zones of influence, and quantifying regional source signatures. [C3] [wp3]

- SCCWRP, SFEI-NMS, and stakeholders designed a 5-session seminar series and panel discussion, geared toward stakeholders and regulators, that focused on how other coastal and estuarine modeling efforts have addressed or quantified uncertainty in modeling, actively incorporated information about uncertainty into their simulation/ analysis workflow, or used that information to guide interpretations.

Evaluating potential impacts of SFB nutrients flux to the coast leaving SFB A sizable proportion (e.g. 50% or more, depending on season) of the nutrients discharged to SFB exit via the Golden Gate to the coastal ocean. This is a multi-year project (collaborators UCLA/UCSC/SCCWRP/SFEI) with the goals of quantifying the effects of SFB's nitrogen export to the coastal ocean on phytoplankton productivity, and dissolved oxygen/ocean acidification [P13]. In terms of the funding level spent, the project is at the roughly 1.2-1.3 year mark, and work was proceeding well through June. The project partners produced a year-1 technical report, focused on tracking the freshwater plume's zone of influence under various forcing scenarios [wp7]. During the next work phase, the focus will shift to tuning the biogeochemical model and interpreting results from those simulations. Due to a recent staffing change (postdoc started a permanent position in China), a temporary work-pause is expected while a new researcher is recruited (which is underway).

Monitoring and Special Studies

Moored sensor monitoring network in South and Lower South Bays In June 2020 there were major uncertainties about the feasibility of basic mooring work moving forward efficiently during the pandemic, given frequent maintenance and logistical challenges of maintaining safe numbers of people on small boats. Expanding the program with additional South Bay shoal stations and additional instrumentation seemed even less likely, despite being an important program FY2021 goal [C2, P17]. However, the SFEI/NMS mooring team, working in coordination with our colleagues at USGS-SantaCruz, developed a clever instrument 'hot-swap' approach, with USGS doing the on-water work and SFEI staff cleaning and recalibrating instruments for replacement within a day or two. So other than a week or so window at one or two stations during Spring 2020, moored data collection continued unabated, including maintenance trips every ~3 weeks [C2]. In addition, working with collaborators in the Sacramento USGS-BGC group, the SFEI/NMS South Bay shoal mooring was redeployed in August 2020. Next, two additional moorings were installed (further east) during September 2020. All three South Bay shoal stations remain in service (one with a SUNA nitrate sensor), installed and maintained in collaboration with USGS-BGC (Sacramento Water Science Center). The planned SUNA-nitrate sensor installation at the Dumbarton Bridge in December 2020 also went smoothly. TheSFEI/NMS mooring team also invested heavily in upgrading its semi-automated QA/QC script, and continued routine QA/QC work.

Ship-based monitoring Ship-based sampling, in collaboration with USGS Menlo Park, normally occurs on a biweekly to monthly basis [C1]. However, as with other NMS projects (discussed below), COVID restrictions shut down cruises from March through mid-July 2020. Cruises resumed in July 2020 at a rate of 1 cruise/month through Summer 2021 instead of the more standard 2 cruises/month (one South Bay, one Full Bay).

It remains uncertain when bi-monthly cruises will resume. There is also important positive news on this front: After 4 years of growing concerns that the USGS might discontinue its funding for the the program, the USGS recently agreed to continue supporting the research vessel and captain. The management of the program is being transferred to the USGS Water Science Center (same center as USGS-BGC collaborators, mooring and mapping work). USGS in-kind contributions include continued support for the ship captain and vessel maintenance and operation, along with additional support during the upcoming year for science oversight and management, along with other matching salary support. The USGS-WSC and NMS/RMP are in general agreement about jointly shaping the scientific program to address each program's science and monitoring needs as well as those of the overall program. Maintaining the long-term monitoring network remains a key priority for USGS and for the NMS/RMP. Given that the NMS/SFEI and USGS-BGC are already working closely on mooring [C2] and shoal mapping [P2], there are exciting opportunities to further integrate the ship-based and moored monitoring, and maximize the attainment of monitoring goals. Several meetings have been held between USGS staff and SFEI staff to move planning ahead related to a longer-term monitoring program structure.

Water quality at SFB perimeter sites During sampling for mussels at sites around the perimeter of Central Bay and South Bay over the prior ~2 years [P5], we have also routinely collected and measured water samples for chl-a and nutrient concentrations, along with other ancillary data. Although funding has not generally been allocated for on-going synthesis of this data, sufficient funds were pooled from related tasks to support analyzing the 18 months of biweekly data, and writing up a concise synthesis document [wp16], examining seasonal and spatial variations in water quality within and among sites. One key observation is that this relatively low-cost approach to monitoring captures some distinct signals and may provide highly complementary information to observations along SFB's deep channel. This type of monitoring also has the potential to address data needs related to assessing condition in margin or perimeter habitats, which has been identified as an emerging priority.

Water Quality Monitoring along South Bay's shoals Among the NMS's earliest recommendations is "*In addition to monitoring along the channel, monitoring is needed in shoal environments, including lateral transects*" (SFEI 2014). High speed biogeochemical mapping was pursued as a pilot study in spring 2017, and it yielded strong and informative spatial patterns in nitrate, chlorophyll-a, and other parameters. While the FY2021 shoal mapping cruises [P2] were at fairly high risk of being scrubbed due to COVID, USGS-BGC and SFEI staff found ways to make them happen. Three cruises supported by FY2021 funds were conducted in spring and early-summer 2021 (March 23, May 5, June 23), with noteworthy heterogeneity in chlorophyll-a and nitrate levels on all dates. We also used these cruises as a platform to collect parallel samples for zooplankton counting and phytoplankton characterization by molecular techniques, two additional high priority data gaps. Shoal mapping work is continuing with FY2022 funding, with cruises in August, September, and October.

HAB toxins in naturally-occurring mussels This project is continuing work started in September 2015, cost-effectively monitoring for harmful algal toxins by analyzing naturally-occurring bivalves harvested from floating docks on a biweekly basis at 8 locations throughout Central Bay and northern South Bay [P5]. In FY2021, a low-cost pilot study was added to measure toxins in mussels from Tomales Bay, to explore whether toxin signatures (multiple toxins, relative levels) are comparable, or different between the two systems (marine: domoic acid, saxitoxin, diarrhetic shellfish toxin; along with microcystins; collaboration with CDPH and Hog Island Oyster Company). Although SFB mussel sampling paused from March through mid-July 2020, sampling has gone since gone smoothly for both SFB and Tomales Bay, and sample analyses are underway. SFB samples from prior years have been analyzed through Oct 2020 (5 yrs), with data available for domoic acid, microcystins, and saxitoxin for ~900 station*date pairs. So there is now a rich mussel-toxin record for upcoming HAB synthesis work (in FY2022).

Biogeochemical field investigations (transformation rates) FY2021 was intended to be the first year of a multi-year field study that targeted the measurement of biogeochemical process rates in the South Bay and Lower South Bay [P1a]. Biogeochemical transformations in the sediments can have strong influences on water column nutrient concentrations (via sediment→water flux), and on oxygen and nitrogen loss via sediment oxygen demand and denitrification. Despite their importance to understanding N cycling and transport, these processes have not been measured in this region of SFB for nearly 30 years. Rate estimates for these processes are thus critically needed for model calibration (see mention under Modeling, above). Yet, similar to the mooring and shoal mapping work, this project was at high risk of not moving forward in FY2021 due to covid restrictions, in particular b/c of this project's major field and lab work components, both requiring multiple scientists working in teams. Through additional careful planning and building in extra precautions, the combined field sampling and lab incubation program was successfully launched, with 4 sampling excursions in FY2021 (10/27-10/28/2020; 2/28-3/1/2021; 5/11-5/12/2021). A subset of the rate data has already been shared with the modeling team, and is in active use for model tuning. Field work is continuing into FY2022, with another successful 2-day excursion in July 2021 and another planned for October 2021.

A second biogeochemical field study is also underway, primarily in the Suisun-Delta region. That work is funded primarily by a Delta Science Program postdoctoral fellowship [P1c], with partial funding (~15%) from the NMS. The postdoc, who is co-advised by Stanford faculty and SFEI staff, is using a different set of techniques (aquatic eddy-covariance) to measure rates like sediment oxygen demand, and during FY2021 conducted pilot measurements in Lower South Bay alongside the NMS funded work, to allow for cross-validation of the approaches.

HAB growth experiments -- Pseudo-nitszchia growth and toxicity vs. light and temperature This project is the second year of a 2-yr study investigating factors influencing the growth and toxin production of *Pseudo-nitszchia* spp (*P-N*) [P5b]. *P-N* is the organism that produced harmful domoic acid levels along the entire US west coast in 2015. Both P-N and domoic acid are detected with reasonable frequency within SFB, but both typically remain below truly concerning levels. However, the factors that prevent greater growth and toxin production are poorly understood. The overall project is funded by both NMS and prop84, allowing the NMS funds to leverage that larger funding source, with NMS funds being used to extend the gradient of conditions tested (light, temperature) to ranges that also represent SFB conditions. Although COVID restrictions slowed progress, work resumed in late-summer/fall 2020, and is proceeding well (see progress report, [wp10], and on track to wrap up in FY2022 (no cost extension).

Assessing the utility of molecular techniques (sequencing) to detect and quantify HABs Over the past few years, including with SEP funds, the NMS has been exploring whether molecular techniques (e.g., qPCR, amplicon sequencing) are a more reliable (accurate) and sensitive set of tools for detecting and quantifying harmful algae, as well as characterizing healthy or nontoxigenic phytoplankton strains. In a recent NMS pilot study, comparisons of molecular techniques and microscopy found that detections and relative abundances of multiple HAB taxa differed considerably between the two techniques, with molecular techniques apparently more sensitive and/or less prone to misclassification than microscopy (SFEI 2020). The differences were particularly stark for *Alexandrium*, which produces paralytic shellfish toxin and is among the organisms of potential major concern. This FY2021 project [P6] built upon the prior work, extending the time-series to 3 years at stations Bay-wide, and developed targeted molecular techniques to measure genes that encode for toxin production, and through groundtruthing results developed a QA'd sequencing database that is tailored to SFB. The results in the recently completed report [wp8] covering FY2021 work indicate that molecular techniques offer substantial promise, in terms of their specificity/accuracy and sensitivity for HAB detection relative to microscopy.

Quantifying grazer abundances in SFB, zooplankton and clams: Model results [wp15] indicated that one or more types of grazers (e.g., zooplankton, clams) play a strong role maintaining phytoplankton biomass at low levels during spring and summer throughout large swaths of SFB. However, south of San Pablo Bay, there are no consistently collected zooplankton data available for the past 25 years. In addition, although USGS collected and preserved benthic samples in South Bay and Lower South Bay for eventual quantification of clams and other benthos, insufficient fund led to those samples not being counted. During FY2021, NMS funds were directed toward counting ~18 months of samples from zooplankton tows throughout SFB [P16] and counting and estimating biomass of clams, starting with high-priority years and seasons [P19]. Contracts are in place for both projects, and work is underway, and some data has already been put to use (clams, summer 2017) in exploratory model runs.

Synthesis

The good news -- that launching major field efforts in FY2021 ended up being possible -- did, as anticipated, impact the amount of effort that could be directed to the slate of synthesis projects included in the FY2021 Program Plan. Nonetheless, there was still considerable progress on the synthesis front. Some of the projects summarized below were primarily synthesis, others were hybrids, with at least one technical foot planted firmly within another Science Focus Area. For ease of organization, however, they are captured here, with their other primary focus indicated in parentheses, where appropriate. Substantial progress was made on the following synthesis-related projects:

- [P7] *Lower South Bay DO synthesis*: Considerable progress was made, yielding a valuable technical report describing very high respiration rates in some Lower South Bay slough habitats, in particular those connected to salt ponds (e.g., Alviso, Guadaluple) [wp4]. A key finding is that O_2 concentrations alone can serve as an insufficient metric for evaluating O_2-related condition, because seemingly-acceptable O_2 concentrations can be observed there is in fact a fragile balance between high O_2 production rates and high respiration rates. An additional synthesis need and opportunity arose in response to the red-out smokey days in September 2020, and the second technical reports analysis clearly demonstrated how O_2 levels can plummet in such a system when production suddenly ceases [wp12].

- [P11A] *Trend Analysis* (also Assessment Framework): Considerable investment was made into developing and testing approaches for detecting and quantifying long-term trends in water quality indicators, and in particular doing so in a way that appropriately accounts for uncertainty or confidence intervals in the estimated seasonal values (e.g., chl-a during summer). That method, presented using SFB examples, was documented in a recent publication [wp6]. It has also been developed into a user-friendly web-application that enables on-going tracking of indicator trends (as new years of data become available), and provides opportunities for stakeholders and regulators to explore the data and various assumptions for themselves [wp11]. The tool includes SFB data through Dec 2019, and allows for exploring dissolved oxygen (%-sat or mg/L), gross primary production, and chl-a.
- [P8a] *Factors influencing high phytoplankton biomass events*: Anticipating how SFB will respond in the future to its nutrient loads requires that we understand (and are able to predict) how it has responded in the past across a diversity of forcings. The conceptual model generally invoked to explain phytoplankton blooms in SFB points to the setup of vertical stratification when sufficient freshwater input co-occurs with relatively weak tidal mixing energy. Through exploring 40-yrs of phytoplankton biomass data, and the conditions preceding blooms and non blooms, analyses suggest that there may be other important factor(s) that influenced a substantial number of the largest biomass events. A technical report describing these analyses is in preparation, and expected to be available in November/December 2021.
- Multiple projects summarized above (or below, see AF) included major emphases on interpretation and synthesis. See bullets below; see main project description for details
    - [C3,P18] Section 5 of the September 2020 modeling report [wp18].
    - [P20,C3] Exploring sources and transport of nitrogen to different regions of the delta, both pre- and post-Regional San upgrade [wp5].
    - [P5a] Water quality at perimeter sites in Central and South Bays [wp16].
    - [P13] Coastal nutrient fluxes, technical report on zone of influence of SFB freshwater plume along the coast [wp7].
    - [P11b] Priority analyses for AF Deep Subtidal, comparing historic SFB water quality with proposed condition metrics and thresholds from Assessment Framework 1.0 (see below) [wp9].

Assessment Framework

The Assessment Framework (AF) project summaries are organized below by Deep Subtidal AF and Lower South Bay slough/creek DO.

Deep Subtidal AF Two projects fall directly under this heading [P11a, P11b], and one that is highly relevant to Deep Subtidal AF but falls firmly under Synthesis [P10a]. The Trend Analysis work [P11a] moved forward substantially, as discussed above. This project is continuing into FY2022, with next steps including: in-depth testing of the suitability of the chl-a approach [wp6] to other indicators like DO (mgL or DO%sat) and GPP; working with stakeholders and regulators to identify anticipated uses (e.g., early-warning, tracking long-term change, etc.); and through those discussions identifying regulatory-relevant time windows for quantifying or detecting trends that balance among the realities of system dynamics, management aims, and desired confidence level. The second project [11b] focused on working with the AF Subcommittee to develop a Deep Subtidal AF WorkPlan. A primary component of those discussions involved identifying the range of potential decisions, gathering participants perspectives on the suitability of specific indicators for each type of decision decision. The AF Workplan is essentially complete, and after a round of discussion and refinements will be available [wp2]. The AF subcommittee endorsed the Work Plan's overall approach. In addition to laying out the overall process, the AF Workplan emphasized the early pursuit of no-regret analyses for deep subtidal work, including those those already included in recent Program Plans, for example: develop and apply trend analysis techniques for likely indicators [P11a]; 'Test Drive' the set indicators and criteria identified during AF1.0, i.e., essentially using those criteria to assess historic ambient conditions [11b, wp9]; synthesis of relevant datasets, including those generated over the past several years with the aim of their eventual use in AF development (e.g., [P10]). The test drive will serve as one set of information or analyses that will be used as technical background for expert advisors, and the report was recently completed [wp9]. The components of the HAB synthesis work [P10a] that describe HAB-related condition in SFB were also identified as clear no-regret analyses or data visualizations within the AF Deep Subtidal, but also a necessary step for the HAB synthesis. The remaining work from [P11a] will continue in FY2022, with convening the initial expert work group meeting being a priority activity (i.e., developing goals and charge questions with the AF Subcommittee; organizing that meeting; developing graphics/analyses needed to inform that discussion).

AF LSB DO slough/creeks [P12a] In May 2020, an expert workgroup was convened to provide technical guidance and recommendations on the types of analyses or studies needed to inform the identification of protective DO conditions in LSB slough and creek habitats. After further input from the AF subcommittee and other participants, the process culminate in the AF Workplan for LSB DO slough/creek (which is being incorporated into the overall AF Workplan discussed above). The suite of projects within the workplan served as the basis for proposed work in FY2021 [P12a, P12b]. Work pursued during FY2021 included reconvening a subset of the experts to advise on major decision points and considerations related to applying the Virginia Province Approach (VPA) as one approach for identifying protective conditions in Lower South Bay sloughs and creeks. Tetra Tech developed a detailed workplan to guide next steps, with work on a subset of tasks beginning in FY2022. Exploratory or scoping-level analyses were also conducted using a Metabolic Index (MI) approach, exploring the feasibility of using this technique to develop a MI for sensitive LSB fish. In addition, a subset of the expert group was convened to gather input on: i) highest priority science questions or hypotheses to pursue pursue with statistical modeling of the LSB fish data, with an emphasis on analyses that would yield useful information related to identifying protective DO conditions (using the fish and water quality data alone, or to complement or in conjunction with, for example, the VPA or MI approaches); and ii) 'high-leverage' data gaps that, if addressed through targeted field work, may overcome important constraints (or uncertainties) encountered during statistical analyses of current data. Fieldwork is currently underway based on that input.

Table 1 NMS FY2021 Program Plan, Approved Budget

	REVENUE		
		Source	**FY2021 funds**
1	**R.1**	Nutrient Permit: FY2021 Funds [1]	2,600,000
3	**R.2**	RMP CY2021 [2]	250,000
4	**R.3**	CY2021 RMP Contribution to ship-based monitoring (CY2021) [3]	250,000
5	**R.4**	Reallocated RMP funds [4]	175,000
6	**R.5**	Delta Stewardship Council Fellowship [5] (for project P1c)	225,000
7	**R.6**	Carry forward from FY2020 projects [6]	545,000
8	**R.7**	Funds for LSB modeling [7]	60,000
9	**R.8**	Delta-Suisun Modeling funds (State Board, DRMP) [8]	250,000
10		**TOTAL REVENUE**	**4,355,000**
	EXPENSES		
			FY2021 Cost
	1. PROGRAM		
	Monitoring		
11	**C1**	Ship-based channel monitoring: sampling, analysis	400,000
12	**C2**	Mooring Network: data analysis, interpretation, maintenance	370,000
	Modeling		
13	**C3**	Biogeochemical model development and application	500,000
	Program coordination		
14	**C4**	Science Program Coordination & Program Management	500,000
		Program subtotal	***1,770,000***
	2. PROJECTS		
15	**P1a**	Biogeochemical Field Studies (South Bay)	225,000
16	**P1b**	Biogeochemical Field Studies (Lower South Bay, sloughs/ponds)	20,000
17	**P1c**	Biogeochemical Field Studies (Suisun/Delta)	265,000
18	**P2**	Lateral Variability (phyto,zoops,nuts,HABs)	75,000
19	**P3**	Sediment/light (field, model)	150,000
20	**P4**	LSB model development	100,000
21	**P5a**	HAB special studies: mussels (SFB, Tomales)	75,000
22	**P5b**	HAB special studies: Pseudo-nitzschia growth (cont'd)	55,000
23	**P6**	Phyto-HAB monitor (seq, molec)	75,000
24	**P7**	LSB DO-synthesis	50,000
25	**P8a**	Synthesis: Factors influencing occurrence high phyto biomass events	75,000

Table 1 continued

26	**P8b**	Synthesis: Long-term trends (e.g, chl, GPP, DO, SSC,phytos).	75,000
27	**P8c**	Synthesis: Synthesis / interpretation of HF mooring data	80,000
28	**P8d**	Annual Report	40,000
29	**P9**	Monitoring workgroup	25,000
30	**P10a**	HAB Synthesis	50,000
31	**P10b**	HAB expert workgroup	25,000
32	**P11a**	AF: Trends (continuation FY2020 project)	50,000
33	**P11b**	AF: Priority Analyses	150,000
34	**P12a**	AF: Lower South Bay - DO data analysis / habitat	150,000
35	**P12b**	AF: Lower South Bay - fish/benthos surveys	50,000
36	**P13**	Coastal nutrient fluxes	150,000
37	**P14**	Risk / Scenario	25,000
38	**P15**	Model Advisory Group	50,000
39	**P16**	Zooplankton monitoring (cont'd from FY2020)	58,000
40	**P17**	Expanded Mooring Program (cont'd from FY2020)	50,000
41	**P18**	Nutrient Dynamics (cont'd from FY2020)	27,000
42	**P19**	Benthos counting, South Bay (cont'd from FY2020)	50,000
43	**P20**	Delta-Suisun Modeling (DRMP, State Board)	250,000
44		***Projects subtotal***	***2,520,000***
45		**TOTAL EXPENSES**	**4,290,000**

[1] Base annual funding = $2.2mill. In 2019, BACWA and WB authorized frontloading funds, with up to $2.8mill authorized for FY2021. Current budget includes $2.6mill for FY2021

[2] Calendar year 2021 special studies funding from the RMP. In FY2021, funds are partially supporting C2 (150k) and P3 (100k).

[3] This funding goes directly to USGS to support ship-based monitoring, and offsets costs under C1.

[4] The RMP had remaining funds from prior years that were reallocated to support NMS projects. These were distributed to cover portions of several projects: P2=25k; P3=25k, P6=25k; P9=25k

[5] Funding from the Delta Science Program to support a postdoctoral fellow based at Stanford investigating nutrients in Suisun/Delta, for project P1c, jointly advised by Stanford and SFEI staff. Additional $40k from NMS funds are used to support that project

[6] Funds remaining from several FY2020 projects were carried-forward/continued as FY2021 projects, augmented with FY2021 funds. While FY2020 funds carried forward are not true new revenue, the costs of the related FY2021 costs are the total total cost (FY2021 funds + carry-forward funds), so the related carry-forward funds are accounted for under revenue to balance the budget. Carry-forward funds are covering costs of C4=100k; P1a=75k; P8a=25k; P8b=45k; P8c=60k; P8d=40k;P12b=25k;P12a=75k; P15=25k; P16 = 27k; P19=50k

[7] Funds from LSB dischargers to support LSB model development (P4). Funds were contributed several years ago, and used to support the initial round of LSB model development. The funds will be used this year to continue the work

[8] Funds from DRMP (FY2018) and State Board (FY18) for Suisun-Delta modeling, supporting P20

[9] For consistency with other documents, the FY2021 Funds and Costs are the same as those in the approved FY2021 Program Plan. Some values changed slightly, and were updated during FY2021. Updated numbers are included in the FY2021 Q4 Budget presented at the June 2021 NMS-SC meeting

Table 2 FY2021 NMS Projects: mapping projects to NMS Science Plan 2.0 Science focus areas and Program Areas, along with projects' focus on or relevance to nutrient management considerations in different SFB subembayments

					Science Focus Area							Program Area							Subembayment				
	Project	Cost	Target	Focus Area	Nuts	phyto DO open	phyto DO marg	HABs	Coast	Risk	Program Area	monit	model	spec study	Synth	AF	Prog Mgmt Coord	Subembaym	Suisun	San Pablo	Central	South	Lower South
C1	Ship-based channel monitoring: sampling, analysis	400,000																					
C2	Mooring Network: maintenance, data management	370,000																					
C3	Biogeochemical model development and application	500,000																					
P1a	Biogeochemical Field Studies (South Bay)	225,000																					
P1b	Biogeochemical Field Studies (LSB, sloughs/ponds)	20,000																					
P1c	Biogeochemical Field Studies (Suisun/Delta)	265,000																					
P2	Lateral Variability (phyto,zoops,nuts,HABs)	75,000																					
P3	Sediment/light (field, model)	150,000																					
P4	LSB model development	100,000																					
P5a	HAB special studies: mussels (SFB, Tomales)	75,000																					
P5b	HAB special studies: P-nitzschia growth (cont'd)	55,000																					
P6	Phyto-HAB monitor (seq, molec)	75,000																					
P7	LSB DO-synthesis	50,000																					
P8a	Synthesis: Factors influencing high phyto biomass	75,000																					
P8b	Synthesis: Long-term trends (chl, GPP, DO, SSC)	75,000																					
P8c	Synthesis: Interpretation of HF mooring data	80,000																					
P8d	Annual Report	40,000																					

Table 2 continued

	Project	Cost	Target	Focus Area	Science Focus Area						Program Area	Program Area						Subembaym	Subembayment				
					Nuts	phyto DO open	phyto DO marg	HABs	Coast	Risk		monit	model	spec study	Synth	AF	Prog Mgmt Coord		Suisun	San Pablo	Central	South	Lower South
P9	Monitoring workgroup	25,000																					
P10a	HAB Synthesis	50,000																					
P10b	HAB expert workgroup	25,000																					
P11a	AF: Trends (continuation FY2020 project)	50,000																					
P11b	AF: Priority Analyses	150,000																					
P12a	AF: Lower South Bay - DO data analysis / habitat	150,000																					
P12b	AF: Lower South Bay - fish/benthos surveys	50,000																					
P13	Coastal nutrient fluxes	150,000																					
P14	Risk / Scenario	25,000																					
P15	Model Advisory Group	50,000																					
P16	Zooplankton monitoring (cont'd from FY2020)	58,000																					
P17	Expanded Mooring Program (cont'd from FY2020)	50,000																					
P18	Nutrient Dynamics (cont'd from FY2020)	27,000																					
P19	Benthos counting, South Bay (cont'd from FY2020)	50,000																					
P20	Delta-Suisun Modeling (DRMP, State Board)	250,000																					

Table 3 Recent NMS Work Products, 6/2020-9 2021, with links to documents.

	Work Product	Date
1	Delta-Suisun Biogeochemical Model: WY2016, WY2011	9/2021
2	NMS Assessment Framework Workplan	2/2022
3	Nutrient Source Apportionment in San Francisco Bay: Pilot Study	9/2021
4	Connections to tidal marsh and restored salt ponds drive seasonal and spatial variability in ecosystem metabolic rates in Lower South San Francisco Bay (refinements/revisions, submission to journal)	8/2021
5	Nutrients In The Northern San Francisco Estuary: Transport, Cycling, And Forecasted Changes After Nutrient Load Reductions	8/2021
6	Multi-scale trend analysis of water quality using error propagation of generalized additive models	8/2021
7	Modeling the Dispersal of San Francisco Bay Plume over the Northern and Central California Shelf	6/2021
8	Harmful Algae Monitoring in the San Francisco Bay Delta: Comparative Study of Molecular Techniques and Microscopy	6/2021
9	'Test-Drive' of San Francisco Bay Assessment Framework 1.0	6/2021
10	Progress Report: Controlled experiments to characterize Pseudo-nitszchia growth and toxicity (focus: light, temperature)	2/2021
11	On-line tool for water quality trend analysis: chl-a, DO, and GPP (extended analyses through 2019, adding depth-avg DOmgL and DO%sat)	3/2021
12	Darkened skies from wildfire smoke, extreme heat trigger hypoxia in the San Francisco estuary	2/2021
13	Modeling Near-surface Suspended Sediment Concentration in the San Francisco Bay for Nutrient Management Strategy: Water Year 2017	12/2020
14	Northern San Francisco Estuary (Delta/Suisun) biogeochemical model development (wy2016)	12/2020
15	Hydrodynamic and Biogeochemical Model Development for San Francisco Bay Technical Update, September 2020	8/2020
16	Water quality at perimeter sites in San Francisco Bay	8/2020
17	Lower South Bay hypsographic analysis (slough & creek areas and volumes)	8/2020
18	Bay-Delta Chlorophyll-a in-situ Sensor and Sample Analysis Intercomparison	9/2020
19	Algal Toxins in San Francisco Bay Anchovy	6/2020
20	Exploring the utility of molecular techniques for quantifying harmful algae and characterizing phytoplankton community in San Francisco Bay	6/2020
21	Delta Nutrients: response to Regional San Upgrade	3/2020

Appendix

Table A.2 Recent NMS Work Products, 6/2020-9 2021, with links to documents. Similar to Table 2, work products are mapped to NMS Science Plan 2.0 Science Focus Areas and Program Areas, along with their focus on or relevance to nutrient management considerations in individual SFB subembayments

					Science Focus Area							Program Area							Subembayment				
	Work Product	Date	Target	Focus	Nuts	phyto DO open	phyto DO marg	HABs	Coast	Risk	ProgArea	monit	model	spec study	Synth	AF	Prog Mgmt Coord	Region	Suisun	San Pablo	Central	South	Lower South
1	Delta-Suisun Biogeochemical Model: WY2016, WY2011	9/2021																					
2	NMS Assessment Framework Workplan																						
3	Nutrient Source Apportionment in San Francisco Bay: Pilot Study	9/2021																					
4	Connections to tidal marsh and restored salt ponds drive seasonal and spatial variability in ecosystem metabolic rates in Lower South San Francisco Bay (refinements/revisions, submission to journal)	8/2021																					
5	Nutrients In The Northern San Francisco Estuary: Transport, Cycling, And Forecasted Changes After Nutrient Load Reductions	8/2021																					
6	Multi-scale trend analysis of water quality using error propagation of generalized additive models	8/2021																					
7	Modeling the Dispersal of San Francisco Bay Plume over the Northern and Central California Shelf	6/2021																					

Table A.2 continued

	Work Product	Date	Target	Focus	Science Focus Area: Nuts	Science Focus Area: phyto DO open	Science Focus Area: phyto DO marg	Science Focus Area: HABs	Science Focus Area: Coast	Science Focus Area: Risk	ProgArea	Program Area: monit	Program Area: model	Program Area: spec study	Program Area: Synth	Program Area: AF	Program Area: Prog Mgmt Coord	Region	Subembayment: Suisun	Subembayment: San Pablo	Subembayment: Central	Subembayment: South	Subembayment: Lower South
8	Harmful Algae Monitoring in the San Francisco Bay Delta: Comparative Study of Molecular Techniques and Microscopy	6/2021																					
9	'Test-Drive' of San Francisco Bay Assessment Framework 1.0	6/2021																					
10	Progress Report: Controlled experiments to characterize Pseudo-nitszchia growth and toxicity (focus: light, temperature)	2/2021																					
11	On-line tool for water quality trend analysis: chl-a, DO, and GPP (extended analyses through 2019, adding depth-avg DOmgL and DO%sat)	3/2021																					
12	Darkened skies from wildfire smoke, extreme heat trigger hypoxia in the San Francisco estuary	2/2021																					
13	Modeling Near-surface Suspended Sediment Concentration in the San Francisco Bay for Nutrient Management Strategy: Water Year 2017	12/2020																					
14	Northern San Francisco Estuary (Delta/Suisun) biogeochemical model development (wy2016)	12/2020																					

Table A.2 continued

					Science Focus Area							Program Area							Subembayment				
	Work Product	**Date**	**Target**	**Focus**	**Nuts**	**phyto DO open**	**phyto DO marg**	**HABs**	**Coast**	**Risk**	**ProgArea**	**monit**	**model**	**spec study**	**Synth**	**AF**	**Prog Mgmt Coord**	**Region**	**Suisun**	**San Pablo**	**Central**	**South**	**Lower South**
15	Hydrodynamic and Biogeochemical Model Development for San Francisco Bay Technical Update, September 2020	9/2020																					
16	Water quality at perimeter sites in San Francisco Bay	8/2020																	c				
17	Lower South Bay hypsographic analysis (slough & creek areas and volumes)	8/2020																					
18	Bay-Delta Chlorophyll-a in-situ Sensor and Sample Analysis Intercomparison	8/2020																					
19	Algal Toxins in San Francisco Bay Anchovy	6/2020																					
20	Exploring the utility of molecular techniques for quantifying harmful algae and characterizing phytoplankton community in San Francisco Bay	6/2020																					
21	Delta Nutrients: response to Regional San Upgrade	3/2020																					