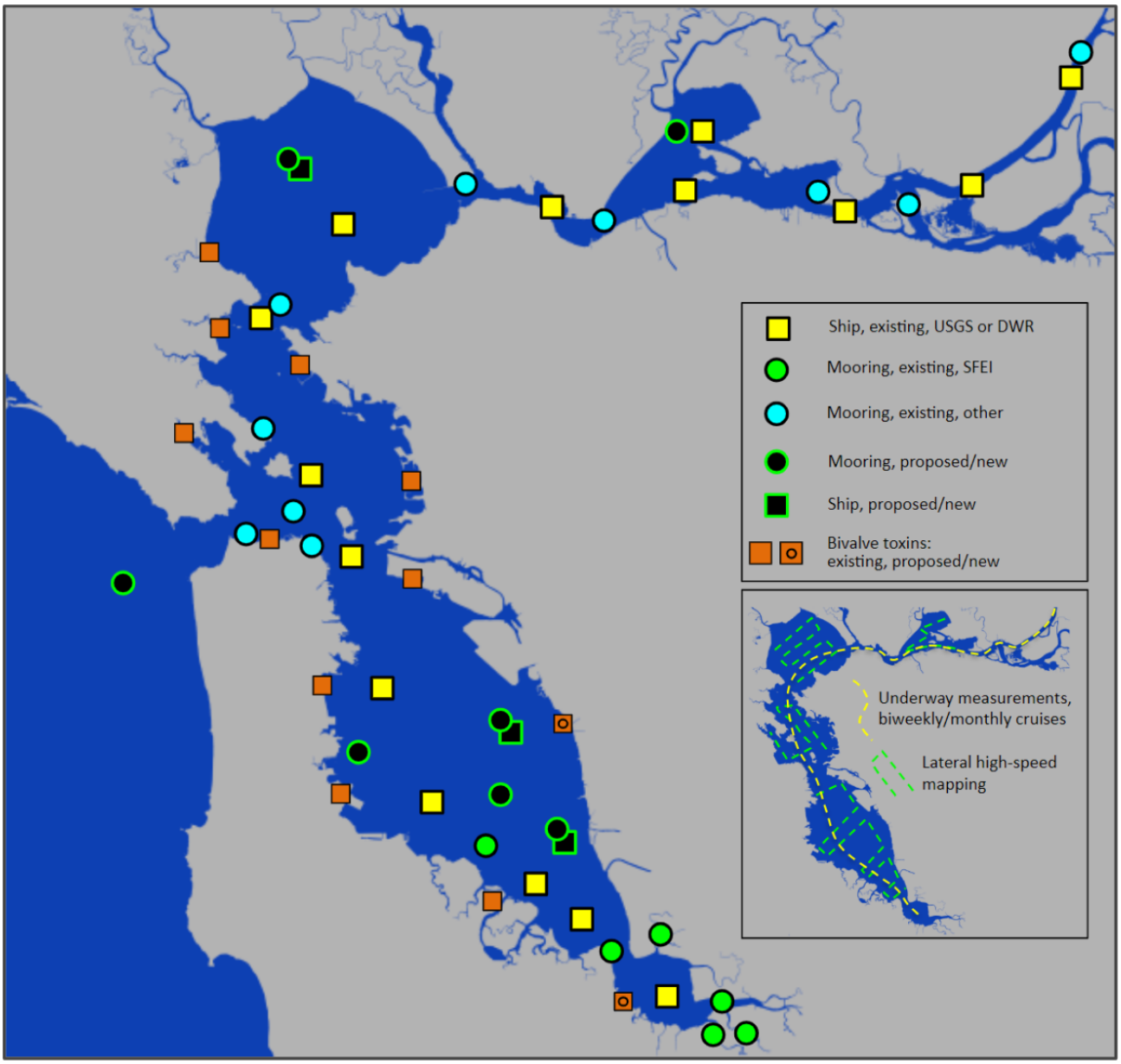
San Francisco Bay
Nutrient Management Strategy
Observation Program



SFEI Contribution #991

1. Introduction

The San Francisco Bay Nutrient Management Strategy (SFB NMS; SFBRWQCB 2012) is a regional science program charged with building the scientific foundation to inform regional nutrient management decisions (Table 1.1). SFB receives large loads of nitrogen and phosphorous from treated wastewater effluent and agricultural inputs, but has historically exhibited resistance to classic symptoms of eutrophication. Recent studies have found that the SFB's response to nutrients is changing in some regions (e.g., Cloern and Jassby 2012; SFEI 2014), spurring the need for improved understanding of nutrient dynamics and ecosystem response in SFB, and spurring the NMS' launch.

Although SFB is a well-studied estuary, SFB's diversity of habitats, its complex physical and biogeochemical processes, and the relatively limited effort invested to date exploring nutrient dynamics and nutrient-related responses create a situation in which there are numerous high priority NMS data gaps (SFEI 2014a, SFEI 2014b, SFEI 2016a). Although SFB hosts several major research and monitoring programs (Figure 1.1), no program or combination of programs fully addresses the NMS needs in terms of data and sustainability. Developing and operating a sustainable nutrient-focused observation program, therefore, stand among the NMS' core objectives.

This document presents a planning-level description of the draft Nutrient Management Strategy Observation Program (NMSOP), including estimated budget and approach for phased growth. *The NMSOP represents the design that is needed to address NMS data needs, not an existing program.* The proposed design represents a balance between two key goals:

- Target high priority NMS data collection needs
- Where feasible, align field work and data collection efforts with other programs' established infrastructure, to enhance cost-effectiveness and sustainability.

While an inter-program collaborative approach is important for securing NMSOP's long-term sustainability, building a reliable consortium will require up-front effort to establish inter-program science, management, and financial agreements. This document focuses on the NMSOP scientific program design and growth, with institutional program development described in a companion work plan (SFEI 2016b).

TABLE 1.1: MANAGEMENT QUESTIONS GUIDING NMS ACTIVITIES

1. What conditions indicate that beneficial uses are being protected? What conditions indicate that nutrient-related impairment is occurring?
2. Which habitats in SFB are currently supporting beneficial uses, and which are experiencing nutrient-related impairment?
3. Under what future scenarios could nutrient-related impairments develop?
4. What management actions are needed to mitigate or prevent nutrient-related impairment?

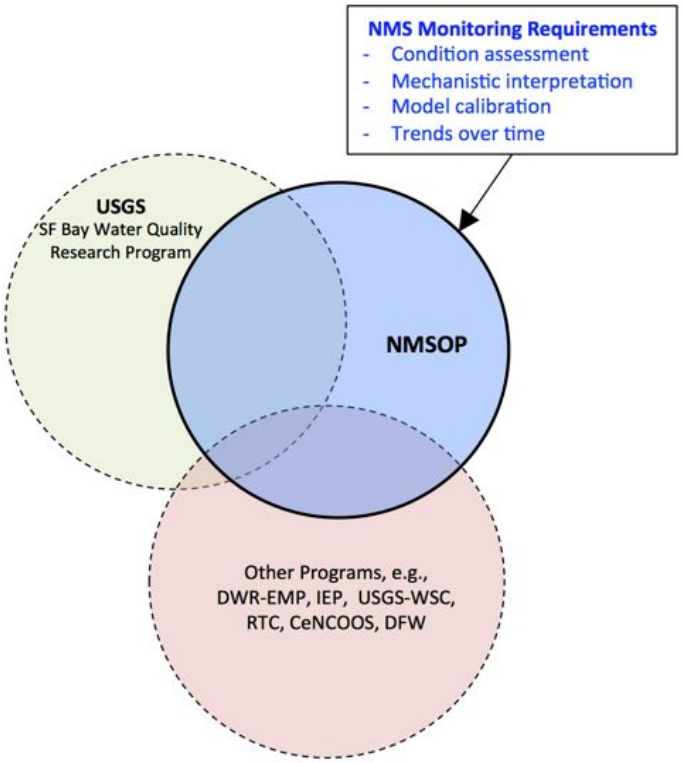


Figure 1.1 The Bay-Delta hosts multiple on-going and independently managed research and monitoring programs. Nutrient Management Strategy (NMS) monitoring requirements will be addressed through maximizing coordination with other science and monitoring efforts in San Francisco Bay-Delta, and by supporting a portion of the work with NMS funding.

Figure 1.2 illustrates the proposed developing NMSOP: begin in CY2017 with the existing program (NMSOPv0.1); refine and build toward an intermediate design by 2020 (NMSOPv1.0); additional refinement and growth to establish the long-term sustained program design (NMSOPv2.0). The specific NMSOPv1.0 components detailed in Section 2 are proposed as a strawman design, with the expectation that they will be tested and modified during Phase 1 to improve program design. This approach -- modest beginnings, analysis and iterative refinement, gradual growth -- is proposed for a few practical reasons:

- The necessary resources and inter-program agreements to support NMSOPv1 and NMSOPv2 are not yet in place.
- Gradually growth will allow program logistics to expand sustainably.
- Pilot studies and on-going data interpretation over the next several years will help inform the remaining highest priority data and knowledge gaps, and guide program growth.

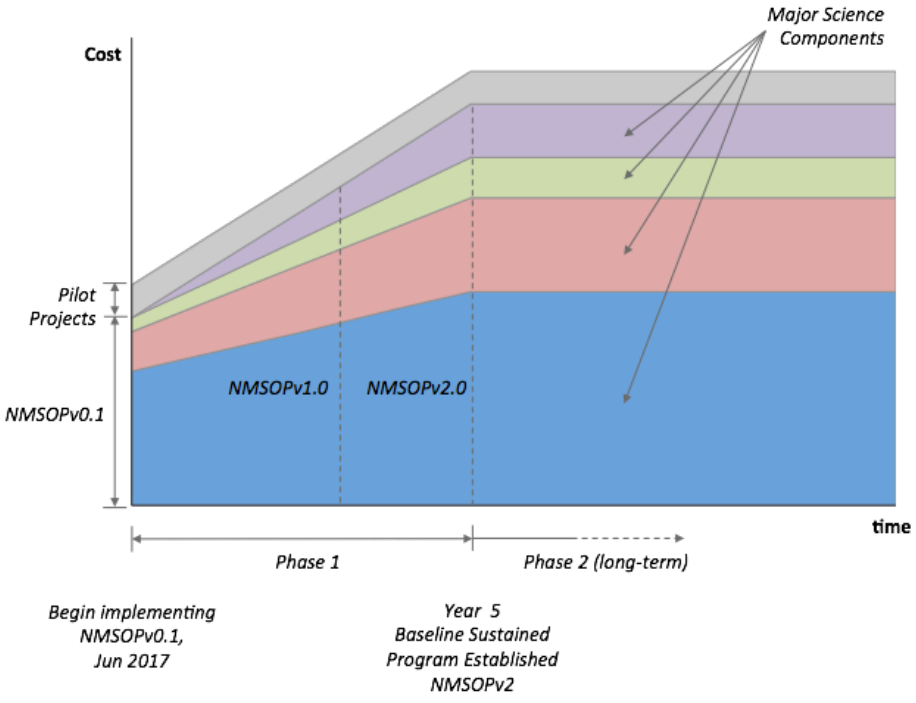


Figure 1.2 Schematic illustrating the anticipated timeline for NMSOP evaluation, growth, and refinement. Major science program components gradually grow during Phase 1, and stabilize in Phase 2. Although not included here, inflationary cost increases need to be factored into budgets.

2. Program Design

The NMSOP design is comprised of four major program areas:

1. Core measurements
2. Pilot Studies
3. Data analysis and interpretation
4. Program Management

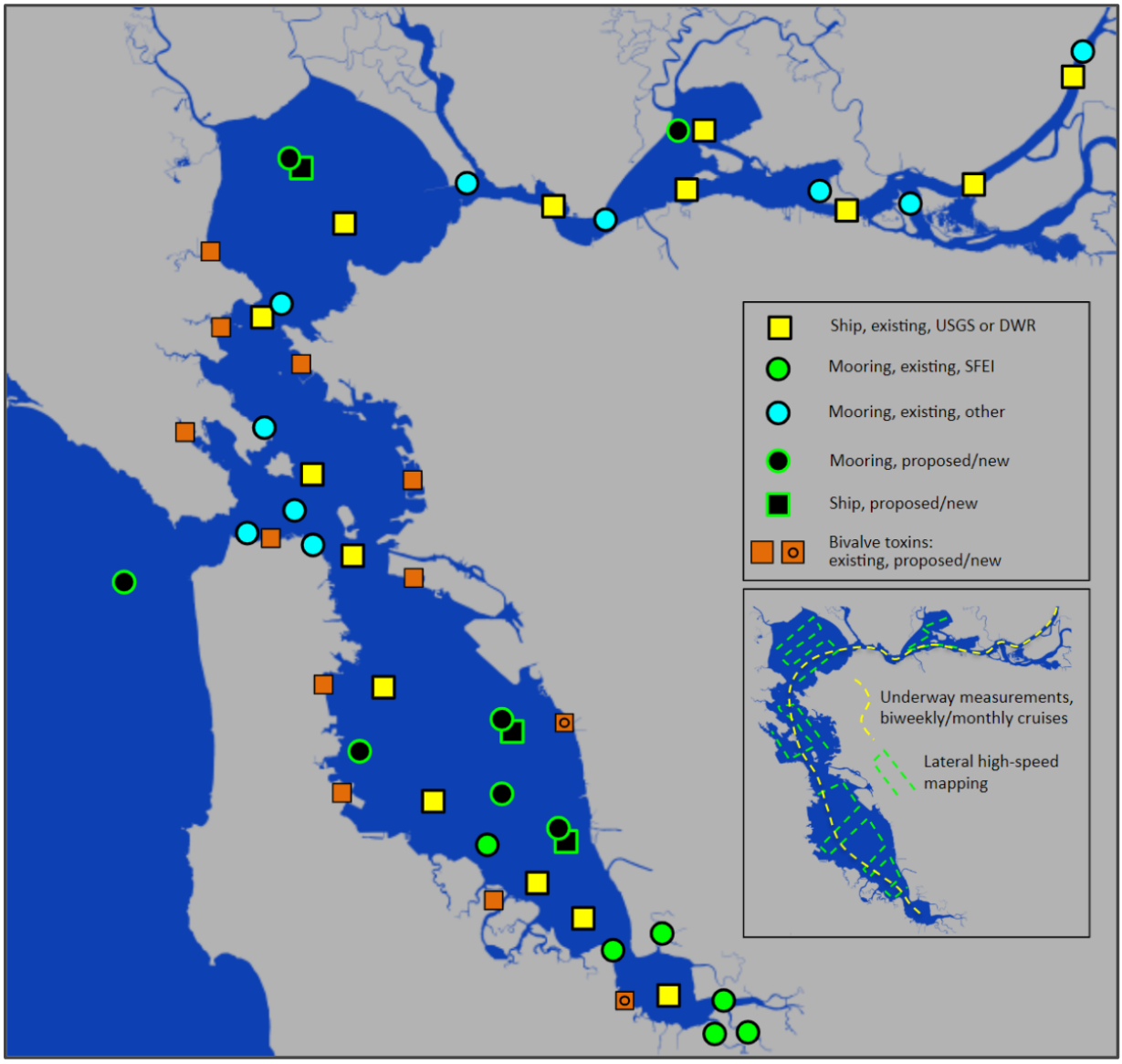


Figure 2.1 The *strawdog* NMS Observation Network v1.0. Measured parameters and basic sampling plan are described in Figure 2.1. The specific NMSOPv1.0 components -- including station locations, sampling frequency, and analytes are proposed as a strawman design, with the expectation that they will be tested, modified, and improved during Phase 1.

2.1 Core Measurements

The NMSOPv1.0 Field Program has three major components (Figures 3.1-3.2):

1. Ship-based water column sampling: biweekly to monthly cruises along the Bay's deep channel; and monthly lateral biogeochemical "mapping"
2. Moored sensor network with high-frequency sensors
3. Biological sampling: initially, for toxins; future, possibly DO-related fish/benthos surveys

Figure 3.1 and 3.2 depict the spatial distribution of sampling stations and major parameters measured for NMSOPv1.0. In Figure 3.2, the designation of "Basic" indicates activities included in NMSOPv1.0, while "Advanced" presents examples of potential program additions for piloting or integration into the core program during Phase 2. The strawman set of Core Measurements is based on high-priority data and knowledge gaps identified through NMS data analysis, expert workgroups, and regulator and stakeholder input (SFEI 2014a, SFEI 2014b, SFEI 2016a). The intent is for NMSOPv1.0 to be rigorously tested, refined, and improved during Phase 1.

Figure 2.2 Details for the major NMS observation program components. Basic parameters are included in NMSOPv1; Advanced parameters are examples for possible program growth during Phase1. Images: R/V *Peterson*, USGS research vessel; native mussels attached to a floating dock; example lateral heterogeneity in chl-a data.

Table 2.1 presents a qualitative overview of NMSOP current status (through December 2016) relative to the NMSOPv1.0 design to indicate where capacity building efforts are needed.

Table 2.1 Current status (thru Dec 2016) of NMSOP core components toward NMSOPv1 Implementation. For example, a 50% grey circle would indicate that current work is addressing approximately half of the design depicted in Figures 3.1 and 3.2. The status of most components is 50% or less. At this point, ship-based lateral mapping has only been conducted through two modest pilot studies. The ship-based channel station field program has the most advanced status, because it is building primarily on the long-standing USGS SFB Water Quality Program, with additional support from the NMS. Although status and funding level are obviously related, the status estimates do not reflect long-term funding security.

	Field Program	Sample Measurements and Analysis	Data Management, Analysis, and Interpretation
Ship-based: Channel stations			
Ship-based: Lateral mapping			
Moored sensors			
Biological sampling			

2.2 Pilot Studies

Results from targeted pilot studies, conducted during Phase 1, will inform decisions related to refining NMSOPv0.1 and NMSOPv1.0. Pilot studies will fall into two broad categories:

- Field studies during which new parameters, stations, or measurement techniques are tested, and results are analyzed to determine the importance of the new data relative to NMS goals and the measurements' technical feasibility or cost-effectiveness.
- Data analysis (e.g., e.g., field data, or model simulations), with the goal of identifying ways to optimize program design (e.g., station locations, or sampling frequency), identify data gaps, and, in general, refine the strawman NMSOPv1.0.

Example priority pilot studies include:

- Apply numerical models to evaluate the efficiency and effectiveness of draft sampling program designs (site locations, sampling frequency)
- Lateral high-speed biogeochemical mapping to determine the temporal frequency and locations that yield the most valuable data.

- Develop a zooplankton sampling module for assessing community composition, abundance, and grazing rate estimates
- Develop a benthos sampling module for assessing community composition, abundance, and grazing rate estimates
- Deploy transplanted mussels/bivalves (i.e., similar to MusselWatch) and/or passive toxin samplers to test their utility relative to native bivalves, or augment bivalve sampling network in areas where native bivalves are not present.
- Test the added value from additional *in situ* sensors for ship-based measurements (vertical CTD casts, underway flow-through) or moorings.
- Test the potential for using remote-sensed data products (e.g., chl-a, suspended sediments, pigments, etc.) through field calibration studies (coincident with satellite flyovers) and/or through evaluating existing products relative to data

2.3 Data Management and QA/QC

Data generated through the NMS need to be efficiently managed, publicly available, and to pass through rigorous and consistent QA/QC protocols. While the long-standing datasets used by the NMS are already being managed and undergoing QA/QC (some by USGS, some by SFEI), new types of data, and much greater amounts, are being generated through early NMSOP work, and the diversity of data types and amounts will expand in the future.

A NMS data management plan is under development, and the adopted plan will build upon best practices developed regionally (e.g., SFEI RMP) and elsewhere (e.g., IOOS, NOAA). Although data management has been integrated into NMS science workflow, to date, data management has not been called out as a major budget line item. The resources directed to data management needs to increase substantially (Table 3.1), with clear need for ~1 FTE within the next 1-2 years, and likely greater need thereafter.

2.4 Data Analysis, Interpretation, and Reporting

The analysis, interpretation and reporting of NMSOP data is as important as the data collection, and will require substantial funding, perhaps at levels that match those directed to the data collection. Standard uses or applications of the data and work products will include:

- Annual reports describing water quality status and trends, and providing updates on new findings
- Develop robust ecosystem health indicators, and support the development of thresholds or criteria against which condition can be assessed.
- Use in periodic condition assessments
- Technical reports and peer reviewed papers documenting important findings.
- Hydrodynamic and biogeochemical model calibration and validation

2.5 Program Management

A large and complex science program that is supporting management decisions and funded by public dollars requires proactive, detail-oriented, and transparent program management. Major program management activities will include: financial management and reporting; contracts and project management; deliverable tracking; fundraising; and stakeholder communication and coordination. If a sizable portion of NMSOP's core work will be carried out through collaboration or coordination with other programs, substantial effort will need to be invested toward inter-program coordination and communication, proactively maintaining partnerships, and managing inter-program data sharing, data QA/QC, ensuring that consistent field and lab methods are used across programs.

4. Budget and Current Support

Figure 4.1 summarizes the estimated NMSOPv1.0 budget, which totals $3.3 mill/yr. These estimates include a rough, and likely low, estimate of non-field scientific staff (~4 FTEs at various levels), in addition to the current USGS staff, to support the program's needs in terms of data analysis/interpretation, data management, and report preparation. The grey bars in Figure 4.1 provide an estimate of current funding levels in each of the program category, i.e., the current level of funding supporting NMSOPv0.1. The two main funding sources are in-kind funding from USGS support the ship-based channel sampling, and NMS other field work and an array of sample analysis. Although USGS supports most of the current ship-based channel sampling program costs, this funding is not guaranteed into the future, and that uncertainty needs to be factored into program planning and fundraising.

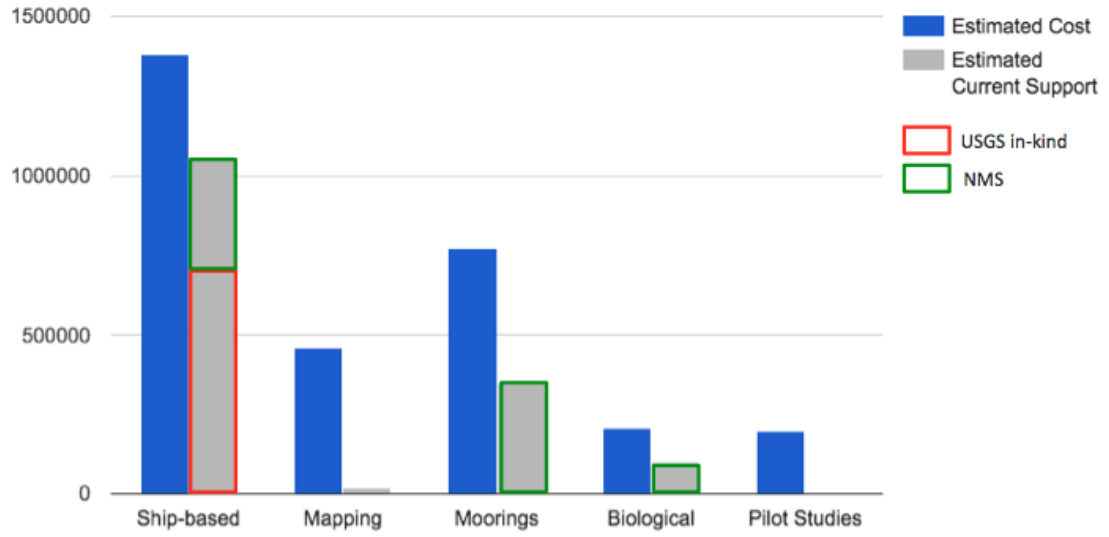


Figure 4.1 Estimated budget for NMSOPv1.0, and estimated current funding (i.e., essentially NMSOPv0.1). Red and green boxes indicate USGS in-kind support and NMS funding, respectively.