Section 7
Implementing Under Uncertainty

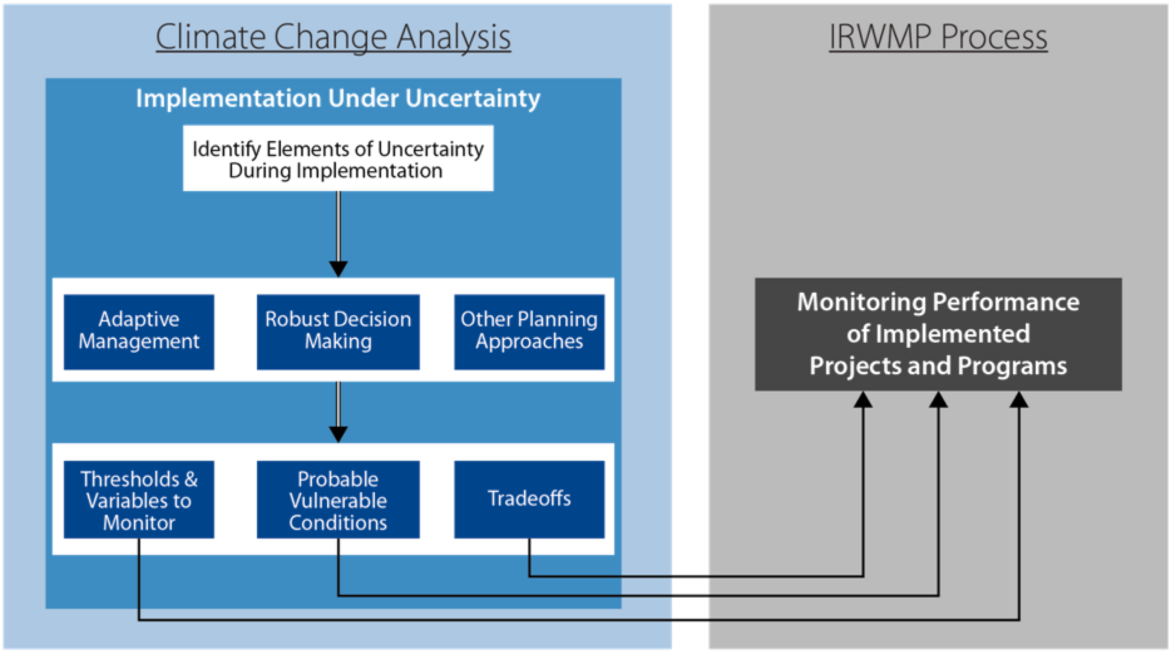


Figure 7-1. Process for Implementing Under Uncertainty as part of an IRWMP.

Section 7 focuses on relating overall decision making strategies with the handbook's decision-support framework. As uncertainty permeates every aspect of the planning process, the overall planning strategies discussed in this section apply to each section in the handbook. Figure 7-1 depicts options for incorporating uncertainties into climate change planning and the ways that uncertainty is linked into the IRWM planning process. This section describes Adaptive Management, Robust Decision Making (RDM), and other related approaches including Decision-Scaling. There are other approaches described in the literature, and planners are encouraged to use planning strategies that fit their regional priorities.

This section focuses on the following areas:

- The steps necessary to apply each approach.
- The relative strengths and limitations of using each approach in the IRWM process.
- Relevant case studies or example applications from the literature.

The approaches discussed in this section influence activities in all other sections of this handbook, as they constitute overarching themes in incorporating uncertainty, including climate change, into the planning process.

Uncertainty is not a new concept, but the uncertainty associated with climate change is often large and difficult to quantify. This fact, however, should not be considered an insurmountable obstacle that forces planners to use a simplistic qualitative analysis. The approaches discussed in this section are especially applicable for systems where uncertainty is high, and sometimes ambiguous, and are useful to develop plans that are still sufficiently quantitative and technically well supported.

Uncertainties in planning are driven by different aspects of the planning process. Some uncertainties are associated with the future state of some variables for which historical records are not a guide or not sufficient (such as GHGs in the atmosphere). Other uncertainties are associated with the future value of a probabilistic variable (e.g., precipitation or temperature). Yet, another type of uncertainty is associated with the ability of planners, scientists, and engineers to accurately model or simulate the environmental variables of interest (i.e., model uncertainties). Appendix C discusses these kinds of uncertainties and presents a discussion on probabilistic methods to address them.

Uncertainty associated with projecting future conditions is expressed in different ways, depending on the variable: assigning a probability to a potential future conditions, or developing a set of scenarios. Both of these approaches are discussed below and in Appendix B.

7.1 Techniques for Managing Climate Change Uncertainty

Uncertainty should be a key consideration of most IRWMP activities, from defining and prioritizing objectives to evaluating projects and project portfolios. There are several strategies for planning under uncertainty, and many are not mutually exclusive. This section discusses the following strategies:

- **Robust Decision Making:** This method involves using performance metric evaluations to identify tradeoffs associated with the various project options and objectives. With the tradeoff information, hedges can be developed from which realistic portfolios can be identified. Iterations are often involved in which portfolios are reevaluated collectively, fine-tuned, and evaluated again (Water Utility Climate Alliance (WUCA), 2010).
- **Adaptive Management:** This method consists of identifying and monitoring the most important uncertainties and translating them into risk triggers or early warning indicators. The values of the variables that constitute early warning indicators can be established deterministically (e.g., a threshold) or probabilistically (e.g., frequency by which a level is exceeded). Adaptive management constructs a flexible path with actions to take when specific triggers occur. This approach is gaining more popularity because the future cannot be accurately predicted (MWD 2010, CDM 2007, DWR 2010a).
- **Other Approaches:** There are many methods for incorporating large uncertainty into the planning process, some of which are variants of RDM and adaptive management. Traditional scenario planning and decision-scaling are among the other methods discussed.

7.2 Robust Decision Making

The main focus of RDM is to select options that are resilient, or that achieve desired results in multiple future scenarios. A RDM strategy can sometimes be in contrast with classic decision analysis, where the set of options that performs most optimally under the most probable future scenario is selected (WUCA 2010). Contrasts may result where alternatives that are optimal for the most probable scenario can perform poorly in other future scenarios (CCSP 2009). Therefore, RDM is ideal for conditions with large, and often unquantified, uncertainty. The CWP includes RDM as a way of managing risk (DWR 2010a).

RDM consists of using project performance metric values, evaluated under several climate scenarios, to identify vulnerable conditions and tradeoffs between alternatives. By plotting the performance of different project portfolios under multiple future climate conditions RDM helps identify project portfolios that perform well under expected or average future conditions, but also perform well under unexpected future conditions. This information is then used to select a set of preferred projects that perform well under several future scenarios i.e., "no regrets" strategies.

7.2.1 Elements of RDM

The RDM process helps select among well-performing projects and programs, and can be incorporated into Strategy Evaluation (Section 6 of the handbook).

7.2.1.1 Identifying Vulnerable Conditions

RDM consists of identifying conditions where the best-performing project alternatives do not perform well. Portfolios of preferred project combinations are subjected to scrutiny for potential vulnerabilities. This analysis would fit well in the evaluations process discussed in Section 6 of this handbook.

RDM relies on performance metrics to determine the most "vulnerable" scenarios. This process is made easier by selecting:

- A wide variety of future scenarios that includes as many potential future conditions as possible, and
- Combinations of initial projects, and project portfolios, which push the boundaries of planning objectives.

After performance metrics have been evaluated for individual potential projects and integrated projects, it is useful to then group the better-performing projects into portfolios, as discussed in Section 6. Initial portfolios can be developed for evaluation in RDM, as a means of identifying vulnerable conditions and tradeoffs between meeting various performance metrics. These initial project portfolios need not be final sets of selected projects. Pasadena Water and Power

(PWP) developed an initial round of portfolios with the goal of "pushing the boundaries" of specific planning objectives in their Integrated Resources Plan (CDM 2011).

Performance metrics are evaluated on preferred project portfolios, typically using a large number of scenarios (WUCA 2010, NAS 2010b, Brekke et al 2009). Scenarios are identified that yield the worst performance for the generally best performing strategies. For example, IEUA worked with RAND Corporation to identify specific events that would cause their existing plans to fail (i.e., not provide enough water). This process involved using a WEAP model developed for the IEUA water supply system, and applying several future climate scenarios in order to identify specific vulnerable conditions. Conditions included combinations of factors like simultaneous decreases in precipitation, groundwater infiltration, and imported water supply (NAS 2010b).

7.2.1.2 Identifying Tradeoffs

If the scenarios yielding poor results (i.e., "vulnerable" conditions) are considered probable, then additional strategies and projects may need to be considered. At this point, tradeoffs need to be identified and iteration may take place. Identifying tradeoffs is the best way to prepare for multiple futures simultaneously (NAS 2010a). Tradeoffs are essential for addressing multiple stressors, which prevents "maladaptation" (i.e., adaptation that results in more harm than good).

RDM evaluates projects that perform well under "vulnerable" conditions for tradeoffs. Some projects that perform well under stressful conditions do not perform the best in "expected" future conditions. This tradeoff needs to be quantified to inform option selection. Where possible, identifying a probability associated with the "vulnerable" scenario helps this decision process. Listing advantages and disadvantages for project alternatives also helps identify the tradeoffs involved with their selection (CDM 2011).

Stakeholder involvement is a critical component of selecting final preferred project portfolios, as minimizing some vulnerabilities may involve sacrificing good performance of other performance metrics. Evaluating these tradeoffs does not require a consensus among planners of what the future will look like, but does require a consensus of priorities (NAS 2011). This type of prioritization is consistent with the IRWMP concept of assigning weights to performance metrics.

7.2.1.3 Selecting Optimal Projects and Planning Strategies

There is no formula for selecting final preferred project alternatives in RDM. Decision makers ultimately need to rely on their own set of priorities, combined with their professional opinions of how likely the previously-identified "vulnerable" scenarios are (WUCA 2010). In cases where formal probabilities can be assigned to scenarios, RDM is less subjective. In this way, RDM is useful for uncertainty analysis where some probabilities are known, if not all (WUCA 2010).

RDM is well-suited to planning under climate change because of its flexibility. Probabilistic information can be incorporated in a way that will improve decision making, but is not required for successful planning. RDM is scenario-based, which allows planners to address climate uncertainty through climate scenarios (WUCA 2010).

7.2.2 Strengths and Weaknesses

RDM 's strengths include:

- RDM is useful for systems where uncertainty is difficult to quantify (NAS 2011). It also helps address multiple stressors (NAS 2010a), and promotes portfolio diversification (NAS 2011).
- Robust strategies help prepare for surprises, or unexpected events (Brekke et al 2009).
- RDM is able to maximize any uncertainty information that is available, without requiring information that is not available. For scenarios with combinations of uncertainty types, RDM allows uncertainty associated with individual events, such as population increasing by a certain amount over a given time period, to be evaluated. (WUCA 2010).
- RDM's flexibility in addressing uncertainty is well suited for collaboration among stakeholders, as it does not require agreement regarding the exact likelihood of future events. In addition, it has been shown to help decision makers feel more comfortable with their decisions regarding climate change (Feifel 2010).

There are also limitations to using the RDM technique:

- If quantitative probabilities are not associated with the scenarios used in RDM, choosing vulnerable scenarios to plan for is a subjective decision, and is largely influenced by individual perceptions of risk (CCSP 2009). This subjectiveness is complicated by uncertainties that are difficult to quantify.
- Another limitation is the need for resources to conduct the in-depth analysis. Identification of tradeoffs is greatly facilitated by having a large number of scenarios. For example, RAND Corporation used four scenarios in an initial RDM analysis and expanded their analysis to include over 200 scenarios (Feifel 2010). This type of in-depth analysis may not be practical for regions with limited resources.
- Not necessarily a limitation, but an important consideration in the application of this approach, is the fact that the technical analysis needs to be supported by a well-defined and robust decision-making process and, potentially, a decision-support tool. As the number of scenarios increases, the information available to make better decisions increases but the *ability* to make decisions decreases, given the difficulty of interpreting all the data. A decision-support tool can help organize and interpret data, but the development of such a tool requires additional resources.

7.3 Adaptive Management Planning

The adaptive management concept is well-known among water resources practitioners and frequently applied, at some level, in water resources projects. The adaptive management process generally includes elements of either scenario planning or probabilities analyses, or both. The key to the process is a formalization of a plan for performance monitoring and project reevaluation in the future. In other words, the process recognizes the inherent uncertainties in water resources planning, and structures an adaptive strategy that responds to new information. For this reason, adaptive management is particularly well-suited for projects that include climate change considerations, where uncertainties are great. As new climate data and model projections become available, adaptive management projects will be able to respond accordingly. The IRWMP Guidelines encourage regions to adopt "policies and procedures that promote adaptive management" (DWR 2010a).

While many variations of adaptive management exist, the fundamental steps related to IRWMP projects, can be summarized as:

1. Identify risk triggers associated with important vulnerabilities or uncertainties,

2. Quantify impacts and uncertainties (this step corresponds to Section 5 and Appendix C of the handbook),

3. Evaluate strategies and define an implementation path that allows for multiple options at specific triggers,

4. Monitor performance and critical variables in the system, and

5. Implement or reevaluate strategies when triggers are reached and monitor system reaction. (Figure 7-2).

Step 2 above is not unique to adaptive management projects; it is a major piece of all IRWMP projects, and has been described elsewhere. Steps 1, 3, 4 and 5 comprise the key elements of adaptive management. Step 1 involves identifying the most important uncertainties and vulnerabilities early in the process, which are then translated into risk triggers or early warning indicators. These triggers are quantified in Step 2 and serve as the basis for the definition of a path for plan implementation in Step 3. The monitoring provides the impetus for project implementation and system reevaluation (Step 5). The reevaluation component of adaptive management has been traditionally the focus of academic work, while in professional practice the project implementation has taken a greater emphasis. Both elements are important in adaptive management: when new knowledge about the state of the system is obtained, actions can be taken in terms of project implementation, but technical analyses can also be conducted or updated based on the new information. The main premise of adaptive management is that over time, we learn more about the water resources system in which the strategies are being implemented. Key to the adaptive management process is continued active participation by stakeholders and a clear understanding of project objectives.

For further details on the adaptive management process, the reader is referred to the proceedings of the American Water Resources Association (AWRA)'s 2009 Summer Specialty Conference focusing on adaptive management. Example applications include Rodrigo and Heiertz (2009) and Adams (2009). The MWD case study at the end of this section (Box 7-1) also provides an example application of adaptive management. The focus of this section is on the use of adaptive management techniques to address uncertainties in climate change studies. Each step of the general process is described further below with particular attention to addressing climate change uncertainties.

7.3.1 Conducting the Adaptive Management Analysis

System vulnerabilities should be identified prior to the adaptive management process. This step is described in detail in Section 4. An identified vulnerability might include instream concentration of a specific pollutant or specific fish species with sensitivity to changes in water temperature. A risk trigger needs to be established for each identified vulnerability to monitor the system's response. Risk triggers can be established deterministically (e.g., a threshold) or probabilistically (e.g., frequency by which a level is exceeded). Risk triggers might include, for example, threshold mean temperatures or annual precipitation levels that fall outside of the historical record used in previous analyses. These new data might allow for recalibration of models describing system response to extreme conditions. Reevaluation efforts would be based on the results of the updated models. Development of a new technology that may implement a strategy in the plan can also be a trigger.

Performance monitoring is critical to the adaptive management process. Monitoring should focus on observed climate fluctuations, how these compare to historical records, and how the targeted system responds to such fluctuations. Monitoring of the state of climate change science should also be an important part of the process. Monitoring should be guided by the identified risk triggers described above.

In setting the risk triggers, it is important that decision makers set them at levels where policies and projects can be implemented before a crisis develops. Reacting to a crisis is not adaptive management. On the contrary, the times for action and reevaluation in adaptive management are set conservatively to avoid the development of crisis.

When and if reevaluation is initiated, all available new information is incorporated into existing tools, and strategies are reanalyzed. This may include an expanded baseline dataset, new climate projections, or changes in uncertainty levels for specific parameters. For example, an existing hydrologic model might be recalibrated for extreme drought conditions if such conditions are observed in the future. This recalibration then might change the results of strategy evaluation and ultimately planning decisions.

Central to adaptive management is the definition of a path with specific actions that managers can take when triggers, or early warning signals, are reached. This is done with quantitative information from the technical analysis of the plan concerning the performance and characteristics of projects. An iterative process may be necessary to define the path. In such a process, the system is quantified (e.g., simulated with models, if available) under different paths to identify the impacts that a given project can have on the system. Figure 7-2 shows an example of an adaptive management path for a typical integrated resources plan.

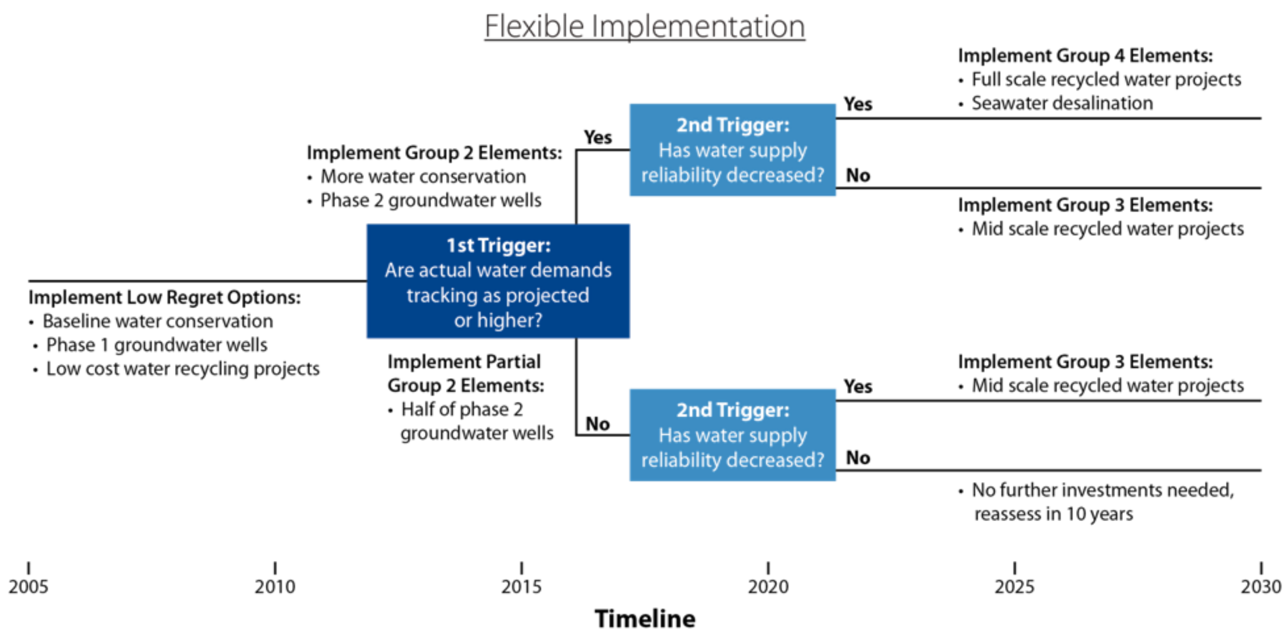


Figure 7-2. Diversity of Options in an Adaptive Management Plan.

7.3.2 Strengths and Weaknesses

The greatest strength of the adaptive management approach lies in its flexible, rather than prescriptive, approach to planning, given large uncertainties. The approach recognizes that all of the information needed to make optimal decisions may not be available now, but may be in the future. As described above, given the evolving science of climate change, adaptive management is a particularly appealing approach for IRWMP projects.

The primary weakness of the adaptive management approach is that it can be more labor intensive and expensive to execute properly compared to traditional implementation processes. It also may require a certain continuum of stakeholder involvement and political support for periods of many years into the future. If such a continuum is not maintained, the process can be compromised.

Two areas that are a challenge in implementing adaptive management, which do not necessarily represent a weakness but can represent obstacles in implementation, are the need for implementation steps that are flexible and "modular," and the difficulty in determining if a trigger has been reached.

Modular implementation: Adaptive management implementation methods are useful under high uncertainty, but adaptive management is harder to implement when the scale of the projects is large, and the magnitude of the actions required to implement the plan is significant. When a diversified portfolio of projects is part of the IRWMP, adaptive management can be more effective. For example, adaptive management would be appropriate if the projects in the plan include decentralized treatment facilities, small scale habitat restoration projects, expandable conjunctive use projects, or reservoir releases.

The strategy in Figure 7-2 shows the great diversity of options included in the plan, which allows managers to take different actions that do not commit the district to any single individual project. Instead, a portfolio of projects is being implemented in phases according to the identified triggers.

Identifying thresholds: The concept of monitoring a variable and identifying the time when that variable reaches a certain threshold is simple and intuitive. In the real world, however, significant challenges exist in defining the state of variables that have uncertainty and natural variability, such as temperature and precipitation. Hydrologic variability presents the same variability characteristics that make it difficult to determine. For example, it is difficult to know whether a drought is beginning or there is just a short dry period that will end soon. Even water demand presents variability from year to year, and a snapshot of water consumption at one moment in time may not be representative of a longer term trend.

Data collection, management, and interpretation need to be part of the IRWMP implementation process in order to be able to identify thresholds for variables that undergo significant inherent natural perturbations. The governance structure defined in a regional plan needs to accommodate the significant task that performance monitoring represents. In the case of climate change, coordination with agencies outside the region (e.g., NOAA) that are better positioned to identify trends and make conclusions about the state of some variables, will be crucial. Access to information from, and communication with, Federal and international agencies and academic institutions that monitor the global climate trends should be a component of IRWMP implementation.

7.4 Other Planning Approaches

There are many decision-making frameworks that incorporate variations of robust and adaptive strategies, including iterative risk management (NAS 2011), decision-scaling (Brown, n.d.), and traditional scenario planning (WUCA 2010). All frameworks rely on stakeholder involvement and engagement. All methods are limited by estimates of uncertainty; planners need to be aware of assumptions made in developing scenario likelihood estimates and the shortcomings of subjective estimates of uncertainty (CCSP 2009).

7.4.1 Decision-Scaling

Decision-scaling applies specific bottom-up planning and analysis methods with concepts from robust planning methodologies. Decision-scaling includes three main steps (Brown, n.d.):

- Bottom-up Analysis: Identification of key concerns and decision thresholds,
- Developing a decision-based climate response function, and
- Estimating relative probability of changing climate conditions.

This type of bottom-up analysis is ideal for adapting to vulnerabilities that are difficult to quantify, such as extreme events like flooding (Cromwell and McGuckin 2010). Many of the general aspects of decision-scaling are incorporated into other parts of this handbook.

7.4.1.1 Bottom-up Vulnerability Assessment

Decision-scaling involves a bottom-up analysis that begins with a decision-driven prioritization of potential climate vulnerabilities, as they relate to planning objectives. The preliminary vulnerability assessment discussed in Section 4 of this handbook involves a similar stakeholder-driven prioritization of climate vulnerabilities and the resulting formation of performance metrics. This assessment could feed into a decision-scaling framework.

Decision-scaling involves developing a "climate-response function" as part of a climate change impact analysis. This is done by conducting a sensitivity analysis (see Section 5) to evaluate a range of conditions that cross a region's tolerance thresholds. This process is similar to the identification of vulnerabilities described in RDM; however, there are two differences: 1) rather than examining a wide array of scenarios, decision-scaling focuses on anticipated vulnerabilities, and 2) decision-scaling does not rely on future scenarios. This type of vulnerability prioritization relative to thresholds and user-based needs is a common aspect of planning (Association of Metropolitan Water Agency (AMWA) 2007, NAS 2010c).

7.4.1.2 Decision-Based Climate Response Function

Section 5 of this handbook lists many options for system analysis methods. Using a sensitivity analysis, conditions where existing or potential plans perform well (or fail) can be identified (Brown, n.d., WERF 2009). Establishing conditions where projects would be preferable aids in the decision-making process. Figure 7-3 shows a sample decision space where Alternative

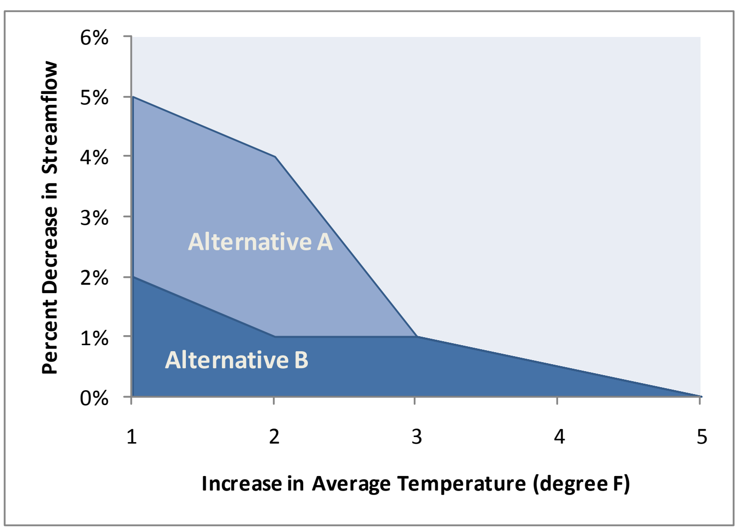


Figure 7-3: Sample Decision Space Showing the Conditions Where Project Alternatives Perform Well.

A performs well under more extreme decreases in streamflow, but not in cases where average temperature increases by more than 3 degrees. Alternative B performs well under most temperature conditions, but crosses a performance threshold where streamflows decrease by more than 2%.

7.4.1.3 Estimating Relative Probabilities

The probability of the selected scenarios is assessed and incorporated into performance metrics resulting from the selected scenarios. Identifying the probability of these scenarios helps planners weight the performance metrics. Appendix C of this handbook discusses ways of estimating probability based on GCM results. Decision-scaling also encourages consultation with local experts. CCSP (2009) recommends caution when basing probabilities solely on individual opinions, as there is inherent danger in being subjective.

7.4.2 Other Related Planning Approaches

Adaptive management, robust decision making, and decision-scaling are not mutually exclusive; as discussed in this section, in many ways they overlap with each other. There are many options for robust decision making and decision-scaling within the adaptive management framework. Similarly, decision-scaling could be used to direct robust decision making. Adaptive management is sometimes thought of as a robust strategy (CCSP 2009), as collectively the project portfolio selected in adaptive management will perform well under multiple future scenarios. The trigger and monitoring framework in adaptive management is a robust way to avoid surprises (NAS 2011).

Deliberation with analysis reflects elements of both adaptive management and robust decision making (NAS 2010c). Deliberation with analysis is similar to adaptive management; it is iterative, encourages stakeholder participation, and relies heavily on performance metrics and monitoring. Iterative risk management incorporates elements of both adaptive management and robust decision making (NAS 2011). It involves reevaluation of strategies as additional data becomes available, and also emphasizes diversification and selecting alternatives that perform well across multiple scenarios.

Robust decision making also overlaps with decision-scaling; the process of conducting a sensitivity analysis to identify thresholds of acceptable performance is similar to the RDM strategy of using a large number of scenarios to identify vulnerable conditions. In both cases, final decision making is facilitated where uncertainties are more easily quantified.

Traditional scenario planning is also similar to robust decision making. It focuses on identifying key uncertainties, and framing future scenarios specifically around these uncertainties. Assessing which projects perform well under more extreme scenarios allows planners to select more robust projects (WUCA 2010). Implications are that projects that perform well under extreme conditions will also perform well under normal conditions.

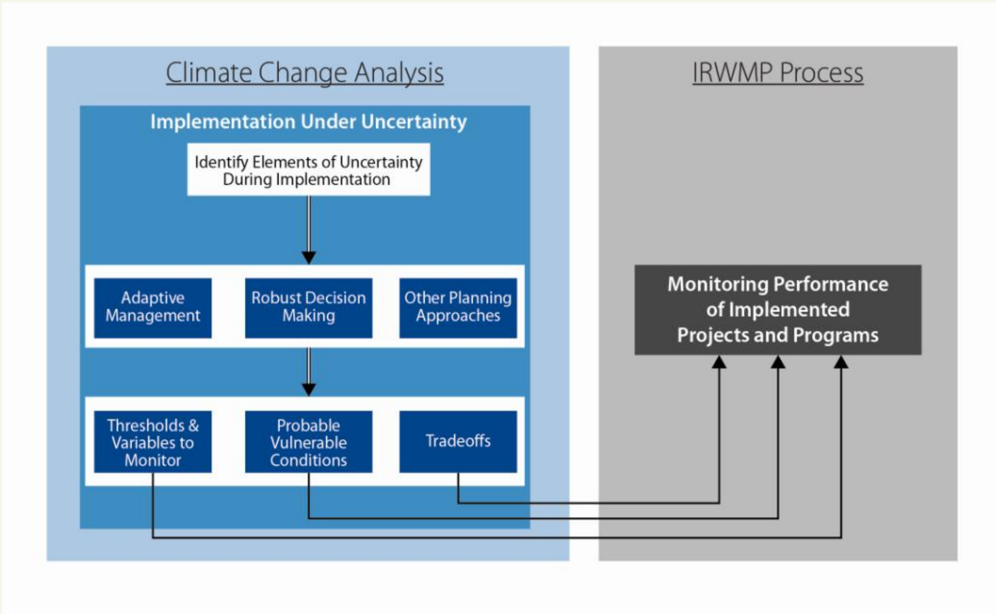
A general reference on decision-support planning methods that can be used in climate change analysis can be found in the Water Utility Climate Alliance's white paper "Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning" (WUCA 2010).

7.5 Planning Under Uncertainty

There are many ways to incorporate uncertainty into the planning process, and variants of these methods are implemented in planning projects regularly. This section focuses on RDM and adaptive management, and also discusses decision-scaling and other planning techniques. While climate change adds an additional layer of uncertainty to water resources planning, it does not necessarily alter the way uncertainty is addressed. The methods discussed in this section, and throughout most of this handbook, are applicable to any planning process. Regardless of which method is used for planning, all plans are limited by data availability and ability to project into the future. The general planning principles of flexibility and robustness are key to planning for climate change.

Case Study: Implement Under Uncertainty

Southern California – Adaptive Management
Metropolitan Water District of Southern California



Background:

- Metropolitan Water District of Southern California (MWD) is a consortium of 26 member agencies. MWD's service area includes portions of the counties of Los Angeles, Orange, San Diego, Riverside, San Bernardino and Ventura.
- Water Sources & Customers: MWD is a wholesale water supplier for 26 water utility districts in Southern California. MWD obtains its water primarily from the Colorado River Aqueduct (CRA) and from the Delta via the State Water Project (SWP).

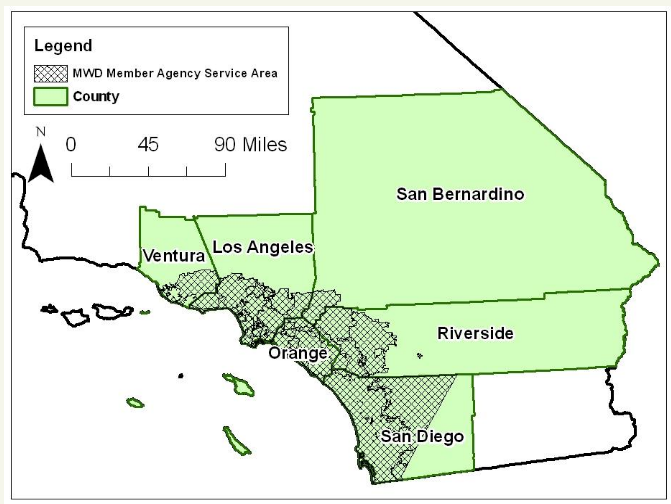


Figure 1: MWD Member Agency Service Areas.

- Planning Setting: MWD has been using adaptive management approaches for several years. MWD's first planning document using adaptive management is their 1996 Integrated Resources Plan (IRP). Updates were made in 2004 and 2010.
- Climate Change Analysis: As part of the 2010 update, MWD conducted a reliability analysis addressing potential climate change impacts along with other uncertainties, and used the results of their reliability study to evaluate and prioritize several management programs.

Box 7-1

- Adaptive Management: Adaptive Management makes sense for the MWD system for the following reasons:
  - Subject to multiple sources of uncertainty
  - High reliance on imported water
  - Desire to keep costs down and reliability up

Adaptive Management involves every step of the climate change analysis process in a cyclical manner. This Case Study summarizes every step of the climate change analysis as outlined in the handbook that MWD has undertaken for the 2010 update of the IRP, in the broader context of Adaptive Management. Because adaptive management is also a cyclical process (Figure 2), this case study refers to work done for the 2010 plan as an *update* from the work done for the 2004 plan.

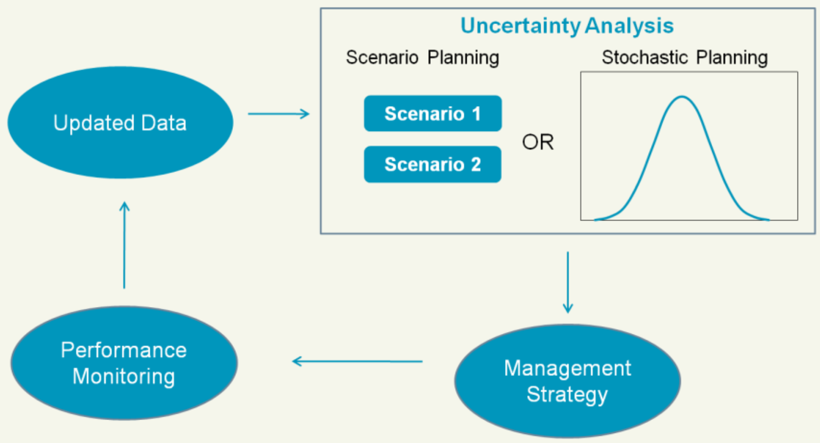


Figure 2: Adaptive Management Framework.

Step 1: Vulnerability Assessment

- Previously identified areas of vulnerability
- Review new literature/data
- Update key sources of reliability uncertainty

Previously identified vulnerabilities (from 2004 update):

- Water quality regulatory compliance risk
- Resource implementation risk
- Increased water demand projections

Update of data/information available for vulnerability assessment:

- Current and projected SWP supplies - CALSIM II model results (including climate change impacts, used 2007 reliability report)
- Current and projected CRA water supplies - CRSS supply model (including climate change impacts)
- Demand projections
- Economy
- Climate change literature

Key Sources of Uncertainty for 2010 update:

- Climate change (impacts on demand and supply)
- Policy/permitting restrictions
- Ongoing drought in Colorado River Basin
- Endangered species protection in the Delta
- Demographic and economic variables

Climate Change potential impacts of concern (from Regional Urban Water Management Plan 2010):

- Demand – increased outdoor residential/agricultural use
- Supply – snowpack reductions
- Supply – sea level rise in the Delta, which could result in pumping cutbacks for SWP, CVP
- Water quality impairments
- Extreme weather events such as drought
- Loss of hydroelectric power generation capacity

Box 7-1 (Continued)

Step 2: Impacts Analysis

- Demand modeling
- Supply gap modeling: IRPSIM Water Balance
- Probability analysis

<u>**Updated Data and Model Projections Since 2004 Analysis:**</u>

- Regional economic, demographic data from Southern California Area Governments (SCAG)
- Water use records
- Supply projections from SWP
- Supply projections from CRA
- Updated Demand data from records and updated projections

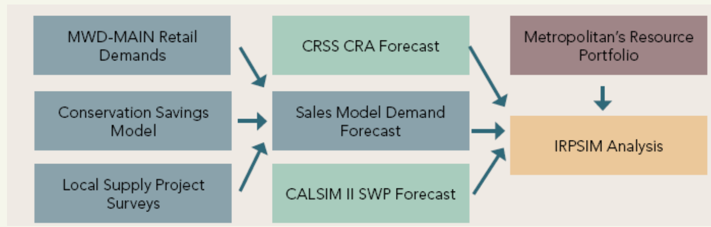


Figure 3: MWD Modeling Suite. Source: MWD, 2010.

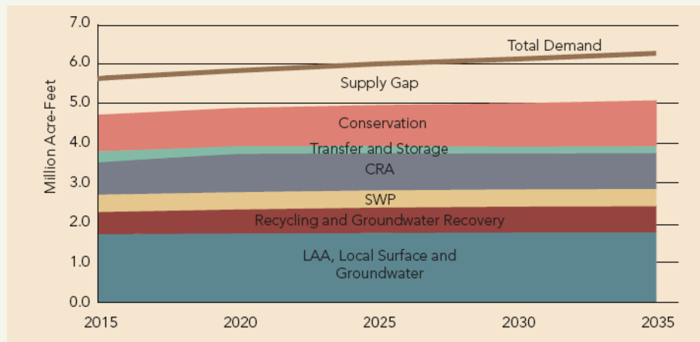


Figure 4: IRPSIM Results: Dry-Year Supply Gap under Existing MWD Resources. Source: MWD, 2010.

<u>**Statistical Demand Modeling: MWD-MAIN**</u>

- Uses historical water use records: trends
- Incorporates economic and demographic projections from SCAG and San Diego Association of Governments (SANDAG)
- Incorporates climate

<u>**Water Supply Modeling: IRPSIM**</u>

- Supplies from SWP
- Supplies from CRA
- Demands
- System Configuration - Current Management Strategy

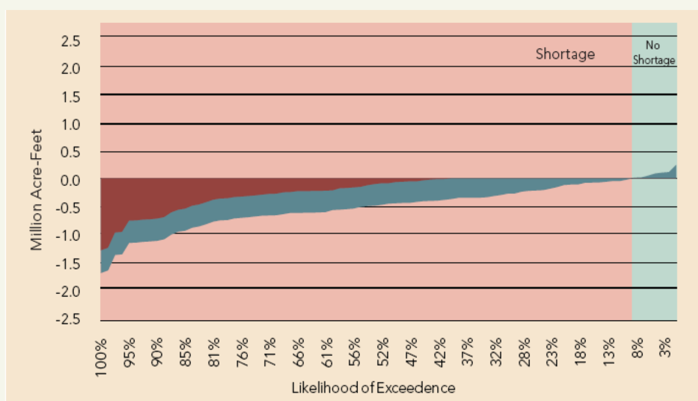


Figure 5: IRPSIM Results: Dry-Year Supply Gap under Existing MWD Resources. Red represents use of storage. Source: MWD IRP 2010.

<u>**Supply Gap Year 2035: Demand - (SWP + CRA + Local Supplies)**</u>

- With Current Resources: maximum shortage of 1.7 MAF
- With Current Resources and Reserve Storage (0.4 MAF storage available for single-year use): maximum shortage of 1.3 MAF

<u>**Uncertainty Analysis**</u>

Run IRPSIM several times with slight hydrologic condition variations based on historical record – generate probability distributions

- With Current Resources: shortage 91% of the time in year 2035
- With Existing Storage Resources (not sustainable source for multi-year use): shortage 59% of the time in year 2035

Box 7-1 (Continued)

Step 3: Evaluate Strategies

- Examine supply gap resulting from different strategies
- Rank strategies

Strategies included in the 2004 plan were evaluated against criteria to create a water portfolio of three tiers: Core Resources, an Uncertainty Buffer, and Foundational Actions. Core Resources comprise "baseline" management programs and activities to prevent the future gap between demands and available supplies. The Uncertainty Buffer is composed of projects that may be implemented should the need arise in the future. Foundational Actions are larger-investment, longer term projects that can be started on an investigative level without incurring extensive costs.

Evaluation Criteria:

1) Flexibility: projects that could be (or need to be) adjusted at a later date are ideal for all 3 tiers in the Water Portfolio below.
2) Cost: higher cost supply projects implemented in more certain needs
3) Time Required to implement:
   a. strategies taking longer to produce supplies were moved to Foundation
   b. strategies that can be implemented immediately were put in the Buffer
4) Current Progress: Strategies already in progress were kept in the Core Strategies
5) Certainty of success: projects with less issues/complications are higher priority project in the final portfolio.

Water Project Portfolio:

Core Resources: "Baseline" Management Portfolio

- Similar to "Preferred Resource Mix" developed in 2004 update
- Resource areas:
  - CRA dry-year programs
  - Mid- and long-term Bay-Delta improvements
  - Facilitate 20x2020 in service area
  - Facilitate additional local supply projects

Uncertainty Buffer

- Minimize costs – only implement when needed
- Monitoring and reevaluation of need is built into plan
- Resource areas:
  - Collaboration with member agencies to achieve 20x2020
  - Local resource programs to be implemented on an *as needed* basis

Foundational Actions: Long-term Planning Actions

- Low cost at first – initial investigative actions are low-investment
- *Prepare* to implement later steps if needed – feasibility studies, research, etc.
  - Monitoring and reevaluation of need is built into plan
- Long-term: timeline for actions going 10+ years into the future before supply is available
- Resource areas:
  - Recycled water
  - Seawater desalination
  - Stormwater
  - Greywater

Box 7-1 (Continued)

Step 4: Implement Preferred Strategies & Perform Monitoring

- Update plan every 4-5 years

MWD developed an Integrated Resources Plan in 1996, which was updated in 2004 and 2010. This plan will continue to be updated as new information, data, and tools are available, and as conditions and needs change. The uncertainty buffer and foundational actions laid out in the water project portfolio require periodic reevaluation.

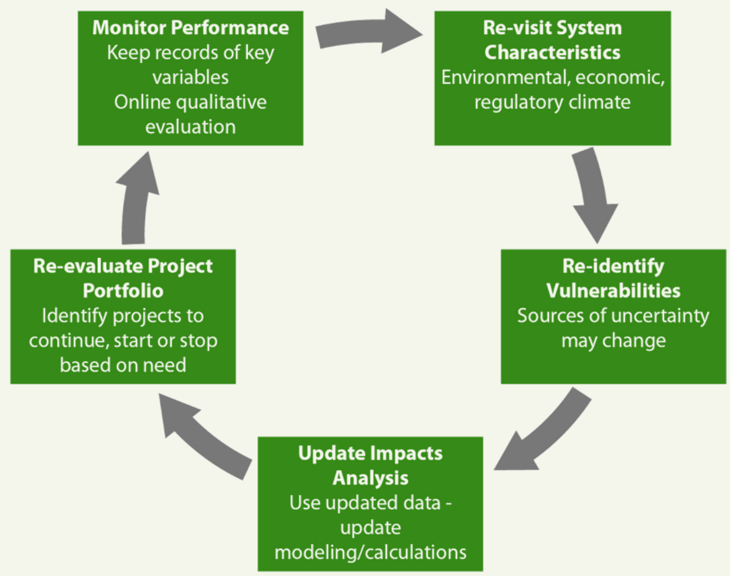


Figure 6: Adaptive Management Cycle Applied by MWD.

For More Information

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Box 7-1 (Continued)

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