San Francisco Estuary Institute
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Nutrient Strategy Meeting

September 15th, 2011
San Francisco Estuary Institute
Second Floor Conference Room
7770 Pardee Lane, Oakland, CA
1:00 PM – 4:30 PM

The goals of this meeting are to:

- Discuss organization and near-term activities (6 month timeframe) of nutrient strategy workgroup;
- Provide feedback on SF Bay draft nutrient strategy, including management questions, goals, and feedback and refinement of priority activities over a five-year planning period;
- Provide feedback on concept proposal to the RMP

DRAFT AGENDA

1.	**Introductions**	1:00 Jay Davis
2.	**Review - strategy team and near term activities** (Attachment – nutrient minutes from workshop) Brief recap from the last meeting and workshop, explanation of workgroup organization and near-term activities.	1:10 Jay Davis & David Senn
3.	**Draft Nutrient Strategy** (Attachments – Nutrient_Strategy and Nutrient_Thumbnail) Discussion on SF Bay draft nutrient strategy, including management questions, goals, and feedback and refinement of prioritization over a five-year planning period. **Desired Outcome:** Input from the group on nutrient strategy and continued refinement of strategy	1:30 David Senn/Martha Sutula/ Naomi Feger
	Break	3:00
4.	**Discussion of 2012 Proposals – RMP Proposal** (Attachment – RMP_Proposal) A concept proposal for nutrients has been developed, for potential funding by RMP. **Desired Outcome:** Input from the group on the proposed Tasks	3:15 David Senn
5.	**Wrap up and Next Steps**	4:15 David Senn

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Nutrient Strategy Session to Outline a Bay Monitoring Program
June 30th, 2011
SFEI First Floor Conference Room
7770 Pardee Lane, Oakland, CA
9:00 AM to 4:30 PM
DRAFT Meeting Summary

List of Attendees

Walter Boynton, Chesapeake Biological Laboratory
Jim Cloern, USGS
Maureen Downing-Kunz, USGS
Tom Gallagher, HDR/ Hydroqual
Kathy Hieb, CDFG
Wim Kimmerer, Romberg Tiburon Center
Raphe Kudela, UC Santa Cruz
Jim Kuwabara, USGS
Anke Mueller-Solger, IEP/DSC
Alex Parker, Romberg Tiburon Center
Dave Schoellhamer, USGS
Tara Schraga, USGS
Martha Sutula, SCCWRP
Jan Thompson, USGS

Amy Chastain, BACWA
Mike Connor, EBDA
Naomi Feger, SFBRQWCB
Arleen Feng, ACCWP /BASMAA
Terry Fleming, USEPA
Chris Foe, CVRWQCB
Tom Hall, EOA/ South Bay Dischargers
Karen Taberski, SFBRWQCB

Rachel Allen, SFEI
Jay Davis, SFEI
Thomas Jabusch, SFEI
Lester McKee, SFEI
Meg Sedlak, SFEI
Don Yee, SFEI

Via Telephone

Dick Dugdale, Romberg Tiburon Center
Chris Francis, Stanford
Stephanie Fong, CVRWQCB
Trish Mulvey, SFEI Board
David Senn, ETH Switzerland soon to be SFEI
Frances Wilkerson, Romberg Tiburon Center

1. Introduction and Goals

Jay Davis introduced the goal of the meeting as "high-powered brainstorming," focused on developing a strategy for monitoring nutrients in the Bay, but recognizing that the overall end product is a long-term, collaborative workplan for nutrient science, including both a sequence of steps and a budget. He emphasized the need to be specific as to what needs to be completed by when (in 2012, 2013, 2015, etc.). He also indicated that a considerable effort is being undertaken to develop Numeric Nutrient Endpoints (NNE) for San Francisco Bay and the two groups should try to work closely to avoid duplication of efforts.

One of the objectives for the day's meeting was to develop an RMP plan for nutrients for 2012 and beyond and to discuss additional partners/ sources of revenue to address this issue. The RMP has tentatively set aside funds for future years: 2012 ($100K), 2013 ($200K), and 2014 ($300K); however, a good plan will be needed to justify these expenditures.

The primary purpose of the end product will be to serve as a science strategy. The second purpose of the strategy will be to serve as a fundraising plan. To be successful in both, the nutrients strategy team will need to build a program that addresses multiple stakeholder groups. Jay also indicated that given the uncertainties of funding, the group will develop different levels of plans. He compared these plans with different types of cars: a minimal program - "Pinto"; a medium sized program – "Civic"; and a detailed deluxe version – "Tesla."

Naomi Feger identified the overarching question, as related to the assessment of beneficial uses: "Are beneficial uses impaired or is there a threat of impairment?" To answer this question, we need a good assessment framework and monitoring program.

2. Numeric Nutrient Endpoints and Information Needs

Martha Sutula focused her presentation on two key questions: 1) What is it that we need to assess nutrient impacts (eutrophication) in San Francisco Bay? and 2) How will a plan be developed? The starting point is assessing eutrophication versus other effects. Key to the NNE approach is to focus on loads rather than on concentrations per se.

In discussing how the San Francisco Bay effort is organized, she explained that the technical team is led by SFEI, with SCCWRP participating to ensure technical consistency.

Martha provided a brief overview of the San Francisco Bay framework, including habitat types considered and candidate indicators. Although there is an overarching framework for NNEs in California, there are specific candidate indicators for San Francisco Bay, such as ammonia and urea. Martha also discussed the indicator evaluation and evaluation criteria, and presented recommended indicators for each habitat type.

Martha described her expected outcome of the meeting as agreement on: the next steps, who will be involved, and how to fund the continuing effort. She emphasized the strong nexus to the Delta, but that the San Francisco Bay NNE's focus is the Bay. One of the main challenges ahead will be to establish thresholds.

In terms of next steps, Martha concluded that 1) work involved in developing the assessment framework depends on the indicators selected, and 2) the projected timeframe for the assessment framework and workplan is about 2-3 years, dependent on future funding.

Walter Boynton noted that in the Chesapeake Bay Program, there is a disconnect between criteria and monitoring. It results from the fact that monitoring was established before criteria were developed. Martha then discussed important elements for the development of the assessment framework. An important consideration is the required temporal and spatial density of data to inform monitoring decisions.

With regards to modeling needs, Martha provided the following recommendations. Models can be as simple or complex as precision requires: 1) loading model(s) (riverine inputs, nonpoint source, groundwater, atmospheric, oceanic exchange) and 2) estuary model(s) (hydrodynamic, sediment transport, eutrophication). Core monitoring needs to include special studies to validate these models.

Next steps for moving towards a workplan for NNE development in San Francisco Bay include 1) prioritizing recommendations from the completed literature review and data gaps analysis (*there are approximately 30 recommendations for multiple habitat types*), 2) assembling the priorities into a coherent strategy and identifying next steps, 3) identifying cooperating institutions (what are their roles and what expertise is required?), and 4) investigating potential sources of funding.

To illustrate what is meant by assessment framework, Martha also presented the Macroalgal Assessment Framework from the European Union's Water Framework Directive. Martha emphasized the need to discuss the NNE with stakeholders and the San Francisco Bay Nutrients Strategy Workgroup.

Arleen Feng asked whether the choice of monitoring activities by the RMP nutrient strategy is one-time or would possibly involve later iterations to refine NNE Assessment Framework. Martha said she was not sure. Arleen clarified that the RMP nutrient strategy should be nested in the NNE Assessment Framework, but cannot be leading or replicating NNE. Martha responded that San Francisco Bay NNE provides a management context for the emerging RMP nutrient monitoring program.

In response to a comment concerning indicator selection, Martha reiterated the need for all four of the indicator evaluation criteria to be met. Arleen commented on the value of NNE as a regulatory framework and to establish regulatory milestones. The Water Board likes to take a position of taking "no regret" actions. Martha considered this a challenge due to the possibility of the long response time of indicators to eutrophication. Chris Foe pointed to the need for assessing connections between the “spine” and peripheral elements (“branches”, sloughs, etc.) of the Bay.

Martha agreed and provided a scenario applying to algal toxin concentrations. For example, if a Harmful Algal Bloom (HAB) occurs in the Delta, there is potential to find the toxins downstream in Suisun Bay, but not in the rest of the Bay. Terry Fleming suggested that the discussion focus on the development of indicators and then address the specifics of where and when to monitor. Mike Connor stated that it does not make sense to monitor cyanobacteria or other HAB toxins downstream of the Delta, because any signs seen in the Bay would be insignificant compared to effects in the Delta, and would not influence management actions upstream at the source. Naomi Feger stated that we should in fact influence management actions upstream, that the indicators established for the Bay should also be ones that can apply upstream to the Delta and that we are concerned about downstream impacts due to cyanobacteria toxin.

3. Chesapeake Bay Nutrient Monitoring

Walter Boynton focused his presentation on how lessons learned from Chesapeake Bay would apply to San Francisco Bay. He pointed out that when the Chesapeake Bay community got serious about thinking about criteria for restoration, Chesapeake Bay was already exhibiting many of the classic indicators of eutrophication, unlike the current conditions of today’s San Francisco Bay. Walter pointed out the importance of resolving tough scientific problems early, such as the ammonia-nitrate-phytoplankton controversy in the San Francisco Estuary. Here are some of the lessons he shared:

Beware of models/modelers. In Chesapeake Bay, for example, decision-makers asked modelers whether the monitoring program should measure dissolved organic carbon? How about silica? Modelers responded: “no, we don’t need these”. As a result, the Chesapeake Bay Monitoring Program does not measure these important indicators anymore.

Beware of financial erosion. Boynton advised planners to be careful and thoughtful before eliminating monitoring activities that may be key to understanding the system. The financial outlook for Chesapeake Bay Program is not good. Walter indicated that because of the elimination of funding, the program no longer monitors plankton and physical-chemical properties of the water column. In addition, the benthic monitoring has been reduced substantially.

Challenges in measuring and controlling loads. Walter noted that the ratio drainage area versus water surface is much larger in San Francisco Bay compared to Chesapeake Bay, meaning that there is a much bigger challenge characterizing and controlling loads in San Francisco Bay than in Chesapeake Bay. Also, in the Chesapeake Bay Monitoring Program, the sampling design did not make adjustments based on tides. With the big spring/neap tide difference here in San Francisco Bay, tidal adjustments need to be considered in the sampling design, to avoid blurring signals. He also suggested thinking about the diversity of the San Francisco Bay system. For example, appendages such as tidal sloughs may have pretty interesting, variable rates.

Use language that decision makers can understand. Walter pointed out that using analogies works, for example explaining "resiliency" as akin to a person sweating and shivering. He also emphasized that it is important for managers and politicians to know that eutrophication is "complicated stuff".

Non-point sources. In Chesapeake Bay, agriculture is the "big gorilla". In addition, nitrogen is "falling from the sky".

Success. Maryland established a "flush tax" in a period with a conservative republican government, to control loads from POTWs. This was passed only with substantial senior political support.

TMDL. The TMDL that is coming to Chesapeake Bay is based on the 303(d) list released in 2008. Bay Program participants brief politicians before policies get released.

Monitoring and Research. The monitoring and research communities need to work together. They need to grow with each other. Agency people are really smart but get pulled in too many different directions to be able to give these issues a lot of substantial thought. .

Take home messages. Walter recommended thinking broadly regarding measurement variables; ecology is complicated. There is a need to ensure that data are of high quality (QA/QC is important) and readily accessible to all interested parties. Measurements should be made available as quickly as possible. Walter also advised getting the loads right: nitrogen, phosphorus, and sediments in the case of Chesapeake Bay. He pointed to the importance of diversity in designing the monitoring and the need for strategizing, because one monitoring system will not be sufficient for all time and space scales. Monitoring needs to be long-term; long-term commitments are needed. He warned against the probability of flat-line funding. Walter further suggested the need for spending sufficient amounts of money, and not just on research. He warned against allocating substantial resources to collection and too little for analysis. He suggested taking advantage of research efforts coupled to monitoring: monitoring tells us about "what is" (status and trends) and research answers the "why" questions, and both are critical. He also recommended including some central rate processes in the monitoring program. These processes underlie the concentrations that are typically measured and increase "explainability". He further advised against putting all the eggs in one analysis basket and making models more complicated than needed, and not solely depending on complex models for analysis and forecasting but instead using parallel analysis approaches. Walter also advised that the San Francisco Bay program would need to put information, such as the monitoring data from wastewater treatment plants, on compelling websites. He urged building support from all interested parties, since local effects are important and it is good to have some local heroes. He also affirmed that the regional view is critical. Federal presence was essential in Chesapeake Bay.

4. Overview of San Francisco Bay Monitoring

The following researchers gave brief descriptions of ongoing monitoring programs in the San Francisco Bay Region and suggestions for monitoring needs.

a. USGS Water Quality Program (Jim Cloern)

Jim Cloern provided a brief overview of the USGS Water Quality Program (http://sfbay.wr.usgs.gov/access/wqdata/).

b. CeNCOOS (Raphael Kudela)

Raphael Kudela suggested that biophysical modeling could provide information on oceanic boundary conditions for San Francisco Bay. He provided a brief overview of the Central & Northern California Ocean Observing System (CeNCOOS) and potential remote sensing applications in San Francisco Bay. One of the objectives for San Francisco Bay is to improve primary productivity estimates, specifically to get different (spatially resolved) data for North and South San Francisco Bay and inform models.

c. Interagency Ecological Program (Anke Mueller-Solger)

Anke provided a short overview of where and what the IEP monitors. She noted that zooplankton monitoring is missing in San Francisco Bay. IEP is monitoring zooplankton in San Pablo Bay, but funders never saw a need for doing that in other parts of the Bay. Mike Connor asked whether USGS and IEP are measuring the same things in San Pablo Bay and if the two programs are seeing different information. Jim Cloern affirmed that the two groups monitor within days of each other and data show good agreement. This may be an area where resources could be redirected to address new needs. Anke explained that IEP's mission is to conduct mandated monitoring in the Bay-Delta, including the Stockton Deep Water Ship Channel. The good thing is that there is monitoring. The bad thing is that there is no flexibility; the monitoring is hard to change. For example, IEP is doing only deep-water sampling, but that's not all there is. IEP does not monitor contaminants, the Delta RMP is supposed to fix this. Eutrophication is a good issue to connect the Bay and Delta.

d. California Department of Fish and Game (CDFG): Bay Studies (Kathy Hieb)

Kathy Hieb provided a brief overview of CDFG's routine biological monitoring of the Bay. She stated that CDFG has a good boat with an equipped deck, which is mostly used in the Delta but could be used in San Francisco Bay. Currently, there is a big push to make CDFG's CDT (conductivity, temperature, depth) data more available. Chris Foe noted that it is important to measure biological and chemical data combined, as done by DFG. Kathy characterized CDFG's monitoring as providing a snapshot view of conditions. She also noted that CDFG could monitor zooplankton but that processing of the data would be very expensive. Anke Mueller-Solger noted that is an important consideration to sample physical, chemical, and biological features such that the data can be used in integrated analyses. Kathy pointed out that there are issues with retrieving data from the IEP database, because of the way the data are organized. Anke noted that the problem is more the web interface than the database. Kathy commented that her program's priority is to get the samples collected.

e. California Ocean Sensing (Wim Kimmerer)

Wim Kimmerer reviewed several ocean sensing stations in the Bay that are used to collect basic water quality indices and used to monitor sea surface current. One of the stations is located at the Romberg Tiburon Center, which is a particularly good spot since the water off the pier is relatively deep, 30 ft, and the site is readily accessible.

f. USGS Suspended Sediment Monitoring Program (Dave Shoellhamer)

Dave Schoellhamer provided an overview of continuous monitoring stations in the Bay maintained by the USGS. This network does a good job in terms of temporal resolution, and a bad job in terms of spatial resolution. One of the main differences between USGS sensors and the continuous sensing stations maintained by Romberg Tiburon Center is that the USGS sensors are active year-round versus the RTC program which is only deployed in summer months. Dave presented new dissolved oxygen measurements from the Dumbarton Bridge station suggesting that tidal variability is important. Four components explain 89% of the variance in DO: 1) tidal variability, 2) diurnal cycles, 3) mixing, and 4) tidal advection. Many processes affect DO, and the margins of the Bay are different from the main channel in this regard. Anke noted that IEP also has YSI sensors but that it has not been a priority to review this data. For example, IEP measures monthly horizontal and vertical profiles, including in the Stockton Deep Water Ship Channel and San Pablo Bay, but the data are completely underutilized. Chris Foe confirmed that the IEP had a wealth of good information (pH, etc.).

g. Regional Monitoring Program (Meg Sedlak)

Meg Sedlak provided a brief overview of the long-term status and trends monitoring of the RMP. She also noted that it would be interesting to know concentrations of key constituents in the margins of the Bay. Although the sites are distributed throughout the Bay based on a randomized design, they are sampled using a boat which limits the access to regions with more than approximately 4 feet of water at high tide. Jim Cloern asked whether the RMP samples benthic macroinvertebrates and whether there is anything the emerging nutrient program can use. Meg responded that benthic macroinvertebrates are sampled once a year. Anke added that IEP samples benthos twice a year, in the fall and in the spring. Sampling by the RMP and IEP in San Pablo Bay and Suisun Bay are somewhat complimentary.

h. Zooplankton and Macrobenthos (Wim Kimmerer/Jen Thompson)

Wim Kimmerer stated that there are lots of things that get measured in San Francisco Bay, that don't get measured in Chesapeake Bay, for example zooplankton. Others get measured in

Chesapeake Bay that don't get measured in San Francisco Bay. Wim clarified that there is no zooplankton sampling in Central and South Bay and only one station in San Pablo Bay. He stated that there has never been a microzooplankton program and suggested that this as well as bacteria be included. Also, the cycling of carbon and carbon budgets are not considered but should be. For example, when production is high, respiration is high, and when production is low, respiration is low.

Jan Thompson discussed the monitoring of Macrobenthos in the Bay, focusing her brief overview on what is known about suspension feeders other than invasive clams. Bivalve numbers are known, otherwise nothing is known; for example, there is no monitoring in South Bay. Walter Boynton commented that the bivalve biomass in San Francisco Bay is large compared to Chesapeake Bay.

i. Monitoring Seagrass and Macroalgae in the Bay (Presentation from Kathy Boyer, presented by Martha Sutula)

Martha discussed interactions of seagrass (eelgrass in the Bay) with epiphyton and macroalgae as a result of nutrient enrichment. There have been a few surveys of the extent of the eelgrass beds in the Bay since the early 2000s– the last CalTrans funded survey is being conducted this year. The largest bed is north of Pt. Richmond. Surveys of seagrass beds observed low levels of epiphyton, which don't seem to cause a problem. A macroalgae bloom was observed at Crown Beach in 2006. Macroalgae is more likely to be observed in sloughs or diked salt ponds because of the longer hydraulic retention times. The recommendation of the NNE technical review was to focus on macroalgae.

Post meeting notes from Kathy Boyer, SFSU:
The low levels of epiphyton typically seen on eelgrass in the Bay are unlikely to have negative impacts, but occasional larger blooms may be detrimental. Macroalgae are also generally low in biomass in eelgrass beds, however, we have measured biomass at times in the range that has been shown to impair eelgrass beds elsewhere in central/northern California (~2000-4000 g wet wet per m^2; Boyer and Huntington 2008 for Gracilariopsis sp. in Tomales Bay, Olyarnik 2008 for Ulva sp. in Bodega Bay). Macroalgal and epiphyte abundance data will be available in a forthcoming masters thesis (Gwen Santos, winter 2011). We do not know the thresholds for impacts to eelgrass beds in San Francisco Bay, nor did the studies cited above evaluate thresholds adequately. Further, increasing light penetration may shift these thresholds and increase the relative abundance of algae and their effects in seagrass beds.

j. Romberg Tiburon Center Monitoring (Dick Dugdale/Alex Parker)

Dick Dugdale provided an overview of measurements taken by RTC's San Francisco Bay Environmental Assessment and Monitoring Station. The rapid sampling off the RTC seawall shows that nutrient and phytoplankton monitoring will have to be based on fixed, automated sampling systems due to the short time scales of physical events and physiological responses. Ways in which this can be accomplished include: 1) automated nutrient analyzers, and 2) automated phytoplankton coverage. For the latter, flow cytometry is a potentially powerful tool that gets at the size fraction of algae based on fluorescent characteristics. Dick provided the flowing recommendations: in addition to regular shipboard sampling, monitoring in support of model development and management will require automated data acquisition at fixed locations. Methods development will be required, especially for ammonium. A powerful combination for monitoring would be CTD, automated nutrient analysis, and flow cytometry at key locations in the Sacramento River, Suisun Bay (and San Pablo Bay), Central Bay, and South Bay. Possible locations include Hood, Rio Vista, Mallard Island, the RTC Pier, and a South Bay location. Data acquisition is the easier part, but there is also a need to budget realistically for analysis, especially for phytoplankton community data. Lester McKee asked why there is no recommendation for a station outside of the Golden Gate. Dick responded that Point Reyes would be really good for an offshore site. He indicated his group is ready for offshore work and putting the resulting data in the SUNTANS model, if they can combine funding with other sources. He affirmed this would be an important thing to do with the nutrient strategy in mind.

Summary of Selected Monitoring Programs in the San Francisco Bay and Delta

Program	Point Person	Lead Agency	Objectives	Description	Duration	Funding Level
Water Quality Program	Jim Cloern	USGS	Following and understanding changes in the water quality of SF Bay	Monthly cruises of the Bay	1969 - present	
CeNCOOS	Raphael Kudela	NOAA				
Interagency Ecological Program	Anke Mueller-Solger	IEP/DSC	Gauging the environmental health of the estuary	IEP projects fall into three large program categories: IEP Core Program, IEP Pelagic Organism Decline (POD) Program, and IEP Coordinated Studies Program	1970 -present	$39.1M
Bay Studies	Kathy Hieb	CDFG	Routine biological monitoring of the Bay	Biological (midwater trawl, otter trawl) and water quality (SBE CTDs)	1980 - present	
California Ocean Sensing	Wim Kimmerer	Romberg Tiburon Center	Implement CeNCOOS in Bay	There are several ocean sensing stations in the Bay that are used to collect basic water quality indices and used to monitor sea surface current		
Suspended Sediment Monitoring Program	Dave Schoellhamer	USGS	Making time series data of salinity, temperature, water level, and SSC in San Francisco Bay available to scientists, resource managers, educators, and the general public.	The USGS maintains a number of fixed monitoring stations in the Bay that monitor for SSC and DO among other parameters.	1989 - present	

Program	Point Person	Lead Agency	Objectives	Description	Duration	Funding Level
Regional Monitoring Program	Meg Sedlak	SFEI	Collect data and communicate information about water quality in the San Francisco Estuary to support management decisions	The RMP conducts annual water cruises in the summer. In addition to organics and inorganic parameters, basic water quality data is collected.	1993 - present	$3M
San Francisco Bay Environmental Assessment and Monitoring Station	Dick Dugdale	Romberg Tiburon Center	SF-BEAMS is part of a larger distributed observatory that monitors marine environments along the entire coast of California.	The station continuously monitors San Francisco Bay water quality, weather conditions, and surface currents in the deep water channel that lies a few hundred meters north of the Tiburon Peninsula.	2002 - present	unfunded

5. Brainstorming Session

Mike Connor facilitated the brainstorming session on important components of a nutrients monitoring program for the Bay. He asked a few questions of the group to initiate brainstorming:

1) Does the Bay currently have a eutrophication problem?
2) What signs would we need to see to determine that there is a eutrophication problem?
3) What signs would indicate change?

Anke Mueller-Solger indicated that whether the Bay is eutrophic depends on the definition of eutrophication.

Jim Cloern noted that the political setting for this issue is unusual because of the unprecedented interest in nutrients, resulting in a higher probability of identifying new sources of funding for this work. Over the last 20 years, there have been clear signals of change in the Bay, although the Bay does not seem to be currently impaired by nutrients. However, the future trajectory is unclear – we could be headed towards hypoxia. In making the case for continued monitoring of the Bay, we should not risk "crying wolf", but rather highlight the known concerns: that the Bay is enriched in nutrients, and an informed evaluation of the condition and projected trajectory for how nutrients are converted into biomass in the Bay relies on all of the monitored parameters.

Mike Connor focused on the second question, asking for specific indicators of eutrophication.

Jim Cloern, building on one of the key points from Walt Boynton's presentation, indicated that multiple indicators would be necessary to conclude that the Bay is impaired. The group put forth a number of indicators that might serve as signs of impairment:

- increasing frequency of DO concentrations below 5 mg/L
- algal toxins at concentrations that affect the health of humans or biota
- proliferation of macroalgae
- increased movement of contaminants in foodwebs (e.g., as a result of uptake in phytoplankton or increased organic matter)
- fish kills
- phytoplankton biomass greater than 30.
- ecologically disruptive algal blooms, such as brown tides
- impacts of plumes of ammonia on the Farallones, or other ecosystems downstream of the Bay
- depletion of silica
- increased productivity
- food web changes (e.g.,fish and zooplankton getting smaller, increase in jellyfish)
- decrease in seagrass
- increases to some threshold for
    - microphytobenthos (benthic algae).
    - sediment nutrients (TOC/TON)
    - macroalgae

Existing signs of impairment and further notes on indicators
During the discussion, it was discovered that a number of these signs have already occurred, at least in part. Naomi Feger pointed out that there is some evidence of microcystis blooms in Suisun Bay. Anke Mueller-Solger noted that fish kills have occurred in Suisun Marsh, and algal toxins have been detected in Antioch as well as upstream. She also indicated that fish have been getting smaller across all trophic levels. Phytoplankton biomass greater than 30 has been observed in the South Bay.

Mike Connor noted that in fact most of what was put forward are indicators that are captured by the NNE project.

In response to the suggestion of evaluating impacts at the Farallones, Martha Sutula suggested eventually expanding the NNE exercise to the ocean.

Jim Cloern pointed out that nutrient enrichment has been strongly tied to jellyfish accretion, such as in Tokyo Bay. It was acknowledged that the life cycle of jellyfish are not well understood but that a strong link between nutrients and jellyfish has been observed in Denmark. Jellyfish were not selected as an NNE indicator as they didn't meet all the selection criteria. They are relatively easy to sample. Anke Mueller-Solger noted that Suisun Marsh has strong data sets on jellyfish.

Regarding macroalgae, Anke Mueller-Solger added that the cooling water intakes at Potrero used to screen out fish; it now screens out macroalgae. Jan Thompson added that macroalgae has been frequently detected in the shallows near Alameda.

Martha Sutula indicated that the NNE effort ultimately decided not to include microphytobenthos as an indicator because it is hard to measure and interpret. Martha Sutula also suggested that sediment TOC should be normalized relative to sediment grain size, and used as a supporting rather than a primary indicator. Jan Thompson noted that while sediment TOC is low, a complete removal of sediment grazers would cause it to increase.

Dave Schoellhamer pointed out that these are management triggers, that is, signs that could indicate to managers that things are wrong ("red flags").

Chris Foe noted that "eutrophication" has not been clearly defined, even with regards to its spatial extent. The indicators put forth so far are primarily focused on the spine of the Bay. Naomi Feger noted that low DO has been reported in marshes in Suisun associated with management of the Duck Clubs. However, in the South Bay, the managed ponds result in low DO within the ponds, rather than low DO discharges. Tom Hall advised the group that the Board has required a number of low DO studies in the Lower South Bay, some of which are currently ongoing.

Further discussion
Given the general agreement on the types of indicators needed, Mike Connor posed a follow up question: how do we design a monitoring program to detect changes in these indicators?

Martha Sutula noted that these indicators are not the only monitoring that will be performed, but that a number of other parameters, such as nutrients in the water, will need to be monitored to provide context for interpretation of the data.

Amy Chastain asked what management actions are available, and what sort of impact they could have on the system. The potential for future management actions should partly inform the design of the monitoring program.

Walt Boynton noted that macrobenthos have been important in the Chesapeake Bay, and that a paper by Herman describes a worldwide relationship between nutrients, food supply, and infauna in estuaries. Jan Thompson pointed out that this paper included a point from South San Francisco Bay. She indicated that the physical energy of San Francisco Bay does not distinguish San Francisco Bay from the Chesapeake as much as their benthos associates them, and that were San Francisco Bay to abruptly lose its bivalves, the response of the Bay would likely parallel what has been seen in the Chesapeake.

Jay Davis informed the group that the RMP has tentatively allocated $100,000 for nutrients special studies in 2012, contingent upon a promising plan for using the funds that is consistent with the developing nutrients strategy. He is looking for ideas for this money from the group.

Jim Cloern noted that Chris Francis from Stanford was listening in on the discussion, and that he should be included in the next phases of monitoring development, as he brings expertise in denitrification processes in the Bay. He will share a paper on denitrification (Mosier and Francis, 2010) with the group.

6) Strawman monitoring for SF Bay system

Jim Cloern presented a strawman proposal for monitoring, highlighting specific questions that will need to be asked and answered in more detail: What to sample? Where to sample? and When to sample? His preliminary proposal only addresses these questions for open water, and was intended more as an exercise than a definitive plan. He also put forth an incomplete list of on-going or proposed pilot studies, and asked for further input from the group. However, the final monitoring program will not be designed immediately or definitively. The program will need to develop and carry out a number of pilot and special studies before settling on a long-term monitoring program.

Martha Sutula noted that there had been minor changes to the NNE from the version that Jim used to mock up the strawman.

What should be included in a monitoring program?
Consistent with Walt Boynton's presentation, Anke Mueller-Solger suggested that the monitoring program emphasize data management and analysis to accompany data collection.

Jim Cloern suggested using part of the RMP's $100,000 to support Dave Schoelhamer's continuous monitoring at fixed stations with additional instrument packages, such as DO and fluorescence sensors, and funding for analysis of the data. Walter Boynton indicated that there is a real need to do more short term/continuous monitoring of DO as the DO levels can fluctuate substantially. Raphe Kudela indicated that he could provide these fixed stations with SPATT sensors (Solid Phase Adsorption Toxin Tracking) for monitoring of phycotoxins and that his group could conduct the analyses for toxins. Terry Fleming asked that this funding include data synthesis, so that those designing the nutrients strategy will be up to date on DO findings and perspective. Jim indicated that he has funding for 2012 to conduct nutrient and phytoplankton composition monitoring but that this funding has been discontinued and there will be a future need.

What to monitor?
Building off the list of primary and supporting indicators proposed by Jim Cloern, Alex Parker suggested including DOC/ DON and POC/PON in the suite of nutrients, and adding nitrogen rates to C13 productivity monitoring. He indicated that depth integrated productivity is also important to include. Mike Connor asked if production, including denitrification, should be monitored. Jim Kuwabara indicated that it will also be important to understand the flux of particulates/nutrients from sediments.

Jim Cloern noted that the parameters generally fall in three categories, designed to support:
1) Evaluation of impairment
2) Understanding of processes
3) Model building and verification

Martha Sutula clarified that primary indicators will be used to make status assessments and management decisions, while co-factors and supporting indicators provide context and information needed to interpret the data.

Where to monitor?
Jim Cloern suggested that monitoring may need to include managed ponds and coastal ocean, as well as the traditional locations in the Bay. Anke Mueller-Solger and Kathy Hieb suggested that the sloughs and tidal marshes are important locations within the Bay, which may behave differently from surrounding areas.

Walt Boynton noted that most modeling will require more spatial than temporal resolution to feed into models. As an example, he stated that in the Chesapeake, they have observed that far greater differences of the rates of nitrification/denitrification occur spatially than temporally.

The group discussed potential locations of sampling sites – transects vs. sampling from moored sensors. It was noted that the temporal variability observed in DO would have likely been missed if the monitoring occurred only at transects, and spatial variability is lost if sampling only occurs at moored sensor stations. Although the USGS monitoring occurs along the spine of the Bay, Alex Parker noted that the data set from the Polaris cruises is a unique and venerable record, and worth continuing in whatever monitoring program is ultimately adopted.

Jim Cloern suggested performing a spatially dense survey once a year during the end of the dry season during a neap tide (to minimize the effects of variable freshwater dilution and intense tides) as a pilot study. This effort will be used to determine the appropriate balance of spatial and temporal intensity.

When to monitor?
Walt Boynton noted that much of the extant monitoring is bi-weekly or monthly, and that data on a shorter timescale will reflect the vacillations of many parameters closely linked to in-bay physics. He added that San Francisco Bay, like the Chesapeake Bay, has a propensity for low DO, and that if the strong physics at work in the bay did not destratify the water, fish kills would be more common.

Wim Kimmerer and Jim Cloern noted that tidal cycles are very important in temporal variability, and in fact much of the temporal fluctuations may in fact be due to passing water masses. Anke Mueller-Solger suggested filling in temporal knowledge with a network of flux stations, designed to measure water bodies travelling by.

Pilot Studies
In addition to the pilot studies outlined by Jim Cloern, Wim Kimmerer proposed developing a conceptual model for nutrients in the Bay, in order to bring the various researchers onto the same page. While the NNE assessment framework could provide the basis for a conceptual model, the NNE is driven by information that is known, while the conceptual model should be driven by questions regarding unknown processes.

Chris Foe noted that detailed monitoring in back sloughs will be important for a monitoring program and would be an interesting pilot study, although Mike Connor indicated that the healthy part of the Bay, in the middle, is where we will make and enact management decisions. Jim Cloern agreed that a spatially intense sampling effort would be a useful special study in 2012. Arleen Feng suggested that this special study work would be helpful in towards establishing a link between local areas and the Bay as a whole, and stated that it also would be essential as a basis and rationale for any further RMP monitoring/special study efforts, although complete monitoring around the edges of the Bay may be too large an effort for the RMP.

The list of pilot studies, as proposed by Jim Cloern and the group, is given below, along with notes on their current status and related work.

- Conceptual Model
    - A conceptual model should be developed to provide a common ground for discussions of nutrient processes in the Bay and to be the foundation for the design of the monitoring program.
    - The conceptual model proposal will be written up by Martha Sutula and Dave Senn for September TRC meeting, requesting some of the $100,000 from the RMP for this project.
    - Jim Cloern and Wim Kimmerer will also provide help on the proposal, perhaps in the context of a brainstorming session like this meeting specifically for the conceptual model.
    - Martha will also look at the interaction between the conceptual model, the NNE assessment framework and the nutrients strategy. She noted that the context for

  - the conceptual model still needs to be developed, as a conceptual model for the deep Bay would be different from one for shallow waters.
  - Anke Mueller-Solger noted that the conceptual model should link the Bay with the Delta. All agreed that this was important.
- Diagnostic pigments (CHEMTAX)
  - Raphe Kudela is pursuing an alternative method to microscopy for measuring phytoplankton composition, HPLC with CHEMTAX, which uses pigment ratios to determine the main taxonomic groups present.
  - This study will begin to answer the question of whether this method can be used in San Francisco Bay for monitoring the phytoplankton composition. It is much less expensive than microscopy and will allow more samples to be collected throughout the system. At this time the extent of phytoplankton composition sampling is limited by funds.
  - Alex Parker is also gearing up to test a flow cytometer and fluoroprobe (belonging to Anke).
  - A pilot study for 2012 is underway, under Tara Schraga's lead to fund Raphe Kudela's HPLC/CHEMTAX analysis and compare it to years of the microscopic counts USGS has funded a taxonomist to complete. Alex Parker will be adding the flow cytometer and fluoroprobe to this year long study to test their viability for accurate determination of phytoplankton groups. USGS will also fund Raphe analyzing some HPLC/CHEMTAX samples for Alex from other stations in the North Bay not on the Polaris track. This project will bring together these efforts and include a summary analysis at the end.
- Urea
  - A pilot study measuring urea in the Bay, led by Tara Schraga and Jim Cloern, is scheduled for monthly sampling (5 stations) for one year (2012).
  - Parker and Dugdale also have five stations that they are sampling annually.
- Algal Toxins
  - In 2012 the USGS is conducting a pilot study collecting samples for phycotoxin analysis throughout the Bay on 1 cruise each month. Raphe Kudela will analyze the samples. Jim Cloern indicated that he needed assistance filtering on the USGS monthly cruises since they are adding this analysis and the CHEMTAX samples .
  - Raphe proposed deploying SPATT collectors at various sites throughout the Bay as a pilot study. The bags integrate the toxins they are exposed to over the period of time deployed.
- Moored sensors
  - Dave Schoellhamer noted that there may be funding from USGS to add sensors at the 6 moored stations, including DO, chlorophyll, fluorescence, and telemetery.
  - The pilot study still needs additional funding for data analysis, so Dave Schoellhamer will put together a proposal for this funding from the RMP, including an inventory of the existing locations and advantages and drawbacks to putting sensors in other locations.
- Productivity method
  - Tara Schraga proposed performing in-water productivity measurements and comparing it to output from a productivity sensor. If there is agreement, the in-

water instrument can collect productivity samples. If the methods are comparable, the in-water method would increase the temporal resolution and be less expensive (both in cost of samples and labor, and in time needed). The Cloern project uses the DO productivity measurement method while Alex Parker prefers C13/N15 labeling.
    - This pilot study is not currently planned for 2012 due to lack of trained staff and funds for staff or instrument.
- Stratification of sampling
    - Jim Cloern noted that a separate meeting should be held to discuss spatial and temporal stratification of sampling, which should follow the development of the Conceptual Model.
    - Naomi Feger and Karen Taberski noted that the estuary portal and the California Water Quality monitoring council are looking at how to integrate data from multiple sampling efforts in the Delta/Estuary and make it available to the public. The IEP is developing an inventory of studies/monitoring efforts with input from the Boards, the RMP, DWR, DFG etc.
    - Naomi Feger will take the lead on developing an inventory of monitoring stations in the Bay Delta.
    - *Post meeting note – Region 5 of the Water Board with SFEI has developed an atlas of current monitoring for the Delta. Naomi Feger will have SFEI GIS staff scope out the level of effort to integrate this information with sampling station information from the Bay based on RMP, USGS and DWR monitoring.*

Nutrients Strategy

Martha Sutula and Arleen Feng noted that the stakeholders are also interested in seeing a clear strategy outlined. Martha offered to help develop the strategy. Arleen Feng asked how the relationship of RMP nutrients strategy team with NNE group would be established. It was suggested that strategy team become the administrative support team for the NNE group, to maximize on existing work and strengths. Jay Davis proposed a meeting in the early September (once Dave Senn has arrived) to discuss the conceptual model proposal, and that the monitoring design discussions recommence after the conceptual model is developed. Mike Connor suggested that this meeting also serve as the next meeting for the nutrients strategy team, and that a number of the scientists currently present will not need to attend this meeting.

Action Items

Jim Cloern reviewed the action items from the meeting

1) Collect side by side samples and compare approaches for assessing phytoplankton communities (Alex Parker)
2) Participate in monthly USGS Polaris cruises with Jim Cloern and Tara Schraga (Karen Taberski, RMP staff, Alex Parker, *a student volunteer was identified following the meeting*)
3) Identify sensors and funding for purchasing them to add to existing mooring stations (Dave Schoellhamer and Tara Schraga)
   - Measurements to potentially include: Dissolved Oxygen, fluorescence, DON, DOC, etc.
   - Contingent on funding, Raphe Kudula to provide SPATTs for fixed moorings.
4) Develop proposals for using the $100,000 from the RMP in 2012 to submit to the RMP Technical Review Committee (meeting in September) and Steering Committee (meeting in October)
   - Proposal 1) Develop a conceptual model of nutrient cycling in the Bay and Delta (Dave Senn)
     - Martha Sutula to work with Dave Senn to write up proposal for September TRC meeting.
     - Martha will also look at the interaction between the conceptual model, the NNE assessment framework and the nutrients strategy.
   - Proposal 2) Support analysis of continuous dissolved oxygen, fluorescence, etc. data from moored stations around the Bay (Dave Schoellhamer)
5) Develop a georeferenced spatial monitoring layer that will show all of the monitoring types and locations in SF Bay and the Delta (Naomi Feger, Anke Mueller-Solger)

Tom Hall added one further item:

6) Develop a schedule and outline for the RMP nutrients strategy (Jay Davis, Meg Sedlak, Naomi Feger, and Martha Sutula)

Nutrient Management Strategy for San Francisco Bay

Draft Version 9-8-2011

1. Introduction and Purpose of Nutrient Strategy

San Francisco Bay has long been recognized as a nutrient-enriched estuary. Nonetheless, dissolved oxygen concentrations found in the Bay's subtidal habitats are much higher and phytoplankton biomass and productivity are substantially lower than would be expected in an estuary with such high nutrient enrichment, implying that eutrophication is controlled by processes other than straightforward nutrient-limitation of primary production. The published literature suggests that phytoplankton growth and accumulation are limited by a combination of factors, including strong tidal mixing, light limitation due to high turbidity, and grazing pressure by clams, although the relative importance of these individual factors is not well-established.

There is a growing body of evidence that suggests the historic resilience of San Francisco Bay to the harmful effects of nutrient enrichment is weakening. Since the late 1990's, regions of the Bay have experienced significant increases in phytoplankton biomass (30- 105% from Suisun to South Bay) and significant declines in DO concentrations (2% and 4% in Suisun Bay and South Bay, respectively; J. Cloern, unpublished data). In addition, an unprecedented autumn phytoplankton bloom in October of 1999, and increased frequency of cyanobacteria and dinoflagellate (2004 red tide event) blooms occurring in the North Bay, further signal changes in the Estuary.

The indications of decreased Bay resilience have come to the fore at a time when the availability of resources to continue assessing the Bay's condition is uncertain. Since 1969, a USGS research program has supported water-quality sampling in the San Francisco Bay. This USGS program collects monthly samples between the South Bay and the lower Sacramento River to measure salinity, temperature, turbidity, suspended sediments, nutrients, dissolved oxygen and chlorophyll a. The USGS data, along with sampling conducted by the Interagency Ecological Program, provide coverage for the entire San Francisco Bay –Delta system. The San Francisco Bay Regional Monitoring Program (RMP) has no independent nutrient-related monitoring program, but instead contributes approximately 20% of the USGS data collection cost. Thus, there is currently an urgent need to lay the groundwork for a locally-supported, long-term monitoring program to provide information that is most needed to support management decisions in the Bay.

The timing also coincides with a major state-wide initiative, led by the California State Water Resources Control Board (State Board), for developing nutrient water quality objectives for the State's surface waters, using an approach known as the Nutrient Numeric Endpoint (NNE) framework. The NNE establishes a suite of numeric endpoints based on the ecological response of a waterbody to nutrient over-enrichment and eutrophication (e.g. excessive algal blooms, decreased dissolved oxygen). In addition to numeric endpoints for response indicators, the NNE framework must include models that link the response indicators to nutrient loads and other management controls. The NNE framework is intended to serve as numeric guidance to translate narrative water quality objectives.

Since San Francisco Bay is the State's largest estuary, and one for which there is currently a relative wealth of data, it is a primary focus of a state-wide effort to develop NNEs for estuaries. As part of the state-wide effort, the San Francisco Bay Regional Water Quality Control Board (Water Board) is working with State Board to develop an NNE framework specific to the Bay. This effort was initiated by a literature review and data gaps analysis to recommend indicators to assess eutrophication and other adverse effects of anthropogenic nutrient loading in San Francisco Bay and summarize existing literature in the Bay using these indicators and identify data gaps (McKee et al., 2011). The review made five major recommendations: 1) develop an NNE assessment framework for the Bay, 2) quantify external nutrients loads, 3) develop a suite of models that link NNE response indicators to nutrient loads and other co-factors, 4) implement a monitoring program, and 5) coordinate development of the the Bay NNE workplan with nutrient management activities in Sacramento and San Joaquin Delta.

At an RMP-sponsored workshop on nutrient management in the Bay (June 29-30, 2011), participants engaged in monitoring activities in the Bay-Delta were convened on day two to discuss elements of a monitoring strategy. They agreed that development of a NNE assessment framework and funding of a monitoring program were priorities, but that these efforts must begin with spatially –explicit conceptual models of the linkages between nutrient loads, ecological response indicators and Bay beneficial uses.

Another issue of importance to the Water Board and stakeholders is that of the potential impact of ammonia/ammonium on Bay beneficial uses. While the USGS has documented a loss of resiliency throughout San Francisco Bay, productivity in Suisun Bay may be controlled by different factors than in the South Bay. Dugdale et al (in press) argue that elevated levels of ammonium actually limit primary productivity in Suisun Bay, and perhaps elsewhere in the Estuary. There is currently disagreement within the scientific community about the potential role ammonium plays in limiting primary productivity, and this issue needs to be resolved. To help resolve the issue, the Water Board supported studies in Suisun Bay in 2010 that showed a strong relationship between ammonium concentrations and impacts on phytoplankton biomass and in the spring of 2011 the Water Board initiated a two-year follow-up study. A follow-up study also includes toxicity test and TIE method development to identify the cause of inhibition of diatom growth in Suisun. These data and information from additional studies being conducted in the Delta should be reviewed and a process should be developed to resolve these outstanding questions and concerns about ammonium.

In addition, given that several factors (light-limitation/turbidity; grazing pressure by clams; tidal mixing) contribute to maintaining phytoplankton biomass at relatively low levels in this otherwise nutrient-rich estuary, improved understanding is needed with regards to the relative importance of these factors, including temporal and spatial considerations, and regarding susceptibility to future changes in the level of control they exert (e.g., decreases in suspended sediment loads).

Considering the compelling evidence of changing conditions in San Francisco Bay, uncertainty about future monitoring programs, and new nutrient policies on the horizon, there is a strong need for a coherent nutrient science and management strategy for the Bay. This document lays out a draft strategy for developing the science needed for informed decisions about managing nutrient loads and maintaining beneficial uses within the Bay. The nutrient strategy first highlights upcoming management decisions related to nutrients and eutrophication. The strategy next lays out a plan, developed collaboratively by the San Francisco Bay Water Board and the Bay stakeholders, for the technical studies required to support decisions regarding nutrient management. Finally, the strategy prioritizes work elements within a five-year planning horizon, and identifies funding to undertake actions related to those priorities, to ensure an efficient use of the available resources.

2. Key Nutrient Management Decisions, Questions

Several key management decisions and questions provide the context for the San Francisco Bay nutrient management strategy. The primary anticipated management decisions include:

1) Establishing Bay nutrient objectives
2) Evaluating the need for revised objectives for dissolved oxygen (in sub-habitats) and ammonium/ammonia
3) Developing and funding a nutrient monitoring program
4) 303(d) listing decisions for the adverse effects of nutrients or ammonium – whether impairment exists currently or is forecast in the future
5) Specifying nutrient limits in NPDES permits (e.g. POTW and MRP) as well as determining additional data collection needs

6) Determining whether management actions are necessary to prevent or address nutrient enrichment impacts and if so, the schedule, and nature for POTW treatment plant upgrades and stormwater treatment

Nutrient management issues may be influenced by, or can influence to some degree, decisions on other issues, such as the regulation of freshwater flow from the Delta, a regional sediment management strategy, recycling of wastewater, and nutrient watershed TMDLs, e.g., Sonoma Creek and Napa River.

These upcoming decisions are the foundation for five key management questions that, in turn, drive the elements of the nutrient strategy, directly correspondend to the recommendations laid out in a recent literature review and data gap analysis that was conducted as an early step in the NNE process (Table 1; McKee et al., 2011).

Table 1. Summary of management questions developed with input from the Nutrient Workgroup, and corresponding recommendations from the San Francisco Bay NNE literature review (McKee et al. 2011).

Type	**Management Question**	**Recommendation From McKee et al. 2011 Review**
Status and trends	Is there a problem or are there signs of a problem? Are trends spatially the same or different in San Francisco Bay? a. Is eutrophication currently, or trending towards, adversely affecting beneficial uses of the Bay? b. Are beneficial uses in segments of San Francisco Bay impaired by any form of nutrients (e.g. ammonium)? c. Are trends spatially the same or different in San Francisco Bay?	Implement a monitoring program to support regular assessments of nutrient support for the Bay beneficial uses. Coordinate with Delta nutrient monitoring and management.
Objectives	What are appropriate guidelines for identifying a nutrient-related problem?	Establish a NNE framework for the Bay
Sources and Pathways	Which sources, pathways, (and processes) of nutrients are of most concern? (Get the loads right!) a. What is the relative contribution of each loading pathway (POTW, Delta inputs, NPS, etc.)? b. What are contributions of internal sources (e.g. benthic fluxes) from sediments and sinks (e.g. denitrification) to the Bay nutrient budgets?	Quantify external sources of nutrients to the Bay and develop a spatially-explicit budget of the Bay.
Fore-casting	What nutrient loads can the Bay assimilate without impairment of beneficial uses? What is the likelihood that the Bay will be impaired by nutrient overenrichment/eutrophication in the future?	Develop load-response models

3. Nutrient Strategy Goals and Work Elements

Generating the scientific understanding needed to fully support all of the management decisions and questions will likely take a decade or more, and will require a significant investment of resources. Therefore, it is imperative that a well-reasoned and cost-effective nutrient strategy be adopted that identifies logical first steps, leverages existing resources, and incorporates elements of adaptive management.

With this philosophy in mind, we propose that the five-year strategy have four principal goals:

1) Document our current understanding of nutrient dynamics in the Bay, highlighting what is known and the crucial questions that need to be answered;
2) Implement a monitoring program that supports regular assessments of the Bay;
3) Establish guidelines (water quality objectives; i.e., assessment framework) for eutrophication and other adverse effects of nutrient overenrichment;
4) Quantify nutrient loads to and important processes in the Bay; and
5) Establish a modeling strategy to support decisions regarding nutrient management for the Bay.

Work elements and a list of major tasks associated with each goal are detailed in the sections below. The phasing and timeframe of these work elements and major tasks is provided in Table 2. Some commitments have already been made by workgroup participants to undertake priority tasks. A list of actions identified during the June 30, 2011 workgroup meeting is included as Appendix 1.

Work Element 1. Monitoring Program Development and Implementation

The purpose of this work element is to lay the technical foundation for the NNE assessment framework and to develop the San Francisco Bay monitoring program. Targeted habitats include unvegetated and vegetated subtidal and mudflat habitat in the Bay. Managed pond habitats will be excluded, as this habitat type will be addressed in a separate work element in the strategy. Five tasks are associated with this work element. Note that the NNE assessment framework (Work Element 2) should be completed before Tasks 1-5 (monitoring work plan and QAPP) is completed and 1-6 (implementation) is initiated.

<u>Task 1-1. Assessment Conceptual model:</u> The purpose of this task is to develop a spatially-explicit conceptual model of NNE indicators and co-factors to be measured to assess status and trends of eutrophication and other adverse effects of nutrients in the Bay. Model(s) will be spatially explicit by Bay segment and by habitat type (deepwater & shallow subtidal, seagrass and intertidal flat). The conceptual model should provide linkages between the Bay and the Delta.

<u>Task 1-2. Synthesize additional existing data on dissolved oxygen concentrations (shallow water subtidal and moored sensors).</u> The Bay NNE literature review and data gaps analysis (McKee et al. 2011) did not summarize dissolved oxygen data available for shallow water subtidal habitat. The purpose of this exercise is to synthesize existing dissolved oxygen data available for shallow water subtidal habitats to assess status and trends relative to Basin plan standards and inform spatial elements of the nutrient monitoring program. In addition, USGS - Dave Schoellhamer has funding to add sensors at 6 moored stations to include DO, chlorophyll, fluorescence, and telemetry. However, there is no funding to conduct data synthesis which will be required in year two to make this data collection effort meaningful.

<u>Task 1-3. Scope Development of Geospatial Database of Monitoring Activities/Sampling locations.</u> Several monitoring program or university have stations with current or planned monitoring activities within the Bay and Delta. In addition, the IEP is conducting an inventory of studies/monitoring programs in the Bay/Delta. The purpose of this task is to scope and cost building on a similar effort completed in the Delta by SFEI and the Central Valley Water Board referred to as the online Central Valley Monitoring Directory (www.centralvalleymonitoring.org). The deliverable for this task is an inventory of the datasets to be included and a cost estimate to develop a Bay version of this online database. SFEI is in the process of developing a draft map of sampling locations.

<u>Task 1-4. Expand USGS Water Quality Sampling to Include Urea and HAB toxins.</u> Augment USGS water quality data collection with sampling urea, HAB cell counts and toxin concentrations (water and faunal tissues) along longitudinal axis of the Bay. Some of this work is planned for 2011-2012; a list of current additional monitoring activities is attached as Exhibit 1 (June 30, 2011 Nutrients Strategy Meeting Minutes)

<u>Task 1-5. Develop a Nutrient Monitoring Program:</u>

<u>Subtask a) Recommend elements of a core Bay monitoring program to assess status and trends</u>. The purpose of this task is to recommend specific indicators and methods, spatial and temporal density of sampling that should be included in a "core" monitoring program to make regular assessments of the status of the Bay with respect to eutrophication and to assess trends in external nutrient loads. The intention is that the San Francisco Bay Water Board will use these recommended monitoring elements to support development of the Bay NNE framework (with action levels or thresholds). The report will also be used to develop a detailed nutrient monitoring program for the Bay.

<u>Subtask b) Develop San Francisco Bay nutrient monitoring program Work Plan and QAPP</u>. The purpose of this work element is to develop the work plan and quality assurance project plan (QAPP) for the Bay nutrient monitoring program. The work plan and QAPP covers

monitoring to assess status and trends in external nutrient loads and ecosystem response of the Bay to those loads. This task includes development of field, sampling handling, laboratory analyses, data management and reporting procedures for data collection.

Task 1-6 Implement the San Francisco Bay nutrient monitoring program.

Work Element 2. Establish Nutrient-Related Water Quality Objectives

The purpose of this work element is to develop the technical foundation and make the policy decisions to establish nutrient-related water quality objectives. This strategy assumes that the development of nutrient related water quality objectives would be accomplished under the umbrella of creation of the "nutrient numeric endpoint framework"—the numeric guidance that would serve as a means to translate narrative water quality objectives.

The Bay NNE literature review and data gaps analysis proposed a suite of primary and supporting indicators appropriate to assess the effects of eutrophication and other adverse effects of nutrients on Bay beneficial uses (McKee et al. 2011). Indicators were proposed for three principal habitat types: 1) subtidal unvegetated habitat, 2) vegetated subtidal (seagrass and other SAV), and 3) intertidal mudflat. The review proposes specific tasks to develop the NNE assessment framework for each habitat types. These tasks are given in Table 3. An initial rank of high, medium and low priority was assigned to each by the SF RWQCB, pending feedback by Bay stakeholders. Prioritization of work elements reflects: 1) percentage of habitat type represented in the Bay and 2) best professional judgment as to whether indicator represents the most sensitive assessment of potential impacts to beneficial uses. Based on these two criteria, phytoplankton and dissolved oxygen were the primary NNE indicators of interest in unvegetated subtidal habitat. Determination of the utility of ammonium as an indicator is pending the completion of funded studies and synthesis by a working group of scientists. Indicators representative of other habitat types such as intertidal flats and seagrass are of high interest in the Bay as well as other estuaries around the state. Several studies are ongoing to support decision on NNE thresholds in California estuaries outside of the Bay. Thus, the strategy was to designate these work elements as moderate priority, with the intention of evaluating the applicability of these studies to assessment of these habitats in San Francisco Bay.

Five tasks were designated as high priority and as such they are components of planned activities during the first five years.

Task 2-1 Phytoplankton NNE Assessment Framework Sponsor a series of expert workshops to develop a draft assessment framework based on indicators of phytoplankton (biomass, productivity, assemblage, cyanobacteria cell counts and toxin concentrations) and dissolved oxygen

Task 2-2. Resolve Ammonium issue in Northern Bay. The purpose of this task is to formulate a working group of Bay scientists to synthesize available data on factors known to control primary productivity in different regions in the Bay, developing consensus on relative importance of ammonium inhibition of phytoplankton blooms to Baywide primary productivity in general and in Suisun Bay specifically. The goal would be to achieve some scientific consensus on the role of ammonium and the need to control discharge of ammonia. It would also be important to determine the need for and approach to next steps with respect to incorporating ammonium into the NNE assessment framework for the Bay.

Task 2-3. Review of Dissolved Oxygen Objectives. Conduct an initial review of Bay dissolved oxygen objectives, either Bay-wide or for specific habitat types such as tidally muted areas (tidal sloughs, estuarine diked Baylands) and develop a more detailed workplan if a decision is made to develop habitat-specific dissolved oxygen objectives.

Task 2-4. Development of a Seagrass Assessment Framework. The purpose of this task is to participate in statewide effort to develop an assessment framework for eutrophication in seagrass, based on indicators phytoplankton biomass, macroalgae, and epiphyte load. The intent is that progress on this work element would be monitored for applicability to San Francisco Bay, while progress is made on Task 2-1 through 2-3.

Task 2-5. Development of a NNE Framework for Intertidal Flats. The purpose of this task is to participate in statewide effort to develop an assessment framework for eutrophication in intertidal flats, based on macroalgae and other supporting indicators. The intent is that progress on this work element would be monitored for applicability to the Bay, while progress is made on Task 3-1 through 3-3.

Work Element 3. External Loads and Preliminary San Francisco Bay Nutrient Budgets

The purpose this work element is to summarize existing data on external loads and internal sources, sinks and transformation of nutrients to San Francisco Bay, identify important data gaps, and prepare a technical foundation for making technically sound nutrient management decisions in the future. This work element consists of four tasks.

Task 3-1. Conceptual Model of External/Internal Nutrient Sources and Sinks. The purpose of this task is to develop a conceptual model of external and internal sources, sinks and pathways of transformation of nutrients in the Bay.

Task 3-2. Bay Nutrient Budget**.** The purpose of this task is to synthesize existing information to develop, to the extent possible, a spatially and temporally explicit budget of nutrient external loads, internal sources, and sinks. A summary of external loads to the South Bay has already been undertaken by SFEI via funding from BACWA. This task would expand that loading work into the Central and North Bay, develop monthly (or seasonal) and annual load estimates, and explore the importance of uncertainties resulting from major data gaps. For the within-Bay analysis, the system will be divided into Bay segments, seasonal and annual budgets will be estimated within each segment and for the Bay as a whole, and critical data gaps will be identified.

Task 3-3 Collect additional external loading information. Based on existing summary of external loads (discussed in Task 3-2 above), identify need for data collection to refine external loading estimates for POTWs discharging to SF Bay. Consider the need for additional stormwater loading information.

Task 3-4. Models to Predict Nutrient Loads and Test Management Scenarios**.** This task will review existing models or types of models that can be used to predict the sources and pathways of nutrient load to the Bay and summarize the data requirements. The task will begin by identifying the types of questions that the model(s) or empirical data must answer. The intent is to review models and tools that can assist in decision-making on nutrient management strategies and test the cost-effectiveness of implementation scenarios. This work element will feed into the development of a modeling strategy.

Task 3-5. Monitoring Elements**.** This task will recommend specific monitoring elements (as core monitoring or special studies) either in support of empirical estimates and/or model development for key within-Bay sources, sinks and rates of transformation. Key findings from Task 3-2 will inform Task 3-5, and recommendations made in Task 3-5 will in turn feed into Task 1-5 and 1-6.

Work Element 4. Modeling Strategy

The purpose of this work element is to prepare the technical foundation for development of a modeling strategy to forecast the ecological response to nutrient loads and other environmental factors in the Bay. Previous work elements have defined conceptual models(Task 1-1, 3-1), management endpoints of concern (work element 2), and reviewed existing models, modeling approaches, and data needs for predicting external nutrient loads and analyzing management scenarios (Task3-3). This work element consists of three tasks:

Task 4-1. Review of existing models and available model approaches to model the ecological response of the Bay to nutrient loads and other co-factors. This task will produce a review of available models and/or modeling platforms that will be the basis for developing a modeling strategy for the Bay. A working group will identify the management questions and endpoints (indicators) of concern and relevant spatial and temporal scales, focusing on hydrodynamic, water quality (dissolved oxygen, nutrients, carbon) and a phytoplankton-zooplankton production and phytoplankton speciation models. A review will be conducted of existing Bay and Delta hydrodynamic and water quality models or other applicable types of models, from simple spreadsheet to complex dynamic simulation models, their data needs, and advantages and disadvantages. Deliverables for this work element include a powerpoint presentation and a technical report. Conceptual models will be developed or cited as needed beyond those already created in Work Element 1 or available in model documentation.

Task 4-2 Conceptual Models of Ecological Response to Nutrient Loads. The purpose of this task is to develop a suite of spatially-explicit conceptual models of the ecological response to nutrients and other co-factors. This conceptual model build on the previous conceptual models (assessment, 1-1) and (external/internal loads, 3-1) to identify the management endpoints, state variables and mechanisms that would be modeled as a part of a Bay nutrient water quality model.

Task 4-3. Modeling Strategy to Support Nutrient Management in the Bay. The purpose of this task is to synthesize information generated from previous tasks to develop a monitoring strategy for the Bay. The strategy would identify questions to be answered by the models, types of models needed (e.g. external loads, bay hydrodynamic and water quality), identify modeling platforms, amount of data required and funding required, schedule, and what policy decisions will be informed.

Table 2. GANTT chart of approximate timing of work elements and tasks associated with 5-yr nutrient plan.

Task No.	Brief Task Description	Yr1	Yr2	Yr3	Yr4	Yr5
Element 1: The Bay Nutrient Status and Trends Monitoring Program Development						
1-1	Assessment conceptual models					
1-2	Synthesize additional existing data on dissolved oxygen concentrations					
1-3	Scope Geodatabase of Monitoring Activities/Sample locations					
1-4	Expand USGS Water Quality Sampling to Include Urea and HAB toxins					
1-5	Develop Ambient Monitoring program Subtask a) Recommend elements of a core Bay monitoring program to assess status and trends Subtask b) Develop the Bay nutrient monitoring program Work Plan and QAPP					
1-6	Implement the Bay nutrient monitoring program					
Element 2: Water Quality Objectives						
2-1	Phytoplankton NNE Assessment Framework					
2-2	Update of Ammonia/Ammonium Objective					
2-3	Review of Dissolved Oxygen Objectives					
2-4	Participate in statewide workgroup to develop a Seagrass Assessment Framework					
2-5	Participate in statewide workgroup to develop a of a NNE framework for intertidal flats					
Element 3: External Loads and Bay Budget						
3-1	External/internal Loads Conceptual Model.					
3-2	Bay Nutrient Budget					
3-3	Collect Additional Data on External Loading					
3-4	Review of loading models to predict nutrient loads and test management scenarios					
3-5	Monitoring Elements within-Bay sources and sinks					

Element 4: Modeling Strategy						
4-1	Review of existing models/platforms to model Bay hydrodynamics & water quality					
4-2	Bay water quality conceptual model					
4-3	Modeling strategy to support nutrient management in the Bay					

Table 3. Specific recommendations for science to support development of habitat-type specific NNE assessment frameworks. Priority designation of "high", "medium" or "low" is a preliminary designation, pending feedback by Bay stakeholders.

Habitat Type	Recommended Action	Priority
All subtidal	Sponsor a series of expert workshops to develop a draft assessment framework based on indicators of phytoplankton (biomass, productivity, assemblage, cyanobacteria cell counts and toxin concentrations) and dissolved oxygen	High
	Form a working group of Bay scientists to synthesize available data on factors known to control primary productivity in different regions in the Bay, developing consensus on relative importance of ammonium inhibition of phytoplankton blooms to Baywide primary productivity, and determining next steps with respect to incorporating ammonium into the NNE assessment framework for the Bay.	High
	Consider a review of the Bay dissolved oxygen objectives, either Bay-wide or for specific habitat types such as tidally muted areas (tidal sloughs, estuarine diked Baylands)	High
Un-vegetated Subtidal	Utilize IEP-EMP data to explore use of macrobenthos to assess eutrophication in oligohaline habitats. Consider including biomass in the protocol to improve diagnosis of eutrophication. Determine whether combination of indicators can be used reliably to diagnose eutrophication distinctly from other stressors.	Low
Submerged Aquatic Vegetation	Conduct studies to establish light requirements for the Bay seagrass species;	Low
	Collect baseline data to characterize prevalence of macroalgal blooms and other stressors on seagrass beds	Moderate
	Evaluate the findings of statewide NNE studies characterizing effects of macroalgae on seagrass for applicability to the Bay	Moderate
	Participate in statewide group to develop an assessment framework for eutrophication in seagrass, based on phytoplankton biomass, macroalgae, and epiphyte load.	High
Intertidal Flats	Evaluate the findings of studies characterizing effects of macroalgae on intertidal flats for applicability to the Bay	Moderate
	Participate in statewide group to develop an assessment framework for eutrophication in intertidal flats, based on macroalgae and other supporting indicators.	High
Tidally muted habitats - managed ponds	Synthesize existing DO oxygen data for tidally muted areas and collect baseline data primary and supporting indicators (macroalgal biomass and cover and phytoplankton biomass, taxonomic composition, and HAB toxin concentrations) in these habitats needed to make a full assessment of status of eutrophication.	High

Appendix 1

List of additional planned data collection efforts – updated from June 30, 2011 Nutrient Strategy Session Minutes

- Diagnostic pigments (CHEMTAX)
    - Raphe Kudela is pursuing an alternative method to microscopy for measuring phytoplankton composition, HPLC with CHEMTAX, which uses pigment ratios to determine the main taxonomic groups present.
    - This study will begin to answer the question of whether this method can be used in San Francisco Bay for monitoring the phytoplankton composition. It is much less expensive than microscopy and will allow more samples to be collected throughout the system. At this time the extent of phytoplankton composition sampling is limited by funds.
    - Alex Parker is also gearing up to test a flow cytometer and fluoroprobe (belonging to Anke).
    - A pilot study for 2012 is underway, under Tara Schraga's lead to fund Raphe Kudela's HPLC/CHEMTAX analysis and compare it to years of the microscopic counts USGS has funded a taxonomist to complete. Alex Parker will be adding the flow cytometer and fluoroprobe to this year long study to test their viability for accurate determination of phytoplankton groups. USGS will also fund Raphe analyzing some HPLC/CHEMTAX samples for Alex from other stations in the North Bay not on the Polaris track. This project will bring together these efforts and include a summary analysis at the end.
- Urea
    - A pilot study measuring urea in the Bay, led by Tara Schraga and Jim Cloern, is scheduled for monthly sampling (5 stations) for one year (2012).
    - Parker and Dugdale also have five stations that they are sampling annually.
- Algal Toxins
    - In 2012 the USGS is conducting a pilot study collecting samples for phycotoxin analysis throughout the Bay on 1 cruise each month. Raphe Kudela will analyze the samples. Jim Cloern indicated that he needed assistance filtering on the USGS monthly cruises since they are adding this analysis and the CHEMTAX samples .
    - Raphe proposed deploying SPATT collectors at various sites throughout the Bay as a pilot study. The bags integrate the toxins they are exposed to over the period of time deployed.
- Moored sensors
    - Dave Schoellhamer noted that there is funding (50K) from USGS to add sensors at the 6 moored stations, including DO, chlorophyll, fluorescence, and telemetery. Bottom DO will be monitoried at San Mateo Bridge, Richmond Bridge, Carquinez Bridge, Benicia Bridge, Corte Madera Creek, Alviso Slough, and a new Central Bay site that will be deeper than their Alcatraz site in 2012. USGS already has a sensor at the Dumbarton bridge that is collecting data.

    - The pilot study still needs additional funding for processing and data analysis, so Dave Schoellhamer will put together a proposal for this funding from the RMP.
- Productivity method
    - Tara Schraga proposed performing in-water productivity measurements and comparing it to output from a productivity sensor. If there is agreement, the in-water instrument can collect productivity samples. If the methods are comparable, the in-water method would increase the temporal resolution and be less expensive (both in cost of samples and labor, and in time needed). The Cloern project uses the DO productivity measurement method while Alex Parker prefers C13/N15 labeling.
    - This pilot study is not currently planned for 2012 due to lack of trained staff and funds for staff or instrument.

NUTRIENTS

Relevant Management Policies and Decisions
Primary
- Nutrient objectives (draft in 2013)
- Evaluate need for revised objectives for DO and ammonia (2013)
- Water quality assessment – impairment listing – 2014, 2016
- NPDES permits (e.g., POTW, MRP) –ongoing
  Data collection – 2012
- Treatment plant upgrades

Secondary
- Delta Flows
- Regional Sediment Strategy
- Watershed TMDLs
- Recycled Water Policy and POTW projects

Recent Advances in Understanding and Priority Information Needs
- There is a growing body of evidence that suggests the historic resilience of San Francisco Bay to the harmful effects of nutrient enrichment is weakening.
- Since the late 1990's, regions of the Bay have experienced significant increases in phytoplankton biomass (30- 105% from Suisun to South Bay) and significant declines in DO concentrations (2.0 and 4.0 % in Suisun Bay and South Bay, respectively.
- USGS findings on declining suspended sediment in the Bay – however, no data available for shallow subtidal regions of the Bay
- Need for a locally-supported, long-term status and trends monitoring program for nutrients and eutrophication
- Bay water quality objectives related to nutrients are limited to un-ionized ammonia and dissolved oxygen
- There are outstanding questions about the role and importance of ammonium with respect to beneficial use impairment

Priority Questions for the Next Five Years
1. Is there a problem or are there signs of a problem?
   a. Are anthropogenic nutrients currently, or trending towards, adversely affecting beneficial uses of the Bay?
   b. Are beneficial uses in segments of San Francisco Bay impaired by any form of nutrients?
   c. Are trends spatially the same or different in San Francisco Bay?
2. What are appropriate guidelines for assessing SF Bay's health with respect to nutrients and eutrophication?

3. Which nutrient sources, pathways, (and transformation processes) contribute most to concern? (Get the loads right!)
    a. What is the relative contribution of each loading pathway (POTW, Delta, NPS, etc.) to the Bay overall and the Bay's key sub-systems, and how do these loads vary seasonally?
    b. What is contribution of nutrient regeneration (benthic fluxes) from sediments and denitrification/nitrogen fixation to SF Bay nutrient budgets?
4. What nutrient loads can the Bay assimilate (without impairment of beneficial uses)?
5. What future impairment is predicted for nutrients in the Bay?

Five Year Goals for Nutrient Strategy

1) Establish guidelines for eutrophication and other adverse effects of nutrient overenrichment

2) Implement a monitoring program that supports regular assessments of the Bay, and characterizes/quantifies key internal processes that exert important influence over the Bay's response to nutrient loading

3) Quantify nutrient loads to SF Bay

4) Establish a modeling strategy to investigate modeling approaches that may provide additional insights into the Bay's response to nutrient loads under current conditions and allows prediction of response under future scenarios

Table 2. Approximate timing and costs of tasks (*note: Costs not yet included)*

Task No.	Brief Task Description	Yr1	Yr2	Yr3	Yr4	Yr5
Element 1: The Bay Nutrient Status and Trends Monitoring Program Development						
1-1	Assessment conceptual models					
1-2	Synthesize additional existing data on dissolved oxygen concentrations					
1-3	Scope Geodatabase of Monitoring Activities/Sample locations					
1-4	Expand USGS Water Quality Sampling to Include Urea and HAB toxins					
1-5	Develop Ambient Monitoring program Subtask a) Recommend elements of a core Bay monitoring program to assess status and trends Subtask b) Develop the Bay nutrient monitoring program Work Plan and QAPP					

1-6	Implement the Bay nutrient monitoring program					
Element 2: Water Quality Objectives						
2-1	Phytoplankton NNE Assessment Framework					
2-2	Update of Ammonia/Ammonium Objective					
2-3	Review of Dissolved Oxygen Objectives					
2-4	Participate in statewide workgroup to develop a Seagrass Assessment Framework					
2-5	Participate in statewide workgroup to develop a of a NNE framework for intertidal flats					
Element 3: External Loads and Bay Budget						
3-1	External/internal Loads Conceptual Model.					
3-2	Bay Nutrient Budget					
3-3	Collect Additional Data on External Loading					
3-4	Review of loading models to predict nutrient loads and test management scenarios					
3-5	Monitoring Elements within-Bay sources and sinks					
Element 4: Modeling Strategy						
4-1	Review of existing models/platforms to model Bay hydrodynamics & water quality					
4-2	Bay water quality conceptual model					
4-3	Modeling strategy to support nutrient management in the Bay					

Multiple Year 1- 2 Project Tasks as identified in Draft Nutrient Strategy

Estimated Cost:	$146,000
Oversight Group:	Nutrient Strategy Team, TRC, NNE Committees
Proposed by:	David Senn, Martha Sutula, Naomi Feger & Monitoring subgroup (6/30/2011 meeting)
Date:	September 15, 2011

Proposed Deliverables and Time Line

Deliverable	**Due Date**
Task 1: Assessment Conceptual Model Technical Report	December 2012
Task 2: Scope Geodatabase of Monitoring Activities/Sample locations	December 2011
Task 3: Synthesize additional DO data a) shallow water data; b) new USGS moored sensor data	a) December 2012 b) December 2013
Task 4: Conceptual Model of External/Internal Nutrient Sources and Sinks	December 2013
Task 5: Bay Nutrient Budget Technical Report	December 2013

1. Background and Justification

San Francisco Bay has long been recognized as a nutrient-enriched estuary, but one that has historically proven resilient to the harmful effects of nutrient enrichment, such as excessive phytoplankton blooms and hypoxia. The published literature suggests that the accumulation of phytoplankton biomass in the Bay is strongly limited by tidal mixing, grazing pressure by invasive clams, light limitation from high turbidity, and potentially in the North Bay, ammonium inhibition of diatom uptake of nitrate. However, since the late 1990s, evidence is building that the historic resilience of the Bay to the harmful effects of nutrient enrichment is weakening (J. Cloern, unpublished data).

In response to the apparent changes in the Bay's resilience to nutrient loading, and recognizing the need for an assessment framework for nutrients as well as a long-term status and trends monitoring and modeling strategy to assess impairment of the Bay, the San Francisco Bay Regional Water Quality Control Board (Water Board), in collaboration with Bay stakeholders, are developing a San Francisco Bay Nutrient Strategy (Appendix 1 – Draft Nutrient Strategy). The draft strategy identifies management questions and presents goals for a nutrient management program. It also prioritizes work elements within a five-year planning horizon.

This proposal to the RMP is requesting funds to support a high-priority subset of the technical studies that the Nutrient Strategy identifies, to be carried out over the next 1-2 years. In addition, Tasks 1 and 2 of this proposal were identified at a June 30, 2011 meeting of the strategy workgroup as high priority tasks that are needed in order to develop a status and trends monitoring proposal for the Bay.

2. Study Plan

The study plan consists of four tasks:

Task 1. Assessment Conceptual Model: *(Task 1-1 in Nutrient Strategy)*

The purpose of this task is to develop a spatially-explicit conceptual model of NNE indicators and co-factors to be measured to assess status and trends of eutrophication and other adverse effects of nutrients in the Bay. Model(s) will be spatially explicit by Bay segment and by habitat type (deepwater & shallow subtidal, seagrass and intertidal flat). The conceptual model will provide linkages between the Bay and the Delta.

Task 2. Scope Development of Geospatial Database of Monitoring Activities/Sampling locations. *(Task 1-3 in Nutrient Strategy)*

Several monitoring program or university have stations with current or planned monitoring activities within the Bay and Delta. In addition, the IEP is conducting an inventory of studies/monitoring programs in the Bay/Delta. The purpose of this task is to scope and cost building on a similar effort completed in the Delta by SFEI and the Central Valley Water Board referred to as the online Central Valley Monitoring Directory (www.centralvalleymonitoring.org). The deliverable for this task is an inventory of the datasets to be included and a cost estimate to develop a Bay version of this online database. SFEI has completed a draft map of sampling locations.

Task 3. Synthesize additional existing data on dissolved oxygen concentrations (shallow water subtidal and moored sensors). *(Task 1-2 in Nutrient Strategy)*

The Bay NNE literature review and data gaps analysis (McKee et al. 2011) did not summarize dissolved oxygen data available for shallow water subtidal habitat. The purpose of this exercise is to synthesize existing dissolved oxygen data available for shallow water subtidal habitats to assess status and trends relative to Basin plan standards and inform spatial elements of the nutrient monitoring program. In addition, USGS - Dave Schoellhamer has funding to add sensors at 6 moored stations to include DO, chlorophyll, fluorescence, and telemetry. However, there is no funding to conduct data synthesis which will be required in year two to make this data collection effort meaningful.

Task 4. Conceptual Model of External/Internal Nutrient Sources and Sinks. *(Task 3-1 in Nutrient Strategy)*

The purpose of this task is to develop a spatially-explicit conceptual model of external and internal sources, sinks and pathways of transformation of nutrients in the Bay. The conceptual model, which will be developed with input from stakeholders and regional scientists, will divide the Bay watershed into subcatchments and the Bay itself into segments, and identify key processes and important unknowns within each segment. The conceptual model will serve as the foundation upon which a spatially and seasonally explicit nutrient budget will be developed (Task 5).

Task 5. Bay Nutrient Budget. *(Task 3-2 in Nutrient Strategy)*

The purpose of this task is to synthesize existing information to develop, to the extent possible, a spatially and temporally explicit budget of external loads, internal sources, and sinks of nutrients. A summary of external loads to the South Bay has already been partially completed by SFEI via funding from BACWA. This task would expand that loading work into the Central and North Bay, develop monthly (or seasonal) and annual load estimates, and explore the importance of uncertainties resulting from major data gaps. For the within-Bay analysis, the system will be divided into Bay segments, seasonal and annual budgets will be estimated within each segment and for the Bay as a whole, and critical data gaps will be identified.

3. Applicable RMP Management Questions

Nutrient strategy management questions:

1. Is there a problem or are there signs of a problem in the Bay?

To answer this question properly, an assessment framework needs to be developed that can inform a long-term status and trends monitoring program. The first step is to develop a conceptual model as described in Task 1 above.

There are multiple current (or recent past) monitoring and/or data collection programs in the Bay and Delta. The data from these programs complement Bay-wide survey data by quantifying different parameters or focusing in specific areas of the Bay. These programs could also be part of (or be a model for) a future coordinated monitoring program. Task 2 addresses the need to have a complete accounting of Bay monitoring programs and existing data. Similarly, Task 3 addresses this question by analyzing existing data on dissolved oxygen in shallow subtidal habitats, and high temporal resolution oxygen data from moored sensors.

2. Which sources, pathways, and transformation processes are of most concern? What is the relative contribution of each loading pathway (POTW, Delta inputs, NPS, etc.)? What are the contributions of internal sources (e.g. benthic fluxes) from sediments and sinks (e.g. denitrification, assimilation) to the Bay nutrient budgets?

To address these questions, conceptual models and budgets need to be developed for the Bay. Given the pronounced seasonality of the region, and the substantial variability in the hypsographic, hydrologic, and nutrient loading characteristics of different Bay segments, the proposed spatially- and temporally explicit approach outlined in Tasks 4 and 5 are necessary.

4. **Budget Estimate**

Description	Cost per Sample ($)	Cost Estimate ($)
Task 1		40,000
Task 2		1,000
Task 3		25,000
Task 4		20,000
Task 5		60,000
Total Cost Estimate		**$ 146,000**

References

McKee, L.J., Sutula, M., Gilbreath, A.N., Beagle, J., Gluchowski, D. and Hunt J., Numeric Nutrient Endpoint Development for San Francisco Bay – Literature Review and Data Gaps Analysis. Southern California Coastal Water Research Project Technical Report No. 644. April 2011