Water Supply Reliability

Background

The CalFed Bay-Delta Program has four main objectives:

- Improve water quality
- Improve and increase aquatic and terrestrial habitats and improve ecological functions Bay-Delta
- Reduce mismatch between Bay-Delta water supplies and demand
- Improve integrity of delta levee system.

The third objective, reducing the mismatch between water supply and demand, can best be accomplished by improving water supply reliability. While reliability is an intuitively appealing concept, quantifying it can be exceptionally difficult, for both conceptual and logistical reasons. Therefore, CalFed has supported efforts to refine and operationalize[1] the concept of water supply reliability so that it can be consistently monitored and used in decision making. The ultimate goal of these efforts is to provide a consistent framework that will allow the individual CalFed programs to assess the effect of their separate efforts on the overall goal of improving water supply reliability. The following sections draw upon work completed in the initial phases of this work.[2] First, they define CalFed's sphere of influence. Next, they identify and discuss key considerations that must be accounted for in the reliability indicators and metrics that are ultimately developed. Finally, they describe a number of example indicators.

CalFed's Sphere of Influence

Because reliability could in principle be measured throughout the entire delivery system, it is important to define the boundary, or sphere of influence, within which CalFed is attempting to develop indicators of reliability. This sphere of influence includes three segments:

- Federal and State Water projects (SWP and CVP, respectively, and "Projects" collectively)
- The interface of the Projects with watersheds
- The interface of the Projects with traditional enduse water consumers (or "endusers").

The Projects include operation and expansion of physical facilities (particularly conveyance and storage facilities) as well as institutional mechanisms (e.g. the Environmental Water Account and water transfers). At many points, the Projects take and manipulate water from watersheds. The amount and timing of water draws by the Projects can have important impacts on the ability of such watersheds to support both human and ecosystem uses, impacts that can be increased or decreased by CalFed policies and actions. Finally, the Projects deliver water to traditional wholesale municipal, agricultural, and commercial endusers. While, for any given enduser, water from the Projects is but one supply source, CalFed's water use efficiency program may

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1 Once defined, reliability must be operationalized. This means:(a) determining the indicators and metrics for measuring reliability, (b) determining reliability standards (for both operating and planning), and (c) designing and establishing reliability monitoring and management mechanisms.

2 This first phase was aimed at (1) providing a framework for investigating water supply reliability and (2) describing how reliability is currently defined and considered in water management activities in California.

significantly affect endusers' water supplies by, for example, reducing peak levels of demand or helping to extend available supplies.

Defining Water Supply Reliability

The uninterrupted stream of drinkable water that flows from an urban consumer's faucet is, perhaps, how most people perceive and understand water supply reliability. Consumers may also experience the failure of this supply as the absence of reliability. In either case, water supply reliability has become an expected part of modern urban living. Similarly, perceptions of reliability are common to other types of demand / supply contexts and engineers have formalized this perception as follows:

> Reliability is the probability that a system does not fail, or conversely, it is the probability of system failure subtracted from one.

In the utilities fields, this is more generally stated as a measure of a utility's ability to deliver uninterrupted service.

All systems, whether natural or human, fail, and they do so for any number of reasons, including structural inadequacies, natural causes exceeding the design parameters of the system (e.g., droughts and floods), and human causes such as population growth that raises the system's demands above its capacity.[3] Thus, reliability is conceptually related to the probability of system failure, and the rate, occurrence, and consequences of failure can be measured in several different but related ways, depending on the needs and relevance of the particular situation. For example, it may be useful to express and characterize the expected length of time between successive failures (i.e., time-to-failure), similar to the notion of a 100-year flood event, an event that is expected to occur on average once in 100 years. Or, as another example, it may be useful to track the number of outages or failures to meet supply commitments. Whatever set of definitions is selected, they must incorporate the processes that affect and/or control water supply as well as the needs and perceptions of endusers.

While reliability is frequently invoked in the planning and operations documents, trade literature, and water forums across the state, it:

- Is often not formally defined by agencies, institutions, or academic disciplines
- Is certainly not consistently defined across those entities
- Concerns are incorporated into different water management entities' operating and planning processes with substantial variation
- Is often considered in qualitative rather than quantitative terms.

Thus, there is no existing and widely accepted framework of definitions and measurement approaches that are applicable across the full range of CalFed's sphere of influence.

Key Considerations

Reliability at key points within the CalFed sphere of influence ultimately depends on the complex interactions of a web of rights, regulations, laws, and rules that affect all institutions that manage water in the state. It will be necessary to understand these interactions in order to develop

[3] The concept of reliability can be confused with other similar but distinct concepts, such as sustainability and vulnerability.

meaningful definitions of water supply reliability and, based on these definitions, related indicators, and metrics for CalFed. These interactions play out across numerous dimensions that include, primarily:

- System scale and complexity
- The specific management function (i.e., operations, planning)
- The purpose of the service, i.e., the intended use of the water.

A major determinant of how reliability is defined is the scale or slice of the water industry that is being addressed. Discussions with water professionals and a review of the literature indicate that differences in system scale (i.e., the boundaries of the system) will have a significant influence on how reliability is defined.[4] Scale can be system-wide, regional, watershed-specific, or local. The main categories of scale, from smaller to larger, are:

- Water distribution system
- Urban water and irrigation districts
- Watershed
- State and federal water projects
- Statewide.

These categories of scale combine geographic, hydrologic, and institutional dimensions and their respective boundaries do not always coincide. Scale is also a function of complexity, in terms of both the number and interconnections of components (e.g., a single component such as a reservoir versus a system such as the combined CVP/SWP network) and the mix of engineered infrastructure and natural elements. As complexity increases, many of the more straightforward engineering concepts and tools for measuring reliability become inadequate. At present, the largest scale at which water supply reliability is operationalized to any extent is in the Projects, which consider reliability in both daily operations and planning for system expansion.

At any given scale, the relevant management function also influences how reliability is defined. Two critical functions in the water management arena are operations and planning. In public utilities, operations and planning functions tend to proceed in parallel and are often not fully integrated. In operations, the focus is on achieving specific goals within short time frames (hourly, weekly, monthly) given the existing infrastructure and supplies. In planning, in contrast, planners determine how to match supply and demand in the longer term through a combination of measures that restrict demand and others that expand supplies and/or infrastructure. While reliability is typically a key goal for both operations and planning, their different timeframes lead to somewhat different definitions and measures of reliability. An important part of CalFed's ongoing work on developing indicators of reliability is thus a further examination and comparison of how reliability is conceived and used in these two contexts.

Water uses have historically been divided into two main categories: consumptive uses and in-stream flows or ecological uses. Consumptive uses have historically been the primary focus of agencies charged with managing water supply. The building and operation of reservoir and transportation systems (e.g., SWP and CVP) were undertaken for the sole purpose of collecting and delivering water supplies from where they naturally occur to human settlements to augment the local and regional water supplies for urban, agricultural, and industrial purposes. Allocating water for maintaining ecosystem health and for aesthetic purposes is a more recent development of the last 25 years. While the federal and state water projects have reflected this direction in their

4 Additional work is required to systematically characterize differences in responses to these six questions as a function of scope.

operations and planning activities, the application of reliability concepts to environmental uses appears to lag behind the application of reliability concepts to consumptive use. Water supply reliability indicators and metrics must therefore be developed to monitor the reliability of both types of service.

Example Water Supply Reliability Indicators and Metrics

No single indicator can adequately measure and communicate all critical dimensions of reliability. Multiple indicators are needed, many of which will be strongly interrelated due to the network characteristics of the water supply system. Some indicators will be more useful for monitoring supply reliability for certain types of service (e.g., residential/municipal vs. environmental) or for different functions (e.g. real-time operations vs. policy development). The following paragraphs discuss a variety of features that could distinguish reliability indicators.

Different Levels of Breadth or Focus: Some indicators will require greater breadth, reflecting the effects of many factors, while some will be more narrowly focused to isolate a particular factor or reflect a certain system scale (e.g. combined operation of SWP and CVP vs. the SWP alone). Operations functions are particularly concerned with having indicators that measure reliability in terms of the factors under their control, in addition to broader indicators dominated by actual inflow levels. Some of the dimensions of breadth or focus are:

- Type of service: Clearer definitions of the services currently provided to different endusers (e.g., consumptive, environmental, inflow) would facilitate the development of indicators and metrics. In other industries, service is often described or defined by specifying requirements related to purpose of use, quantity and temporal/geographical distribution of deliveries, and quality and delivery curtailment provisions.
- Temporal scale and distribution: e.g. hourly, monthly or annual
- Spatial (or geographical) scale and distribution: The scale refers to, for example, storage data is aggregated to the combined Project level or is disaggregated at the individual reservoir level.
- Climate normalization: For available supply indicators, both metrics that are normalized for climatic variability and those that aren't will be valuable to CalFed. When normalized, metrics will reflect how efficiently the existing storage and transportation system is being used. When not normalized, reliability of the system including the biggest failure in supply availability or inflow is tracked.

Condition and Outcome Indicators/Metrics: Factors that affect reliability can be translated into indicators of reliability, for which metrics can be crafted. "Indicators are statements of what is expected to change if the program shows progress towards the objective, or if problems begin to arise."[5] Indicators may identify outcomes, or conditions and features that are believed to influence outcomes. Indicators of condition can provide insight into the mechanics of reliability and may be components of outcome indicators.

Physical and Financial Indicators/Metrics: Reliability indicators that reflect physical phenomena such as the supply delivered or allocated need to be paired with financial indicators that describe the costs associated with reliability as the level of those physically-based indicators change. It is important to monitor cost in order to develop policy positions on the desired level of reliability, and to answer questions about the cost of different possible levels of reliability.

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[5] Luoma, Samuel N., Status of the Development of Performance Measures for the CALFED Bay-Delta Program, Presentation to ISP November 2001.

Forecast versus Actual: Some outcome indicators could compare actual to forecasted or expected/desired service dimensions. Some metrics might utilize forecast data while others may reflect what has actually happened. For example, one measure of reliability at the Project level may be the initial monthly allocation to contractors (developed in the first quarter of the water year) relative to the final allocation that is produced in the third quarter of the water year (summer). For some customers (e.g. agricultural), the closer these values are, the more reliable Project supplies are to them. Further, for indicators/metrics that embody forecast values, the dependency of the outcome on the nature of the forecast must be carefully considered. For example, for metrics that involve the allocation as a measure of supply, the degree of conservativeness in the runoff forecast will influence the values of the reliability metric. In other words, the less risky (more conservative) the Projects are in the inflow forecasts that are the basis of allocations, the more likely they will be to actually meet that allocation.

Deterministic and Probabilistic Indicators: Both deterministic metrics as well as probabilistic metrics (discrete probabilities or probability distributions) will be useful.

Quantitative and Qualitative Indicators/Metrics: Some metrics will be quantitative while others will be qualitative (e.g. those related to institutional failures).