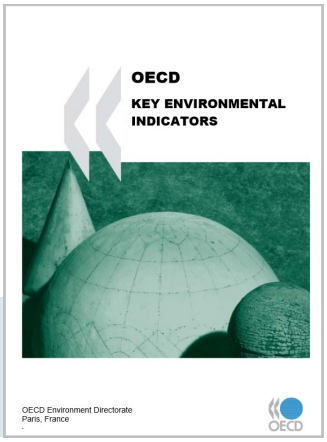
Background on Watershed Indicators as a Tool for Reporting on Environmental Conditions and Stressors

A watershed indicator is a metric that reports on the status of or trends in watershed health. The indicators may report on a wide variety of information important for understanding current conditions and the future management of a watershed. A variety of measurements or metrics can be used to represent the environmental condition on which the indicator is reporting. For example, a Secchi disk, a round black and white saucer, is regularly lowered into Lake Tahoe until the black/white contrasting sections can no longer been seen clearly. The depth to which the disk is lowered reports on the clarity of the lake. Secchi disk depth is a simple measurement, but it has very important implications for the health of Lake Tahoe, therefore, it makes an excellent metric for an indicator of lake health.

The organizational structure of an indicator report is referred to as the indicator framework. One of the main functions of the framework is to provide the basis for identifying and selecting indicators. There are 2 major indicator frameworks that have been used to describe watershed health: The Pressure-State-Effects-Response (PSER) model and the US EPA Science Advisory Board's (SAB) system for reporting on ecological or watershed conditions. The Dry Creek watershed indicators are a blending of both of these frameworks.

The PSER Model

The Pressure-State-Effects-Response model, or PSER model, was originally developed by the Organisation for Economic Cooperation and Development, an international organization that promotes policies to improve economic and social well-being. This model has been used throughout the United States to report on conditions in a variety of environments, including by Cal/EPA. It was developed for the purpose of providing information to guide environmental management and decision-making.



The Organization for Environmental Cooperation and Development, part of the European Union, has been using environmental indicators for decades to inform environmental policy and decision-making.

Watershed Indicators Framework

The key difference between the original PSER model and the one used in this report is that watershed indicators consider the source of stressors (drivers) while the traditional PSER model does not include this category of indicators. **Drivers** are activities on the land that influences the conditions in and around the waterway.

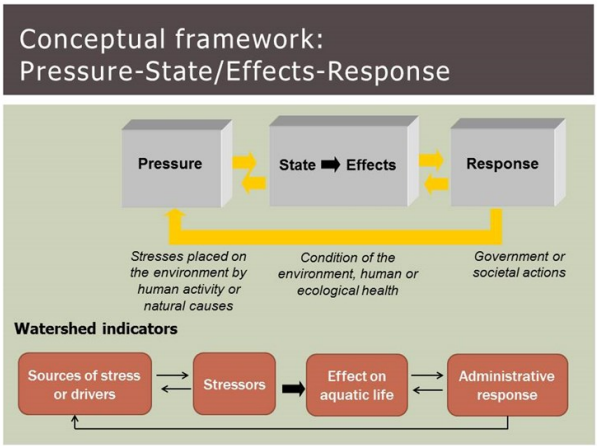


Figure 1. The pressure-state-effects-response model, used widely for reporting on environmental conditions, provided the foundation for the watershed indicator system used in this report.

Pressures are stressors placed on the environment by natural causes or human activity. The result of these pressures is a change in the environmental conditions, or **state**. These changed conditions have the potential to cause adverse **effects** on humans, fish, or wildlife. When recognized, citizen groups as well as local, regional, or state government have the ability to **respond** to the circumstances to reduce the pressures and improve conditions. For example, poor management of hazardous waste could alter the conditions in a neighborhood, having a negative effect on the more vulnerable in a community. Local government or a state regulatory body could take enforcement actions or implement cleanup measures to reduce the problem. A response on the part of local decision makers could reduce the stressors on the community or mitigate the adverse effects. This same model can easily be applied to watersheds, as illustrated in the bottom portion of Figure 1. In a watershed, environmental conditions refer to the quality of the habitat, including water quality. If habitat conditions are poor, they could have an adverse effect on fish, insects, birds, and other animals. In response to this information, changes in management practices could be implemented to reduce the source of stressors and their adverse effects.

The SAB Model

A complementary approach to the PSER model is one developed by the US EPA's Science Advisory Board (SAB) and described in the report, *A Framework for Assessing and Reporting on Ecological Conditions* (US EPA,2002). The SAB Report presents a framework for assessing conditions in a variety of ecosystems. The US EPA's Healthy Watersheds Initiative has adapted it to understand conditions within a watershed. The framework focuses on the assessment and integration of processes and factors that influence watershed conditions. The emphasis is not on management response as it is with the PSER model, but on a thorough characterization of the ecosystem and how it functions. This model emphasizes assessing key ecological parameters such as hydrology, geomorphology, and natural disturbances and their relationship to physical, chemical, and biological conditions. Six essential ecological attributes have been used to understand the condition of an ecosystem. In the context of watershed indicators, the 6 attributes are:

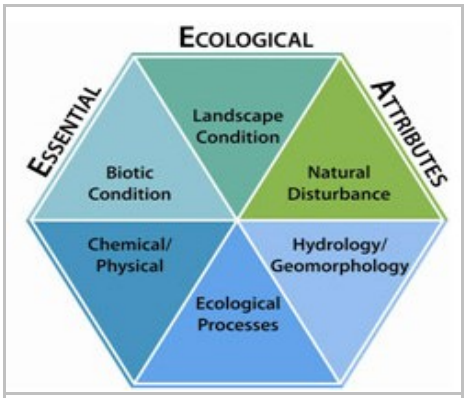


Figure 2. The SAB framework for watershed indicators.

- Landscape conditions - refers to land uses within the watershed, with special emphasis on stream corridors,
- Natural disturbances - refers to naturally occurring perturbations such as fires and floods,
- Hydrology and Geomorphology - refers to the water cycle within the watershed and how it affects stream morphology. One key issue addressed by this attribute is the way in which urbanization has increased the volume and altered the timing of stormwater runoff and its consequences on aquatic habitat,
- Ecological processes - refers to biogeochemical (or nutrient) cycling, energy flow and community dynamics,
- Chemical and physical attributes - refers to water quality and aquatic habitat conditions , and
- Biotic conditions - refers to the health of aquatic organisms, including fish and benthic macroinvertebrates.

The Dry Creek Framework

The framework used for the Dry Creek Indicators is based on the PSER model, but also integrates essential ecological attributes identified in the SAB report. The Dry Creek report is focused on providing the best available scientific information to guide the management of the watershed. This report examines both natural and anthropogenic factors that influence watershed conditions, with special emphasis on stressors, their sources, and the effects on aquatic life. The report evaluates a wide variety of conditions and processes, so that the majority of factors that influence the aquatic ecosystem and their relationship to each other are considered, as identified in the SAB report.

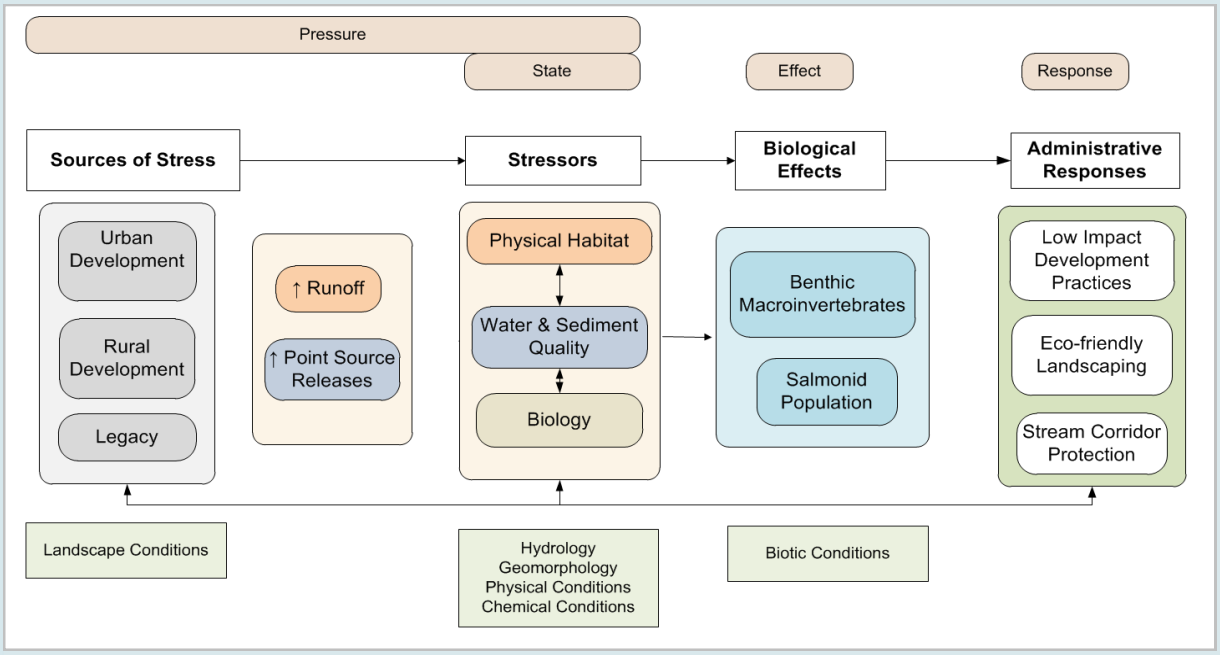


Figure 3. Simplified model of the Dry Creek watershed indicators. This diagram shows relationship of key factors influencing aquatic life in Dry Creek and the feedback loop that informs environmental decision making. The beige boxes at the top indicate key categories identified in the PSER model; blue/green boxes at the bottom reflect the categories identified in the SAB Report as the Essential Ecological Attributes. Data was not available on ecological processes or natural disturbances.

Watershed Indicators Framework

The analysis of Dry Creek was based on an understanding of the relationship between the sources of stress and the stressors. The sources of stress can be natural or anthropogenic. One example of a natural stressor is the erosive nature of the Dry Creek landscape, which produces sizeable amounts of fine material. The model, however, focuses on anthropogenic stressors over which we have some control. Using the same example, due to the erosive nature of the landscape, human disturbances will have a larger impact on the waterways of Dry Creek than in other watersheds. The sources of stress give rise to the stressors, which can cause adverse effects on fall run Chinook salmon as well as benthic macroinvertebrates, large larval and adult invertebrates that live in the streambed and provide food for young salmon. Lastly, a list of management actions that could be taken to reduce the impacts of the stressors is also identified. This conceptual diagram incorporates the 4 categories of the PSER model, as shown in the boxes above the main diagram. Note that the category "stressors" in the Dry Creek conceptual model includes both pressures and state/condition as defined in the PSER model. This might be best understood with the following example: When constituents in the water such as dissolved oxygen (DO), fall within a certain window of values, DO does not act as a stressor, but reflects the current concentration. However, when DO concentrations fall below 7 ppm, it poses a risk to salmon and other aquatic life. In this circumstance, DO acts as a stressor. Because many physical and chemical characteristics of the aquatic environment can be both a state and a pressure, depending on the concentration of a constituent or the condition, both of these categories fall into the stressor group of the Dry Creek model.

To briefly review the 4 key components of the Dry Creek conceptual model:

Sources of Stress: This category addresses the changes in landscape conditions. Since a watershed is defined by topography, changes in the landscape, in particular urbanization, plays a major role in altering conditions in and around the waterway.

Stressors are constituents, either naturally occurring or introduced by people, which adversely affect biological life. Physical stressors could include an increase in the percent of fine particles in the streambed, high water temperature, or a decrease in the amount of streamside vegetation.

Water/sediment quality stressors are primarily chemicals such as pesticides and metals. However, other stressors that impair water quality such as suspended solids are also included in this category.

An example of a biological stressor could be an invasive plants or fish species that is competing with the native organisms for food and shelter. In this report, data were not available on biological stressors.

Effects refer to the changes that occur in the diversity or abundance of aquatic life. In most cases, watershed assessments originate from a concern over a decline in the number or diversity of fish or more generally aquatic life.

Administrative responses are actions taken by local, regional, or state government or local environmental organizations to remedy the problems that caused the decline in the health of aquatic life. Since a watershed analysis focuses on the relationship between landscape factors, conditions in the waterways, and effects on aquatic life, these responses frequently involve changes in land management practices. In urban areas, this translates into changes in the pattern and/or practices of development. It also might include modifications in the management of the stream corridor itself. Administraive responses are not included in the SAB model of essential ecological attributes.

Selection of Indicators

The indicators reflect the results of a watershed assessment that was performed on Dry Creek watershed data (see chapter on Causal Assessment Methodology for details). The assessment was structured to answer the question: what are the causes of the decline in aquatic life within the watershed? To address this question, a large amount of data were reviewed. Statistical methods were used to identify correlations, or relationships and between metrics of aquatic life health and potential stressors and their sources. To aid in the interpretation of this information, a method known as causal assessment or stressor identification, was used. Stressor Identification is a weight-of-evidence approach that identifies the strongest relationships between an endpoint, in this cases metrics of benthic macroinvertebrate health, and stressors. This methodology is described in detail in the chapter on Causal Assessment Methodology. Those stressors that were selected as indicators fell into one of two categories: 1) stressors for which there was sufficient data to perform a complete causal analysis, and 2) stressors for which some information was lacking, so a causal analysis could not be performed, but for which preliminary data suggested the stressor was important and needed further study. Those stressors, which fell into the first group, were identified as having either a low, moderate, or high-risk level. The risk level reflects the degree to which this stressor could contribute to the biological impairment, which is the focus of the assessment. In the case of Dry Creek, the biological impairment is the decline in the abundance and diversity of benthic macroinvertebrates. Stressors that fell into the second group were assigned a risk level of 'unresolved'. This designation reflects the fact that the data for this stressor did not meet the criteria for performing a complete causal assessment yet existing data suggested that the potential stressor could contribute to the conditions in the Dry Creek watershed.

TYPE OF INDICATOR	EXAMPLES
Stressors	Pesticides Instream Cover Dissolved Oxygen Flow Diversity Flashiness/Altered Hydrology Metals Temperature
Sources	Urbanization
Effects	Fall run chinook salmon Benthic Macroinvertebrates
Administrative Responses	Stream restoration Low impact development (BMPs) Creek corridor management Source control Riparian zone protection

Table 1. The list of watershed indicators included in this report.

Presentation of the Indicators

Figure 4 illustrates the way each indicator is presented in the report. In addition to the name, information provided with each indicator includes:

- The type of indicator, either stressor or a source of stressors,
- The category into which each stressor fits, as indicated in Figure 3, for example a physical habitat or water/sediment quality (often due to contaminants) stressor,
- The level of risk assigned to each stressor, based on the results of the causal analysis.

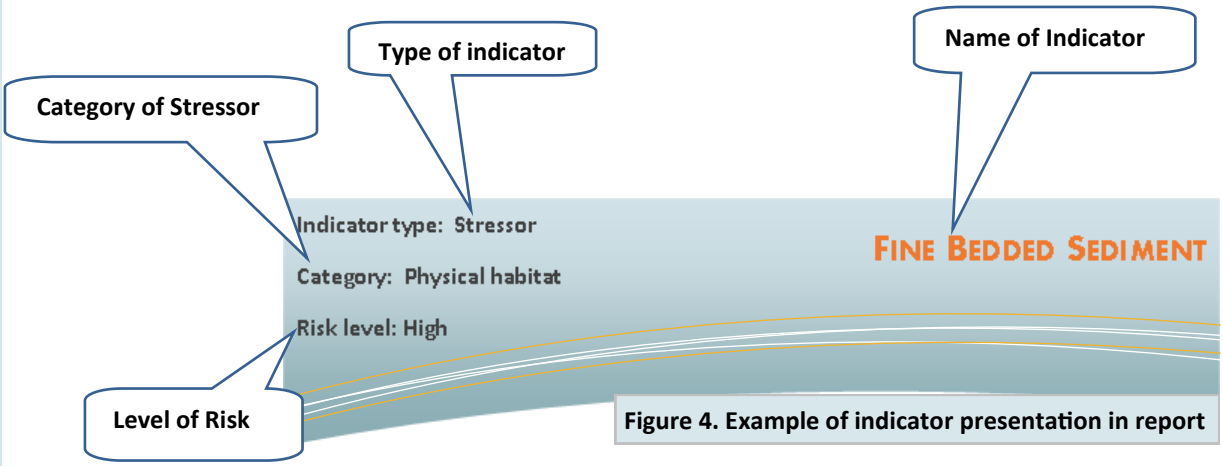


Figure 4. Example of indicator presentation in report

The subsequent chapter, on Causal Assessment Methodology, reviews the methods and criteria used to evaluate data for each potential watershed stressor.

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US EPA Science Advisory Board. 2002. A Framework for Assessing and Reporting on Ecological Conditions. Posted at: http://water.epa.gov/polwaste/nps/watershed/framework.cfm.

Information on the application of the US EPA SAB Framework to California's watersheds is posted at: http://www.water.ca.gov/watersheds/framework.cfm.