# Using Indicators to Measure Water Resources Sustainability in California

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## ABSTRACT

As part of the California Water Plan Update 2013, the California Department of Water Resources has teamed with the University of California, Davis and U.S. EPA Region 9 to develop an analytical framework to quantify water resources sustainability indicators for California. The California Water Sustainability Indicators Framework ("Framework") describes indicators that will inform us about water system conditions and relationships to ecosystems, social systems, and economic systems. The Framework provides: 1) a logical hierarchy of goals and objectives for organizing indicators, 2) a suite of suitable indicators and 3) analytical methods for measuring sustainability relative to targets. The Framework is being tested at state and region scales. The Framework includes the Water Footprint (the water required to provide goods and services) as an index of sustainability in its own right. The sustainability indicators are being presented in an online "decision-support tool" to improve California's assessment of water sustainability.

## INTRODUCTION

The California Water Plan (DWR 2005, 2009) is mandated by state law and updated every five years, is developed by the California Department of Water Resources (DWR), and is used to guide regional and statewide water policy decisions. With a growing recognition that California's water systems are finite, and faced with impacts from climate change, growing population, and more stringent environmental requirements, decision-makers, water managers, and planners are becoming increasingly aware of the need to both sustainably manage water and respond to changing availability and constraints on water. In the California Water Plan Updates 2005 and 2009, DWR refocused attention on the sustainability of

California's water systems and ecosystems in light of current water management practices and expected future changes. However, one recurring question from stakeholders has been,

> "*How can we ascertain that the objectives of the California Water Plan, associated resource management strategies, and recommended actions would lead to sustainable water use and supply for the State and its ten hydrologic regions*?"

To respond to the above concern, one of the guiding principles established for decision-making in the California Water Plan Update 2009 was:

> "*Determine values for economic, environmental, and social benefits, costs, and tradeoffs to base investment decisions on sustainability indicators*."

However, there are major impediments to evaluating the state's water sustainability using sustainability indicators. These include inconsistent terminologies and definitions used; absence of a systematic analytic framework and methodologies for quantification of water sustainability indicators; potential inconsistent social/political support for using indicators; lack of broad understanding of indicators; and a potential lack of data to undertake the appropriate analysis to assess sustainability of water resources through the development and on-going tracking of a set of sustainability indicators.

As part of the California Water Plan Update 2013, DWR, in collaboration with the University of California, Davis and the U.S. Environmental Protection Agency Region 9, has developed an analytical and quantitative framework, and a set of preliminary sustainability indicators. The California Water Sustainability Indicators Framework (Framework) (DWR 2012) is intended to help us identify, compute, and evaluate a set of relevant sustainability indicators that would help monitor progress towards sustainability of natural and human water systems.

**What is sustainability?**

The word "sustainability" has been widely used in recent years for a wide variety of planning activities, and often no definition is provided with its use. The need for "sustainable development" or "sustainable use of resources" may have somewhat different meanings depending on the perspective of the user. A system or process that is sustainable can generally continue indefinitely. A system that is sustainable should meet today's needs without compromising the ability of future generations to meet their own needs. A sustainable system generally provides for the economy, the ecosystem, and social well-being and equity.

The California Water Plan includes a vision statement laying the foundation for how California can be sustainable in water use and management. The vision is the following:

> *California has healthy watersheds and integrated, reliable, and secure water resources and management systems that: Enhance public health, safety, and quality of life in all its communities; Sustain economic growth, business vitality, and agricultural productivity; and Protect and restore California's unique biological diversity, ecological values, and cultural heritage*.

In order to help meet the vision of the California Water Plan, the following definition for sustainability has been adopted:

> *Water sustainability is the dynamic state of water use and supply that meets today's needs without compromising the long-term capacity of the natural and human aspects of the water system to meet the needs of future generations*.

**What sustainability problem are we solving?**

Water systems are complicated, interlinked, and dynamic, as are societal water needs. To achieve sustainability in water supply and use, management actions will need to adapt to the current and potential future state of natural and man-made water systems. This is perhaps possible when managers understand and appreciate, and operate within boundary conditions set by society and nature. The Framework under development for the California Water Plan is designed to facilitate evaluation of progress toward sustainability through a set of relevant indicators and providing information about specific aspects of water systems. Indicators can help decision-makers, managers, and others to measure and assess status (condition and performance) and trends of natural and human systems and to respond appropriately. By considering economic, social and ecological systems as integrated parts of a whole as envisioned in the analytical and quantitative framework discussed in detail subsequently, decision-makers and managers are more likely to make choices that benefit the whole.

**Water Sustainability Indicators**

Indicators are qualitative or quantitative parameters selected to represent parts of ecological, social, or economic systems. Indicators provide a way to collect information about a condition and to report and evaluate changes over time. Sustainability indicators measure the condition of parts of the systems, relative to a desired and an undesired condition for those parts. They also measure performance of our actions. Finally, they are useful in evaluating our distance from and progress toward a range of sustainability, which assumes that sustainability is more usefully defined as ranges of conditions rather than a fixed point. Examples of indicators relevant to water sustainability include: "Historic amounts and availability of anadromous fish"; "Historic flooding conditions (extent and timing)"; "Historic fire conditions"; "Historic availability of clean drinking water from surface or ground

sources"; "Community satisfaction/happiness"; "Equitable access to decision-making".

Indicators provide the connection between statements of intent (e.g., objectives) and measurable aspects of natural and human systems. Because of the importance of the indicators in determining findings and basing decisions, the indicators should be carefully chosen. Explicit criteria must be used to select indicators to ensure that the resulting evaluation is robust and usable in decision-making. For the California Water Plan Update 2013 more than 80 indicators were selected from an original list of >1,000, which were derived from a review of sustainability and water system indicators from around the world. The indicators were chosen to both measure progress toward the goals and objectives, as well as to represent five domains or categories of natural and human systems: water supply reliability, water quality, ecosystem health, adaptive and sustainable management, and social benefits and equity shown in Table 1.

**Table 1. Categories of Water Sustainability Indicators**

| Category | Definition |
|---|---|
| ***Water Supply Reliability*** | *the provision of water of sufficient quantity and quality to meet water needs for health and economic well-being and functioning* |
| ***Water Quality*** | *the chemical and physical quality of water to meet ecosystem and drinking water standards and requirements* |
| ***Ecosystem Health*** | *the condition of natural system, including terrestrial systems interacting with aquatic systems through runoff pathways* |
| ***Adaptive and Sustainable Management*** | *a management system that can nimbly and appropriately respond to changing conditions and that is equitable and representative of the various needs for water in California* |
| ***Social Benefits and Equity*** | *the health, economic, and equity benefits realized from a well-managed water system, including management of water withdrawal and water renewal* |

## THE CALIFORNIA WATER SUSTAINABILITY INDICATORS FRAMEWORK

The Framework has been developed to assess and monitor progress towards water sustainability through a set of relevant indicators. The Framework uses the structure of a vision-goals-objectives-indicators nested hierarchy (Figure 1). It is organized into a series of steps and each step builds on the previous one. Completing each step leads to subsequent steps and all steps are necessary for a full evaluation of

water sustainability. A sequence of steps begins with developing vision, goals, and objectives (going from left to right), identifying indicators for each objective, evaluating indicator condition relative to reference conditions, and reporting indicator conditions to inform knowledge development and policy decisions. Thus indicators can be used to assess and monitor achievement of objectives and progress toward goals.

Specific geometric shapes are used in the Framework (Figure 1) to illustrate a group of related activities, stakeholder interaction, or process outputs. The steps used in the Framework are represented by rectangles, while the inputs to the various steps in the form of modeling, data, and analysis are represented by parallelograms. The agency interaction, input, and feedback in the development of vision, goals, objectives, and indicators are represented by circles, while how assessment of indicator performance may relate to agency mission and public education and influence public policy and decision making are represented by ellipses.

The foundation of the Framework is a set of sustainability goals and associated objectives. The water sustainability goals and objectives included in the Framework derive their meaning and much of their text from the California Water Plan statements of intent as reflected in its goals, objectives, and resource management strategies, but attempt to make clearer connections with the idea of sustainability across ecosystem, social system, and economic system. Thus the Framework can be used to evaluate whether advancing the goals, objectives, and resource management strategies of the California Water Plan leads towards sustainable water management in California. The eight sustainability goals of the Framework and the associated objectives are shown in Table 2. Indicators were selected for each goal and objective to evaluate condition and trend including equity and effects of climate change.

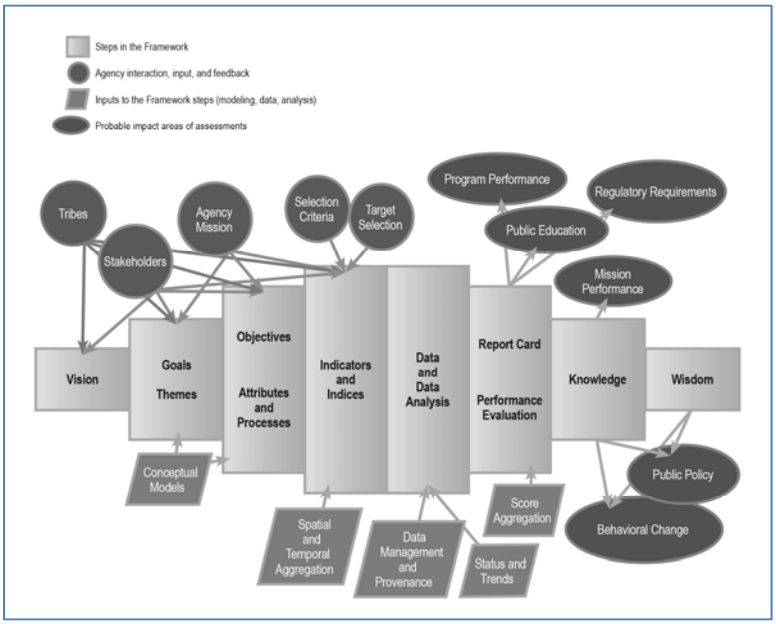


Figure 1. The California Water Sustainability Indicators Framework

**Table 2. Sustainability Goals and Objectives for California Water**

| Goals | Objectives |
|---|---|
| 1) Manage and make decisions about water in a way that integrates water availability, environmental conditions, and community well-being for future generations. | *Reflects overall goal of sustainability* |
| 2) Improve water supply reliability to meet human needs, reduce energy demand, and restore and maintain aquatic ecosystems and processes. | *Improve water use efficiency; Increase water recycling; Increase water conservation* |
| 3) Contribute to social and ecological beneficial uses and reduce impacts associated with inter-basin water transfers and to the Sacramento-San Joaquin Delta. | *Improve regional water movement operations and efficiency; Investigate new water technologies; Protect ecosystem services and benefits provided by an intact and naturally-functioning Delta.* |
| 4) Increase quantity, quality, and reliability of drinking water, irrigation water, and in-stream flows | *Increase conjunctive management of new and recycled water from multiple sources.* |
| 5) Safeguard human and environmental health and secure California water supplies | *Protect and restore surface water and groundwater quality; Protect the natural systems that maintain these services.* |
| 6) Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes. | Practice, promote, improve, and expand environmental stewardship. |
| 7) Integrate flood risk management with other water and land management and restoration activities. | *Improve land-use/cover to reduce flood risk; Improve floodplain-channel connections.* |
| 8) Support decision-making, especially in light of uncertainties, that support integrated regional water management and flood and water resources management systems. | *Improve and expand monitoring, data management, and analysis.* |

Source: California Department of Water Resources 2012.

**Testing the Framework**

Water planning and management in California is conducted at local, regional, and state scales. The Framework is undergoing testing at various spatial scales as a proof of concept and to determine whether there are scale-dependencies in the Framework. Update 2013 will include analysis of a finite set of indicators that can be applied across all 10 hydrologic regions in the State to test the Framework at a statewide scale. In addition, Update 2013 is applying the Framework in a pilot study with the Santa Ana Watershed Project Authority (SAWPA) and its constituent agencies to identify regional specific goals, objectives, and sustainability indicators. The SAWPA pilot study will try to address the following questions:

1) Does the existing Framework function at the local and regional scales?
2) If regional and local partners make changes, are they still consistent with the Framework?
3) Are new indicators needed that are not included in the broader statewide scale?
4) Are these new indicators potentially useful at the state scale, or for other regions?
5) Do local and regional partners appear willing and able to evaluate sustainability using indicators and an approach that is developed at the state scale?

## INFORMING DECISIONS ABOUT SUSTAINABILITY

One of the great challenges for water management is having access to the right information to support evaluations and decisions. To support the Framework, a decision-support tool (DST) is being developed that provides access to ecological and water use information through mapping, charting, and tabular interfaces. The DST will provide indicator-based evaluation of conditions in California, including background information for each indicator and provenance pathways for the data and calculations that are used in the evaluations. The specific purposes of the DST are to:

1) Report status and trends of water sustainability indicators; capturing the social, economic, and ecological conditions attributable to water sustainability goals and objectives envisioned in the California Water Plan.
2) Enable data provenance so that a user can easily and transparently drill down or roll up data, information, and results for traceability; and
3) Provide policy-relevant planning and implementation information within a decision-analytic environment for decision makers and agency staff and support for public input into planning processes.

The DST under development for Update 2013 will contain several elements, including an ecological footprint and water footprint that have recently been developed for California. These are calculations of the area of Earth and the amount of water, respectively, that are required to support our various economic choices and needs. The DST will also include information about California's ecological

productivity (Plant Growth Index) and water storage (remote sensed groundwater storage). Finally, the DST will provide indicator-based evaluation of conditions in California, including background information for each indicator and provenance pathways for the data and calculations that were used in the evaluations.

## CONCLUSION

For the California Water Plan Update 2013, DWR has teamed with the University of California, Davis and U.S. EPA Region 9 to develop an analytical framework to quantify water resources sustainability indicators for California. The California Water Sustainability Indicators Framework describes indicators that will inform us about water system conditions and relationships to ecosystems, social systems, and economic systems. The Framework is being applied in statewide and regional scale pilot studies to test how water sustainability indicators can help monitor progress towards sustainable management of California's natural and human water systems. Results of these pilot studies will be presented in Update 2013 due to be published in early 2014.

## REFERENCES

(DWR) California Department of Water Resources. 2005. California Water Plan Update 2005. California Department of Water Resources. http://www.waterplan.water.ca.gov/previous/cwpu2005

(DWR) California Department of Water Resources. 2009. California Water Plan Update 2009. California Department of Water Resources. http://www.waterplan.water.ca.gov/cwpu2009

(DWR) California Department of Water Resources. 2012. The California Water Sustainability Indicators Framework. California Department of Water Resources. http://www.waterplan.water.ca.gov/docs/cwpu2013/ae/sustainability-framework.pdf