To:	RMP Technical Review Committee
From:	David Senn and Emily Novick
Re:	CY2015 Nutrient Proposals

June 22, 2014

Dear TRC:
Attached please find a set of proposals for San Francisco Bay Nutrient Science Program Projects. The proposed projects were identified with input from technical advisors and are aligned with recommendations laid out in the draft Conceptual Model Report, Monitoring Program Development Plan, and Modeling Development Plan. SFEI staff are working with collaborators, Water Board staff, and stakeholders to develop a Nutrient Science Plan. The Science Plan will be developed over the subsequent year and will be broadly vetted among technical advisors and stakeholders, and will eventually receive external review by an expert panel.

Until the draft Science Plan has been vetted, our plan is to continue moving nutrient work forward, recommending and carrying out work that can be considered "no regrets", as we have done over the past 2 years. By no regrets, we mean that the proposed work is considered to be broadly essential across all projects, or as both appropriately timed and falling along the critical path toward informing important management decisions.

Nutrient Science Program Funding: Currently, RMP and funding through the Nutrient Watershed Permit are the primary sources of revenue for San Francisco Bay Nutrient Strategy related work in the Bay. The RMP Multi-Year Plan from 2013 proposed $500,000 in funding for nutrient-related work in 2015, distributed among the focus areas presented in the table below. Total proposed funding for those focus areas is shown in the column second from the right. The accompanying packet contains a slate of proposed projects for the entire Nutrient Science Program Budget in FY2015, with the value identified in the second column from the left being the RMP support requested toward that activity. Any remaining funding will be requested through the Nutrient Steering Committee or other potential funders.

	RMP Allocation in Multi-Year Plan for CY2015 ($1000s)	Overall Proposed Nutrient Science Program Funding FY 2015 ($1000s)	Related Project among FY2015 projects
Modeling (forecasting):	$100	$500	P.1
Moored sensors:	$300	$340	P.3
Monitoring Program Development	$50	$270	P.4
Conceptual model (interpreted here as updates to conceptual models through data synthesis and interpretation)	$30		P.4 (i.e., data synthesis)
Science Coordination/Program Management	$20	$200	P.15
Total	$500	$1310	

				Program Area				Adverse Impact Pathway				
#	Project	Priority for FY2015	Estimated Cost ($1000s) FY2015	Monitoring	Special Study	Modeling	Assessment Framework	High Biomass LowDO Deep Subtidal	LowDO Shallow/Margin	HABs	Altered phytoplankton community	Low production
1	Modeling	High	500			X		X	X	X	X	X
2	Toxin measurements and phytoplankton composition	High	200	X	X		X			X	X	
3	Moored sensor program development/expansion	High	340	X				X	X	X		
4	Monitoring Program development, assessment framework: Analysis of historic data, program design	High	270	X				X	X	X	X	
5	Stratification scenarios for DO and HABs	High	110			X	X	X		X	X	
6	Using monitoring data in conjunction with existing hydrodynamic modeling output to inform monitoring program design	Medium	120	X		X		X		X	X	
7	DO objectives (lit review, data analysis)	High	100				X	X	X			
8	Dissolved Oxygen in shallow habitats	High	300		X				X			
9	Additional Monitoring at current main channel stations in SFB, USGS cruises: phytoplankton taxonomy, nutrients	High	100	X				X		X	X	
10	Suisun Phytoplankton Growth: Continuation of pure culture experiments	High	60		X							X
11	Contribution to shared Research Vessel Purchase, in collaboration with USGS and other potential partners	High	400	X				X		X	X	X
12	Targeted mechanistic studies of HABs, phytoplankton composition, related to nutrient concentrations, forms	Medium	200		X					X	X	
13	Fish/benthos studies in margin habitats to inform site specific DO objectives	Medium	200		X		X	X	X			
14	Sediment flux studies: Benthic oxygen demand, nutrient fluxes/transformations	Medium	250		X			X	X			
15	Program management/science coordination	High	200									
16	External Review	Medium/ High	50									
	Total		3,400									

P.1 Water Quality and Hydrodynamic Modeling	
FY2015 Cost = 500,000; Year 1 funding of a multi-year project. (Note: $350,000 already secured through RMP)	**Priority = HIGH**
Collaborators: SFEI, USGS-Menlo, UC Berkeley, Stanford, UC Davis, key consultants	

This project will begin the development of a water quality (WQ) model for San Francisco Bay to inform nutrient management decisions, and in parallel contribute to the development of the underlying hydrodynamic model through collaboration with USGS-led project CASCaDE II.[1] WQ modeling is the highest priority undertaking for FY2015 for two reasons:

- It will play fundamentally-important roles along the critical path toward informing most management decisions related to assessing health/impairment relative to primary indicators and identifying management actions that would mitigate or prevent impairment.
- Considerable work is needed to develop reliable WQ models

While there are numerous hydrodynamic models for the Bay, there are no WQ models coupled to hydrodynamic models that can be applied toward informing nutrient management decisions. Therefore, the primary Year 1 focus of this multi-year project will be on building regional capacity in WQ modeling. Hydrodynamic model development will move forward through collaboration with the CASCaDE II project, allowing the Nutrient Science Program to leverage ~$2mill in project funding from the Delta Science Program and USGS internal monies. WQ model development and application will be a multi-year effort, and that effort is anticipated to be among the more resource-intensive activities over the next several years. Fortunately, $350,000 in funding has already been allocated by the RMP toward developing this model (combined funds set aside from CY2012-2014) and can be used toward the total estimated cost in FY2015.

The phrase “water quality modeling”, as used here, covers a wide range of parameters and processes, and would be more accurately called biogeochemical (or reactive-transport) modeling plus ecosystem or ecological modeling. Numerous parameters/state variables and processes will be included within the WQ model:

- Predicted nutrient concentrations, and the loads, transformations between nutrient forms, uptake, and losses that create the predicted concentrations
- Phytoplankton biomass (i.e., total biomass) and production rate, loss rate (settling, death, grazing)
- Benthic grazer abundance and grazing rates (e.g., filter feeding clams) and pelagic grazer abundance and grazing rates
- Dissolved oxygen concentrations and the various process add or remove oxygen (+ primary production, air:water exchange; – phytoplankton and planktonic microbial respiration, sediment oxygen demand, nitrification, etc.)

[1] http://cascade.wr.usgs.gov/

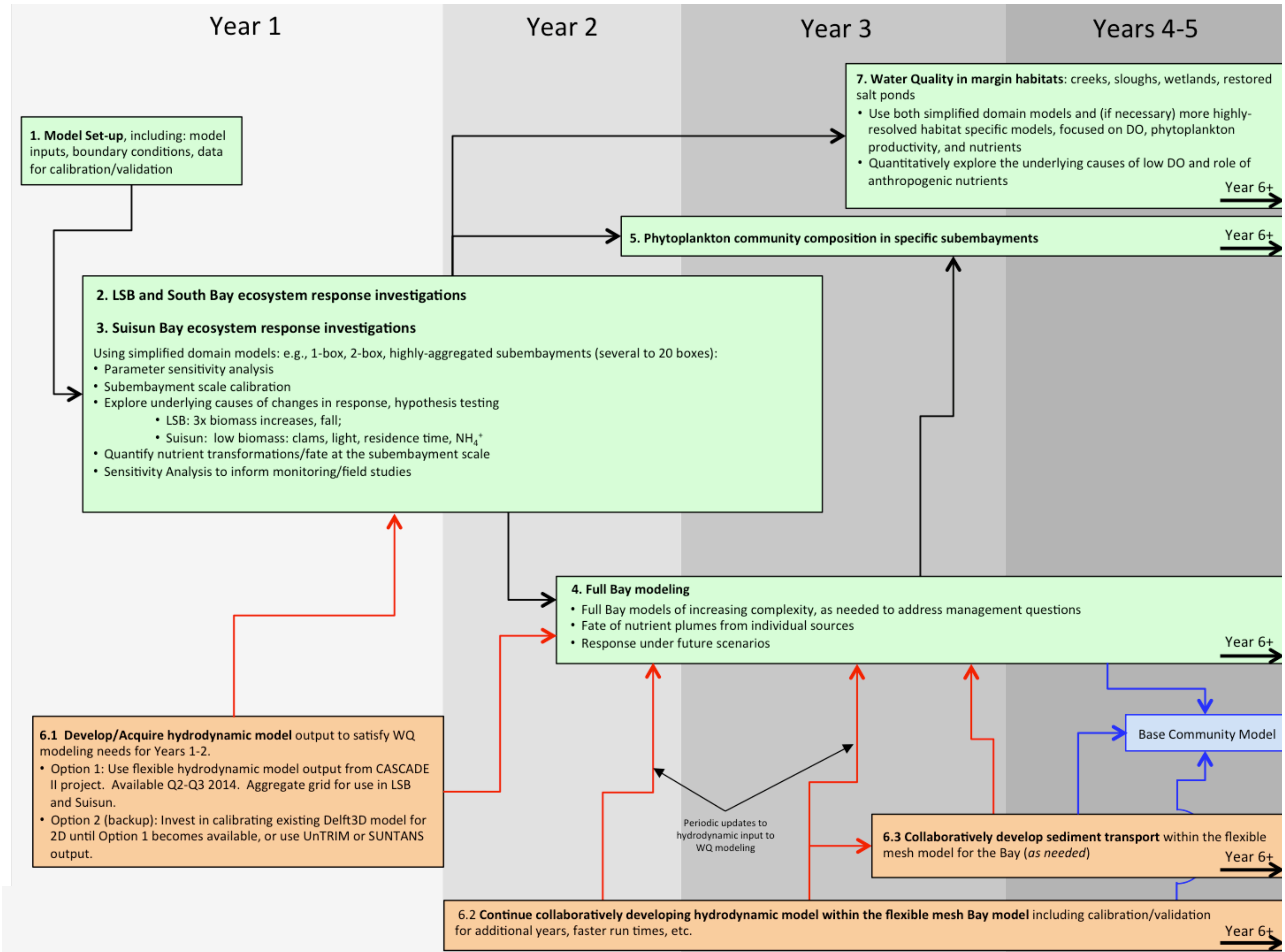
- Nutrient and DO fluxes between the water column sediments, and similar reactions as above within the sediments that drive these fluxes
- Phytoplankton community composition: abundance of several classes of phytoplankton, class-specific growth requirements and growth rates
- Light availability, based either on suspended sediment output from the hydrodynamic model, or specified through a seasonally/spatially varying input file

WQ modeling will proceed in a phased approach (see schematic on p.2), as recommended by a team of modeling experts. After thorough examination of modeland potential platforms, the team recommended that we proceed with Deltares suite of models.[2] The Year 1 focus will be on addressing several key questions related to ecosystem response in simplified-spatial-domain subembayment models (important questions in South/Lower South Bay and Suisun Bay), allowing us to focus more energy on understanding the complex water quality processes, biological response, and physical drivers. In addition to building a solid quantitative-conceptual foundation over that year, work will proceed on gathering/building the key input files and setting up higher spatial resolution models at subembayment and whole-bay scales that will be the focus of work in Year 2 and beyond. While the primary hands-on modeler will be a new SFEI staff person, we plan to continue convening a technical advisors (including experts from Deltares, who will be major collaborators), some providing high level technical guidance and some providing hands-on support.

Year 1 Deliverables
A technical report document will be produced in June 2015 to describe Year 1 progress, and to identify recommended next steps next steps.

Budget
The majority of the salary will be directed toward a full time WQ modeler and collaborating staff (~$300k). The remainder will go toward technical collaborators ($100k) and hydrodynamic model development through the collaboration with USGS ($100k).

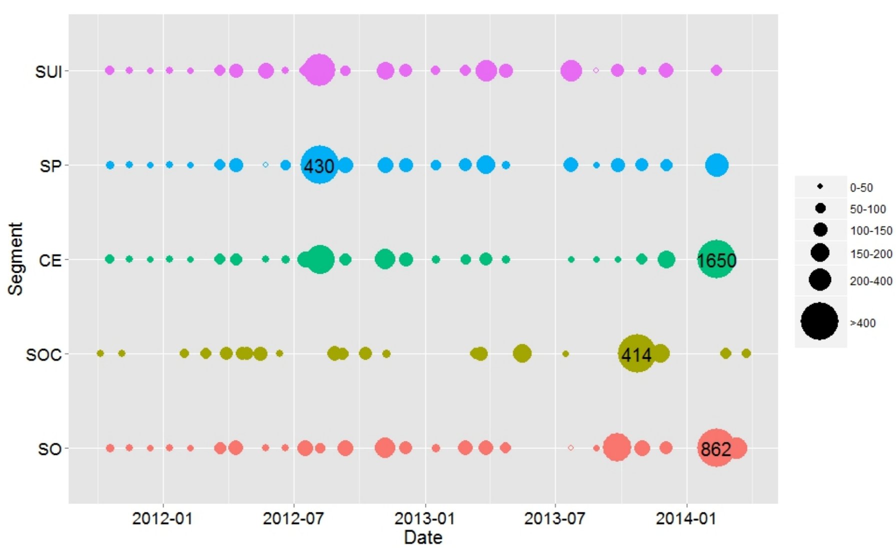
[2] http://www.sfei.org/sites/default/files/Nutrient_Modeling_Approach_draftFINAL_Jan212014.pdf


Year 1
Year 2
Year 3
Years 4-5
7. Water Quality in margin habitats: creeks, sloughs, wetlands, restored salt ponds
• Use both simplified domain models and (if necessary) more highly-resolved habitat specific models, focused on DO, phytoplankton productivity, and nutrients
• Quantitatively explore the underlying causes of low DO and role of anthropogenic nutrients
Year 6+
1. Model Set-up, including: model inputs, boundary conditions, data for calibration/validation
5. Phytoplankton community composition in specific subembayments
Year 6+
2. LSB and South Bay ecosystem response investigations
3. Suisun Bay ecosystem response investigations
Using simplified domain models: e.g., 1-box, 2-box, highly-aggregated subembayments (several to 20 boxes):
• Parameter sensitivity analysis
• Subembayment scale calibration
• Explore underlying causes of changes in response, hypothesis testing
• LSB: 3x biomass increases, fall;
• Suisun: low biomass: clams, light, residence time, NH_4^+
• Quantify nutrient transformations/fate at the subembayment scale
• Sensitivity Analysis to inform monitoring/field studies
4. Full Bay modeling
• Full Bay models of increasing complexity, as needed to address management questions
• Fate of nutrient plumes from individual sources
• Response under future scenarios
Year 6+
Base Community Model
6.1 Develop/Acquire hydrodynamic model output to satisfy WQ modeling needs for Years 1-2.
• Option 1: Use flexible hydrodynamic model output from CASCADE II project. Available Q2-Q3 2014. Aggregate grid for use in LSB and Suisun.
• Option 2 (backup): Invest in calibrating existing Delft3D model for 2D until Option 1 becomes available, or use UnTRIM or SUNTANS output.
Periodic updates to hydrodynamic input to WQ modeling
6.3 Collaboratively develop sediment transport within the flexible mesh model for the Bay (as needed)
Year 6+
6.2 Continue collaboratively developing hydrodynamic model within the flexible mesh Bay model including calibration/validation for additional years, faster run times, etc.
Year 6+

P.2 Develop a 3-yr monthly time-series of algal toxins and phytoplankton community composition in San Francisco Bay	Priority = HIGH
FY2015 Cost = $200,000	
Collaborators: UC Santa Cruz, USGS, SFEI	

In this study, we propose to measure algal toxin concentrations in ~300 archived water column samples collected throughout the Bay between 2011-present; additional water column samples collected during FY2015; and a limited number of bivalve samples. All of the archived water column toxin samples have co-located algal pigment samples, and have been analyzed as part of a currently-funded project, which will allow us to explore the relationship between toxin abundance, chl-a, and phytoplankton community composition.

Developing an improved understanding of the relationship between HABs/toxins and nutrients in San Francisco Bay – and ambient conditions related to toxins and HAB-forming species – are among the highest priority science and monitoring needs for San Francisco Bay. Some phytoplankton species form harmful algal blooms (HABs) that produce toxins that adversely impact both aquatic life and humans. Links between nutrients and HABs/toxins have been shown in some estuaries. However, the relationship is complex, numerous factors contribute to the probability or frequency of HAB occurrence, and there has been limited investigation to date in the Bay exploring these linkages. To better understand both the linkages between nutrients and HABs/toxins in the Bay and ecosystem condition, substantially more data on toxins and phytoplankton composition are needed. Although no HABs have been noted in the Bay over the past few decades, potentially harmful species are commonly detected in low numbers by the USGS. The frequent presence of seed organisms, and the Bay's abundant nutrients, mean that HABs could develop if appropriate physical conditions prevail (stratification, temperature), as evidenced by the Fall 2004 red tide bloom in South Bay (Cloern et al., 2005). Pilot studies (2012-present) carried out by USGS-UCSC, in collaboration with RMP (2013-present), have found that the toxins domoic acid and microcystin commonly occur throughout the Bay. These pilot studies used a



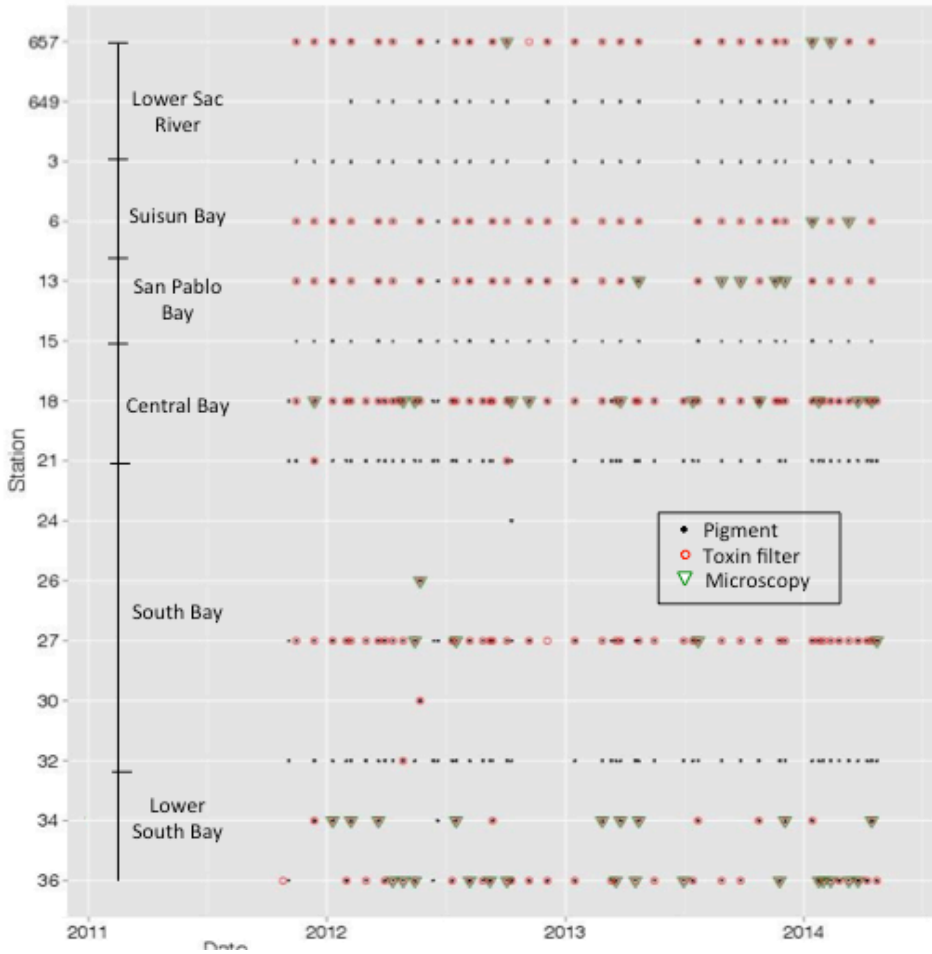
Domoic acid (DA) concentration captured by resin (ng DA/g resin). On some cruises South Bay and Central Bay were combined. SO=South Bay (including LSB); SOC = South + Central Bays; CE = Central Bay; SP = San Pablo Bay; SUI = Suisun + Lower Sacramento River. Numbers represent values of samples greater than 400 ng/g. Data: R Kudela resin that binds several common toxins, and collected subembayment-integrated samples by continuously pumping water from the Bay past the resin while the ship was underway. This approach provides a cost-effective survey for toxins. However, the subembayment-integrated samples are likely too spatially-coarse to improve our understanding both about the magnitude of toxin plumes and the conditions under which toxins were created. An additional difficult with this resin-based technique is that extrapolations back to ambient concentrations are highly uncertain.

The project will achieve the following goals:

- Substantially advance our understanding about current conditions and important mechanisms in SFB with respect to algal toxins.
  - Determine how algal toxin concentrations vary seasonally and spatially, and, to some degree, how they vary interannually (over this relatively short period of record);
  - Assess how toxin concentrations compare to thresholds known to adversely impact ecological health;
  - To the extent possible, develop an improved understanding of, and testable hypotheses for, the physical/chemical/biological factors that contribute to the occurrence of higher/lower toxin abundance.
- Inform monitoring program requirements for toxin measurements, including:
  - Necessary spatial/temporal sampling resolution to adequately describe variability and to capture "events of concern" through comparison of discrete filter samples and subembayment–integrated measurements ;
  - Appropriate analytical methods (e.g., integrated resin-based samples vs. discrete locations) and optimized analytical techniques (e.g., methodologies for extracting the most relevant spectrum of toxins from a single sample).

Sample Collection and Measurement: This project will include several "Definite" (D) sets of analyses and one or more "Optional" (O) analyses. The choice among optional activities would depend both on available time and resources, and on indications from early measurements about which direction(s) would be most informative. Activities will include:

1. Measure toxin concentrations in filters collected during past or on-going monitoring at existing USGS sites
   - D.1 Archived filters collected beginning in 2008, after salt ponds were breached, through Apr 2014, generally at monthly or greater frequency, at stations in Lower South Bay (40 samples). Salt ponds are hypothesized to act as an incubator for harmful phytoplankton species.
   - D.2 Archived filters collected monthly from Nov 2011-Jun 2014 at one station per subembayment on a monthly basis (~240 samples, including 40 from Lower South Bay noted above). At all of those stations, pigment filters were also collected and recently analyzed in 2013-2014 as part of a related project.
   - O.1 Filters collected at 6-12 stations per full-Bay cruise from Jul 2014-May 2015 (100+ samples)



Locations and dates for archived toxin samples, along with co-located pigment and microscopy samples

2. Measure toxin concentrations in bivalve samples
   - D.3 Archived samples from Mussel-watch sites, RMP sampling, and other relevant past sampling activities (12 samples from 2012, 10-15 samples from 2014)
3. As part of other planned field activities in Fall 2014 (P.8), collect filter samples at 6-9 sites on a monthly basis. (2-3 sloughs, 3 sites per slough, and 1 station at the down-estuary end of Coyote Creek; Aug-Nov = 30-40 samples)
   - O.2 These samples could be collected during other fieldwork and would not require their own field campaign. For any newly-collected samples, pigment samples will also be analyzed.

Deliverables

- Progress update at 6 months
- Technical report at project's completion

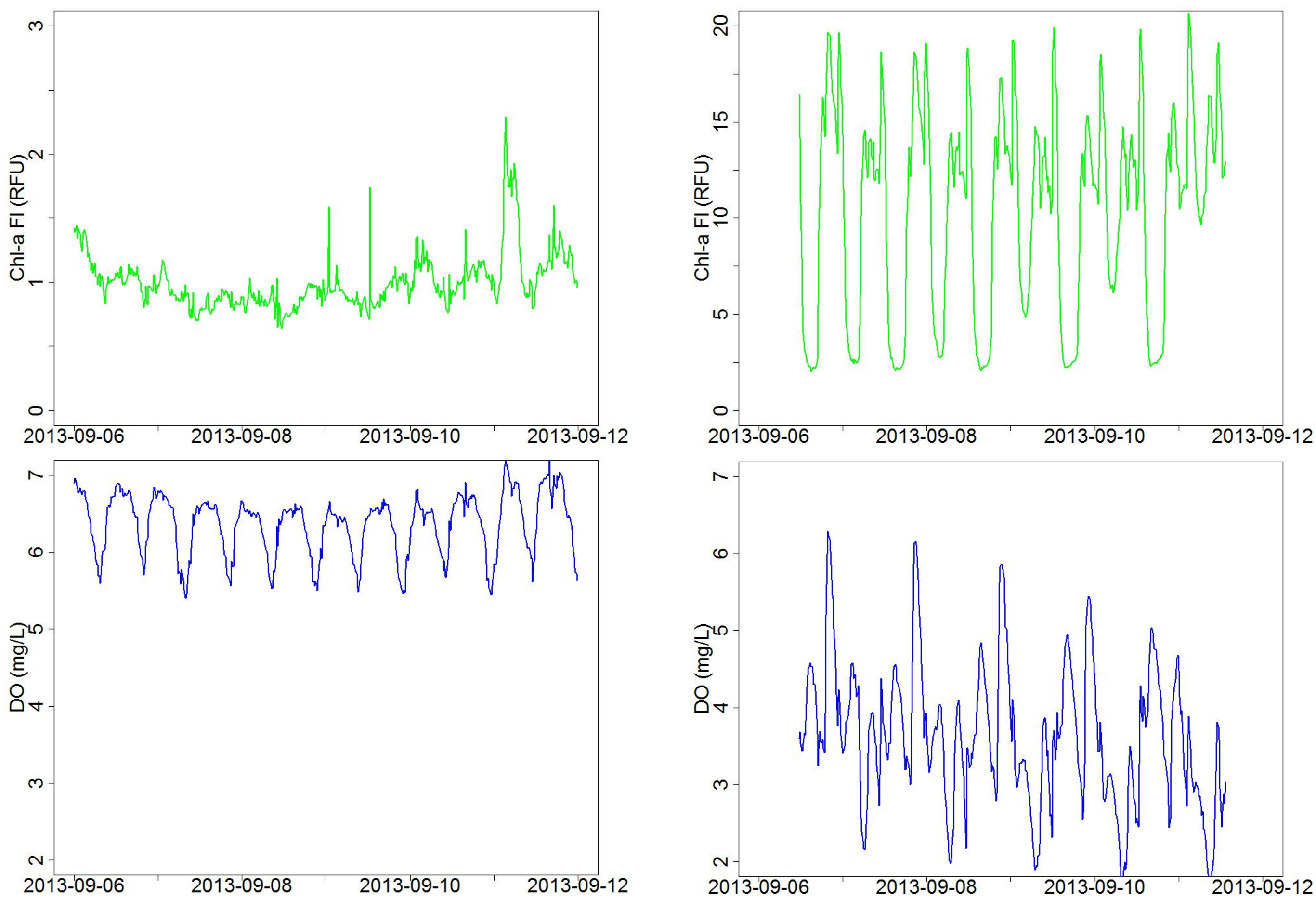
Budget

Funding will support a 1-year postdoc at UCSC to carry out sample analysis, data interpretation, and report preparation; analytical costs (lab supplies and consumables); collaborator support/supervision (total: $170k); and SFEI staff support (30k).

P.3 Moored sensor program development/expansion	Priority = HIGH
FY2015 Cost = $340,000	
Collaborators: SFEI, USGS-Sac, USGS-Menlo, SanJose	

While scientific studies and monitoring by the USGS, DWR-EMP, and RMP provide us with several decades of water quality data in the Bay, most of that data has been collected at weekly-monthly time intervals. Phytoplankton biomass and related parameters such as nutrients, dissolved oxygen, and suspended sediments vary strongly over much shorter time scales (hours) due to diel cycles, mixing, biogeochemical processes, and tides. To better assess the Bay's condition, and to collect high-frequency data to calibrate water quality models, the RMP began funding a moored sensor network in 2013. This proposed study will: maintain existing stations; add one additional station; and continue data analysis and on-line data. visualization/download work; and inform on-going monitoring program development.

In Summer 2013, sensors for chl-a, dissolved oxygen, turbidity, temperature and other parameters were deployed at 3 stations in Lower South Bay and South Bay in



Chl-a (relative fluorescence units; RFU) and Dissolved Oxygen (mg/L) at Dumbarton Bridge and Alviso Slough (4km upslough from confluence with Coyote Creek) over a 5 day period. At both sites, chl-a fluorescence varied tidally, but maximum values were 10-15 times greater at Alviso than Dumbarton (note different y-axis scales. Although the fluorescence signal is prone to interferences, the large differences here suggest that maximum phytoplankton biomass at Alviso (~50 µg/L) was substantially greater than at Dumbarton (3-5 µg/L), and emphasize the strong spatial and temporal variability in chl-a. DO also varied tidally at both sites. The DO minima at Dumbarton occurred at low tide, which could be the result of low DO draining shallow margin habitats mixing with open-bay water and moving past the sensor. DO was substantially lower at Alviso than Dumbarton and exhibited a multiple strongly-periodic maxima and minima.

collaboration with the USGS's sediment group, who already have infrastructure for continuous monitoring for a subset of parameters in these areas. One of the sites, the Dumbarton Bridge, telemeters data every 15-minutes to a server, which will allow for eventually viewing data in near-real time. Year 1 efforts focused on installation, developing capacity for moored sensor maintenance and operation (including creating procedures for maintenance and data processing/management), and interpreting data to identify sites for network expansion. At present, moored sensors have been installed at Dumbarton Bridge, San Mateo Bridge, and in Alviso Slough.

In FY2015, we propose to add a 4^{th} station in South Bay or Lower South Bay. Potential locations include Coyote Creek near where it enters Lower South Bay, or on a channel marker in the southern quarter of Lower South Bay, based on the strong north-south gradients in nutrients, chl-a, and suspended sediments in Lower South Bay. To allow for improved estimates of chl-a and phytoplankton biomass, we will design and execute experiments to better constrain the chl:fluorescence relationship and estimate uncertainty. We will also add telemetry to new and existing stations, where possible given site-specific logistical constraints. Due to increasing data, we will also invest further in developing standard procedures for data management and processing, including automation where possible, and developing a database. We will also further develop a web-accessible data visualization and download tool for accessing real-time and historic sensor data (pilot project begun in year 1). The goal is for this web interface to host data from multiple programs (SFEI/RMP, 2 USGS groups, and possibly others) and allow for intuitive data visualization, including viewing time series data from multiple stations and multiple parameters simultaneously.

Deliverables

A progress report will be submitted June 2015. In that report, we will analyze data to inform system understanding, identify lessons learned from year 2 of the program, and make recommendations for moored sensor priorities in year 3.

Budget

The budget for this task for FY2015 is \$340,000. \$250,000 of this is for personnel support across a range of tasks: sensor installation, maintenance and operation; data processing and management; data visualization; and data analysis and reporting. \$70,000 will be used to purchase equipment for a 4^{th} station, including telemetry, as well as to purchase one additional nitrate sensor. \$20,000 will be used for field logistics support for our collaborators at USGS-Sacramento.

P.4.A Analysis of historic data to inform monitoring program development, assessment framework development, and synthesis/mechanistic interpretations P.4.B On-going development of monitoring program structure	Priority = HIGH
FY2015 Cost = $270,000	
Collaborators: SFEI, UC SantaCruz, USGS-Menlo, RTC, other technical advisors, SCCWRP	

P.4.A Analysis of historic data to inform monitoring program development, assessment framework development, and synthesis/mechanistic interpretations

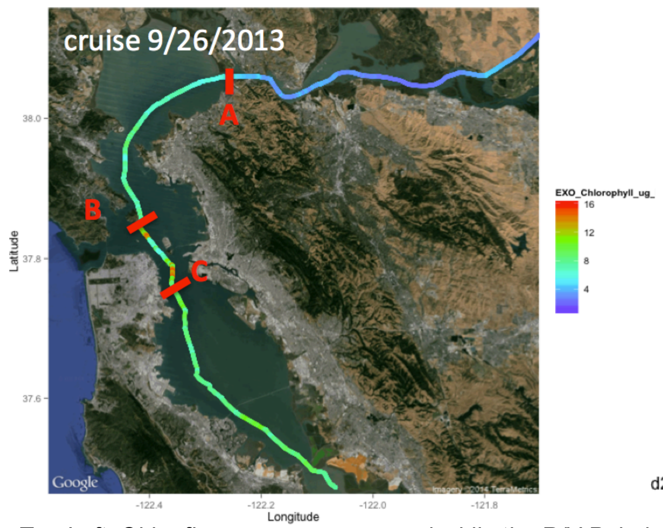
Summing over the many years of anticipated water quality monitoring ahead, the monitoring program will likely account for the largest portion of overall nutrient program costs. Therefore, there is considerable benefit to carefully planning and designing the most efficacious yet cost-effective program. We are also fortunate - for monitoring and assessment framework development and on-going synthesis/mechanistic interpretations - that long-term systematically collected monitoring data (~40 years) exist, plus data from a number of special studies, that can be extensively mined.

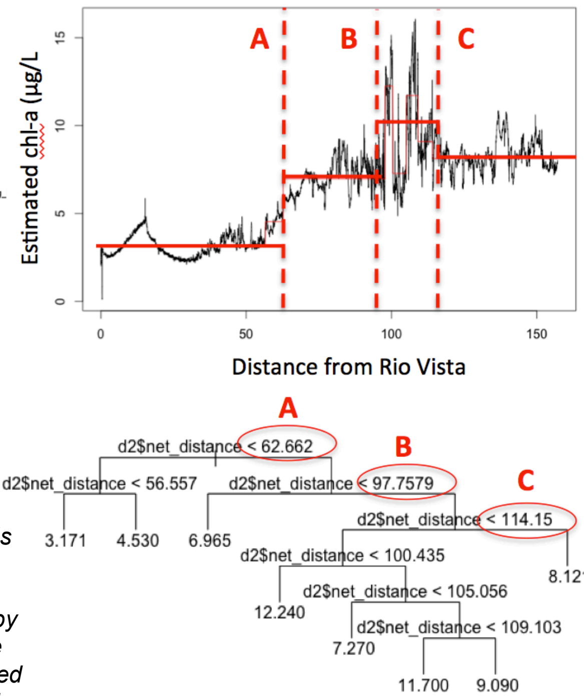
Through this project we will use historic monitoring data and other more focused data sets to explore key questions that technical advisors identified as important for informing monitoring program design, assessment framework development, and our overall understand of ecosystem response to identify data gaps and priority studies. Example questions include:

1. What is the optimal spatial/temporal resolution of sampling?
    a. What sampling spatial resolution is needed along the longitudinal axis of the Bay to capture most of the variability across a range of relevant parameters, seasons, etc.?
    b. What sampling spatial resolution is needed laterally, as a function of subembayment and season?
    c. In South Bay, what is the minimum temporal sampling during important periods (e.g., spring blooms)?
    d. What are characteristic scales (space/time) of phytoplankton blooms in Suisun Bay?
    e. Where should moored sensors be placed? What is the optimal blend of ship-based sampling and moored sensors?
2. Identifying spatial/temporal resolution of priority “events” (i.e., what are we trying to detect?)
    a. What levels of toxin concentration are problematic? How do these translate into spatial, concentration, and duration scales?
    b. What changes in phytoplankton composition or occurrence of potentially harmful species do we need to detect?
    c. What sampling resolution (lateral, longitudinal) is required to capture the priority “events” described above?

3. How has phytoplankton community composition in South Bay, Central Bay, and Lower South Bay changed over the past 20 years? What changes in physical, chemical, or biological drivers can explain those changes?
4. How frequently (and under what conditions) does the relationship used to estimate productivity in SFB (based on chl-a concentration and PAR, i.e., Cole and Cloern 1987) need to be validated/calibrated?

As each of these questions is explored, the results will be summarized as technical reports and, where appropriate, peer-reviewed publications. These technical reports will either be stand-alone documents, or included as sections within other reports related to monitoring program development or assessment framework development.





Top Left: Chl-a fluorescence measured while the R/V Polaris moved throughout the Bay during sampling on 9/26/2013. Top Right: Estimated chl-a vs. distance on 9/26/2013. Faint red line trace indicates multiple break-split points detected by tree-based regression, but does not indicate the importance of those breaks. Dashed vertical lines and thick horizontal red lines indicate the splits determined to be the most important. Bottom Right: This tree illustrates the relative importance of splits, with A, B, and C representing the largest splits. Similar analyses will be carried for multiple dates/seasons, multiple parameters (chl-a, turbidity, T, salinity, nutrient concentrations) to identify the optimal spacing of stations along the Bay's axis.

P.4.B On-going development of monitoring program structure

In March 2014, we completed a draft monitoring program development plan with input from a team of technical advisors. That plan is being circulated to stakeholders and other collaborators in June 2014 for additional input. The report lays out a number of priority activities – from analysis of existing data to inform optimal program design (spatial/temporal sampling frequency) to identifying a set of tiered recommendations for program implementation (new analytes, methods, costs, etc.).

During FY 2015, 2 meetings will be held with technical advisors, and 2 meetings with the Nutrient Technical Workgroup to obtain feedback from a group with a range of perspectives. With guidance from the technical advisors and the NTW we will undertake the highest priority activities, using those recommended in the program development plan as a starting point.

Deliverables

Interim progress reports and updates will be produced in the form of powerpoint presentations or memos in advance of technical advisor or NTW meetings. Meeting summaries will also be prepared. An annual progress report on program development will also be prepared, bringing together results/recommendations for program structure (based on data analysis) with other programmatic advances (e.g., new analytes, methods, costs, tiers). An additional option is to produce an Nutrient Science Program annual report that summarizes progress on multiple fronts, describes monitoring-related observations (status, trends), and presents noteworthy results from special studies. If this product is viewed as a high priority, the budget/planning for this task may need to be reevaluated.

Budget

Funding will support staff effort on data analysis, program development, and report preparation (~235k), technical advisors/collaborators (35k).

P.5 Stratification scenarios for DO and HABs	Priority = HIGH
FY2015 Cost = $80,000	
Collaborators: UC Berkeley, SFEI, SCCWRP, USGS-Menlo	

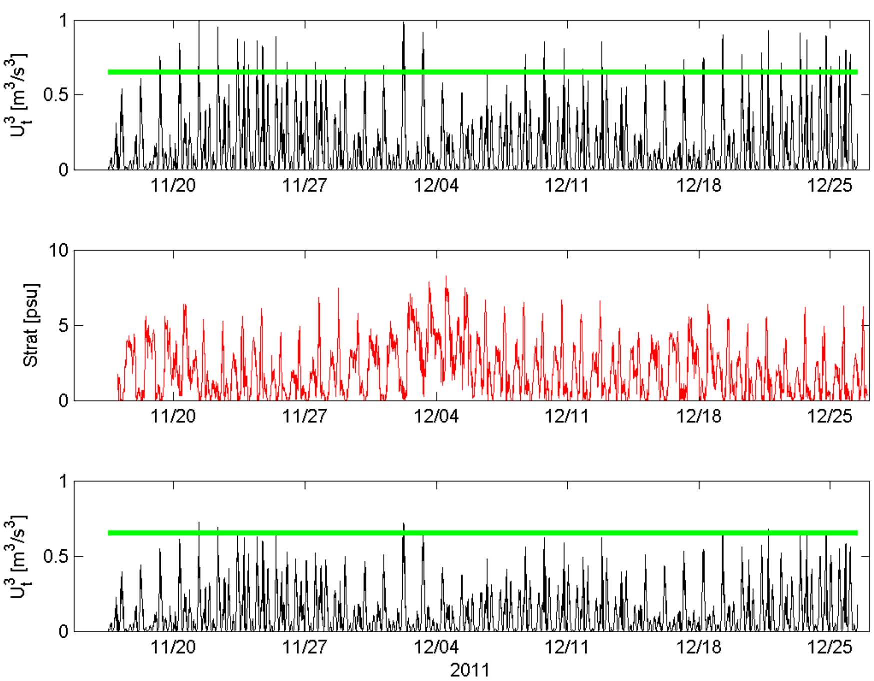
The frequency and duration of water column stratification events in SFB is an important determinant of whether low DO and harmful algal blooms could become problems in deep subtidal habitats, in particular in South Bay and Lower South Bay. Initial worst-case-scenario calculations indicate that phytoplankton blooms of realistic magnitude could translate into low DO in bottom waters. However, those calculations assume that the water column stratifies for a long enough interval that the bloom can develop, and remains stratified long enough to allow low DO to develop and persist such that adverse impacts occur. Prolonged stratification also creates conditions under which HABs can form: e.g., the Fall 2004 red tide bloom in South Bay (Cloern et al, 2005). Under current conditions, stratification in San Francisco Bay is known to be variable at a wide range of timescales due to the strong tidal forcing and seasonal cycle in river flows and associated density gradients. This study will examine the relation and competition between the drivers that cause and break down stratification, assess the potential for this relationship to change such that stratification persists long enough to cause adverse impacts. More specifically, this study will address the following questions:

1. How frequently does stratification develop in different areas of the Bay and for how long does it typically persist?
2. What combinations of physical forcings lead to the set-up and break-down of stratification in key areas of SFB? What regulates the magnitudes of these opposing forcings, in particular around periods when shifts between stratified and destratified tend to occur? What could alter the magnitudes of these forcings?
3. How would changes in forcings translate to changes in stratification duration as determined through simplified domain modeling?

Analysis of long-term observations from Suisun Bay and South Bay will be combined with highly detailed shorter observation periods from the same basins to establish current stratification conditions. A focus of this analysis will be on establishing the relationship between stratifying processes that vary on seasonal, hydrographic (i.e., freshwater flow) event and tidal (semi-diurnal, diurnal and spring-neap) timescales and mixing processes that act to maintain an unstratified water column. We anticipate that both basins experience tidally-periodic stratification, with some persistence across multiple tidal cycles occurring during neap tides. We will explore the likelihood of stratification persisting for a spring-neap period (14+ days) under current conditions. The persistence of stratification across the spring-neap cycle is a critical threshold, since once stratification persists across one spring-neap cycle, it is likely to persist across multiple, potentially resulting in stratification that lasts for months.

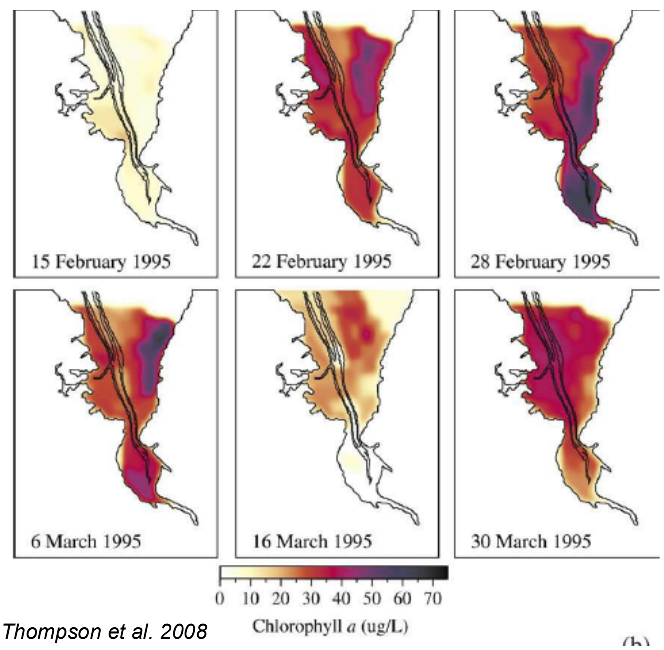
To evaluate how future scenarios of change will influence the variation of stratification, we will build on the observational analysis using a combination of theoretical and numerical analysis. The theoretical analysis will compare stratifying and destratifying processes using dimensionless groups and evaluate the probability of various lengths of stratification persistence under scenarios of climate change. Combining this analysis with simplified numerical models, which resolve the vertical structure of the density and flows (i.e., for a water column), will allow us to explicitly evaluate future scenarios and determine under what set of future conditions stratification may persist across the spring-neap cycle. Future scenarios will probe variation in stratification that may arise from changes to (a) freshwater flows/density gradients; (b) shorelines (whether by management action or sea level rise) and associated changes to the tides; (c) atmospheric heating; and (d) wind mixing. The future scenarios will be described by changes in tidal forcing (informed by considering scenarios for shoreline change; and analysis of sea level rise and inundation performed under separate funding) and alterations to the local buoyancy forcing (salinity gradients induced by freshwater flows). The balance between stratifying and destratifying processes will be evaluated using the numerical water column analysis with a particular focus on the threshold for stratification to persist across an entire spring-neap cycle.

To illustrate the importance of these analyses, preliminary analysis of data from a Suisun Bay site indicates the potential for long-term persistent stratification under future scenarios. The top panel presents a metric of mixing (turbulent velocity cubed) and the second panel shows the co-located stratification (top-bottom salinity difference). The stratification is seen to be strongly periodic tidally, but a period of persistent stratification develops around December 4. Based on this stratification record, an estimated threshold for destratification is overlaid on the top panel (green horizontal line). In the bottom panel, the same comparison is made as in the top panel, but now with the tidal velocities uniformly reduced by 10%. If the threshold for destratification remains the same, even this minor change in tidal forcing is expected to lead to stratification that would persist for 2 weeks or more, as only a few tidal periods have sufficient energy to pass the threshold for destratification.



P.6 Apply hydrodynamic modeling output to inform monitoring program design	**Priority = MED**
FY2015 Cost = $120,000	
Collaborators: SFEI and collaborators	

The vast majority of water quality data collection in San Francisco Bay occurred in deep habitats along the Bay's main channel. However, it is well known that phytoplankton blooms commonly begin along the Bay's broad shoals. The Bay is generally considered to be a light-limited system throughout most of its area and much of the year. Along the shoals, the shallow water column allows for higher light levels, and higher phytoplankton growth rates. Other processes, such as biogeochemical transformations at the sediment:water interface, likely also have a more pronounced effect on water column chemistry than in deep subtidal areas.



Thompson et al. 2008

Tidal and wind-driven mixing also exert strong influences on the measured concentrations of various constituents. In that sense, the water mass at any location in the Bay is actually a time- and space-integrated sample, a mixture of water masses from different locations that contribute unique amounts to the final concentration of constitute. Therefore, designing the optimal monitoring program – one that captures the desired degree of spatial and temporal variability in key parameters and is capable of detecting "events of concern" (e.g., a phytoplankton bloom of a certain size; a plume of algal toxins) – will require hydrodynamic modeling.

Motivated by a similar goal as P.4, this project will combine output from existing hydrodynamic simulations with event scenarios or historic water quality data to achieve the following goals:

1. Introduce events of concern, such as major blooms or algal toxin events, and identify the optimal sampling scheme to reliably capture a range of priority events
2. Using backward trajectory modeling, identify the sources of water (space, time) that contributed to ambient concentrations at existing stations along the Bay's main channel; constrain the originating conditions that could have created observed conditions; and reveal zones that are poorly captured by the current program design.

Existing hydrodynamic model outputs that could be considedered include 1-2 years of Bay-wide SUNTANS simulations, or multiple years (up to 20) of output from UnTRIM.

<table>
<tr><td>P.7 DO objectives (lit review, data analysis)</td><td rowspan="3">Priority = HIGH</td></tr>
<tr><td>FY2015 Cost = 100,000</td></tr>
<tr><td>Collaborators: SCCWRP, SFEI, technical advisors</td></tr>
</table>

This project will be a data analysis and literature review study focused on identifying what DO levels are protective beneficial of beneficial uses. It will address the following questions:

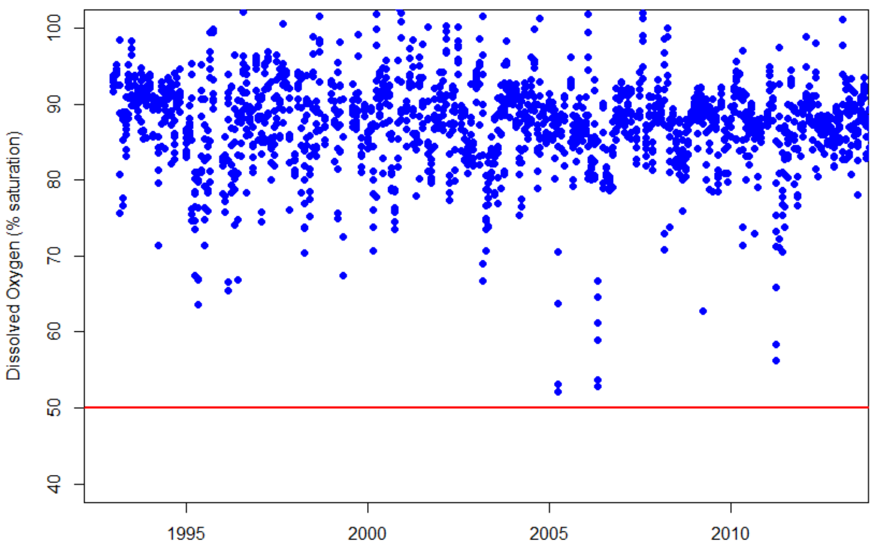
- What beneficial uses, and more specifically, what aquatic organisms are we aiming to protect in various habitats (deep subtidal, sloughs, creeks, wetlands)?
- What levels of DO are optimal or protective for those beneficial uses and organisms during life stages when they utlize those habitats?
- What low DO conditions would adversely impact those habitats/organisms - DO concentration, duration of events, spatial extent, seasonality (eg., relative to critical life stages)?
- How have other estuaries or coastal zones addressed the issue of site-specifc DO criteria, and “naturally” low DO in margin/shallow habitats?

The San Francisco Bay Regional Water Quality Control Board has secured $100,000 for this project, will support SCCWRP and SFEI staff and technical team for data analysis, literature review, and report preparation.

P.8 Dissolved oxygen in shallow margin habitats	**Priority = HIGH**
FY2015 Cost = 300,000 This is a 1-year funding request for a project that would likely continue over 2+ years.	
Collaborators: SFEI, SanJose Santa Clara Valley Wastewater Agencylester, USGS-Sac	

This proposed project will install, maintain, and interpret results from a several-station network of continuous monitoring stations for DO and other parameters in shallow margin habitats (creeks, sloughs) in Lower South Bay to assess condition with respect to DO and inform our understanding of major drivers.

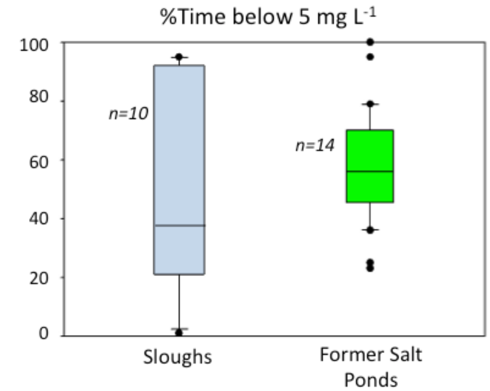
Low dissolved oxygen (DO) is a common symptom of excessive nutrient loads to estuaries and other water bodies, and results from oxygen consumption during

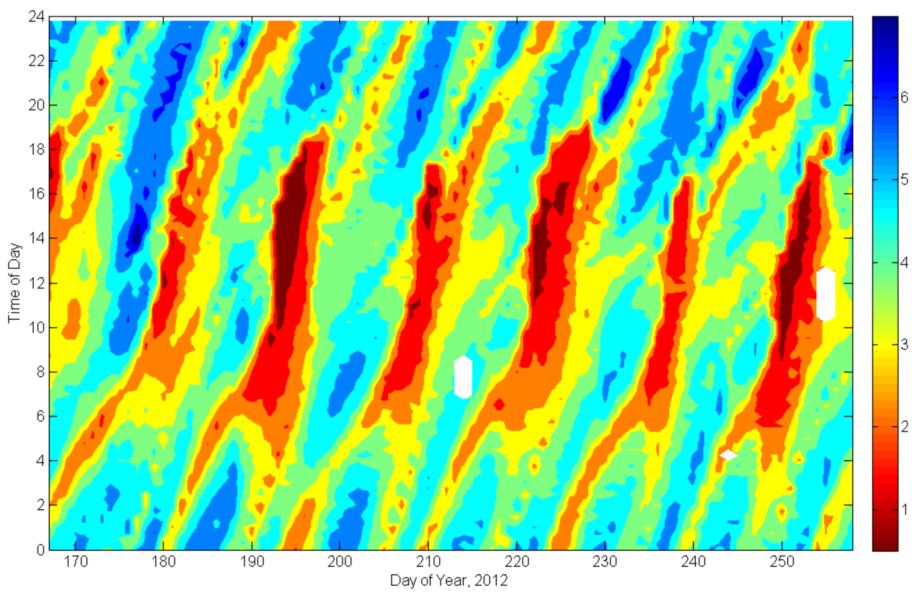


DO %saturation in bottom waters in deep subtidal areas at all USGS stations south of the Bay Bridge, 1993-2013. 100% saturation corresponds to 8.5±1.5 mg/L depending on temperature and salinity.

microbial degradation of organic matter (e.g., phytoplankton). Because of its well-established mechanistic link to nutrients, dissolved oxygen concentration is among the likely indicators of nutrient-related ecosystem health in San Francisco Bay. Most data on dissolved oxygen concentrations over the past ~20+ years have been collected in deep subtidal habitats, and DO concentrations, in general, have substantially exceed the Basin Plan criterion of 5 mg/L. Considerably less data is available for shallow margin habitats in San Francisco Bay, including sloughs, creeks, tidal wetlands, and former salt ponds undergoing restoration. Although these areas represent important habitats for aquatic organisms at certain life stages, there is no coordinated, systematic monitoring across a representative set of sites.

A recent survey of existing continuous DO data collected over a 12 year period by assorted programs in South Bay and Lower South Bay margin habitats showed that DO was frequently below 5 mg/L (40% and 55% of the time, averaged across sites, in slough and former salt ponds, respectively). Low DO occurs naturally in margin habitats like wetlands and sloughs. However there is currently insufficient information to characterize the frequency, duration, and severity (how low) of events, or to explore the underlying causes (importance of natural vs. anthropogenic factors). One excellent data set, collected in Alviso Slough demonstrates that low DO exhibits strong periodicity and persists at levels <2-3 mg/L for 12 hours or more over several days. This station is, however, 2.5 miles upslough from the confluence with Coyote Creek, and the spatial extent of low DO there, and how representative this condition of other sites, are unknown.





DO (contours; mg/L) as a function of date and time of day, Jun 15 –Sep 14 2012. Sensor was ~2 ft above the bottom. Low DO occurred during strongly periodic windows that coincided with weak neap tides. During these windows, DO was lowest during daylight hours when oxygen production would otherwise be expected, and DO increased during highest tide of the day, which occurred during the late evening. One hypothesis that can explain the daily pattern is that stratification developed due to low tidal mixing energy during these weak neap tides, and oxygen was rapidly consumed in the bottom layer due to sediment oxygen demand. An alternate hypothesis is that the entire water column had low DO concentrations, and the low DO water mass was pushed further upstream during high tide. Data: M Downing-Kunz; SFEI 2014.

Funding is being requested for Year 1 of a 1-2 year field study to determine the frequency, duration, and spatial extent of low DO in representative margin habits (sloughs, creeks) using moored sensors complemented by field sampling/calibration. This project's major goals, include:

1. Characterize temporal (tides, diel) and spatial patterns in DO and related parameters across a sites having a representative range of physical/biological characteristics;
2. Determine the frequency and duration of events with DO < 5 mg/L (and other relevant thresholds);
3. Through additional field measurements (vertical profiles during longitudinal transects), characterize the spatial extent of noteworthy events or common conditions,

4. Through the use of basic modeling and field data, semi-quantitatively test hypotheses for why low DO occurs.

Instruments will be installed at up to 6 sites, and will require maintenance and data download approximately every 2-4 weeks, depending on the time of year and rate of biofouling. During regular maintenance trips and some special field trips (to coincide with events), DO will be measured in vertical profiles at stations along longitudinal transects in creeks and sloughs to spatially-characterize conditions.

Ideally, 2-3 of the sites for this project would be installed in August-September 2014, since low DO is most pronounced in Summer/Fall.

Deliverables

Progress updates will be given in the form of presentations and meeting materials at technical team meetings and NTW meetings. A final technical report will be produced at the project's completion.

Budget

Funds will be directed toward instrumentation and equipment (110k), staff time for maintenance and data interpretation (150k), and field support for USGS (40k).

P.9 Additional Monitoring at current main channel stations in SFB, USGS cruises: phytoplankton taxonomy, nutrients	**Priority = HIGH**
FY2015 Cost = $100,000	
Collaborators: USGS, SFEI/RMP	

Currently, the USGS analyses samples for phytoplankton composition on only a limited number of stations, and only under certain conditions (typically only when chl-a exceeds 5ug/L), typically <5 stations per full-Bay cruise. Much more information – and collected consistently at a defined set of stations – is needed on community composition to determine if adverse shifts in phytoplankton composition are occurring, or harmful species are present at concerning levels, and to explore the underlying mechanisms leading to such shifts.

Similarly, nutrients are not a core part of the USGS research program and "optional"; therefore the full suite of analytes (i.e., no TN or TP) is not measured and spatial/temporal frequency is lower than is needed.

Deliverable and Budget
This project would support the measurement of 300 sets of nutrient analyses ($35k) and taxonomy on 300 samples for phytoplankton community composition and biovolume ($65k).

The results of these analyses would be made publicly available through USGS's website.

P.10 Physiological Assessment of the "Bad Suisun" Phenomenon: Light and Nutrient Interactions	**Priority = HIGH**
FY2015 Cost = $60,000	
Collaborators: UCSantaCruz, AMS	

Ammonium (NH_4^+) inhibition of phytoplankton productivity in Suisun Bay has been inferred from increases in chlorophyll during mixed-assemblage incubations, coinciding with depletion of ammonium and increasing use of nitrate during the incubation period (Dugdale et al. 2007, Parker et al. 2012). These results may be confounded by changes in irradiance, growth rates and species composition between ambient and test conditions. To tease apart environmental and community effects from physiological effects, and to determine if elevated concentrations of NH_4^+ directly cause a decline in primary production under controlled conditions, this project will test 1) the NH_4^+ tolerance, 2) the influence of differences sources of nitrogen (N), and finally 3) the relative importance of N sources versus irradiance in regulating growth of individual phytoplankton species endemic to Suisun Bay.

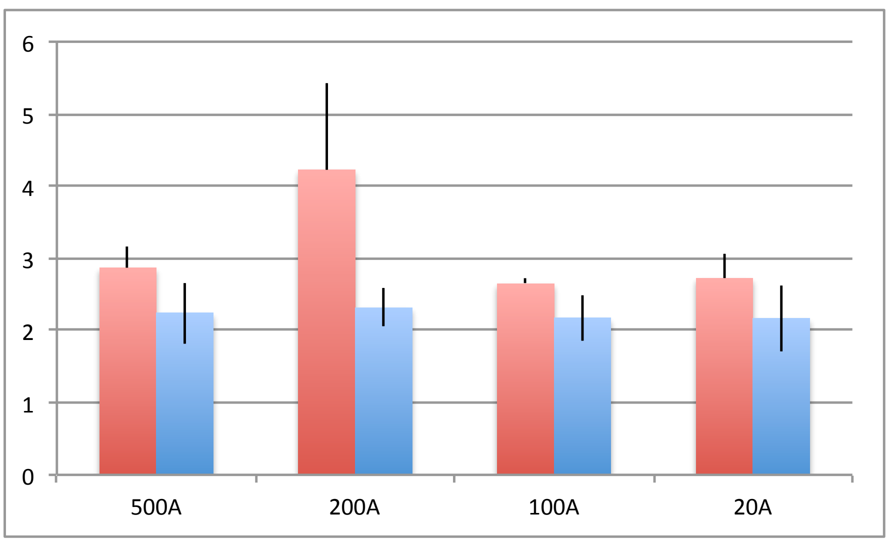


Figure 1. Carbon fixation (μg C μg Chl a-1 hr-1 on the y-axis in the diatom *Thalassiosira weissflogii* as a function of NH_4^+ (red bars) or NO_3^- (blue bars) at concentrations of 20-500 μmoles L^{-1} on the x-axis.

To date, eight species of phytoplankton from Suisun Bay have been isolated into pure culture. Only three of these have been tested for their tolerance to NH_4^+, as well as for growth on NH_4^+ relative to nitrate (NO_3^-). In one of the tested species, the diatom *Thalassiosira weisflogii*, the rate of carbon fixation was similar when grown on NH_4^+ compared to NO_3^-, and optimal NH_4^+ concentration for growth was 200 µmoles NH_4^+ L^{-1}. No inhibition of growth occurred in the range of NH_4^+ concentrations (20-500 µmoles L^{-1}) tested here (Figure 1). We would like to test the remaining five species for their NH_4^+/ NO_3^- tolerance levels, and to perform irradiance-nutrient interaction experiments on three of the eight species isolated. One of the eight species of phytoplankton isolated is the diatom *Thalassiosira pseudonana*. This diatom is also in culture at the National

Center for Marine Algae (NCMA) and has had its genome sequenced (Abrust et al. 2004). It was originally isolated in 1958 from Moriches Bay in Long Island, NY, and we would like to compare the tolerance levels of the freshly isolated *T. psedonana* strain from Suisun Bay with that from NCMA to determine whether NH_4^+ tolerance levels are similar or dissimilar in these two cultures. This comparison will give us information on how large a role acclimation to culture conditions over a period of more than four decades may play in modulating the NH_4^+ tolerance thresholds of algae.

Using a similar rationale, we would like to isolate two-four species of phytoplankton from the southern part of San Francisco Bay (South Bay) in order to test their NH_4^+ tolerance thresholds. Comparison of tolerance levels between species already isolated from Suisun Bay with those from South Bay will tell us whether phytoplankton tolerance levels are similar or dissimilar in species from the two endpoints of the Bay. Both the comparison of phytoplankton isolated from Suisun with a species in the NCMA culture collection, and with species from South Bay, will help us understand whether NH_4^+ tolerance thresholds are largely genetically determined and/or how much a role acclimation to different regions and conditions play. These comparisons between literature, cultures and endpoints of the Bay will provide a mechanistic understanding of the interactions between NH_4^+ concentration and phytoplankton productivit, information that is necessary to make sound management decisions regarding the degree to which nutrients forms and concentrations exert negative control over the food web in Suisun Bay.

<table>
<tr><td>P.11 Contribution to shared Research Vessel Purchase, in collaboration with USGS and other potential partners</td><td rowspan="3">Priority = HIGH
(but may not be possible this year)</td></tr>
<tr><td>FY2015 Cost = 400,000</td></tr>
<tr><td>Collaborators: USGS, SFEI, multiple partners</td></tr>
</table>

The USGS research vessel needs to be retired sometime within the next 2 years. USGS has a long-term personnel and operation budget to continue supporting a vessel and associated research and monitoring activities. However, USGS is limited in its access to funds to purchase another research vessel.

USGS has signaled its interest in partnering with organizations affiliated with the Nutrient Steering Committee on the purchase of a replacement research vessel. Contributing to the research vessel's purchase would secure the continuity of the 40-year water quality record for the Bay. USGS would continue docking, maintaining and operating the vessel. From a long-term (10 year) strategic and financial standpoint, contributing to the vessel purchase would ensure priority future research vessel use that could amount to a large cost savings for the region.

While directing funds toward this purchase may not be feasible with the current FY2015 budget, this is an important opportunity to ensure data collection continues through a federal-regional partnership. It is recommended that this remain a high-priority topic for discussion during the first half of FY2015, and that the Nutrient Steering Committee consider options for identifying or raising funds to support this collaborative effort.

P.12 Other targeted mechanistic studies exploring the role of nutrients in shaping phytoplankton community composition (including HABs), causing decreased primary production, or other effects	**Priority = MED** (wait for FY2016)
FY2015 Cost = 200,000	
Collaborators: xxx	

This project would test hypotheses of N:P, high NH_4, and high NO_3 on phytoplankton community, individual cell composition, etc. as one step along the path of evaluating whether these effects are occurring, and assessing their relative importance alongside other drivers.

While more studies on this topic will likely be needed to inform management decisions, given the number of recently completed (but still being written up) and on-going studies on this topic in the Suisun/Delta, it is proposed that no additional studies be sponsored during FY2015 from the Nutrient Steering Committee resources.

P.13 Fish/benthos field investigations in margin habitats to inform site specific DO objectives	**Priority = MED** (wait for FY2016)
FY2015 Cost = 200,000/yr, multi-year study	
Collaborators: UCDavis, SCCWRP, SFEI	

This project would conduct fish/benthos surveys in Lower South Bay (open waters) and in slough/creek habitats to identify species abundance and richness. The work would help inform several of the questions raised in P.7 related to habitat suitability with respect to DO for supporting fish and benthos. DO and T data would also need to be collected.

This project is a ultimately a high priority for determining if current conditions are supporting the expected habitat requirements of important species. Given budget constraints, this multi-year project could begin in FY2016. Starting in FY2016 would also allow DO data collected in FY2015 through P.8. to inform sampling design (and a continuation of P.8 during FY2016 would provide the necessary DO data to accompany biota survey data). However, if additional resources become available, the startup of P.6 and P.13 during the same year could allow for considerable overall cost savings.

P.15 Science Coordination/program management	**Priority = HIGH**
FY2015 Cost = 200,000	
Collaborators: SFEI	

This project supports science coordination across projects, coordination with Nutrient Steering Committee, regulators and stakeholders, outreach, project management, contract management, and basic reporting. Funding would support 40% the Nutrient Science Program Lead Scientist (the remainder of support for the Lead Scientist is included within individual projects) and other SFEI staff for program management.

As the Nutrient Science Program moves into its second (first official) year and the number of work products and general progress increase, it may be important to begin generating an annual report – to serve as a progress report and to disseminate information to targeted audiences (managers, regulators, politicians). In particular, the editorial committee of the *State of the Estuary* has inquired whether the Nutrient Science Program could take the lead an effort developing the nutrient section during FY2015 and FY2016 (report publication date in FY2016). The Nutrient Science Program is well-positioned to take on that role. However, guidance is sought from the NSC, both about whether this is indeed an appropriate role and how it ranks among other priorities. Note: Costs associated with either an annual progress report or the *State of the Estuary* effort have <u>not</u> been included in the above budget.

P.16 External Review	**Priority = MED/HIGH**
FY2015 Cost = 50,000	

Convene an external advisory panel to review key aspects of the Nutrient Science Program and key work products (science plan, etc.), hold meeting with the NSC, stakeholders, and collaborators/experts.

The question here is not whether external review is important. Instead the question is whether this should be carried out first in FY2015 or FY2016.

Approximately $30k from a FY2014 contract with BACWA for coordinating external review is being carried forward to FY2015,


November 2012

San Francisco Bay Nutrient Management Strategy

San Francisco Bay Regional Water Quality Control Board

1. Is SFB experiencing nutrient-related impairment, or is it likely to in the future?
    - What types of impairment?
    - What forms of nutrients?
    - What future scenarios?

2. What are the major nutrient sources?
    - POTWs ?
    - stormwater ?
    - agriculture ?

3. What loads/concentrations are protective?
    - most sensitive endpoint ?
    - transport, mixing ?
    - reactions (transformations, losses) ?

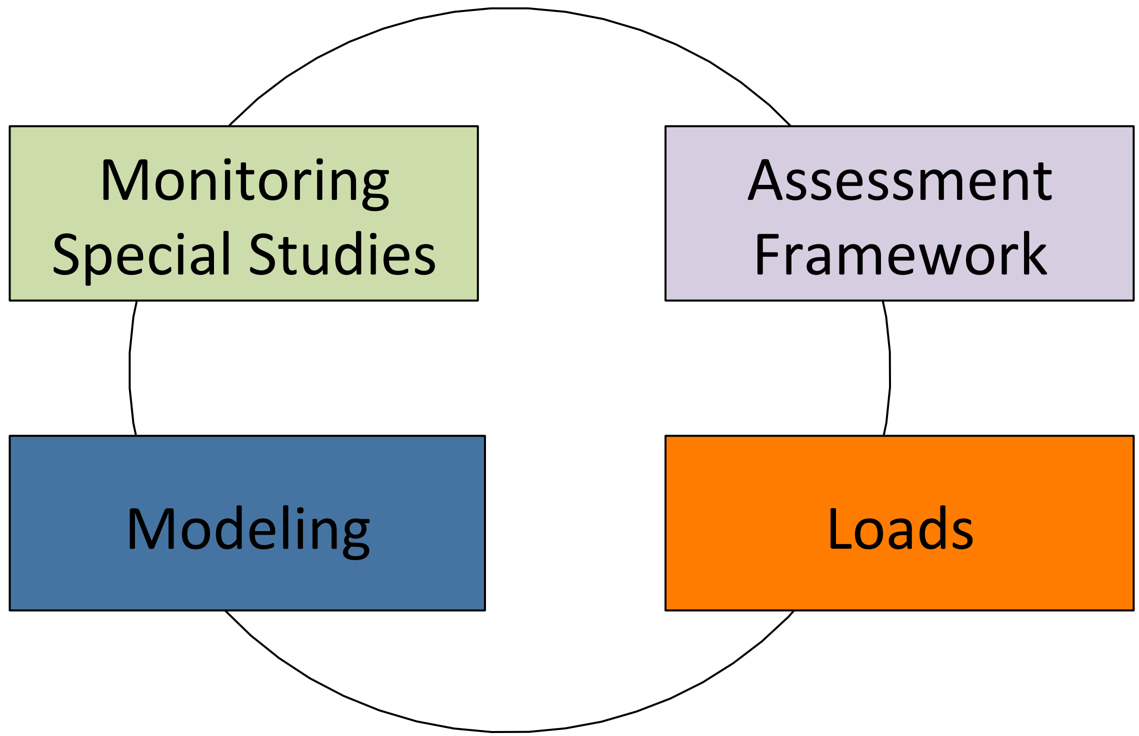
4. What reductions will protect ecosystems?
    - transport, mixing, reactions ?
    - benefit/cost ?


November 2012

San Francisco Bay Nutrient Management Strategy

San Francisco Bay Regional Water Quality Control Board

Nutrient Science Program

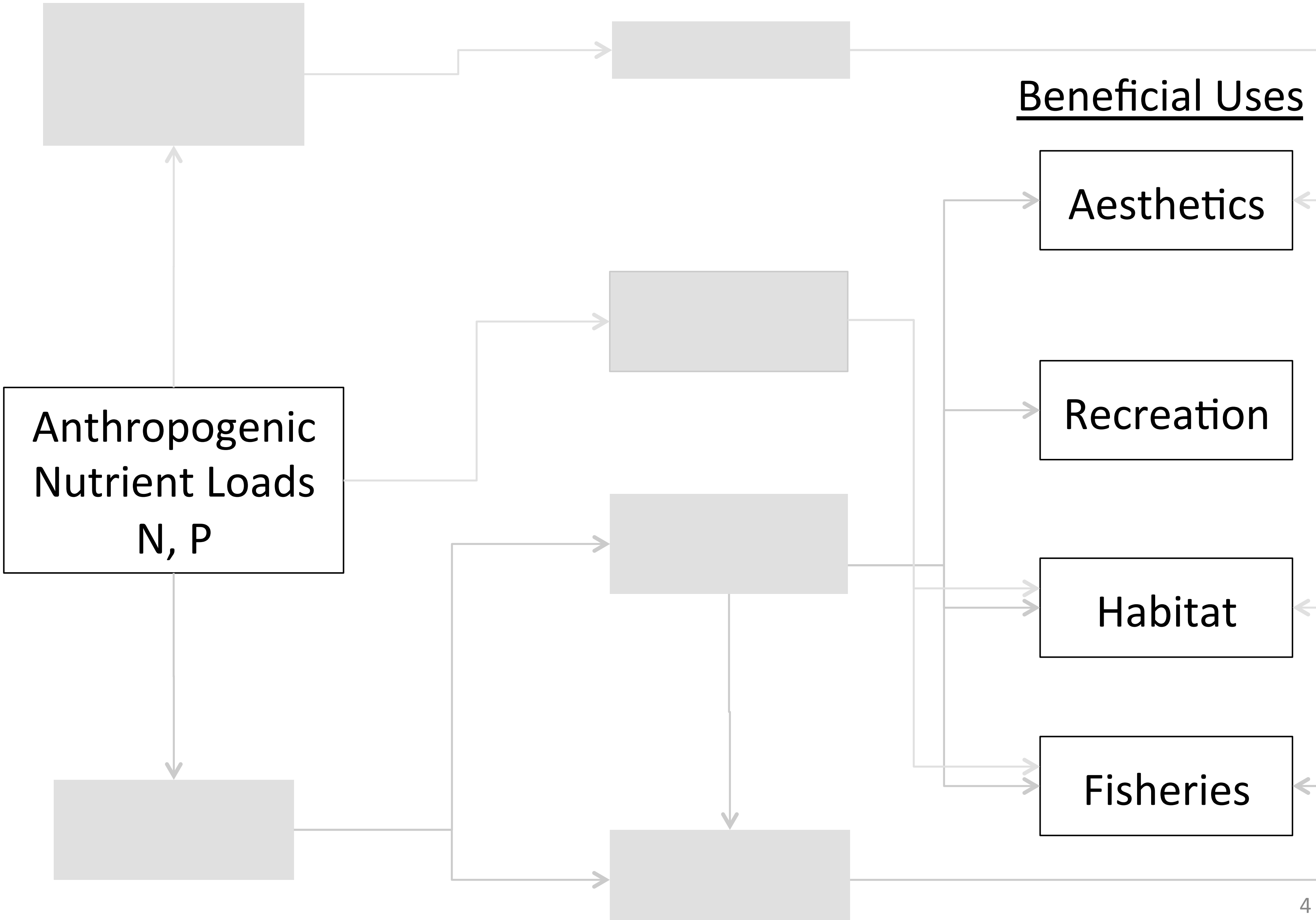


Highest Priority Nutrient Issues in SFB

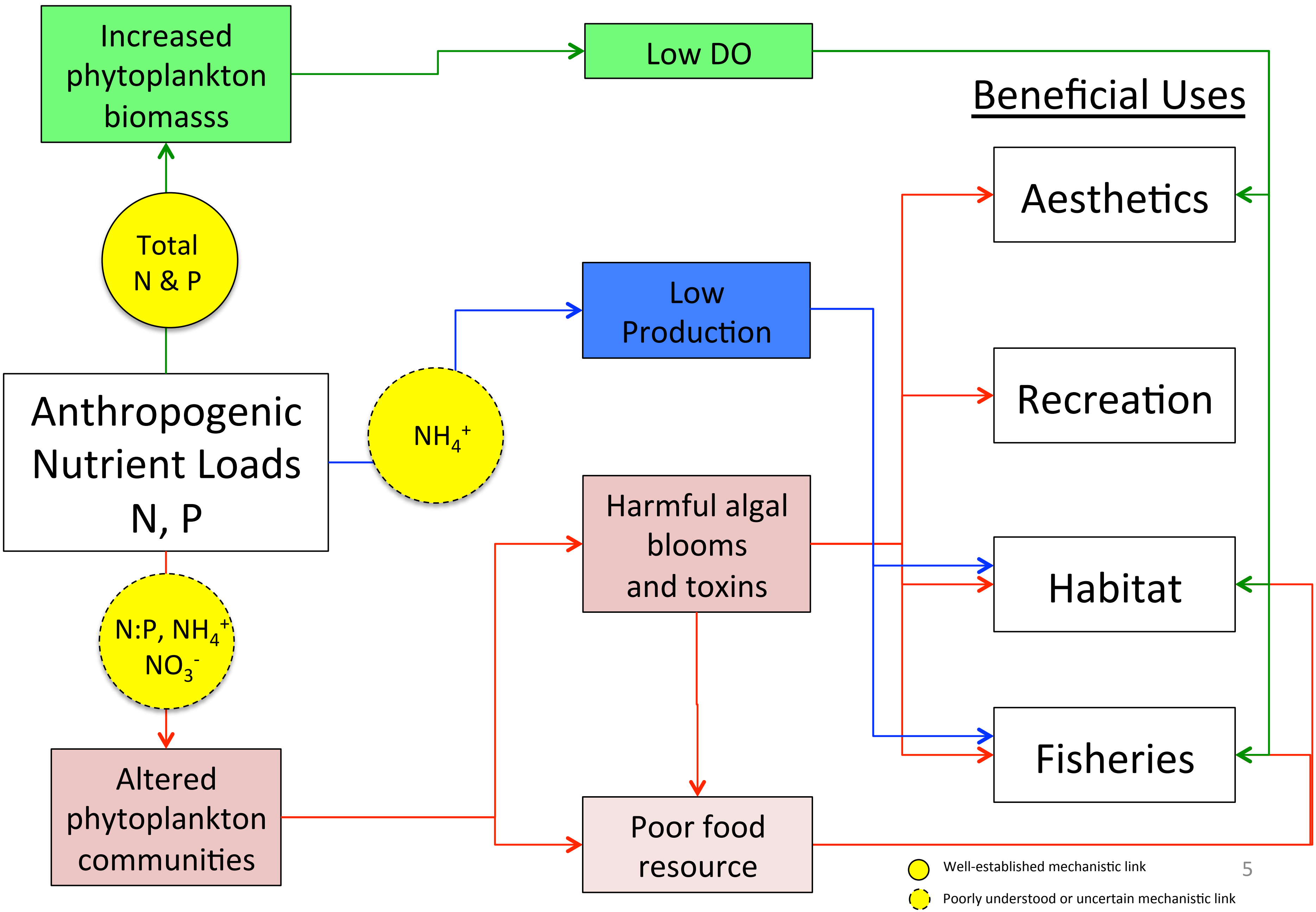
- Determine whether increasing biomass signals future impairment
- Quantify factors that adversely affect phytoplankton composition, including the potential for Harmful Algal Blooms and toxins
- Determine if low DO in shallow habitats causes impairment
  - Quantify role of nutrients
- Test future scenarios that may lead to worsening conditions
- Quantify nutrient contributions to different areas of the Bay
- Test mitigation/prevention scenarios

SFEI 2014b

Potential Pathways to Adverse Impacts



Potential Pathways to Adverse Impacts



2011-2014

Past Studies or Studies Underway

External Loads Study

Effluent Characterization

Effluent Characterization

Delta Loads

Hydrodynamic and Water Quality Modeling

NNE Report

Nutrient Strategy

Conceptual Model

Suisun Synthesis I

Science Plan

LSB Synthesis

Suisun Synthesis II

Assessment Framework Planning

Evaluate Assessment approaches

HAB Toxins

On-going monitoring

Suisun Field Studies

Suisun Field Studies

Pilot: Phyto pigments

Pilot: Moored Sensors

Data Analysis/ Interpretation

Program Design/ Development

On-going monitoring

Suisun phyto studies

Quantify Loads

Load Reductions: Scenarios

Modeling

Synthesis, Science Plan

Assessment Framework

Monitoring, Special Studies

Key Background Documents (and recommendations)

- Nutrient Strategy

http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/amendments/estuarineNNE/Nutrient_Strategy%20November%202012.pdf

- Scientific Foundation for a San Francisco Bay Nutrient Strategy (aka, Conceptual Model Report)

SFEI 2014a
Draft. Final in May 2014
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/amendments/estuarineNNE/SAG-June-2013/Nutrients_CM_DRAFT_May12013.pdf

- Suisun Bay Ammonium Synthesis

http://www.sfei.org/sites/default/files/SuisunSynthesisI_Final_March2014_0.pdf

- External Nutrient Loads to San Francisco Bay

SFEI 2014b
http://www.sfei.org/sites/default/files/NutrientLoadsFINAL_FINAL_Jan232014_0.pdf

- Approaches to a Nutrient Assessment Framework

SCCWRP 2013
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/amendments/estuarineNNE/SAG-June-2013/NNE_Framework_White_Paper.pdf

- Characterizing Nutrient Trends, Loads, and Transformations in Suisun Bay and the Delta.

SFEI 2014d
http://www.sfei.org/sites/default/files/IEP%202014%20ENovick%20FINAL.pdf

- Model Development Plan

http://www.sfei.org/sites/default/files/Nutrient_Modeling_Approach_draftFINAL_Jan212014.pdf

- Numeric nutrient endpoint development for San Francisco Bay – Lit review and data gaps analysis

http://www.sfei.org/sites/default/files/644_SFBayNNE_LitReview%20Final.pdf

- Approaches to a Nutrient Assessment Framework, Draft

http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/amendments/estuarineNNE/SAG-June-2013/NNE_Framework_White_Paper.pdf

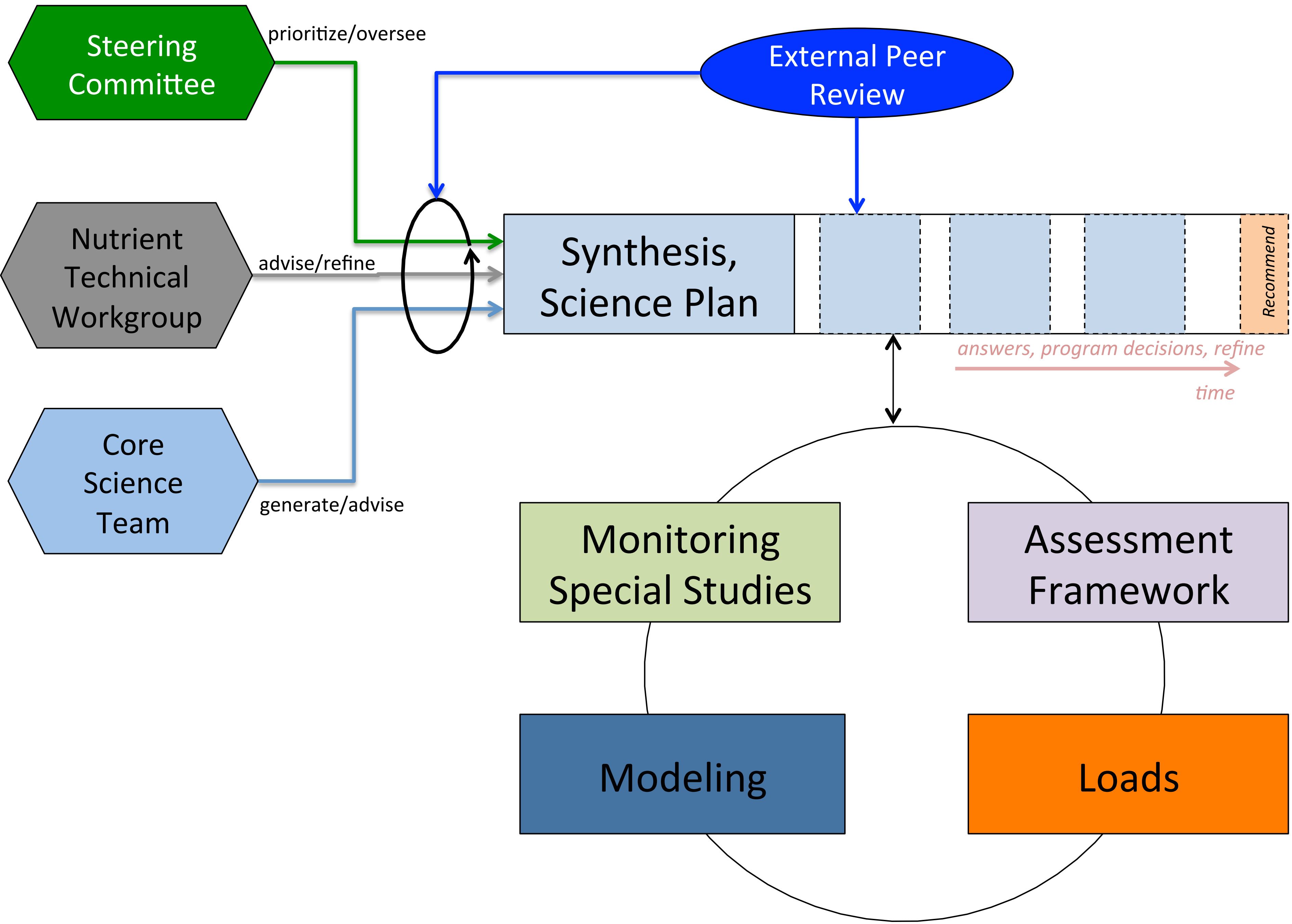
Available Funding for FY2015

Program	Amount	Notes
new		
Nutrient Steering Committee	~$800	
RMP*	$500	moored sensors, modeling
SFB Water Board	$65k	Science Plan Development
SFB Water Board	$100k	Dissolved oxygen objectives
Carry forward		
RMP Modeling	~$300k	From prior years
total	$1.8mill	

*Provisionally allocated

Science Plan

- The science plan will be developed over the coming year and will serve as a guide, prioritization, and workflow/schedule for major activities needed inform nutrient management decisions in SFB.
- Over the past two years, we've been identifying and prioritizing projects based on recommendations from the draft Conceptual Model Report, and recruiting input from technical advisors and stakeholders
- For the FY2015 proposed projects, while developing the longer term (5yr) Science Plan, we are following a similar approach, and ensuring that the proposed projects are "no regrets" studies that will ultimately be part of the Science Plan, and ones that would implemented in its early phases.
- It is expected that the Science Plan will be consistent with the broad recommendations laid out in the Nutrient Strategy. The Science Plan will, however, go into substantially more detail in terms of specific study and data needs, a proposed workflow schedule, and estimated costs. In large part, the Science Plan will actually integrate across recommendations laid out for the major Nutrient Science Program components…monitoring, modeling, special studies, assessment framework.
- While the Science Plan is not yet developed, several of the key reports whose recommendations will inform much of the Science Plan are complete or in draft form. Recommendations for FY2015 are based on recommendations or priorities identified in:
  - Conceptual Model Report
  - Suisun Synthesis I
  - Monitoring Program Development Plan
  - Modeling Plan
  - Assessment framework plan
- Relevant excerpts from those reports are included at the end of this document. The full Monitoring Program Development Plan is also included.



Steering Committee
prioritize/oversee
External Peer Review
Nutrient Technical Workgroup
advise/refine
Synthesis, Science Plan
Recommend
answers, program decisions, refine
time
Core Science Team
generate/advise
Monitoring Special Studies
Assessment Framework
Modeling
Loads