# SCIENCE PLAN TO SUPPORT THE STATE WATER BOARD'S BIOTIMULATORY-BIOINTEGRITY PROJECT FOR CALIFORNIA WADEABLE STREAMS

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## INTRODUCTION AND GOAL OF DOCUMENT

The State Water Resources Control Board staff (hereto referred to "State Water Board") is proposing to adopt a statewide water quality objective[1] for Biostimulatory Substances and a program to implement it as an amendment to the Water Quality Control Plan for Inland Surface Water, Enclosed Bays and Estuaries of California (ISWEBE Plan). "Biostimulatory" refers to substances such as nutrients (i.e. nitrogen and phosphorus) or conditions, such as altered temperature, hydrology, etc. that can result in the accelerated accumulation of organic matter, in a process called eutrophication (Nixon 1995). As a part of this policy, the State Water Board intends to establish a Biointegrity Assessment Implementation Plan. Collectively, these components are hereto referred to as the "Biostimulatory-Biointegrity Project." This initial phase will specifically apply to perennial and non-perennial wadeable streams.

The purpose of this Science Plan is to develop technical information that can be used by the State Water Board in support of its Biostimulatory-Biointegrity Project. This document describes the background and context, the major scientific elements, the conceptual approach, and timeline for deliverables to support policy decisions on numeric guidance in wadeable streams. Implementation Plan technical support is not comprehensively addressed in this version of the science plan, because detailed policy options are still under consideration by State Water Board. However, technical work elements relevant to implementation that are either in the concept phase, funded with existing work plans, or completed with available technical reports have been assembled in a curated list, with hyperlinks to available documents. Though not specifically stated, all elements include outreach to actively engaged regulatory, stakeholder and science panel advisory groups to solicit critical review of technical work plans and products. This will be accomplished through distribution of relevant documents in advance of meetings and oral presentations and discussions at meetings.



[1] Key terms used throughout this document are defined as follows: 1) "objectives" refer to, in this case, regulatory requirements; 2) "assessment endpoints" refer to policy decisions on numeric guidance for bioassessment indices; 3) "targets" refer to policy decisions on numeric guidance for nutrient and eutrophication response indicators (e.g. benthic chl-a, ash-free dry mass) established as statewide or regional "default" values or as targets derived for specific sites based on watershed-specific analysis and management strategies; and 4) "Thresholds" are derived analytically based on available data or from a structured synthesis of expert interpretations, and do not involve value judgments, but they may constitute a line of evidence in the formulation of policy decisions on objectives.

**Comment [MS1]:** I appreciate the definitions in the footnote. Just looking forward, the scope of EPA's review under CWA § 303(c) will be determined by whether the new or revised standards are legally binding, address uses/criteria/antideg, and express/establish desired condition or instream level of protection. See https://www.epa.gov/sites/production/files/2014-11/documents/cwa303faq.pdf. Those considerations could be different than the distinctions being drawn in the footnote b/t objectives, assessment endpoints, targets, etc.

**Comment [MS2]:** Agreed, because Water Board staff has not begun to draft the policy, it was helpful to standardize on language and provide operating definitions during interactions with Water Board staff, advisory groups and science panel. Language can be revised to align with policy requirements.

**Comment [MS3]:** The definition of threshold seems to exclude a BCG-type approach? "Thresholds are derived strictly analytically based on available data, and do not involve interpretation or value judgments, but they may constitute a line of evidence in the formulation of policy decisions on objectives." The BCG, per my understanding, is a structured synthesis of expert interpretations. I suggested edits in the footnote to this effect.

**Comment [MS4]:** Agreed-footnote revised to apply more broadly to analytically or expert-derived thresholds

## REGULATORY CONTEXT FOR PROPOSED SCIENCE

The State Water Board has established five guiding principles which frame the regulatory approach for the Biostimulatory-Biointegrity Project and provide important context for the science required to support policy options under consideration (State Water Board Biointegrity Work Plan 2010; State Water Board Nutrient Control Plan, 2014; State Water Board Focus Group Outreach Document, 2016).

1. The Biostimulatory Substances Amendment could include: a statewide numeric objective or a statewide narrative objective (with or without a numeric translator), and various regulatory control options for point and non-point sources including a watershed management approach. The numeric objective or numeric guidance is hereto referred as numeric guidance for simplicity.
2. Environmental variables such as hydrology, etc. can modify ecosystem response to nutrients. Anthropogenic activities that alter these environmental variables can be biostimulatory, even under low-nutrient conditions. Therefore, the Biostimulatory Substances Amendment should address both nutrient pollution and biostimulatory conditions.
3. The Biostimulatory Substances Amendment should have a strong linkage to beneficial use. Eutrophication results in adverse ecological responses in a water body. These ecological responses are directly linked to beneficial uses. The State is considering the option that the Biostimulatory Substances Amendment may consist of a set of numeric targets for these ecological response indicators and nutrients.
4. The State should have numeric guidance for all water body types, including wadeable perennial and non-perennial streams, non-wadeable rivers, lakes, estuaries, and nearshore waters. The State Water Board intends to develop numeric guidance that translates the narrative nutrient objective for all water body types.
5. There should be statewide consistency with regional flexibility. Statewide consistency is important for equity among stakeholders. However, the State has many different ecosystems, each of which has varying biological characteristics. Therefore, a defensible statewide program must accommodate the unique qualities of each ecoregion. Furthermore, our knowledge of the ecology of our water bodies varies throughout the State so the refinement of numeric guidance will likely proceed at different rates in different regions.

These principles are internally consistent and compatible with that of the 2010 Biointegrity project (www.swrcb.ca.gov/plans_policies/biological_objective.shtml). Additional historical context for each of the biostimulatory and biointegrity projects is detailed below.

**Biostimulatory/Nutrient Amendment.** In 1999, State Water Board began development of biostimulatory/nutrient objectives, focused on streams and lakes. Pilot studies were conducted to analyze existing data and explore alternative approaches. Based on these pilot studies, in 2011 State Water Board proposed two options for Biostimulatory Substances Amendment under consideration for CEQA scoping: 1) nutrient numeric guidance based on EPA ecoregional reference criteria (US EPA 2000a) and 2) the Nutrient Numeric Endpoint (NNE) approach (SWQCB Nutrient Policy CEQA Scoping 2011). The State Water Board designated the NNE as their preferred option, so the technical elements proposed in this plan are focused on supporting the NNE approach.

As originally envisioned, the NNE was comprised of two components (Tetra Tech 2006). First, a suite of ecological response indicators that have numeric assessment endpoints are used to assess beneficial use support (Figure 1). Second, these assessment endpoints serve as goals with which to derive numeric nutrient targets and to evaluate other potential restoration actions or management controls on biostimulatory conditions. The linkage of assessment endpoints to nutrient numeric targets and other management controls can be done using statistical or mechanistic models or other EPA-approved approaches.

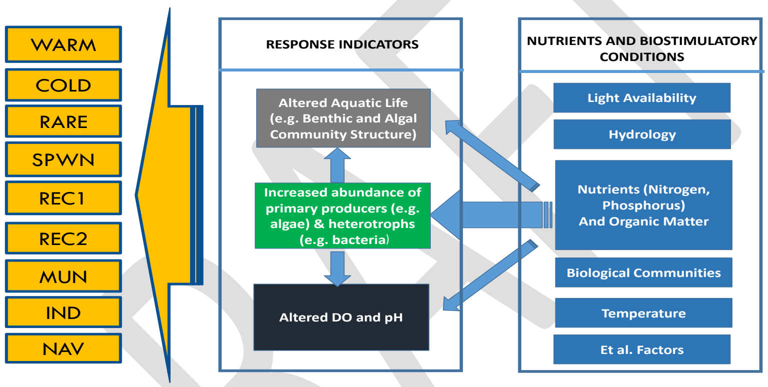



**Figure 1. Conceptual model underlying the Nutrient Numeric Endpoints (NNE) approach. Assessment endpoints are linked to ecosystem services and beneficial uses. Statistical or process models could be developed to link those assessment endpoints back to management of nutrient and stream co-factors (which include biostimulatory conditions).**

Statewide wadeable stream bioassessment data can be used to establish statistical models of the empirical relationship between ecological responses (statewide bioassessment indices), eutrophication response indicators (e.g. benthic chlorophyll-a, ash free dry mass), and nutrient concentrations. However, mechanistic, process-based models may provide greater flexibility in devising nutrient restoration strategies at the watershed scale. While intending to establish nutrient and eutrophication targets derived from statewide statewide models can be used as "default" values, State Water Board staff is exploring options for stakeholders to work with their respective Regional Boards to develop watershed-based approach supported by adequate data and EPA-approved modeling approaches. Under such a watershed approach, the stakeholders and scientists could conduct additional monitoring, modeling and other science in determining

**Comment [MS5]:** I think I understand the gist of the sentence, but I'd suggest clarifying a bit. I'm not aware of reasons that canopy cover, shading & substrate, couldn't be included in a statistical model as predictors of chl-a & AFDM. Perhaps this could say that these data aren't always readily available or of adequate resolution (i.e. in national/state GIS coverages). Likewise, mechanistic, process-based models may be better suited for testing nutrient restoration strategies at the watershed scale b/c they're spatially-distributed/explicit, but I'd hesitate to say that statistical frameworks cannot be used to evaluate management scenarios. e.g. Borsuk, M. E., Stow, C. A., & Reckhow, K. H. (2004). A Bayesian network of eutrophication models for synthesis, prediction, and uncertainty analysis. *Ecological Modelling*, 173(2), 219-239.

**Comment [MS6]:** Text has been clarified to point out that mechanistic models can provide a more flexible approach to watershed-based management of nutrients the site- or watershed-specific nutrient numeric targets that can meet the established assessment endpoints.

**Biointegrity Implementation Plan**. In 2010, State Water Board began a project to develop a Biointegrity policy, leveraging significant state, federal and regional investments in bioassessment methods development, training and quality assurance, data acquisition and management. The Biointegrity Project funded scientists at the California Department of Fish and Wildlife and SCCWRP to develop: 1) a definition for wadeable stream reference condition, 2) a statewide bioassessment index to interpret benthic macroinvertebrate (BMI) taxonomic data in a standardized measure of stream biological condition (hereto referred to as the California Stream Condition Index [CSCI]), and 3) technical tools for assessing the cause of degraded biological integrity (hereto referred to as causal assessment). Recently, the State Water Board has focused on three goals (Maxfield, 2015):

1) Establish consistent statewide methods for conducting biological assessments and interpreting biological data as bioassessment indices in California's surface water,
2) Identify streams or stream reaches in which biological condition is healthy and prevent degradation inasmuch as it is within the State's authority to do so, and
3) Identify streams or stream reaches in which biological condition is different from healthy conditions and use this information to determine whether additional information is needed and to prioritize actions necessary to improve biological condition as appropriate.

## WADEABLE STREAM SCIENCE PLAN ELEMENTS AND APPROACH

The Science Plan to support the Biostimulatory – Biointegrity Project in California perennial and non-perennial wadeable streams consists of two major elements, which are explained in detail below:

Element 1: Conduct and Synthesize Science Supporting Development of Numeric Guidance for Wadeable Streams

Element 2: Provide Technical Support for Implementation Plan Development

### ELEMENT 1. CONDUCT AND SYNTHESIZE SCIENCE SUPPORTING DEVELOPMENT OF NUMERIC GUIDANCE FOR WADEABLE STREAMS

Technical work to support the development of numeric guidance for wadeable stream has three major elements, all of which can be used for formulate numeric guidance for the Biostimulatory-Biointegrity Project (Figure 2).

1.1. Develop bioassessment indices as measures of aquatic life use support;

1.2. Determine the numeric range of bioassessment indices that correspond to the support of aquatic life use and related beneficial uses; and

1.3. Determine the numeric range of stream nutrients and eutrophication response indicators that correspond to the numeric ranges of bioassessment indices.

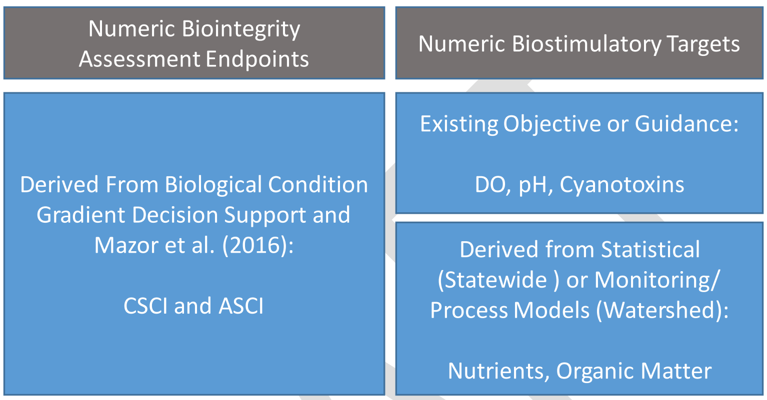



**Figure 2. A conceptual view of numeric biointegrity assessment endpoints and biostimulatory targets. The biointegrity assessment endpoints would be based on bioassessment indices. Statewide, the biostimulatory numeric targets could be based on existing objectives or guidance (for DO, pH, cyanotoxins) or derived from statistical relationships between biointegrity assessment endpoints and nutrients and organic matter. At a watershed scale, the relationship between in-stream nutrient concentration, organic matter accumulation, DO, pH and biointegrity can be assessed with a combination of mechanistic, process-based models.**

The progress that has been made towards these goals and proposed work moving forward, is detailed below.



### ELEMENT 1.1 DEVELOP BIOASSESSMENT INDICES AS MEASURES OF AQUATIC LIFE SUPPORT

The State Water Board is supporting the use of standardized bioassessment indices to quantify the ecological condition and aquatic life use support of perennial and non-perennial wadeable streams in response to gradients of increasing stress. Beneficial uses associated with aquatic life use include WARM, COLD, WILD, but also include protection of threatened and endangered as well as migratory species (RARE, SPAWN, MIGR). These indices become the technical foundation for the Biointegrity Amendment. As part of this endeavor, the State has developed a California Stream Condition Index (CSCI; Mazor et al., 2016) that uses BMI communities to measure the impact of human disturbance on biological communities. The purpose of this work element is to develop a second stream condition index based on assessments of algal assemblages. For the purposes of this science plan, perennial and non-perennial streams are defined by those reaches where application of bioassessment indices is considered to be valid.

**Background and Previous Work.** BMI and algae are often chosen as bioassessment indicators because of their high numbers, known pollution tolerances, limited mobility, wide range of feeding habits, varied life spans, and dependence on physical and chemical influences of the land environment around the stream. When chemical grab samples are taken, they are really a snapshot of the water at that moment, that can change rapidly, but the algae and BMI live there all the time and provide an integrated snapshot of environmental quality of their habitat. Decades of investments in bioassessment sampling, research, quality assurance, and protocol developments have yielded a robust statewide data set of BMI, diatom, and soft-bodied algae from wadeable streams (Ode et al. 2016a). Much of this work has focused on defining and characterizing ambient and reference conditions (Ode et al. 2016b), the development of CSCI (Mazor et al., 2016), as well as regional algal indices of biotic integrity (Fetscher et al. 2014a). These indices are now widely used to assess bio-integrity in numerous monitoring applications, such as ambient surveys, permits, and compliance assessment.

**Proposed Work.** Although no statewide algal index is yet available, the Water Board's SWAMP Bioassessment Program is now developing a statewide Algal Stream Condition Index (ASCI) to infer biologic condition and give partners an additional tool for determining impacts of human development, specifically those related to nutrient over-enrichment, eutrophication, and water chemistry. The purpose of this element is to develop the ASCI as new algal bioassessment index. This index is intended to have statewide applicability and site specificity, comparable to the CSCI. That is, scores from the ASCI will have the same interpretation in the different stream-types found in California, and natural factors will have minimal influence on index scores. Following the design of the CSCI, the ASCI will be designed to measure stream health by comparing observed algae taxonomy data (e.g., species occurrence or metric values) with expectations predicted from environmental factors that are minimally altered by watershed disturbance (e.g., climate, latitude, elevation). Following Fetscher et al. (2014a), we will explore developing separate indices for three types of assemblages: diatom data, soft-bodied algae data, and for both assemblages combined in a "hybrid" index. Thus we are developing multiple indices, but refer to only one index, the ASCI, throughout.

The objectives of Element 1.1 are to: 1) develop a predictive index of biologic integrity based on algal species composition and ecological traits in California streams; 2) evaluate the performance of the algal index in California streams across diverse geochemical and geographic landscapes and under the influence of various stressors; and 3) provide guidance on the implementation of ASCI scores in conjunction with other bioassessment indices for the assessment of California streams. These objectives entail several tasks:

1. Assembling the ASCI development data set (i.e., algae taxonomy data and associated environmental data from a statewide data set);

2. Evaluating levels of anthropogenic stress and identifying reference sites from the development data set;
3. Developing a predictive index of taxonomic completeness and ecological structure;
4. Evaluating ASCI performance; and
5. Communicating findings via oral presentations and a technical report.

A generic description of the dataset is provided in Appendix 1. Detailed background, approach and method are provided in the ASCI work plan (Theroux et al, 2016, Appendix 2).

Deliverables for this element include: 1.1.1) Oral presentation on reference site characterization, preliminary results of index construction and performance (i.e. comparison of ASCI performance to other indices) and 1.1.2) draft and final report.

#### ELEMENT 1.2. DETERMINE THE NUMERIC RANGE OF BIOASSESSMENT INDICES THAT CORRESPOND TO ATTAINMENT OF BENEFICIAL USES.

The State Water Board requests information about the numeric ranges of the CSCI and ASCI (Element 1.1) that correspond to varying levels of beneficial use support, in order to establish assessment endpoints that: 1) Identify and protect high-quality streams, 2) Identify streams or stream reaches in which biological condition is significantly different from reference condition and use this information to prioritize actions necessary to improve biological condition as appropriate, and 3) can be used to establish numeric targets for nutrients and other intermediate eutrophication response indicators that have a prescribed probability of meeting CSCI and ASCI assessment endpoints.

**Background and Previous Work.** Mazor et al. (2016) provided a set of CSCI benchmarks that are based on a comparison of the organisms found at a site and those expected to be there if the stream was healthy, as a percentile of the distribution of scores from reference sites. While this approach is particularly useful to identify and protect high quality streams, the deviation from reference does not easily communicate to policy makers and the public the impacts to beneficial uses associated with the decline in the index. That is, when an index score decreases, what aspects of ecosystem condition and related beneficial uses have been lost?

The "biological condition gradient" (BCG) is a conceptual model that describes changes in aquatic communities, measured by aquatic life indicators (e.g., fish, BMI or algal assemblages), as a function of stress (e.g. nutrients; Davies and Jackson 2006; Figure 3). This conceptual model describes the characteristic transition of biotic communities as a function of increasing stress, from pristine and intact assemblages, to slightly altered ecological condition, then moderate, and finally, very altered ecological condition and assemblages. Even in different geographic and climatological areas, a similar sequence of biological alterations typically occurs in aquatic ecosystems in response to increasing stress.

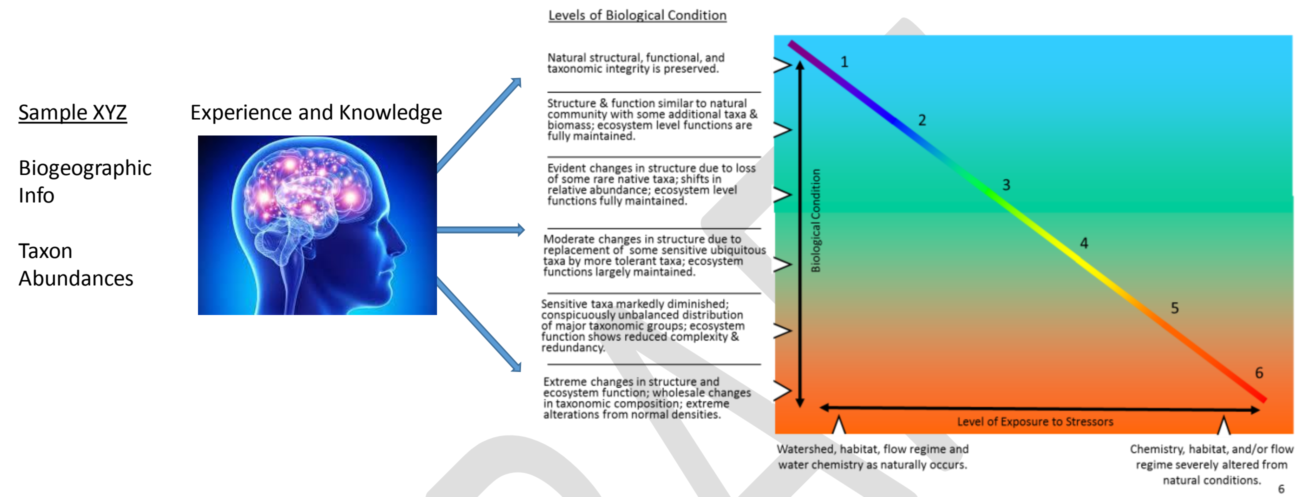
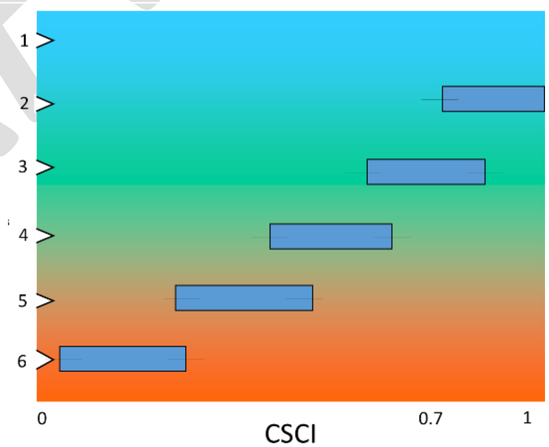



**Figure 2. Schematic of how BCG model is developed (top panel), then used to generate ranges of bioassessment indices that corresponding to levels of BCG bins representing gradient in condition (bottom panel).**



Over the past decade, scientists have developed an approach to develop BCG models as decision support tools for a variety of different water body types. This process relies on expert evaluations of taxonomic data for BMIs, algae, or, fish assemblages to rank sites within six bins along a conceptual gradient of biological condition. These bins can be mapped back to specific stressor gradients. As envisioned here, a BCG model for California wadeable streams is not intended to serve as an additional bioassessment index, but rather as a decision support framework for policy decisions on assessment endpoints that can inform water quality management and stream restoration.

**Proposed Work**. The goal of this element is to use ecologists with expertise in California wadeable streams to interpret the taxonomic data onto classify stream algae and BMI assemblages into bins that represent categories of biological condition (Figure 2, top panel). This exercise will be used to categorize or benchmark CSCI and ASCI scores into bins of ecological condition and, implicitly, beneficial use support. These numeric bioassessment index ranges associated with BCG bins can be used to made decisions on assessment endpoints. These CSCI and ASCI assessment endpoints can be translated via statistical models to numeric targets for eutrophication response indicators (benthic chlorophyll-a, ash-free dry mass; see Element 1.3 below). The approach for this element is described in a separate work plan (Sutula et al. 2016), but is summarized briefly here.

The work will be accomplished through a series of webinars and workshops. Approximately 16 experts in stream algal and BMI ecology will be identified. During preliminary webinars and the first workshop, these experts will identify the methodology they will use and the site data necessary to independently categorize data from selected sites into bins of BCG condition (e.g., 1-6, Figure 3, top panel). Following the first workshop, the experts will independently score ~ 250 sites into BCG categories. At subsequent workshops and webinars, differences will be reconciled within assemblages and consensus achieved on classification of sites and the ecological rationale used for this classification, to the extent possible. These expert-calibrated ranges of CSCI and ASCI scores can then be used by the Water Board and its advisory groups to discuss the tradeoffs for choosing assessment endpoints at different BCG levels (Figure 3, bottom panel).

Deliverables for this subtask include: 1.2.1) oral presentations, 1.2.2) draft and final report chapter(s) summarizing findings of BCG expert synthesis, mapped to CSCI and ASCI binned ranges, and 1.2.3). compendium of scored sites with BCG expert ratings and supporting data.

### Element 1.3. Determine the numeric range of stream nutrient Concentrations and eutrophication response indicators that correspond to CSCI and ASCI Assessment Endpoints

The State Water Board has expressed its interest in identifying the range of numeric targets for nutrients and eutrophication responses that can constitute Biostimulatory objectives for wadeable streams. The purpose of this element is to conduct analyses and synthesize available information to quantify the numeric range of stream nutrient concentrations and intermediate responses (e.g. organic matter accumulation indicators, DO, pH, algal or BMI metrics) that are indicative of eutrophication and that correspond to BCG-binned ranges of CSCI and ASCI. Three components are key to this synthesis:

1) Describe a eutrophication conceptual model identifying key pathways of impairment and linkage to beneficial use support;
2) Review of the ability of candidate response indicator and selected bioassessment index component metrics to diagnose eutrophication and synthesize science supporting decisions on endpoints; and
3) Develop statistical models that can be used to relate CSCI and ASCI assessment endpoints to numeric targets for nutrients and eutrophication response indicators.

***1.3.1 Conceptual Model, Response Indicators and Metrics*** **--Background and Previous Work**. The pathways by which eutrophication leads to aquatic life impairment are well documented (EPA 2013), providing a clear conceptual model and a suite of candidate ecological response indicators that are diagnostic for eutrophication. Adverse effects of eutrophication in streams generally fall into one of three types: 1) increases in the amount of algae and macrophytes as well as live and dead organic matter, 2) changes in the community structure of prokaryotes, stream algae, and fauna (e.g. BMIs, fish, etc.) and 3) alterations in water chemistry, including increased diel fluctuations in water column dissolved oxygen and pH as well as increases in harmful algal bloom toxins (Figure 1; EPA 2013). Tetra Tech (2006) reviewed eutrophication response indicators relevant for assessment of eutrophication in streams and rivers. Since then, additional science related to this topic has been published. In 2013, EPA sponsored a workshop to achieve consensus among experts on appropriate indicators for assessment of eutrophication in wadeable streams. In California, Fetscher et al. (2014a) screened algal abundance indicators currently included in the California wadeable stream algal bioassessment protocol (Ode et al. 2016a) for the nature and strength of relationships with benthic macroinvertebrate and algal community structure metrics (representative of aquatic life). Finally, selected component metrics of the CSCI and ASCI can be used for rapid causal assessment of eutrophication, as a foundation for more detailed causal assessment. If used as multiple lines of evidence, these metrics can be part of a dashboard of information that provides early clues on drivers for eutrophication and relevant management options to consider to improve bioassessment scores.

***Conceptual Model, Indicators and Metrics--*** **Proposed Work.** The purpose for this review is to support State Water Board decisions on the indices and indicators that constitute primary and supporting lines of evidence to assess eutrophication in wadeable streams. This element will: 1) provide a conceptual model to communicate pathways of impairment related to nutrient pollution and biostimulatory conditions in wadeable streams and how they link to beneficial uses and 2) summarize available literature on wadeable stream eutrophication response indicators and eutrophication causal assessment metrics. Indicators will be evaluated based on five suitability criteria:

- The indicator has a clear link to conditions influencing one or more beneficial uses (WARM, COLD, etc);
- Has a predictive relationship with causal factors such as nutrient concentrations/loads and other factors known to regulate response to eutrophication (hydrology, etc.). This relationship could be empirical (modeled as a statistical relationship between load/concentration and response, or modeled mechanistically through process models;
- Has a scientifically sound and practical measurement process;
- Shows a consistent trend of eutrophication with an acceptable signal-to-noise ratio; and
- Entails data types that are either already routinely collected by State programs, or can be added relatively easily.

Deliverables for this element include: 1.3.1) a draft chapter in Wadeable Streams Nutrient Objective Scientific Synthesis Report on recommended eutrophication response indicators/metrics.

**1.3.2.** ***Modeling to Support Decisions on Numeric Targets for Nutrients and Eutrophication Response Indicators*****--Background and Previous Work.** Conceptually, the State is supporting the use of standardized bioassessment indices to quantify the ecological condition and aquatic life use support of wadeable streams in response to gradients of increasing stress. The eutrophication stressor gradients, in the context used here, can be represented by nutrient concentrations or by eutrophication responses such as organic matter accumulation, or levels of DO and pH. Element 1.3.1 provides conceptual framework and rationale for selection of indicators that can be used to assess eutrophication as primary and supporting lines of evidence. Numeric targets are needed for ambient assessment, 303(d) listing, and permitting. Basin Plan objectives exist for some of these indicators (DO, pH). For other indicators, such as organic matter accumulation and nutrients, the State Water Board is requesting science that can support decisions on numeric targets. This combination of existing DO and pH basin plan objectives and numeric targets for nutrients and eutrophication response indicators can constitute the basis for decisions on numeric guidance for biostimulatory objectives.

**Comment [MS7]:** Not clear if they're being used as targets or objectives? If they're used for CWA § 303(d) assessment and deriving NPDES WQBELs under § 402, then they seem to be water quality criteria/objectives.

**Comment [MS8]:** I am using the language that we defined on the front page; targets= numeric translator for narrative objective, which the Water Board staff has said that they prefer over numeric objectives

Two types of models could be used to estimate the range of numeric targets that meet specific biointegrity assessment endpoints and DO/pH objectives, encompassing a range of possible models: 1) regional or statewide statistical models, useful to establish "default" expectations at regional/statewide scale, but which have less flexibility for evaluation of site-specific management scenarios and 2) reach- or watershed- specific mechanistic, process-based models, which require extensive data to develop, but are more temporally and spatially explicit, can better simulate the effect of a combination of nutrient loading and other management actions (e.g. restoration) to mitigate or prevent eutrophication.

Statewide, it is impractical to develop site-specific process models for all water bodies. However, statistical models have great utility in quantifying the concentrations of stressors that have a prescribed probability of meeting assessment endpoints representative of beneficial use goals (Yuan et al. 2014, Yuan and Pollard 2015). The output of statistical models of the relationship between bioassessment indices and eutrophication stressors gradients can provide the basis decisions on "default" numeric targets for nutrients and eutrophication response indicators. As mentioned previously, the State Water Board has expressed an interest in allowing stakeholders to working with their respective Regional Boards to develop watershed or site-specific water body numeric targets for nutrients and eutrophication response indicators, supported by adequate data and EPA-approved modeling approaches.

Statistical modeling will be conducted to support decisions on statewide default numeric targets. Existing field data that capture these gradients can be used to explore the quantitative relationships between stress, response and desired levels of narrative beneficial use support.

Analytical approaches for determining the ranges at which a stream ecosystem transitions from no apparent effects to detrimental effects in response to increasing stress (*e.g.*, from low to high nutrient levels) have typically involved one or more of the following (US EPA 2010, Figure 4), depending on the response model suggested by exploratory analyses.

1. Use of statistical methods to determine breakpoints or abrupt changes (a.k.a. "thresholds") in an aquatic life indicator measures (e.g. bioassessment index) as a function of increasing stressor levels and relating such changes to desired beneficial use goals;
2. Use of conditional probability or predictive regression models to estimate stressor "levels" that are linked to a quantitative target for an indicator representative of beneficial use support (*e.g.*, CSCI or ASCI assessment endpoints, based on thresholds derived from BCG tiers or the distribution of scores at reference sites).

Fetscher et al. (2014b) explored relationships and identified statistical thresholds of adverse effects of nutrient concentrations and organic matter accumulation on CSCI and Southern California Algal IBI scores in California wadeable streams. They then investigated thresholds in ecological responses to nutrient and algal abundance gradients in California wadeable streams using a variety of statistical methods (Approach 1; Figure 4, right panel). They found a narrow range of thresholds of along water-column nutrient and benthic algal concentration gradients that significantly degraded CSCI and algal IBI scores (Fetscher et al. 2014a); they also demonstrated relationship between algal community metrics and nutrients. They interpreted these results within the context of statewide and regional reference and ambient distributions of biomass and nutrient concentrations.

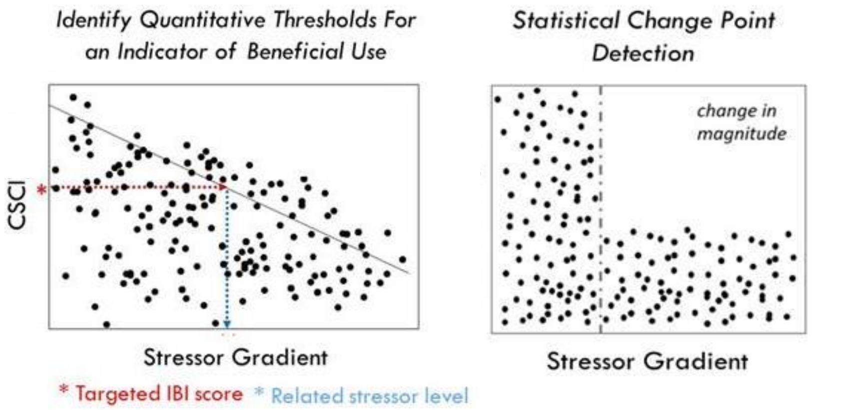



**Figure 4. Examples of statistical approaches to determining numeric targets. The right panel illustrates a "step function" in the relationship between stressor and ecological response; here statistical methods can be used to identify the threshold, as indicated by the dashed line at which bioassessment index score or component metric changes abruptly. The left panel illustrates stressor-response statistical modeling, illustrating a quantile regression in which a target value for CSCI or ASCI is used to interpolate the level of stressor (e.g., in terms of nutrient concentrations or algal biomass) that should not be exceeded in order to protect biotic integrity.**

**Proposed Work.** Elements 1.1 and 1.2 will produce binned ranges of CSCI and ASCI scores that correspond to ecological condition categories and levels of beneficial use support (Element 1.2). This element will map these binned ranges back to quantitative targets for nutrients and intermediate response indicators that are diagnostic of eutrophication.

The purpose of this work element is to: 1) develop and describe the performance of statistical models of the relationship between bioassessment indices and diagnostic indicators of eutrophication (e.g. nutrients, organic matter) and 2) use the best performing models to quantify the ranges of nutrients and intermediate response indicators that have a prescribed probability of achieving BCG-binned ranges of CSCI and ASCI scores. Analyses will reply on a statewide ambient and reference bioassessment database that has been recently updated for ASCI development (see ASCI work plan, Theroux et al. 2016 Appendix 2). Statistical modeling approach and final model selection will be informed by exploratory analyses and preliminary model selection, in combination with feedback and guidance from the Independent Science Panel. The output of the final statistical models, BCG-referenced ranges of nutrients and intermediate response indicators and associated uncertainty, will be compared to statistically derived thresholds (Fetscher et al. 2014b). The synthesis of this information should be placed within the context of the distribution of concentrations at minimally disturbed reference and ambient monitoring sites across the state.

Deliverables for this subtask include: 1.3.2) interim oral presentations on results of exploratory analyses, preliminary modeling results and oral presentation on final modeling selection, and a 1.3.3) draft chapter on selected models, regression equations, and the range of nutrient and intermediate response indicator targets corresponding to BCG binned ranges of CSCI and ASCI; 1.3.4) final report including, executive summary, technical chapters summarizing 1.3.1- 1.3.3 and recommendations.

## ELEMENT 2 IMPLEMENTATION PLAN TECHNICAL SUPPORT

The purpose of this task is to identify technical elements needed to support the implementation of the combined Biostimulatory-Biointegrity amendments. As noted previously, Implementation Plan technical support is not comprehensively addressed in this version of the science plan because, at the time of its drafting, detailed policy options are under consideration have not been detailed by the State Water Board. However, the Technical Teams supporting Biointegrity and Biostimulatory projects have been have made significant progress on some technical work elements relevant to implementation. The section below provides the major work elements with brief descriptions of the projects, principal questions and approaches. Concept proposals, work plans and completed projects are available upon request. Implementation technical work elements can be updated on an ongoing basis as policy options under consideration are clarified. They can also be updated with specific suggestions from the advisory groups.

Four major topical areas currently addressed by completed, ongoing, or near-term prospective work include: 1) assessment framework, 2) automated assessment tools, 3) biointegrity causal assessment and 4) case studies.

### ASSESSMENT FRAMEWORK

**Spatial and temporal representativeness of bioassessment samples**. The Technical Team has conducted a number of studies to evaluate the role of spatial and temporal variability of bioassessment data. These analyses are designed to answer questions, such as: What portions of a reach or watershed are adequately represented by available data to support management decisions (Mazor et al. in review)? Does sampling season influence the interpretation of index scores (Mazor et al. 2016)? What is the long-term variability of index scores? Does sample collection method affect interpretation of indices (Rehn et al. 2007, Fetscher et al. 2014a)? Many of these questions have already been addressed for the CSCI, with planned work to extend the analyses to algal indices.

**Interpretation of indices in streams where biological integrity is constrained by landscape development**. Developed landscapes are associated with an increase of many stressors in streams, such as elevated contaminant and nutrient concentrations, altered flow regimes, sedimentation, and habitat degradation. Often, these stressors are difficult to mitigate or remove under the traditional mechanisms available to the Water Boards. In these circumstances, the range of CSCI or ASCI scores may be constrained in channels in developed landscapes. With an understanding of these constraints, the Water Boards can prioritize appropriate actions for different streams. Key technical questions underpinning this research are: Where is biological integrity constrained by development in the catchment? How can they be identified and mapped? What are the ranges of conditions they can support? This project will develop models and create maps to help understand how landscape development constrains the range of expected CSCI and ASCI scores (**Work plan available, Appendix 2**).

**Comment [MS9]:** It's not clear to me if/how "Predicting Biological Integrity of Streams Across a Gradient of Development in California Landscapes" relates to biostimulatory substances objectives? I read the relevant workplan, and seems like a very interesting and worthwhile analysis, but, I'm unclear on the likely/anticipated application. i.e. will the information be used to delineate areas for UAA's, variances, site specific objectives? Will the targets or objectives be different in those locations? Is the problem of constrained channels in developed landscape more related to ag or urban landscapes (or the entire spectrum of landuses)? Those might be difficult questions still under consideration, but having even a tentative answer of the likely application could inform how SCCWRP develops the tool.

**Comment [MS10]:** This work could inform biointegrity assessment endpoints, which could then link to biostimulatory substances targets.

We agree that the policy context for this approach is not well established. The workplan sequence is intended to generate discussion among the Water Board and its advisory groups on its intended applications.

**Assessing the biological integrity of nonperennial streams.** The Technical Team, in partnership with the Water Boards and stormwater agencies, have undertaken a number of projects to assess the biological integrity of nonperennial streams (including intermittent streams that flow more than a month in typical years, and ephemeral streams with shorter-lasting flows). This work includes validating and/or refining assessment indices in nonperennial streams (e.g., Mazor et al. 2014), developing new indicators to assess dry streams (e.g., Stein et al. 2011), calibrating hydrologic models to characterize flow regimes, and evaluating the relationships between flows and biological conditions (e.g., Stein et al. 2016).

### FACILITATING CALCULATION OF ASSESSMENT INDICES

**CSCI and ASCI calculators**. The Technical Team in partnership with CSU Chico, and the Water Boards has developed a protocol to streamline and standardize calculation of the CSCI (Mazor et al., 2015). In addition, automated online tools are in development, to broaden access to practitioners that lack proficiency in GIS or R. When the ASCI is complete, it is expected that similar tools will be developed.

**Physical habitat assessment**. The Technical Team in partnership with Moss Landing Marine Labs has developed tools to automate the calculation of metrics that characterize stream physical habitat. An assessment framework for physical habitat data (potentially including an index of habitat quality) is currently in development.

### BIOINTEGRITY CAUSAL ASSESSMENT

**Evaluation of causal assessment methods.** For streams that have poor biointegrity, causal assessment can determine the likely causes and allow managers to take appropriate actions to restore health. The Technical Team has explored the EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS) to evaluate identify stressors responsible for degraded bioassessment scores in a number of case studies, resulting in guidance for adapting CADDIS to California (Schiff et al. 2015). Currently, The Technical Team is exploring ways to extend CADDIS to inform management actions, such as the selection and placements of stormwater control measures, which could support compliance efforts associated with TMDLs or stormwater permits.

**Rapid screening of candidate causes.** A major outcome of the evaluations of CADDIS was the recognition of a need to conduct simple, coarse-scale causal assessments on a routine basis (e.g., in association with every bioassessment where scores fail to meet desired endpoints). SCCWRP and the EPA are developing tools to automate the selection of appropriate comparator sites from large regional databases, and to evaluate several lines of evidence to support or weaken candidate causes (Gillett et al. in review). In addition, CADFW and SCCWRP are exploring the development of biological metrics that support the diagnosis of stressors responsible for poor biological condition (e.g., algal metrics tuned to detect eutrophication, or macroinvertebrate metrics tuned to detect pesticide impacts) (Rehn 2007). It is expected that these tools will enable causal assessment to become a low-cost part of routine reporting of bioassessment data, supporting more intensive investigations using CADDIS or other stakeholder-driven approaches where needed.

## CASE STUDIES

**Watershed approaches to managing nutrients.** During 2007, U.S. EPA Region IX sponsored a series of four case studies designed to explore the use of the NNE tools (Tetra Tech 2006) in developing TMDL targets in four nutrient-listed waters: Chorro Creek, Santa Margarita River, Malibu watershed (both lakes and streams), and Klamath River (including mainstem impoundments). The Klamath River case study was further refined as part of the TMDL development process in 2008. A document presents a summary of those case studies (Tetra Tech 2012).

**Pilot Projects Demonstrating a 'Watershed Approach' to Deriving Site-Specific Numeric Targets for Biostimulatory Substances:** The Santa Margarita River Nutrient Management Initiative (SMR NMI) is a case study for a combined biostimulatory-biointegrity approach, applied to a 303(d) listing for nutrients. Several stream reaches and the estuary in the SMR watershed are on the 2010 Clean Water Act section 303(d) list of water quality limited segments (303(d) list) for eutrophication, based on the biostimulatory narrative objective in the San Diego Water Board Basin Plan. In light of the recent science, stakeholders in the SMR, in cooperation with the San Diego Water Board, have identified the need to develop a watershed process for evaluating and addressing the 303(d) listings utilizing the best available science and information. In Phase I of the project, numeric targets for macroalgal biomass, TN and TP have been derived for SMR Estuary using a combination of watershed and groundwater loading and estuary receiving water process models (Sutula et al., 2016). In Phase II, nutrient loading and bioassessment monitoring is ongoing in the SMR main stem; watershed and groundwater loading models and river receiving water process models are under development to support discussions of biostimulatory targets.

**Schedule of Deliverables**

| Task No. | Description of Deliverable | Estimated Completion Date |
|---|---|---|
| **Element 1. Conduct and Synthesize Science Supporting Numeric Guidance for Wadeable Streams** | | |
| **TASK 1.1** | **ASCI DEVELOPMENT AND EVALUATION** | |
| 1.1.1 | Oral presentation on preliminary results of index construction and comparison of ASCI performance to other indices | July 2017 |
| 1.1.2 | ASCI draft report | September 2017 |
| 1.1.2 | ASCI final report | January 2018 |
| **1.2** | **RANGE OF CSCI AND ASCI CORRESPONDING TO VARYING LEVELS OF BENEFICIAL USE SUPPORT** | |
| 1.2.1 | BCG oral findings for CSCI and ASCI | July 2017 |
| 1.2.2 | BCG draft report, CSCI only | July 2017 |
| 1.2.2 | BCG updated report, with ASCI | September 2017 |
| 1.2.2 | BCG final report | January 2018 |
| 1.2.3 | Compendium of score sites with BCG expert ratings and supporting data | July 2017 |
| **1.3** | **EUTROPHICATION SYNTHESIS** | |
| 1.3.1 | Draft chapter on eutrophication conceptual models, reviewed indicators and causal assessment metrics | July 2017 |
| 1.3.2 | Interim oral presentations on results of exploratory analyses, preliminary modeling results and oral presentation on final modeling selection | May 2017 |
| 1.3.3 | Draft chapter on selected models, and the range of nutrient and intermediate response indicator targets corresponding to BCG binned ranges of CSCI and ASCI | September 2017 |
| 1.3.4 | Final report including, executive summary, technical chapters summarizing 1.3.1- 1.3.3 and recommendations | January 2018 |

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**APPENDIX 1. DESCRIPTION OF WADEABLE STREAM BIOASSESSMENT DATA TO BE USED IN SUPPORT OF ASCI DEVELOPMENT, BCG DEVELOPMENT AND STATISTICAL STRESS-RESPONSE MODELING**

Wadeable stream bioassessment data that will support proposed analyses were compiled from several California wadeable stream monitoring programs:

- Statewide Perennial Stream Assessment (PSA),
- Statewide Reference Condition Management Program (RCMP), and
- Southern California Stormwater Monitoring Coalition (SMC)

Taken together, the available data represent the majority of wadeable stream-reaches throughout the State (Figure A1), which were sampled from 2000 through 2015 (algae taxonomy samples date back to 2007). Sampling is largely conducted as one-time site visits within the time frame spanning late spring to early fall, with the majority occurring in May through August, although a subset of These data will be used for creating the ASCI, modeling biointegrity responses to biostimulatory substances, and estimating constraints on biointegrity in developed landscapes.

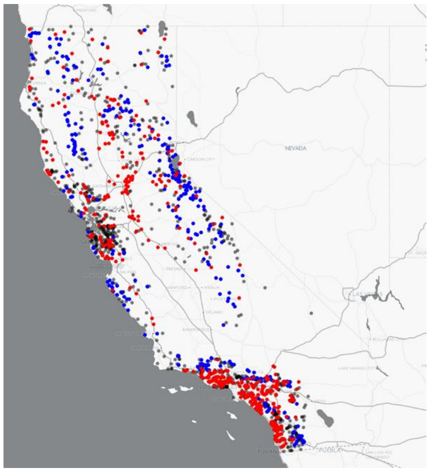

**Figure A1. Sampling sites for which data are available. Grey circles are all sampling sites, reference sites in blue and stressed sites in red.**

The types and distribution of algal biomass indicators across channel habitats can widely vary among stream types. For this reason, it is important to assess biomass within a stream in a number of different ways, because each individual indicator captures this distribution differently. For example, both benthic chlorophyll *a* and ash-free dry mass (AFDM) measure algal biomass, but chlorophyll *a* is a proxy for the measurement of live algal biomass, while AFDM measures both live and dead biomass, as well as organic matter imported into the survey site.

**Table A1. Examples of variables available to support the Science Plan work elements (see Appendix 2).**

- **BENTHIC INVERTEBRATE TAXONOMY**
    - CSCI and component metrics
- **DIATOM AND SOFT-BODIED ALGAL TAXONOMY**
    - ASCI and component metrics
- **ALGAL ABUNDANCE AND ORGANIC MATTER ACCUMULATION VARIABLES**[2]
    - benthic chlorophyll *a*
    - benthic ash-free dry mass (AFDM)
    - macroalgal percent cover (PCT_MAP)
- **EXPLANATORY VARIABLES**
    - **Nutrients**
        - total nitrogen (TN)
        - total phosphorus (TP)
        - nitrate + nitrite ($NO_x$)
        - orthophosphate ($PO_4$)
        - ammonium ($NH_4$)
    - **Landscape - geographic**
        - site elevation
        - watershed area
        - geology (e.g., percent nitrogenous geology in the catchment)
        - climate (e.g., long-term mean annual rainfall)
        - land cover, road density, and impervious surfaces
    - **Local physical habitat ("PHab")**
        - streambed substrate composition
        - slope and channel morphology
        - flow-habitat diversity
        - instream habitat complexity
        - riparian conditions
    - **Water quality (general)**
        - alkalinity
        - conductivity
        - turbidity
        - temperature

All data are collected by SWAMP's Standard Operating Procedures (Odel et al. 2016a) and related methods. The SWAMP protocol is based largely on the procedures of EPA's

[2] Note that while dissolved oxygen and pH are recognized to be important factors influenced by stream nutrients, and they have great potential to affect beneficial uses relating to aquatic life, they are no included here due to lack of appropriate data on these parameters for use in the modeling exercise.

Environmental Monitoring and Assessment Program (EMAP; Peck et al. 2006). For benthic macroinvertebrates, most data were collected with the "reach-wide benthos" method, where collections are made at 11 equidistant transects across a 150-m sampling reach, at positions 25%, 50%, and 75% of the stream width; in this method, all microhabitats are represented in the composite sample in proportion to their availability in the sampling reach. Some older data were collected with the "targeted riffle" method, where 9 locations are sampled from three riffles within a 150-m sampling reach; with this method, only riffles are represented in the composite sample, and pool habitats are excluded. All algae samples are collected were collected with the reach-wide method. Algae samples are split into four subsamples: two for taxonomic analysis (one each for diatom and soft-bodied algae taxonomy), and two for biomass (one each for benthic chlorophyll-a [using EPA445.0] and ash-free dry mass [WRS 73A.3]).

Sites may be grouped into classes based on a human activity gradient for some analyses. Reference sites will be identified with the approach described in (Ode et al. 2016a). Briefly, landscape-scale measures of human activity (e.g., % urban land cover, table A2) are calculated at the watershed and local scales are compared to levels where biological responses to activity are minimal. Failure to meet these criteria, as well as field-based measures of riparian disturbance and local expertise, may exclude a site from the reference class. A class of high human activity sites are identified using criteria described in Mazor et al. (2016); these sites have levels of human activity that exceed a minimum criterion (e.g., more than 50% urban land cover in the catchment within 1 km of the sampling location). Sites that meet neither reference high-activity criteria are classified as intermediate activity sites.

**Table A2. Variables used for assigning sites to "site disturbance classes" per the state's bio-objectives process (adapted from Ode et al. 2016). WS: Watershed. 5K: Watershed clipped to a 5-km buffer of the sample point. 1K: Watershed clipped to a 1-km buffer of the sample point. W1_HALL: proximity-weighted human activity index (Kaufmann et al. 1999). In order to be considered "Reference" condition, all criteria listed in the "Threshold" column for "Reference" must be met. If any of the criteria in the "Stressed" column apply, that site is considered "Stressed". Sites not falling into either of these categories default to "Intermediate". Data sources are as follows: A: National Landcover Data Set (2006, http://www.epa.gov/mrlc/nlcd-2006.html). B: Custom roads layer (P. Ode, pers. comm.). C: National Hydrography Dataset Plus (v2, http://www.horizon-systems.com/nhdplus/). D: National Inventory of Dams. E: Mineral Resource Data System (MRDS 2014). F: Field-measured variables (Fetscher et al. 2009).**

| Variable | Scale* | Threshold (Reference) | Threshold (Stressed) | Unit | Source |
|---|---|---|---|---|---|
| % Agriculture | 1k, 5k, WS | 3 | 50 | % | A |
| % Urban | 1k, 5k, WS | 3 | 50 | % | A |
| % Ag + % Urban | 1k and 5k | 5 | 50 | % | A |
| % Code 21[3] | 1k and 5k | 7 | 50 | % | A |
| | WS | 10 | 50 | % | A |
| Road density | 1k, 5k, WS | 2 | 5 | $km/km^2$ | B |
| Road crossings | 1k | 5 | - | crossings/ $km^2$ | B, C |
| | 5k | 10 | - | crossings/ $km^2$ | B, C |
| | WS | 50 | - | crossings/ $km^2$ | B, C |
| Dam distance | WS | 10 | - | km | D |
| % canals and pipelines | WS | 10 | - | % | C |
| Producer mines | 5k | 0 | - | mines | E |
| W1_HALL | reach | 1.5 | 5 | NA | F |

* For variables in which multiple spatial scales are used for determining site classification, in the case of the "Reference" boundary, the value indicated must apply to all spatial scales listed, whereas for the "Stressed" boundary, the indicated value need only apply for one of the listed spatial scales.

Secondary data for watershed characterization (to serve as environmental co-factors, among the explanatory variables) will be derived from the sources described in Table A3.

[3] "Code 21", or "developed open space" encompasses a wide range of land uses primarily characterized by heavily managed vegetation (e.g., low-density residential development, parks, golf courses, highway medians)

**Table A3. Sources of data for landscape, meteorological, and geological explanatory variables to be evaluated in predictive models.**

| Type of spatial data | Source or Model | Reference |
|---|---|---|
| Climate | PRISM | http://www.prism.oregonstate.edu |
| Geology and mineral content | Generalized geology and mineralogy data | Olson and Hawkins (2012) |
| Atmospheric deposition | National Atmospheric Deposition Program National Trends Network | http://nadp.sws.uiuc.edu/ntn/ |
| Predicted surface water conductivity | Quantile regression forest model (Meinshausen 2006) | Olson and Hawkins (2012) |
| Groundwater | MRI-Darcy Model (Baker et al. 2003) | Olson and Hawkins (2012) |
| Waterbody location and attribute data | NHD Plus | http://www.horizon-systems.com/nhdplus/ |
| Dam location, storage | National Inventory of Dams | http://geo.usace.army.mil/ |
| Land cover, imperviousness | National Land Cover Dataset | http://www.epa.gov/mrlc/nlcd-2006.html |
| Elevation | National Elevation Dataset | http://ned.usgs.gov/ |
| Mine location and attribute data | Mineral Resource Data System | http://tin.er.usgs.gov/mrds/ |
| Road location and attribute data | CSU Chico Geographic Information Center | CSU Chico Geographic Information Center |
| Railroad location and attribute data | CSU Chico Geographic Information Center | CSU Chico Geographic Information Center |

## APPENDIX 2 SUPPORTING DETAILED WORK PLANS: ASCI, BCG MODEL DEVELOPMENT, PREDICTING BIOASSESSMENT SCORES ACROSS A GRADIENT OF DEVELOPMENT IN CALIFORNIA LANDSCAPES