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Framework for indicators for science, management and adaptive management in the CALFED Bay-Delta Program

Purpose:

Indicators will be used by the CALFED Bay Delta Program to:

- Inform progress towards program goals
- Help understand cause and effect relationships between actions and outcomes

Indicators will be used to help answer questions such as:

- Is CALFED meeting program goals?
- Is the system working the way that was expected? (e.g. are the outcomes what were expected?)
- Is CALFED doing the right actions – and the highest priority actions?
- Are their other factors influencing the system that can't be controlled, or hadn't been considered?

Two types of indicators for different purposes: understanding cause and effect, and reporting on progress

To effectively manage the system and help understand cause and effect relationships, indicators should be closely linked with conceptual models that describe and document our current scientific knowledge of how drivers and outcomes are related. A more comprehensive set of indicators at different scales is needed for this purpose. Given the limited resources and the complexity of the issues, a lot of thought will need to go into the selection of these indicators to best understand the underlying mechanisms at work in the region, and to provide support for diagnostic capabilities. This more comprehensive and detailed set of indicators (often at different scales) are intended for a technical audience and will assist in making management decisions and doing adaptive management.

A subset of indicators can be used to assess progress and be selected to answer questions directly related to the goals and objectives of the program. This smaller set of indicators should be derived from the more technically detailed indicators and include discussion of the factors that are most likely affecting the outcome of the system. For example, adult salmon escapement may be used as an indicator to report progress towards recovering salmon populations. To understand the "why" behind this outcome, a much broader suite of indicators is needed, such as proportion of hatchery escapement, age structure of spawning adults, conditions during spawning, rearing and migration, ocean conditions, abundance of juveniles, ocean and inland harvest.

The terms "performance measures" and "indicators" have often been used interchangeably – but this can be misleading. Indicators are a larger group of measurements that help us understand how the system is working. Performance measures are a subset of indicators that can be used to measure the performance of a particular project, program or agency. One difficulty in choosing performance measures,

is that an outcome of particular interest (for example, returning salmon populations) may be affected by many different factors: some that may be influenced by management actions, and some that may not.

Evaluating outcomes using indicators and performance measures should be part of a periodic program assessment. The program assessment should also evaluate the broader process of adaptive management. Adaptive management includes incorporating the latest science into management decisions, evaluating the effectiveness of management actions, and adjusting planning and policy based on new information.

Basic framework: types of indicators and how they can be used:
Below is a description of some general levels of indicators, and a conceptual model of how indicators relate to management, science and adaptive management. This basic framework or approach can be used by the program elements in the development of appropriate indicators.

Types of indicators:
The basic framework includes 3 general levels of indicators:

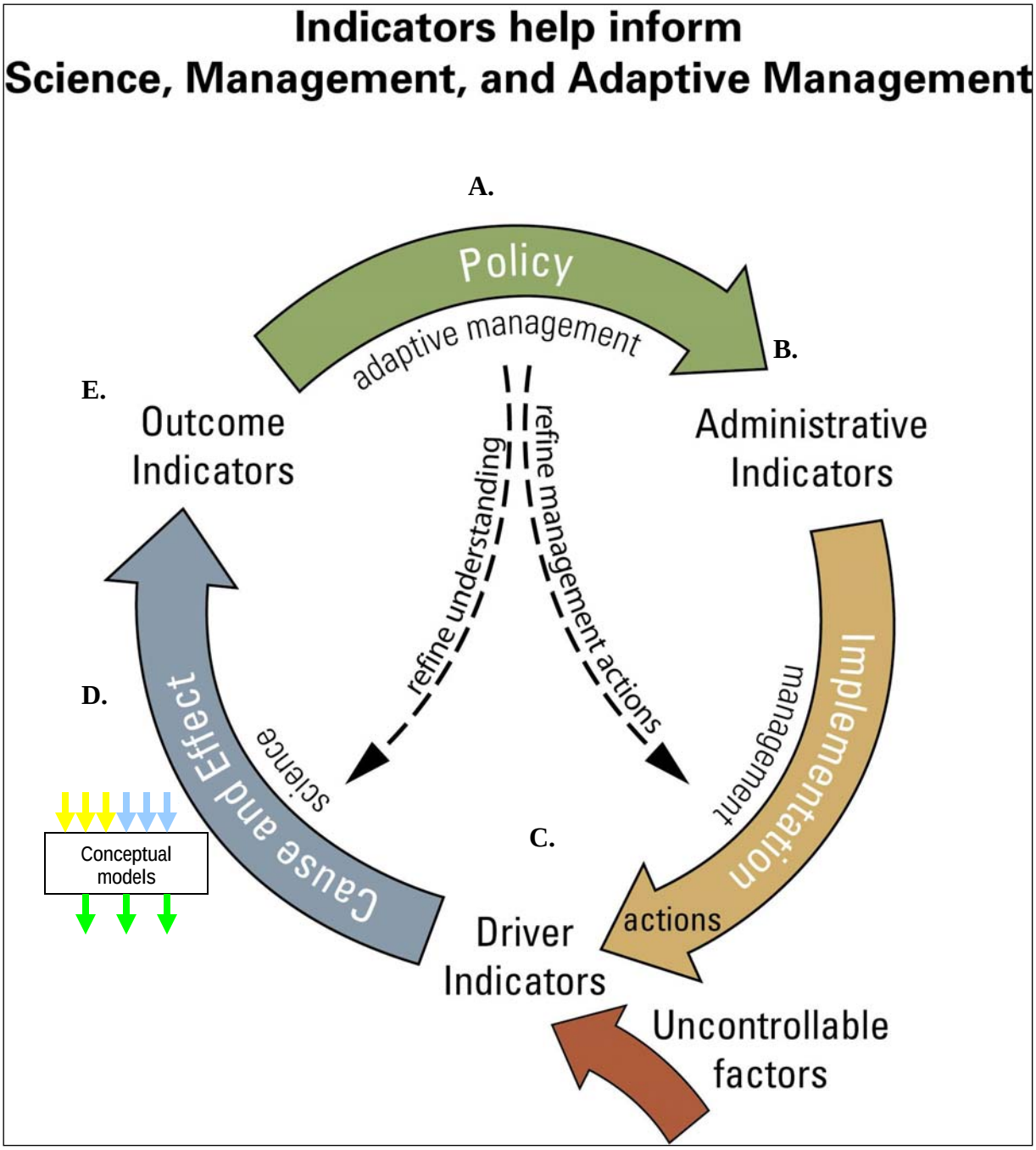
1: **Administrative indicators**. These describe what resources (funds, programs, projects) are being implemented (or plan to be implemented).
Example: Dollars spent, number of projects implemented

2: **Driver indicators** (can also be called "pressures," "management actions" and "other factors"). This class of indicators describe the factors that may be influencing outcomes and may include on-the-ground implementation of management actions (acres of habitat restored) or other uncontrollable factors not directly related to management actions (population growth, weather and hydrologic fluctuations, climate change).

3. **Outcome indicators** (can also be called "response," "ecosystem status or state" or "results" indicators). This class of indicators describe measurements related to the ultimate outcome of the drivers – and should be closely related to the goals and objectives of the program. Examples: For water quality, indicators may include measures of public health protection for tap water and cost of treatment. For water supply reliability, indicators may be related to the ability of supply to meet demand. For ecosystem restoration, indicators can be population level of key species, diversity indices, or other indicators of ecosystem status and processes.

These categories are flexible so that the framework can be more easily adapted to the different program elements within CALFED. The distinctions between the categories are not rigid. In some cases, an "outcome indicator" for one purpose, may become a "driver indicator" for another purpose.

How indicators can be used to link science, management and adaptive management
Indicators can be an integral part of informing policy decision making, tracking implementation, and helping to improve our understanding of how the system works.



The diagram above describes the relationship between the 3 different levels of indicators and the activities of managing a complex system in the environment.

A. Policy decisions are made based on a desired outcome, as described in the goals and objectives of the program.

B. Administrative indicators can be used to track the financial resources allocated to address the problem, documenting how funds are spent. Management oversees implementation of the policy decisions – essentially turning financial resources into on- the-ground actions.

C. These actions may result in physical changes to the environment, such as levee maintenance or habitat restoration. **Driver indicators** are used to track these physical changes due to management actions (often called "outputs"). However, there may also be other "uncontrollable factors" in the environment that also affect an outcome of interest. Driver indicators can also track the "uncontrollable factors" so that we can better understand how these multiple drivers interact and affect an outcome of interest. For example, enhancing urban water use efficiency is a management action related to reducing demands on water supplies. The amount and form of precipitation in California is an "uncontrollable factor" that also affects an outcome of water supply reliability. Both precipitation and water use efficiency may be used as driver indicators for the outcome of water supply reliability.

D. Science can help explain and document the relationships between drivers and outcomes, which are often quite complicated. Most management actions are taken with the intention of a specific outcome in the environment.

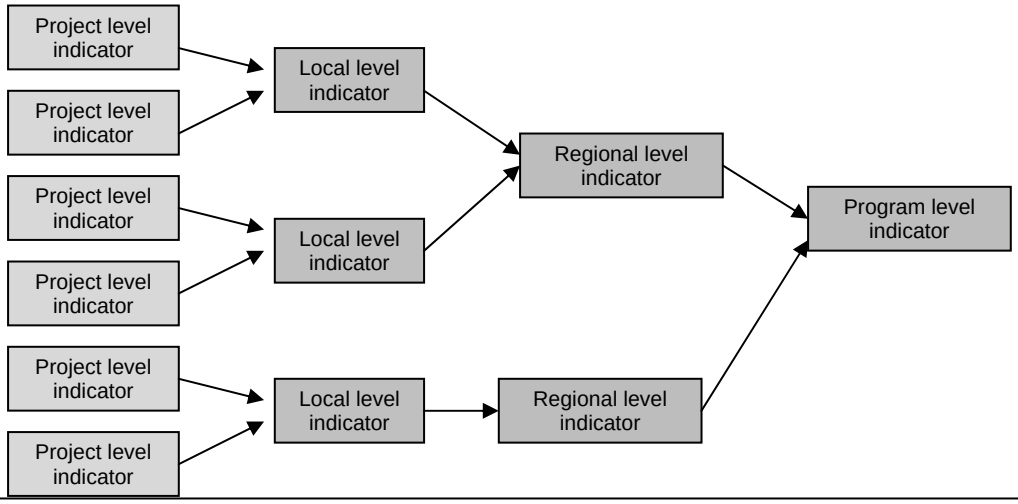
Conceptual models and quantitative models can be used to develop, refine and document a common understanding of the system, including assumptions about intended outcomes from actions. Conceptual models can provide a basis for incorporating new information and continually improving our knowledge of the system. Scientific research and monitoring of indicators play a critical role in understanding "cause and effect" relationships.

E. Outcome indicators need to be closely related to the goals and objectives of the program to help inform progress toward goals. Outcome indicators can also be used to evaluate the effectiveness of management actions and help refine our understanding of how the system works, or in other words – can be used to inform adaptive management.

Indicators at different scales

These classes of indicators can be used at many different scales. In developing indicators, it is important to consider how indicators at smaller scales can be combined or aggregated to inform larger scale decision making. This will be a challenge for all of the program elements to consider. Figure 2 is a basic diagram depicting indicators at different scales and how they relate to one another. For example, indicators for salmon in a particular reach of a river may be combined and summarized to inform understanding about the entire river. Data on indicators from several rivers (Feather, Yuba, American) may be combined to describe salmon populations for all of the Sacramento River Region. Data on indicators from both the Sacramento and San Joaquin may be combined to describe the status of salmon populations for the entire Central Valley.

Figure 2: Indicators and conceptual models need to be appropriate for the scale being studied – and be able to "roll up" to inform larger scales.



Policy decision makers decide on desired outcomes and on the resources allocated to achieve them

Policy decision makers look at the "current state" of the system or environments and develop goals and objectives related to a "desired outcome." For the CALFED Bay Delta Program, the mission is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system. The "desired outcome" is described in the 4 program objectives:

- Provide good water for all beneficial uses
- Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.
- Reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system.
- Reduce the risk to land use and associated economic activities, water supply, infrastructure and the ecosystem from catastrophic breaching of Delta levees.

Policy makers decide on the resources to be directed toward achieving the desired outcome. These resources may include bond funds, general funds, programs and personnel. Policy makers also decide on a course of action to achieve the desired outcome.

Outcome indicators are used to inform policy makers on the current state and trends of aspects of the system related to the goals and objectives. Administrative indicators are used to track the allocation of resources and how they are spent to address the "problem."

Managers use resources to implement actions
Managers use administrative resources (funds, staff, etc.) to implement management actions, carrying out the course of action decided by policy makers. Hence management is the linkage between administrative indicators (such as dollars) and driver indicators (implemented management actions). Implementation activities might include:

- more detailed allocation of funds
- selecting program priorities and developing solicitations for proposals
- selecting projects and contract administration
- project implementation and performance

When making decisions, policy makers and managers base their decisions on either implied or explicit "conceptual models" of how the system behaves and what expected outcome the management actions will have. Explicit conceptual models can be beneficial for management decision-making because they can:

- document the rationale for making a specific decision related to the expected outcome
- allow for multi-disciplinary review and discussion among experts which facilitates better understanding, and reduces the chances of faulty reasoning or unintended consequences
- provide a basis for incorporating new information and improving our understanding of how the system works

It is also important to realize that there is a time lag in order to carry out implementation. A typical time frame for implementation, from fund allocation to project completion, is probably 5 to 6 years. It may be much longer for multi-phase projects, such as a restoration project that includes acquisition, planning, environmental review, and construction. Following construction, it may take many more years before the ecosystem responds with a measurable outcome. For example it may take years to decades before salmon spawning habitat has a measurable effect on returning adult salmon populations.

Science describes cause and effect
The relationship between management actions (measured by driver indicators) and the outcome of the actions is based on assumptions or understanding about the "cause and effect" between drivers and outcomes. The "cause and effect" between drivers and outcomes is informed by science. (The term "cause and effect" is used very broadly here and does not infer that there is a specific documented causal relationship, in a scientific sense.) In choosing to take an action, there is an expectation or assumption of an expected outcome. These choices are based on a current understanding of how the system works or might respond to some controlling factor.

Conceptual models document a common understanding of the system
Conceptual models are a graphic and/or narrative description of how we believe the system works and how the outcome or response might be affected by the controlling factors (drivers). These conceptual models may also be quantitative or predictive models. Research and monitoring activities are essential to develop and refine conceptual models. To optimize the linkage between drivers and outcomes, the conceptual model should be:

- as explicit and complete as possible, or as needed for the situation
- based upon the best available science
- consider all of the controlling factors, including potential management actions and other environmental or uncontrollable factors that may influence the outcome
- be a basis for discussion of expected outcomes from different management scenarios, including acknowledgement of uncertainty (lack of understanding) and predictability (uncontrollable and unpredictable factors such as weather)

Some typical frameworks for conceptual models that describe environmental outcomes include the Pressure-State-Response model, or the Driver-Linkage-Outcome model. Either type of conceptual model may be appropriate for linking drivers and outcomes, as may other frameworks.

The Driver-Linkage-Outcome (DLO) framework for conceptual models includes an analysis of all of the drivers, their interrelationship, and how they are likely to affect the outcome. For example, a conceptual model related to salmon life cycle, may include drivers such as: spawning habitat, flow conditions, rearing conditions, lotic food web, ocean conditions, predation, pumps, diversions, impediments to passage and effects of contaminants. Outcomes may include: number of adults returning to spawn, number of redds, etc. DLO conceptual models should discuss the relative magnitude of the linkages (i.e. influence on the outcome) as well as uncertainty and unpredictability.

The Pressure-State-Response (PSR) framework for conceptual models is similar but is a simplified and more linear version that focuses on one driver (pressure) and its relationship to an outcome (state). The PSR model could be considered a simplification or focusing of the DLO model, which may be appropriate in some situations. For example, discharges of a specific constituent causing toxicity in an organism of interest has a simple and linear relationship – it may not be necessary to examine it in the context of a broader conceptual model. DLO conceptual models are necessary to understand outcomes affected by many factors (such as adult salmon returning to spawn), or can provide a broader context for a number of PSR sub-models.

Adaptive management

Indicators can be useful tools for facilitating adaptive management by helping to answer questions such as:

- Are we meeting program goals?
- Is the system working like we expected?
- Are we implementing the right (and highest priority) management actions?

It is critical to monitor and evaluate the response of the system to management actions, as well as other controlling factors that may be affecting the outcome. This evaluation can help identify the need for refinement of the conceptual model, or underlying assumptions in taking management actions, as well as identify a changing system where new and uncontrollable factors may suddenly emerge and affect the desired outcome. If the outcome of management actions (or inaction) is different than expected, then the assumptions (i.e. underlying conceptual model) that the decision was based upon must be

re-evaluated and future management decisions refined. These actions may result in additional resources for research and monitoring to refine the conceptual model. One consideration in this process is the time lag between a management decision, its implementation and the anticipated response of the system. This would give weight to the argument that a fairly comprehensive set of indicators would need to be monitored and quickly analyzed to allow a timely management response to changes in the system.

Using indicators for program assessment:

Indicators are useful and necessary tools for doing program assessment, and can be used as "performance measures." Not all indicators should be considered "performance measures" for the program, since many may be measuring factors that are beyond the program's control, but are nonetheless affecting its outcome and progress. Program assessment should also evaluate whether the program is being effective in implementing actions, and if there are processes being used to evaluate outcomes and do adaptive management (revise conceptual models, revise management actions). Program assessment should consider whether decisions are being made on the basis of explicit conceptual models – and whether those models utilize the latest scientific understanding. In summary, a program assessment should include:

- Evaluation of "performance measures" – indicators at all levels and scales that are relevant to program goals and reflect program activities. There may be some value in identifying quantitative targets or goals associated with specific performance measures.
- Evaluation of whether management actions taken are based on explicit conceptual models of expected outcomes, based on the most current technical knowledge or scientific information. (Are we doing the right things?)
- Evaluation of effectiveness of implementation of management actions (Are we doing things right?)
- Are adaptive management processes working to refine conceptual models and refine management actions in a timely manner?