Identifying Healthy Watersheds in California

Modified Technical Approach and Draft List of Indicators

The original draft technical approach for the California Healthy Watersheds Integrated Assessment (dated November 28, 2011) described two separate, but interrelated, processes for evaluating watershed health at two spatial scales (HUC8 and HUC12). Much of the HUC8 analysis would have relied on data collected under a probabilistic monitoring design to construct a multimetric index. A thorough review of the data has revealed that there is an insufficient amount of data for a probabilistic analysis at the HUC8 scale.

The proposed modification to the original technical approach is to integrate the two assessment processes into one statewide analysis of watershed health at the HUC12 scale. This will be accomplished through the use of statistical models that will estimate the values of those watershed health indicators with limited spatial coverage for every HUC12 watershed in the state. These indicators will then be combined into sub-indices for each healthy watersheds attribute (Table 1) and an overall multimetric Index of Watershed Health. Indicators requiring the use of statistical models for estimation are denoted with an asterisk (*) in this document and working hypotheses are described for each. The results and limitations of the statistical analyses used to estimate each indicator will be fully described in the final report. This approach will assist the Healthy Streams Partnership with their goal of supporting hypothesis-driven data collection, analysis, and reporting to provide more useful and more integrated information to decision makers.

The Reference Condition Management Program (RCMP) has used statewide probability assessments to estimate the extent of healthy areas based on biological condition scores and their associated stressors. The Healthy Watersheds Integrated Assessment described here builds on the success of that program and adds additional indicators of watershed health for consideration (Table 1).

Table 1 Draft list of indicators for each sub-index of watershed health. Indicators with an asterisk (*) will be estimated through the use of statistical models.

Landscape Condition	Habitat Condition	Hydrologic Condition	Geomorphic Condition	Water Quality	Biological Condition
% Natural Land Cover in Watershed	Riparian Vegetation*	Indicators of Hydrologic Alteration*	% Sands and Fines*	Total Nitrogen*	O/E Macroinvertebrate Scores*
Landscape Connectivity	Stream Habitat Complexity*	Groundwater Stress		Total Phosphorus*	Wetland Biotic Structure*
% FRCC 1 in Watershed	Stream Habitat Fragmentation				

The values for each indicator will be scaled relative to their statistical distribution within each ecoregion. For example, the Stream Habitat Complexity indicator has different expected values within each ecoregion as a result of natural environmental gradients. The "cutoff" for stream habitat health will therefore be different in each ecoregion. Additionally, the Mojave and Sonoran Desert ecoregions will use a smaller subset of the indicators used for all other ecoregions due to their unique characteristics and greater reliance on groundwater versus surface water.

Landscape Condition Sub-Index

Indicator 1: N-Index (Percent Natural Land Cover in Watershed)

Rationale: Research conducted by the California Stream Pollution Trends (SPoT) and California Perennial Streams Assessment (PSA) programs, as well as by a vast number of national research programs, has documented the detrimental impact of agricultural and urban land uses on aquatic ecosystems. These impacts include increased levels of sediment toxicity, decreased biological condition scores, degradation of physical habitat, and overall degradation in chemical water quality parameters. The PSA and Reference Condition Management Program (RCMP) have identified thresholds of 10% agricultural and/or urban land cover (the U-Index) for identifying reference sites. The N-Index, which is the inverse of the U-Index, places the emphasis on healthy areas and will be used in the California Healthy Watersheds Integrated Assessment.

Indicator 2: Landscape Connectivity

Rationale: Landscape connectivity is important for ensuring the survival of many species. An isolated forest patch, for example, is not a high quality habitat for most species; however, a number of forest patches interconnected by forested corridors can provide outstanding habitat for these same species. Connectivity of large, unfragmented blocks of native vegetation is widely considered an indicator of a healthy ecosystem. As part of the California Essential Habitat Connectivity Project, a green infrastructure assessment was conducted to evaluate the "intactness" and connectivity of California lands. Results from the California Essential Habitat Connectivity Project, specifically percent of watershed covered by either Natural Landscape Blocks or Essential Habitat Connectivity Areas, will be used as the landscape connectivity indicator in the California Healthy Watersheds Integrated Assessment.

Indicator 3: Landscape Natural Disturbance Regime

Rationale: The Fire Regime Condition Class (FRCC) is an evaluation of the extent to which natural disturbance processes are intact across the landscape. When natural disturbance regimes are altered, the system becomes vulnerable to extreme events. For example, large fires can decimate landscapes and contribute substantial sediment loads to aquatic ecosystems. The percent of the watershed with a FRCC score of 1 (natural fire regime) will be used in the California Healthy Watersheds Integrated Assessment as an indicator of the landscape natural disturbance regime.

Habitat Condition Sub-Index

Indicator 1: Riparian Vegetation*

Rationale: Riparian vegetation provides habitat for semi-aquatic species, provides shading that helps to regulate stream temperature, and provides a buffer and filter for nonpoint sources of pollutants. Field assessments of the type, quantity, and structure of riparian vegetation were performed at 393 sites in California as part of the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) and the California Environmental Monitoring and Assessment Program (CMAP) (Figure 1).

Working hypothesis: Riparian vegetation cover, as evaluated in the field through the EMAP and CMAP assessments, is expected to correlate strongly with the percent natural land cover in the Active River Area[1] (an ecologically relevant delineation of the riparian area), as evaluated through remote sensing methods. A multiple linear regression model will be used to evaluate the relationship between riparian vegetation scores and the percent natural land cover in the Active River Area, as well as other predictor variables. The regression model will then be used to estimate riparian vegetation scores for every HUC12 watershed.

Indicator 2: Stream Habitat Complexity*

Rationale: Instream habitat, such as large woody debris, is critical for maintaining natural levels of stream biodiversity. Field assessments of stream habitat complexity were performed at 393 sites in California as part of the EMAP and CMAP assessments (Figure 1).

Working hypothesis: Stream habitat complexity, as evaluated in the field through the EMAP and CMAP assessments, is expected to correlate strongly with the percent forest in the Active River Area as evaluated through remote sensing methods. A multiple linear regression model will be used to evaluate the relationship between stream habitat complexity and the percent forested land cover in the Active River Area, as well as other predictor variables. The regression model will then be used to estimate stream habitat complexity for every HUC12 watershed.

Indicator 3: Stream Habitat Fragmentation

Rationale: Dams, culverts, and other instream structures can prevent species from migrating to upstream spawning areas and from recolonizing suitable habitats. The California Fish Passage Assessment Database contains an inventory of major instream structures that may fragment stream habitat (Figure 2). The density (number per stream mile) of these structures will be used as an indicator of stream habitat fragmentation.

[1] http://www.conservationgateway.org/file/active-river-area-conservation-framework-protecting-rivers-and-streams

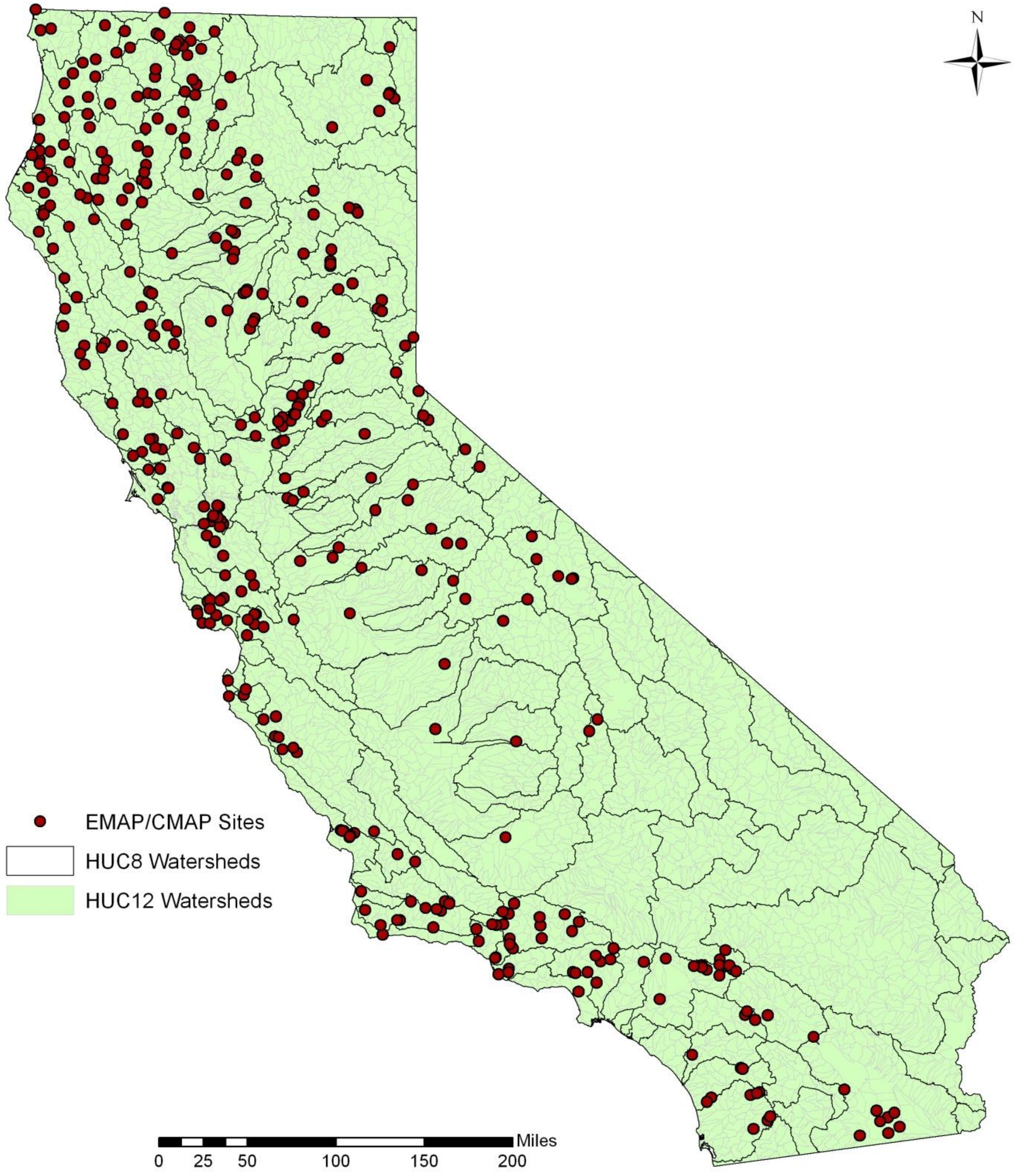

Figure 1 Spatial distribution of Environmental Monitoring and Assessment Program (EMAP) and California Monitoring and Assessment Program (CMAP) sites with geomorphic and physical habitat data in California.

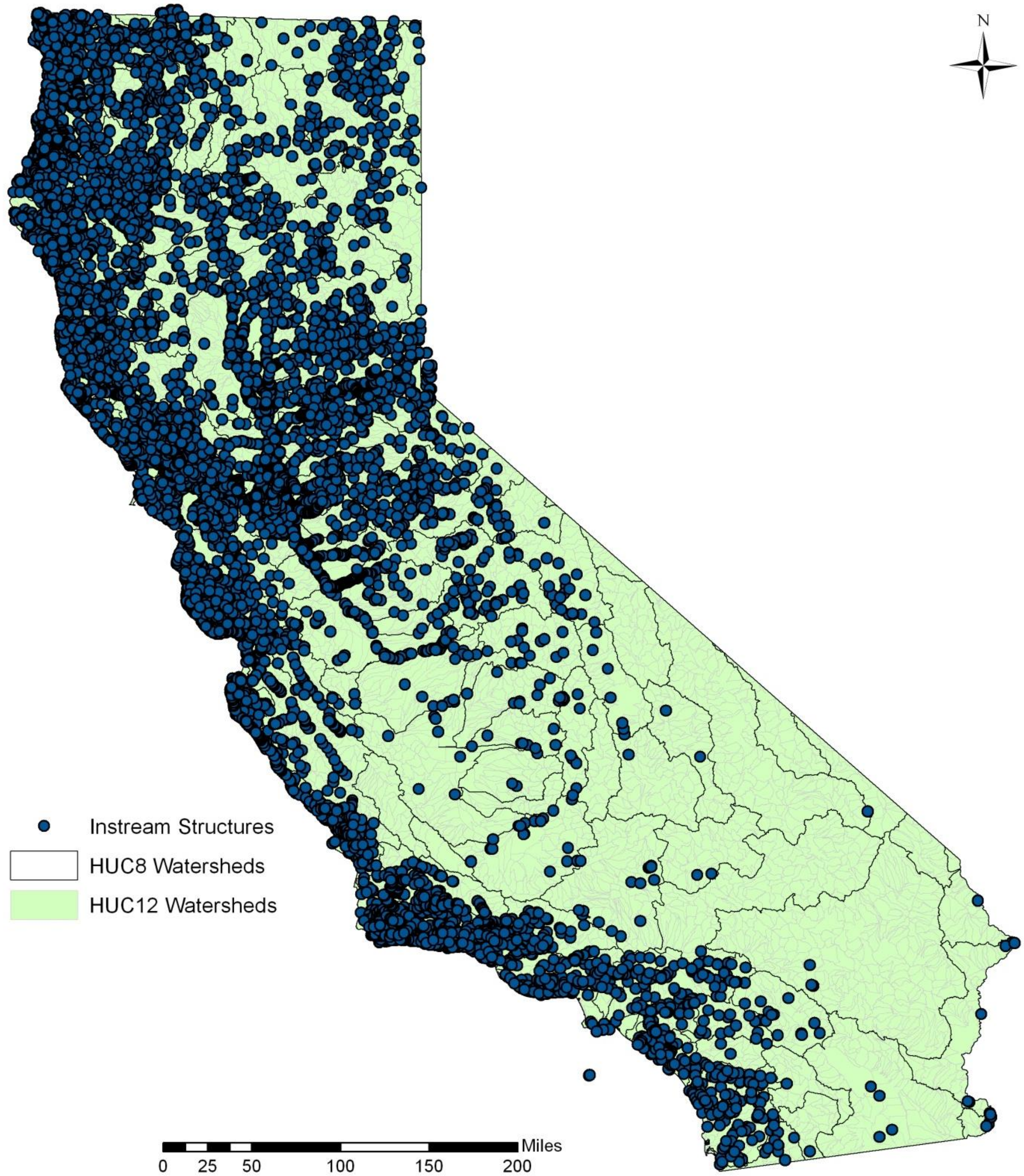

Figure 2 Spatial distribution of instream structures (from the California Fish Passage Assessment Database) with potential habitat fragmentation effects in California.

Hydrologic Condition Sub-Index

Indicator 1: Indicators of Hydrologic Alteration (IHA) statistics for surface water flows*

Rationale: The natural flow regime is considered one of the fundamental drivers of aquatic ecosystem condition. Different components of the flow regime are responsible for regulating different aspects of biological community structure. The Indicators of Hydrologic Alteration (IHA) are a suite of 33 ecologically-relevant stream flow metrics. However, different subsets of these indicators are more ecologically relevant than others in a given system, and many of the indicators are highly correlated with one another. The Cadmus Group, Inc. (under a contract with EPA) calculated IHA statistics for a representative sample of stream flow gages in California and applied Principal Components Analysis (PCA) to these data in order to select a subset of the 33 IHA parameters that best describes statistical variability in ecologically important flow metrics. The following six metrics were identified as those that explain 95% of the variation in stream flow variability in California:

- Mean annual flow
- Base flow index
- Number of zero flow days
- Number of flow reversals
- Date of annual maximum flow
- Date of annual minimum flow

These six ecologically important flow metrics will be evaluated for changes over the entire period of record to assess hydrologic alteration at each USGS stream flow gage in California (Figure 3). A statistically significant change in one or more variables will result in that stream gage receiving a rating of 'hydrologically altered'. Relationships between these indicators and other variables will be examined in order to predict alteration of these six IHA statistics for every watershed in the state.

Working Hypothesis: The following variables are expected to be correlated with changes to the IHA statistics:

- Dam storage volume
- Surface water diversion volumes
- Ground water diversion volumes
- Point source discharge volumes
- Percent natural land cover in the watershed

These and other watershed variables will be evaluated to identify relationships with alteration of one or more of the IHA statistics. Logistic regression will then be used to estimate the probability of hydrologic alteration for every HUC12 watershed in the state based on various landscape predictor variables.

Indicator 2: Groundwater Stress

Rationale: Groundwater is a particularly important resource in many parts of California and many ecosystems rely on groundwater inputs to function properly. Evaluation of the baseflow index as part of the surface water hydrologic alteration assessment will account for much of these impacts. However, impacts to non-riparian ecosystems (e.g., springs and seeps, isolated wetlands, etc.) remain to be accounted for. The Nature Conservancy has conducted a statewide assessment of groundwater dependency for every HUC12 watershed in the state. The groundwater dependency index from this assessment will be weighted by the volume of groundwater withdrawals to calculate an index of groundwater stress for each for each HUC12 watershed in the state.

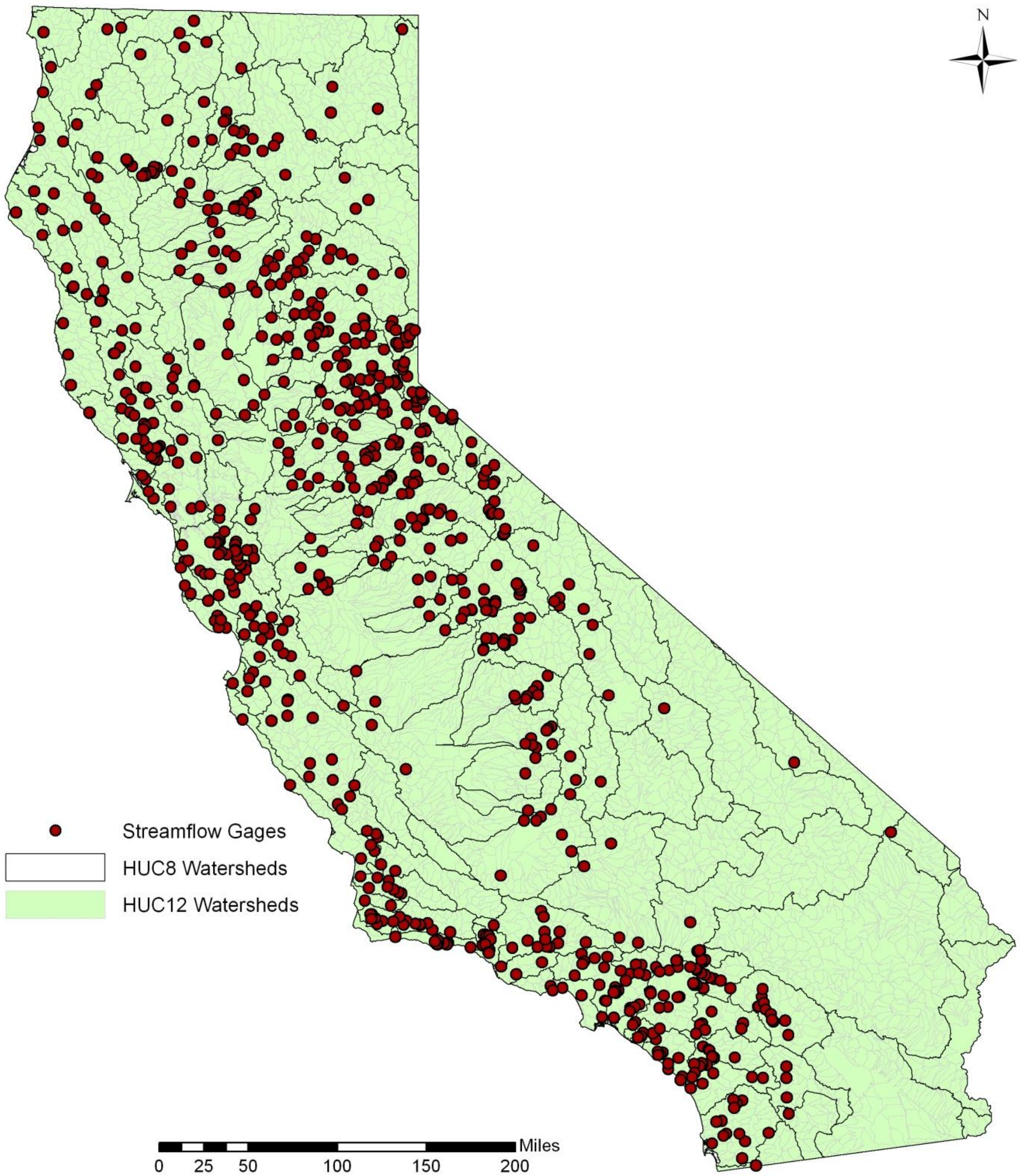

Figure 3 Spatial distribution of USGS stream flow gages in California.

Geomorphic Condition Sub-Index

Indicator 1: Percent Sands and Fines*

Rationale: Geomorphic condition and physical habitat condition are similar concepts. A stable stream channel, with natural rates of sediment input and discharge, provides a physical habitat template upon which healthy aquatic communities depend. A variety of metrics are available for representing geomorphic and physical habitat condition. However, virtually all of them require extensive field measurements. The EMAP and CMAP assessments collected geomorphic and physical habitat data at 393 sites throughout California (Figure 1). Three of the metrics measured as part of the EMAP and CMAP assessments (relative bed stability, percent sands and fines, and embeddedness) are highly intercorrelated (Table 1). Therefore, the metric with the strongest response to watershed stressors will be chosen (through the use of linear regression techniques) to represent geomorphic condition. Preliminary analysis shows that 'percent sands and fines' responds most strongly to watershed land cover (Figure 4).

Working hypothesis: Aside from watershed land cover, it is expected that the percent natural land cover in the Active River Area will also be a significant predictor of geomorphic condition. This has been demonstrated to be the case in other states. Other potential predictors include road/stream crossing density, dam density, etc. A multiple linear regression model will be developed for estimating the 'percent sands and fines' metric for every HUC12 in California based on these and other predictor variables.

Table 2 Correlation matrix of EMAP/CMAP physical habitat and geomorphic indicators. A value of 1 or -1 signifies a perfect correlation and a value of 0 signifies no correlation. All correlations shown are statistically significant at p<0.05.

	Relative Bed Stability	% Sands & Fines	Embeddedness
Relative Bed Stability	1	-0.88	-0.87
% Sands & Fines	-0.88	1	0.94
Embeddedness	-0.87	0.94	1

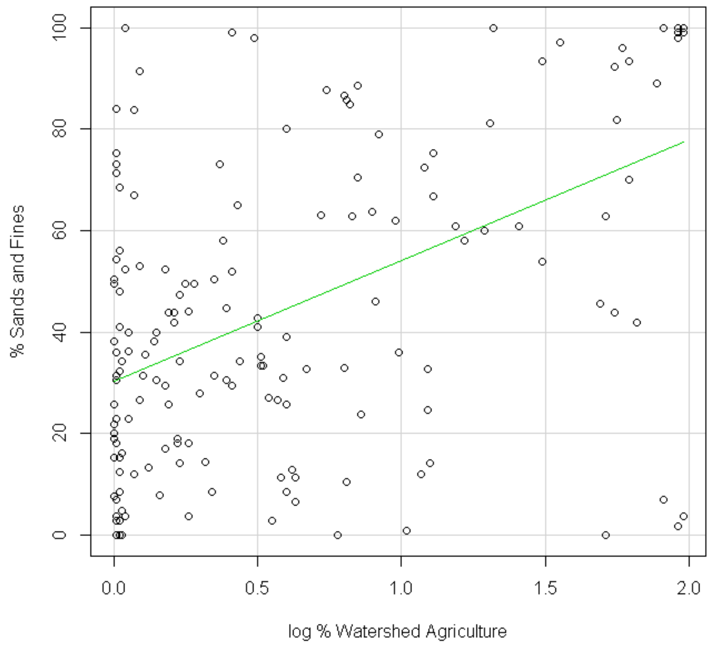

Figure 4 Response of the percent sands and fines metric to increasing levels of agricultural land use in the watershed (R^2=0.42 after controlling for natural variability).

Water Quality Sub-Index

Indicator 1: Predicted Total Nitrogen

Indicator 2: Predicted Total Phosphorus

Rationale: Nutrient enrichment is one of the most prevalent causes of water quality degradation. High levels of nutrients are often found in water bodies with other pollutants of concern, including pesticides, bacteria, and metals. Table 3 displays a correlation matrix of water quality parameters measured as part of the EMAP/CMAP assessments. Building off of the USGS SPARROW model, multiple regression models will be developed and average predicted concentrations of total phosphorus and total nitrogen will be estimated for every HUC12 watershed in California. These predictions will be used to represent water quality in California. The Reference Condition Management Program has identified thresholds for total phosphorus and total nitrogen of 0.5 and 3 mg/L respectively. Concentrations below these levels are expected at reference sites. These screening criteria will be used to identify watersheds with high water quality.

The N-Index, used as an indicator of landscape condition, also captures many of the water quality impacts resulting from human land use. For example, statewide toxicity monitoring has demonstrated that the vast majority of water column and sediment toxicity is a result of pesticide use in urban and agricultural land uses. These water quality variables will be largely accounted for through the landscape condition indicators.

Table 3 Correlation matrix of water quality parameters in California. All correlations shown are statistically significant at p<0.05.

	Chloride	Conductivity	Nitrogen	Phosphorus	TSS	Turbidity
Chloride	1	0.88	0.62			0.31
Conductivity	0.88	1	0.74			0.32
Nitrogen	0.62	0.74	1			0.36
Phosphorus				1	0.52	0.56
TSS				0.52	1	0.88
Turbidity	0.31	0.32	0.36	0.56	0.88	1

Working hypothesis: Watershed land cover is expected to be a significant predictor of nitrogen and phosphorus concentrations. Other potential predictors include point source discharge and fertilizer application rates. A multiple linear regression model will be developed for estimating the nitrogen and phosphorus metrics based on these and other variables for every HUC12 watershed in California.

Biological Condition Sub-Index

Indicator 1: O/E Scores*

Rationale: Biological condition is frequently measured by comparing the observed biological community of macroinvertebrates to the community expected in that stream type and ecoregion. A score of Observed vs. Expected (O/E) is typically used to represent overall biological condition at the site. Biological condition has been evaluated at 1,387 sites through the Perennial Streams Assessment (PSA) (Figure 6). The O/E scores from these sites will be evaluated against various landscape-level metrics and a regression model will be built to estimate O/E scores for every HUC12 watershed in California.

Working hypothesis: O/E scores are expected to be strongly correlated with landscape variables, such as the U-Index (Figure 5) and dam density, as well as instream habitat and variables such as nutrient concentrations and percent sands and fines.

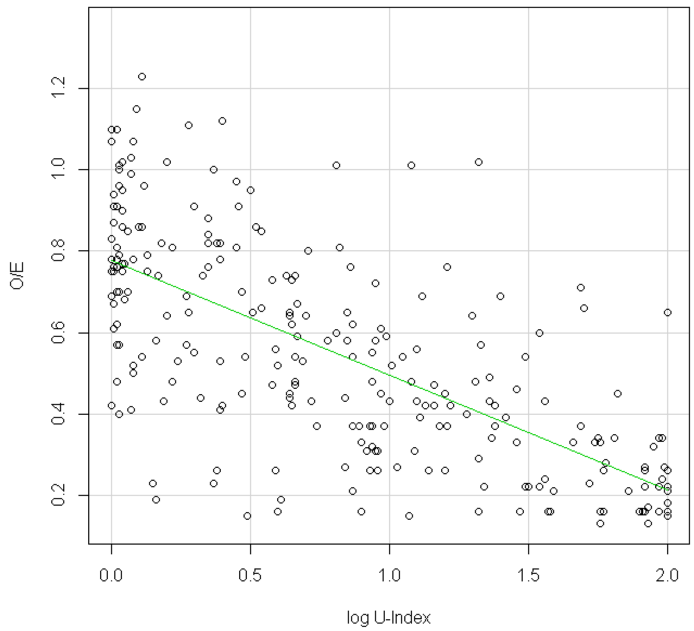

Figure 5 Biological response to increasing levels of anthropogenic land use in a watershed (R^2=0.48).

Indicator 2: Wetland Biotic Structure*

Rationale: In addition to instream biological communities, such as macroinvertebrates, wetland plant communities are also an important indicator of biological condition. Wetland and riparian plants are valuable resources in and of themselves; they also provide habitat and food for fish and macroinvertebrate communities. The California Rapid Assessment Method (CRAM) tool was used to assess wetland plant biotic structure at 1,078 sites across California. 73% of these sites are riparian wetlands (Figure 7). The CRAM biotic structure scores, which incorporate metrics that represent dominant species richness and percent invasive species, from these sites will be evaluated against various landscape-level metrics and a regression model will be built to estimate wetland biotic structure for every HUC12 watershed in California.

Working hypothesis: Wetland biotic structure scores are expected to be correlated with landscape connectivity variables such as road density, percent of watershed occupied by natural landscape blocks, proximity to agriculture, etc.

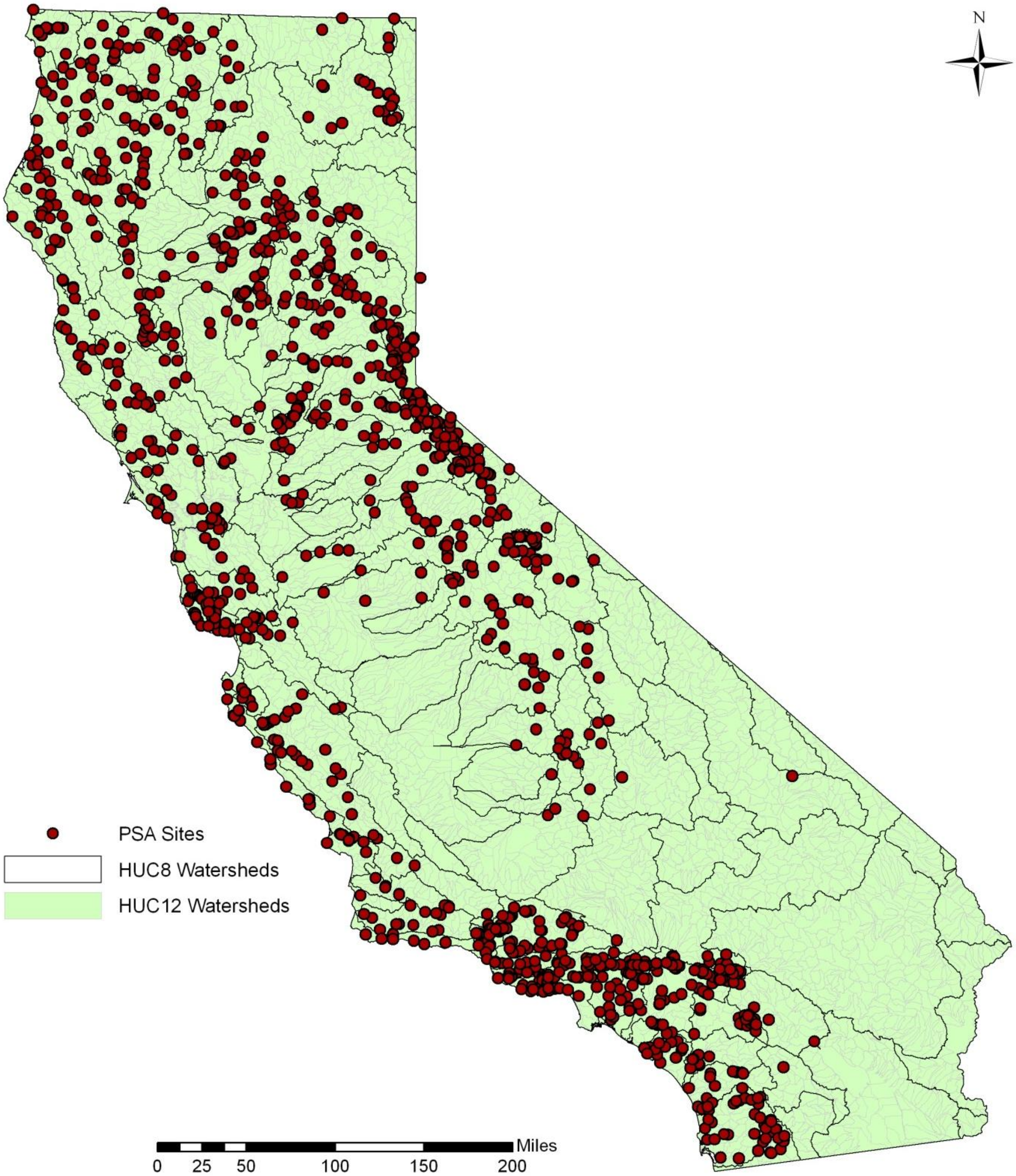

Figure 6 Spatial distribution of Perennial Streams Assessment (PSA) sites in California.

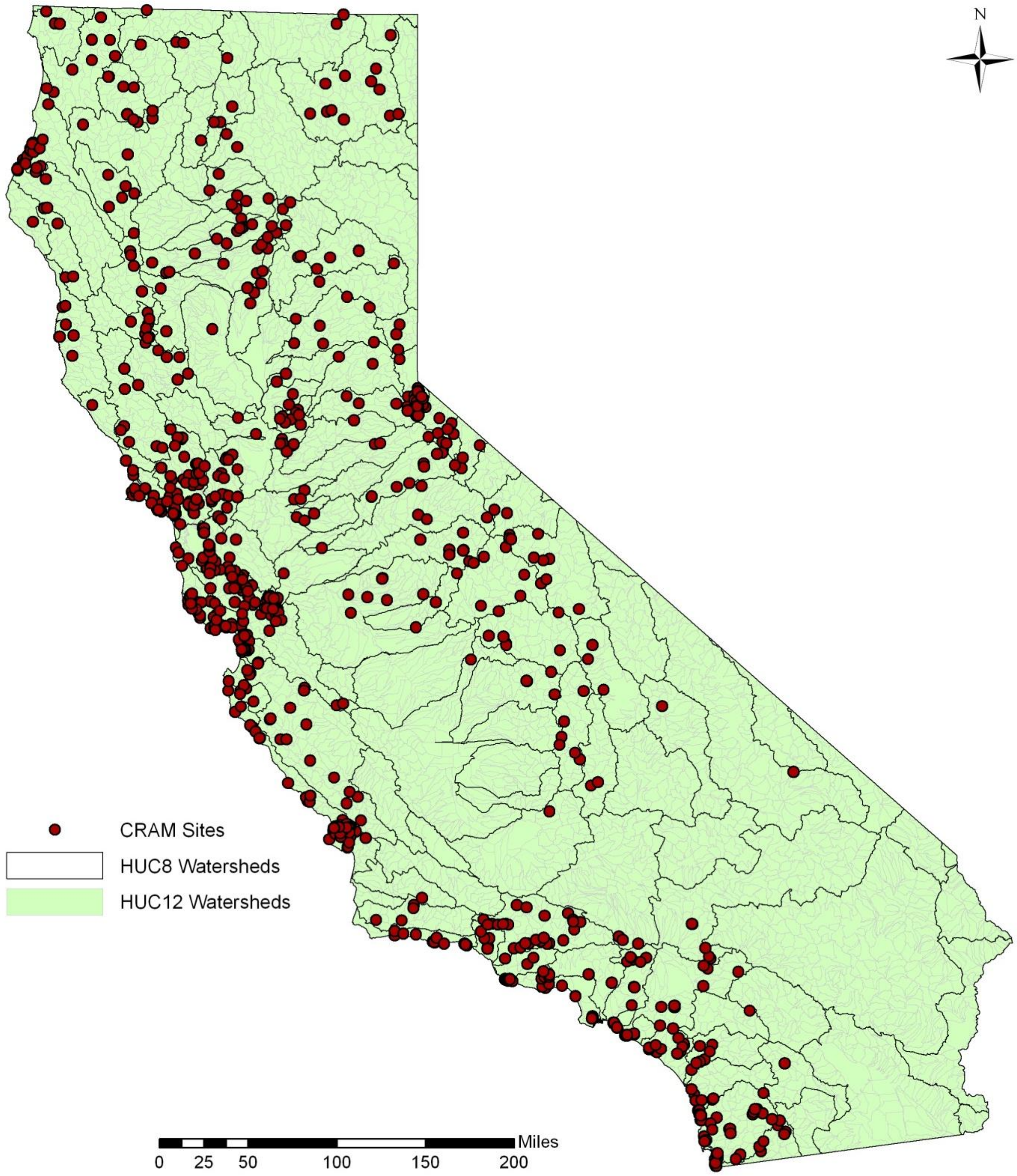

Figure 7 Spatial distribution of California Rapid Assessment Method (CRAM) wetland sites in California.

Index of Watershed Health

All of the indicators described in the preceding pages will be used to construct a multimetric Index of Watershed Health. Once each indicator has been calculated for every HUC12 watershed in California, a technical memo detailing the distribution of the indicator scores and potential methods for calculating the overall index will be provided to the Healthy Streams Partnership. Input will be sought on the weighting of individual indicators and the proposed methods for normalizing the indicator scores. The final result will be an Index that assigns one score representing overall watershed health to each HUC12 watershed in the state. The sub-index scores will also be calculated for each HUC12 watershed, and the raw indicator scores will be available as well. GIS shapefiles with all indicator, sub-index, and watershed health index scores will be provided to the Healthy Streams Partnership for use in their online mapping applications. The structure and format of the final report will also be discussed with the Healthy Streams Partnership at that time.