Concept Proposals
To Improve Management Confidence in the Regional Ocean Modeling System with Biogeochemical Elemental Cycling (ROMS-BEC)
August 18, 2022, Draft

The purpose of this document is to present the conceptual proposals for the nine optional tasks intended to improve management confidence in ROMS-BEC. Tasks 1-6 were proposed/discussed in the timeframe of Fall 2021 through July 2022 by the OAH Modeling TAG. Tasks 7-9 were proposed by CTAG members subsequent to the August 2022 meeting.

These options will be ranked by CTAG using Google forms. The intent is to provide sufficient detail on goal, approach, and products to facilitate this ranking process. After polling is complete, and the Commission weighs in on the final set of priorities, the ranked concept proposals will get further fleshed out and costs developed, in order to make a final judgment of what will be funded.

Click on the hyperlink title to read each of the concept proposals for the nine options.

Model Skill Assessment

What Is Skill Assessment? Model skill assessment is one of the most basic and fundamental of approaches to quantify model uncertainty. Ensuring that models are reliable for addressing management questions requires evaluating their skill in representing real-world processes and dynamics. Skill assessment requires a comparison of model output to observations across the physical and ecological processes. Multiple metrics are often applied to assess model skill because these metrics may emphasize different aspects of skill.

Previous Work. The science team previously performed a model skill assessment of ROMS-BEC in the Southern California Bight (SCB), focused on the gradients of coastal eutrophication resulting from land-based nutrient loading and its effects on algal productivity (carbon), nitrogen, oxygen, and dissolved inorganic cycles (Kessouri et al. 2021a). A CTAG special committee worked with the science team to get consensus on the skill assessment metrics and statistics in data-model comparisons. The skill assessment covered the modeling period of 1997-2000. As a result, model skill was not tested against newer improved data sources that have come online since 2013, including moored time series, and regional maps of aragonite saturation state documented in multiple Bight regional monitoring program studies (2013, 2018). In addition, land-based nutrient loading has changed in the last 20 years. Nitrogen management has been implemented at several Publicly Owned Treatment Works (POTWS). In addition, potable water recycling has begun to be implemented, which provides an opportunity to compare how the model predicts the environmental response to these changes relative to real-world observations.

Proposed Work. The purpose of this project would be to update the ROMS-BEC skill assessment in the SCB, repeating a subset of the Kessouri et al. (2021a) metrics and statistics and expanding to include new ones, based on new data availability or new anthropogenic gradients of interest not previously documented in Kessouri et al. 2021. A CTAG special subcommittee, co-chaired by SCCWRP (McLaughlin) and City of San Diego (Jaeger) would query SCCWRP member agencies on their high priority metrics, attributes, visualization tools, and statistics, in consultation with community science advisors, and formulate a work plan. The work could be leveraged by in-kind support from SCCWRP member agencies that are interested in providing quality assurance of their monitoring data, in order to expedite the skill assessment. Two options for this work have different resource implications: 1) skill assessment with existing simulations (2013-2017) and 2) skill assessment with new simulations through 2020 (three new years of ocean + land-based forcing). Note that some of the moorings have better continuity, more biogeochemical parameters, and fewer QA problems after 2018, thus the reason for extending model runs.

Product. Landing page on SCCWRP website that demonstrates model skill for a selected set of metrics and statistics. Specifically, the metrics and statistics would capture the percent difference between observed and predicted for environmental outcomes of interest.

Model Intrinsic Variability

What is Intrinsic Variability? ROMS-BEC is a 3-D model of ocean circulation, atmospheric coupling, tides, and surface gravity waves, linked biogeochemical cycles that predict lower ecosystem response to inputs from the ocean boundary, land, and atmosphere. Model predictions of algal productivity, oxygen and pH are likely to vary to a small degree due to the stochastic variability introduced by submesoscale processes like eddies, internal waves, etc. Thus, we define intrinsic variability to be the variance in outcome parameters of interest in separate model simulations with the same or similar boundary forcing, due to the modeling of stochastic processes.

Previous Work. UCLA has examined some of the physical processes involved in intrinsic variability in the Southern California Bight; however, no work has been explicitly done to examine the contribution of intrinsic variability to the predictions of algal productivity, O2 and pH loss by ROMS-BEC.

Proposed Work. The purpose of this project is to quantify the influence of model intrinsic variability in ROMS-BEC simulations. The goal is to quantify what minimum extent of change due to anthropogenic inputs is interpretable, given that intrinsic variability can be causing minor amounts of differences between model runs. Perturbation of initial conditions at the “boundaries” is one way of characterizing model intrinsic variability. We will run two simulations of 27 months in length of 1) ocean only and 2) the 2016-2017 ocean plus land-based forcing simulation, in which we perturbate the ocean boundary conditions by a small amount (e.g., 1%).

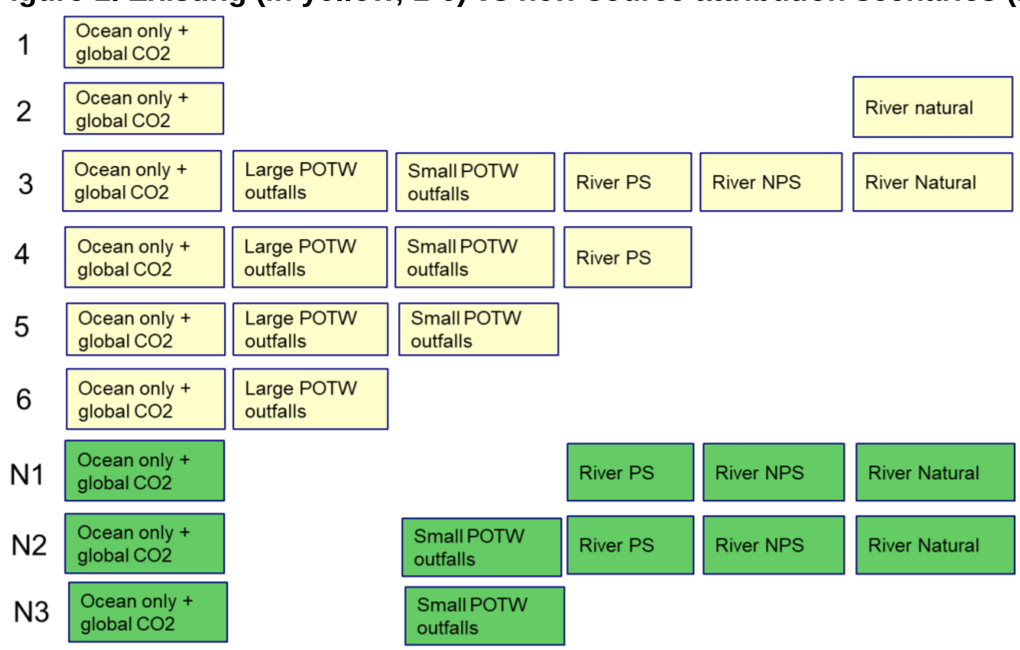
Product: The product of this work will be an assessment of the minimum amount of percent change that is interpretable in anthropogenic change assessments. We expect the result of the work to be published in a peer review manuscript, either alone or as a contribution to a manuscript currently in prep, describing the limits to interpretation of an anthropogenic “change assessment.”

Non-linearity of Response to Sources

What is Non-linearity of responses? ROMS-BEC simulates the response of the coastal ocean to the inputs of nutrients from point sources delivered via 23 ocean outfalls and from a combination of point source, non-point source and natural sources delivered via riverine runoff. Source attribution scenarios attempt to estimate the relative contribution of each of these land-based scenarios to the change in environmental outcome of interest (e.g., algal productivity, oxygen, and pH changes). This is done by sequentially removing a source from the forcing, running the simulation, then quantifying the difference between successive simulations that is attributable to the source that was removed. However, intrinsic variability can cause a non-linearity of response to the removal or addition of land-based sources, such that the sum of the whole does not equal the component parts attributed to sources.

Previous Work. The modeling team has already conducted a suite of six source attribution runs intended to quantify the relative contribution of point-source, non-point source and natural sources (Fig. 1). However, it is not clear to what extent the relative attribution of sources would change if the source were removed in a different order.

Figure 1. Existing (in yellow, 1-6) vs new source attribution scenarios (in green, N1-3)



Proposed Work. The purpose of this task is to run three additional simulations (shown in green below) that will allow us to calculate how the order of source addition (or removal) is affecting the percent change detected and attributed to a single source.

Product: The product of this analysis will be an enhancement of the source attribution manuscript that provides estimates of the minimum interpretation of percent of the change in algal production, O2 and pH loss that is attributable to point, non-point source and natural.

Model Sensitivity Analyses

What is Sensitivity Analysis? Model sensitivity analysis is the assessment of changes in outcome variables of interest (e.g., algal production, oxygen, or pH) varies as a function of changes in the inputs or parameters in a numerical model. If model inputs or parameters are uncertain, then sensitivity analyses can tell you how this uncertainty is relevant for model findings, among other applications.

Previous Work. CTAG has previously agreed that managers have a lower level of confidence in BEC relative to ROMS, which has been used in various applications for decades. The central paradigm that is being investigated in the overarching project is that nutrients will stimulate phytoplankton growth which in turn sinks to depth and is remineralized causing changes in pH and DO. Multiple BEC parameters are key contributors to the processes controlling pH and DO at depth (Table 1). Therefore, BEC sensitivity analyses are of great interest. Sensitivity analyses were conducted during model development and verification stages of the US West Coast version of ROMS-BEC at a 5 km resolution, but the thorough documentation of the results were not incorporated into Deutsch et al. 2021. Furthermore, that sensitivity analysis was not conducted on the final version of BEC now in management application.

Proposed Work. The purpose of this task is to make available existing documentation on sensitivity of BEC parameterization, and to conduct additional sensitivity analyses based on that information as needed in order to identify the parameters that most affect model outcomes.

Table 1. BEC parameters that are candidates for sensitivity analyses

Priority Ranking	Parameter to Test	Parameter Description	Parameter	Parameter Value	Parameter Units
1	Maximum growth rate of large phytoplankton group (i.e., diatoms)	max phyto C-specific growth rate at Tref (GD98) for diatoms	PC_{ref}^{diat}	3	/day
2	Grazer population size	zooplankton quadratic mortality	λ_{zoo}^{mort}	0.42	/ mmol C m^3 day
3	Zooplankton maximum grazing rates on large phytoplankton (diatoms)	maximum grazing loss for diatoms	$J_{diat}^{g,max}$	*1.95*	/day
4	Grazer natural mortality rate	Zooplankton linear mortality	λ_{zoo}^{mort}	*0.08*	/day
5	Limits grazing once grazers reach a certain population size	grazing coefficient, used in density dependent grazing modification	β_{z}^{grz}	1.05	C /m^3
6	Carbon fluxes of large phytoplankton from the photic zone, i.e., remineralization rate of dead diatoms	Maximum aggregation rate for diatoms	$\tau_{diat}^{agg,max}$	0.75	/day
7	Small phytoplankton growth	max phyto C-specific growth rate	PC_{ref}^{sp}	3	/day

Priority Ranking	Parameter to Test	Parameter Description	Parameter	Parameter Value	Parameter Units
		at Tref (GD98) for small phytoplankton			
8	Zooplankton maximum grazing rates on small phytoplankton	maximum grazing loss for small phytoplankton	$J_{sp}^{g,max}$	2.5	/day
9	Carbon fluxes of small phytoplankton from the photic zone, i.e., remineralization rate of dead small phytoplankton	Maximum aggregation rate for small phytoplankton	$\tau_{sp}^{agg,max}$	0.75	/day

Task work would consist of:

1. Examination, re-analysis, and documentation of previously conducted sensitivity analyses conducted at a 5 km scale, and refinement of the sensitivity analysis work plan;
2. Run of pseudo-2D model that provide a quick test of the relative sensitivity of model outcomes to parameterization (see table above) in order to prioritize the final list of parameters to be tested;
3. Run model simulations at the 4-km scale to conduct sensitivity analyses on the response of 3-5 parameters on perturbations (4 simulations per parameter, for a total of 12- 15 simulations. Two-year simulations at the 4-km scale can be run in two days, so total model run time would be 24-30 days.

Product: The product of this task would be an analysis of the relative sensitivity of algal productivity and subsurface oxygen and pH to changes in BEC parameterization, documented in a report that would be posted online, along with a simple primer of the BEC functionality, on the SCCWRP website.

Mechanistic Analysis: Role of climate variability in driving eutrophication outcomes

What is Climate Variability and How Does it Influence Ocean State? Climate variability is the shift in climate from its long-term mean. In the ocean, climate variability is often seen in changes in temperature, salinity, and mixed layer depth from the average. The Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), and the El Nino Southern Oscillation (ENSO) are some of the relevant indices that identify climate cycles that influence ocean conditions in the Northeastern Pacific Ocean.

Previous Work. Kessouri et al. (2021b) documented that land-based nutrient loading is causing an increase in algal blooms and subsurface oxygen and pH loss. However, ocean state, controlled by climate variability, appears to greatly modulate the extent and magnitude of the physical and biogeochemical processes that are responsible for these effects, as evidenced by the range of responses over the 1997-1999 in which El Nino occurred followed by La Nina.

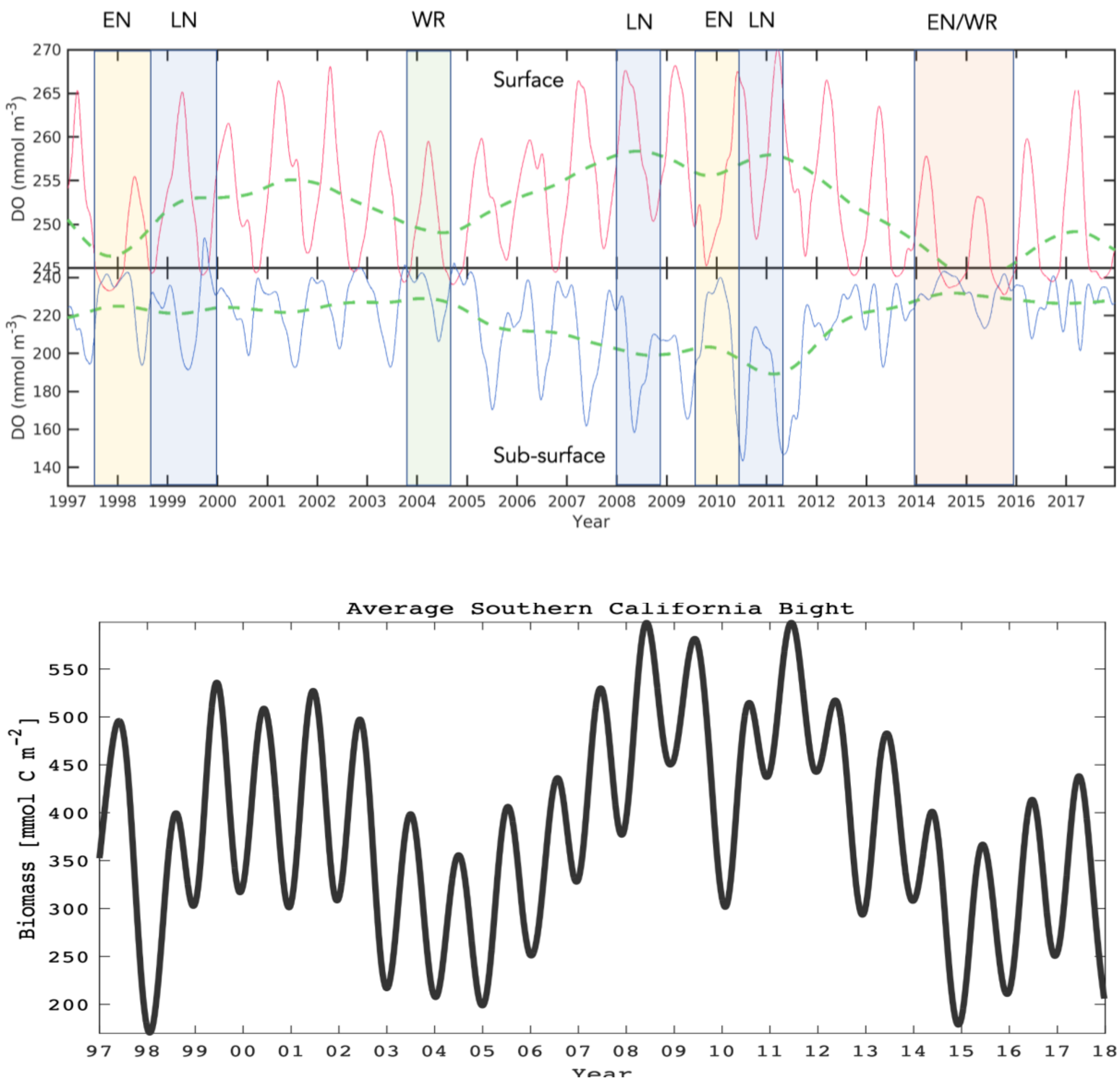
Three questions are relevant for the types of decisions facing water quality managers: 1) what ocean state represents the critical condition for anthropogenic effects on acidification and oxygen loss and their biological effects? 2) To what extent does the time period of peak biological effect coincide with time periods of greatest anthropogenic effect? And 3) what are the mechanisms by which climate variability and its influence on ocean state controls the magnitude of eutrophication response to anthropogenic nutrient loads?

To investigate these questions, it is essential to conduct a suite of scenarios to simulate the effects of ocean state, while holding nutrient loading constant. To leverage this, the science team currently has 4 years with the same land-based nitrogen loading (1997-1999, 2016-2017).

Proposed Work. This task would be to run two additional sets of ocean base years: 1) 2004-2005 (low NPP and heat waves) and 2) 2010-2011 (high NPP and cold years) to understand the control of the ocean state on eutrophication response to land-based nutrients. The outputs will be analyzed by biogeochemical mass balance methodologies and interpreted using OA thresholds and oxygen metabolic indices, in order to provide an understanding of mechanisms controlling fate and biological effects.

Product: The product of this effort will be a manuscript, which will answer the management questions and can support improved understanding of the role of ocean state in controlling eutrophication, which can be used to factor into water quality policy decisions.

Figure 2. Twenty-year time series of 1 km carbon biomass (smoothing average with 90 days window) and surface versus subsurface dissolved oxygen in the southern California Bight, showing differential ocean states (top graphic), relative to primary productivity (bottom graphic). EN = El Nino. LN= La Nina, WR= Warming regime. The years 1997-1999 represent ENSO+ and ENSO- with neutral NPGO and PDO (blue shade), which means the ocean was warmer than average and stratified in 1998 and, colder and more productive than average in 1999. The years 2016-2017 represent a period of long-term warming. This period contains some of ENSO+ (blue shade) followed with a NPGO- during which the ocean has been warm and moderately mixed and productive.



Data Visualization

Previous Work. The Uncertainty Workshop highlighted the importance of getting modeling simulations in the hands of end-users, in various forms from raw outputs to maps and graphical outputs (Sutula et al. 2021). The Regional Associations of the Integrated Ocean Observing System (IOOS) have specialized in translation products for diverse end-users, using innovative database management practices linked to high-performance computers.

Proposed Work. SCCOOS will leverage federal investment in its regional database serving southern California and the soon-to-be-released CA IOOS Data Portal to produce a project-specific webpage within the portal that will be designed to facilitate access of ROMS-BEC model outputs and data visualization products by end-users. The structure, look, and feel of the mini portal will be directed by our partners in the management community and scientific end-users, with a focus on CTAG member agencies. We will work with the CTAG on graphics and data visualizations that have the best utility for their needs. SCCOOS partners with a private contractor, Axiom Data Science, to develop innovative tools tailored to specific decision-making requirements. For this project, we will build directly upon the analytical tools created for a joint OPC-funded MPA monitoring project that compiled ocean physics, biogeochemistry, and ecosystem data and model output for managers to assess conditions and easily cross-reference atmospheric and runoff status. These curated data views capture data from numerous sources into a virtual California MPA Dashboard of current and past conditions. Curated elements can be recombined in myriad ways to support condition assessment from regional to statewide scales by mapping and plotting multi-stressor indices with metabolic and habitat indices in a way that easily conveys risk to disturbance. A postdoctoral scholar at SCCOOS, advised by Anderson and SCCWRP, will bring oceanographic domain expertise and knowledge of data science techniques to co-develop useful products that meet user requirements. The postdoc will evaluate methods for translating model and climate change projection outcomes to the management community and further develop methods for accessing model/data layers. Similarly, habitat vulnerability as predicted by our model simulations and climate projections will be made available in a wide array of formats, visualizations, and annotated syntheses, such that technical and non-technical practitioners will have ready access to critical information for research questions and practical decision-making.

Product: The product of this task will be a landing page on the SCCOOS website that provides access to ROMS-BEC model outputs, from raw to various forms visualized through graphics and tables.

Sensitivity Analysis and Model Skill Assessment of Outfall Plume Dispersion

Definitions of Model Sensitivity Analyses and Skill Assessment. *See other linked concept proposals.*

Previous work. The characteristics of river and outfall plumes and the environmental controls on their dispersion in the nearshore represents an important control on magnitude of phytoplankton productivity, oxygen, and pH loss predicted in model simulations. Outfall plume characteristics and dispersion have previously been validated using an idealized nonhydrostatic model (Ho et al. 2021). However, sensitivity analyses have not been conducted that characterizes the change in dispersion relative to changing outfall effluent characteristics, particularly as they would occur with potable water recycling, relative to season and location on the coast.

Proposed Work. The purpose of this task is to conduct sensitivity analyses on the parameterization of the wastewater plume dispersion in ROMS-BEC with increased water recycling and revisit model skill assessment of the dispersion of the wastewater plumes at selected ocean outfall operators (voluntary). Specific tasks include:

1) Revisit model skill assessment of plume dispersion in scales from the nearfield to farfield with recent data collected by POTW monitoring programs.
2) Use non-hydrostatic ROMS simulations of the plume nearfield, conduct multiple model runs to test the sensitivity of dispersion of wastewater plumes with increasing water recycling, under a range of current conditions, seasonal water column attributes, and realistic bathymetry in the near-intermediate field to mechanistically parameterize large POTW outfalls. (e.g., stratification, dilution, rise height, etc.).
3) Analyze effect of range of parameterizations on environmental outcomes of concern in the ROMS-BEC farfield at 300m resolution with a new set of scenarios intended to compare with selected existing wastewater recycling scenarios.

Products include 1) a manuscript to be published in a peer review journal that details how altered parameterization of the effluent plume with increasing water recycling affects the prediction of environmental outcomes and 2) Recommendations for improved monitoring that can help to better validate plume dispersion in the future.

ROMS-BEC Modeling Quality Assurance Project Plan (QAPP)

What is a QAPP? A quality assurance project plan for a modeling project is a document outlining the procedures that will be used use to ensure the outputs that generates meets project requirements for the intended applications. EPA Order 5360.1 A2, applicable to internal EPA agency projects, dictates a QAPP is a necessary step of model development and evaluation, the guidance for which can be found here, with a check of recommended elements found here. For EPA, environmental data includes information collected directly from measurements, produced from models, and compiled from other sources such as data bases or the literature.

Previous Work. ROMS-BEC formulation and skill assessment have been published in peer-reviewed literature, but no QAPP has been established.

Proposed Work. The purpose of this task is to establish a quality assurance manual for ROMS-BEC applications to assessments of the environmental fate and effects of anthropogenic discharges to the southern California Bight.

The product is a written document, available on the SCCWRP website, that establishes QA procedures and has gone through CTAG review.

ROMS-BEC Modeling Independent Review Panel

Why Independent Review Panel of ROMS-BEC? Independent peer review of science is a valuable tool for stakeholders to get advice on the scientific and technical aspects of modeling and their application to environmental problems and solutions. Independent peer review can range from more narrowly focused blind reviews of documents or manuscripts, or a multi-member panel of experts that perform a comprehensive review of the body of work in order to respond to specific charge questions.

Previous Work. ROMS-BEC formulation and skill assessment have been "pper-reviewed" via the publication process in peer-reviewed journal. However, ROMS-BEC in its US West Coast formulation has not undergone extensive review by an independent panel of experts.

Proposed Work. The purpose of this task is to conduct independent peer review of the model and modeling science that is being considered to support coastal water quality management decisions. The panel composition, scope, charge questions etc. would be negotiated during the process of workplan development.

The product is a written document, available on the SCCWRP website, that reports out on the findings and provides specific recommendations to SCCWRP member agencies for science to improve confidence in models/model applications.

References Cited

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