City of San Diego Long-Range Water Resources Plan

(2002-2030)

The City of San Diego
Water Department

City of San Diego
Long-Range Water Resources Plan
Citizens Advisory Board

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Abbreviations

AF	Acre-feet
AFY	Acre-feet per year
ASA	Alvarado Service Area
BMP	Best Management Practices for urban conservation
CAB	Citizen's Advisory Board
CDM	Camp Dresser & McKee Inc.
Cfs	cubic feet per second
CWA	San Diego County Water Authority
EPA	Environmental Protection Agency
ESA	Endangered Species Act
Gpd	gallons per day
GW	groundwater
IID	Imperial Valley Irrigation District
MAF	million acre-feet
MSA	Miramar Service Area
MWD	Metropolitan Water District of Southern California
NRC	Natural Resources Corporation
OSA	Otay Service Area
PMCL	Planning and Management Consultants, Ltd.
Ppm	parts per million
RO	reverse osmosis
SDSIM	San Diego Simulation

SLC	State Lands Commission
SWP	State Water Project
TDS	Total dissolved solids
ULFT	ultra-low flush toilet
UWMP	Urban Water Management Plan

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Executive Summary

Executive Summary

Introduction

Background

The City of San Diego (City) has the reputation of being one of the country's most desirable places to live and conduct business because of its climate, economy, and quality of life. It is the seventh largest city in the United States and the second largest in California. Although the City is located in a semi-arid coastal climate, it has successfully provided a reliable water supply to its residents for the last 100 years. The challenge for the City is to continue providing its residents with a reliable and safe drinking water supply into the future, while doing so in a cost-effective and environmentally sound manner.

An outcome of the City's 1997 ***Strategic Plan for Water Supply***, which focused mainly on the development of a capital improvements program (CIP), was the realization that the City should become more engaged in the planning and development of its own water supply in order to become less reliant on imported water. Prior to the strategic planning process, the City had relied almost entirely on the San Diego County Water Authority (CWA) to plan for, and acquire necessary water supplies.

The City's population is currently more than 1.2 million persons. Projections developed by the San Diego County Association of Governments (SANDAG) indicate that the City's population will increase to over 1.9 million residents by 2030. This population growth will translate into water demands increasing from the current 244,000 acre-feet per year (AFY) in year 2000 to approximately 252,000 AFY in 2010 and 297,000 AFY by 2030, under normal weather conditions. The demand projections assume the City continues with its aggressive water conservation program. Demand projections without conservation are expected to be 287,000 AFY in 2010 and 350,000 AFY in 2030, under dry weather conditions.

The City currently purchases up to 90 percent of its water from CWA, a wholesale water agency that provided approximately 600,000 acre-feet per year (AFY) of imported water to its 23 member agencies in San Diego County in 2001. The CWA, in turn, currently gets its imported water from the Metropolitan Water District of Southern California (MWD), which is comprised of 26 public water agencies. MWD obtains its water from the Colorado River and northern California, via the State Water Project (SWP). In year 2001, MWD delivered almost 2.3 million AFY of imported water to its customers. Both CWA and MWD are developing storage and additional supplies, such as water transfers to augment their imported water.

Need for Water Resources Plan

As the City's population and economy grow, it will become increasingly more dependant on imported water that is not within its direct control. Imported water is becoming more uncertain due to hydrologic variability (e.g., droughts), increased competition, new and more restrictive environmental regulations, and water quality.

To illustrate the need for future water supply investments, a comparison of projected demands with existing, firm supplies is required. Under many hydrologic and weather scenarios, the City may have adequate supplies. But during dry years and critically dry years, supply shortages are expected. For planning purposes, the 1977 drought event was used to define the City's critically dry hydrologic scenario. Figure 1 compares the City's existing, firm water supplies under a critically dry scenario to projected water demand without conservation for the year 2030. Based on this comparison, the City could experience water shortages of over 120,000 AFY.

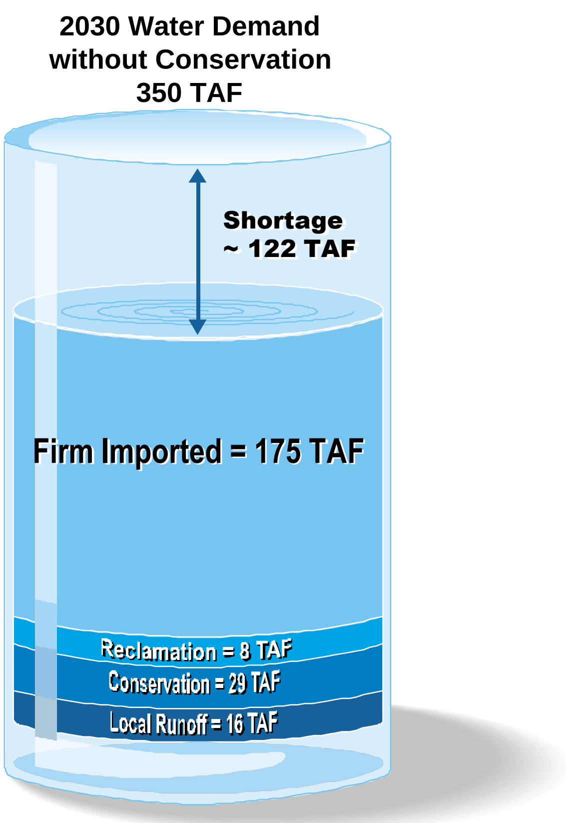


Figure 1
Comparing Existing Supplies with Projected Water Demands (2030) Under a Critically Dry Scenario (TAF = thousand acre-feet)

Emerging Trends

There are a number of emerging trends in the water industry that offer the City opportunities to mitigate potential water shortages in the future. These include:

- Water marketing (transfers)
- Private sector emergence (offering more choice in water supply)
- Wholesale water agency rate structure reform (dealing with long-standing equity issues)
- Advances in technology (e.g., desalination cost savings)
- Funding opportunities (e.g., CALFED and state water bonds)

These opportunities translate into viable water supply options that the City should evaluate, which include: additional conservation and reclamation, groundwater resources, ocean desalination, water transfers and others. However, with so many options available, the real question is what is the appropriate mix of water supply that the City should develop to meet its long-term needs. To answer this question, a comprehensive water resources plan is required.

This Executive Summary presents an overview of the City's water resources plan, developed over a two-year, participatory planning process involving San Diego's stakeholders.

Water Supply Options

Having identified the projected need for additional supplies, the next step in developing a water resources strategy is the identification of new water supply options. The information provided in this report should only be used in the context of developing a water resources plan and strategy. Although every attempt was made to obtain reasonable supply yield and cost data, certain estimates had to be made based on prior studies and/or professional engineering judgment. Before any supply option is actually implemented, a detailed investigation would be required. What is presented here for each supply option is an assumed level of development. The actual level of development for any of these options could be very different. The City is currently conducting field investigations and pilot studies to help determine the feasibility of implementing many of these options.

For each water supply option, the following information was collected or estimated:

- water supply yield
- impact on supply yield from hydrology and weather
- cost of supply development (including related infrastructure cost for delivery and treatment)
- water quality attributes
- risk factors (institutional, environmental, consumer acceptance)

Table 1 summarizes the potential water supply options available to the City.

Table 1
Summary of Supply Options for City of San Diego

Supply Option	Existing Supply (AFY)	Range in Potential Supply (AFY)	Range in Unit-Cost ($/AF)[1]
Water Conservation	21,000	42,000 (by 2030)	$50 - $75
Water Reclamation	8,000 [2]	33,000	$300 - $600
Groundwater Desalination (Safe Yield Supply)	0	6,000 – 20,000	$650 - $1,200
Groundwater Storage (Dry Year Supply)	0	10,000 – 48,000	$550 - $700
Ocean Desalination	0	10,000	~ $1,400
Marine Transport	0	20,000	~ $700
Central Valley Water Transfers (Dry Year Supply)	0	10,000 – 60,000	$500 - $580 (untreated)
Imported Supply from CWA/MWD (Firm Dry Year Supply)	175,000 [3]	200,000	$430 - $600 (untreated)

[1] Range in unit cost reflects cost of existing supplies and ranges of potential cost for new supplies.
[2] Although the City is currently delivering about 4,000 AFY of reclaimed water, it has the system capacity to deliver 8,000 AFY without the need for additional facilities.
[3] The City can get as much as 260,000 AFY from imported water during normal and wet years. However, in a repeat of a critically dry event, such as 1977, the estimated firm imported supply is 175,000 AFY.

Planning Objectives and Development of Alternatives

A crucial step in the development of a water resources plan is to define the planning objectives. Objectives form the overall goal of the plan and are used to communicate it to others. Once objectives are defined, performance measures need to be developed. Performance measures are indices that are used to determine when objectives are being adequately achieved.

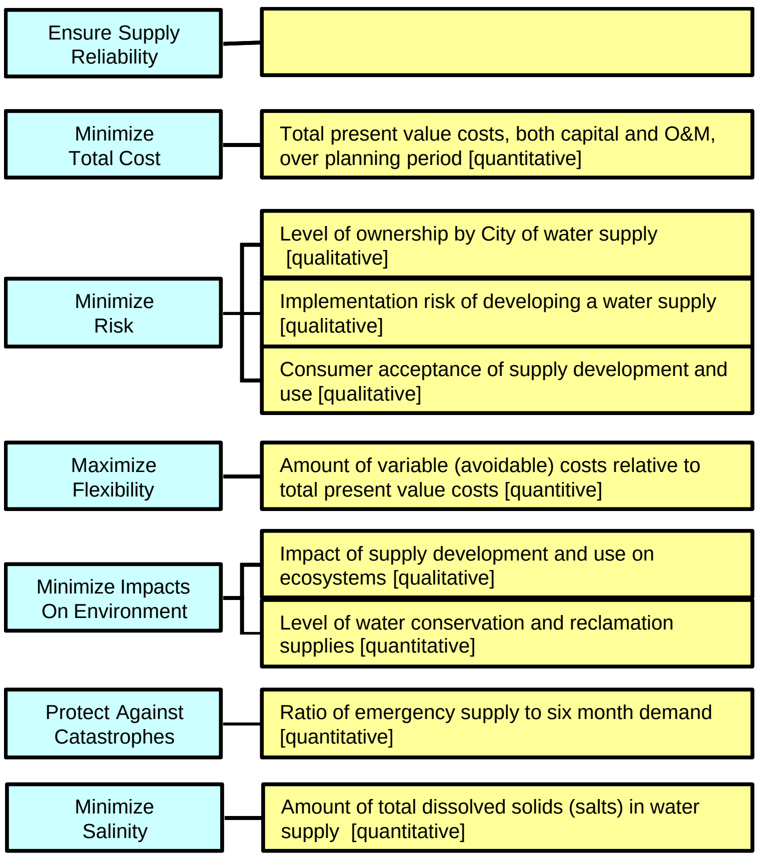


Figure 2
Planning Objectives and Performance Measures

To help define the planning objectives and develop performance measures, the City's Water Department utilized its Citizens Advisory Board (CAB). CAB members represent a variety of community interests and groups, such as: San Diego Association of Realtors, San Diego County Apartment Association, San Diego Chamber of Commerce, Building Industry Association, San Diego Taxpayer's Association, American Society of Landscape Architects, San Diego County Water Authority Board, San Diego State University Graduate School of Public Health, League of Women Voters, and Sierra Club. Figure 2 summarizes the planning objectives.

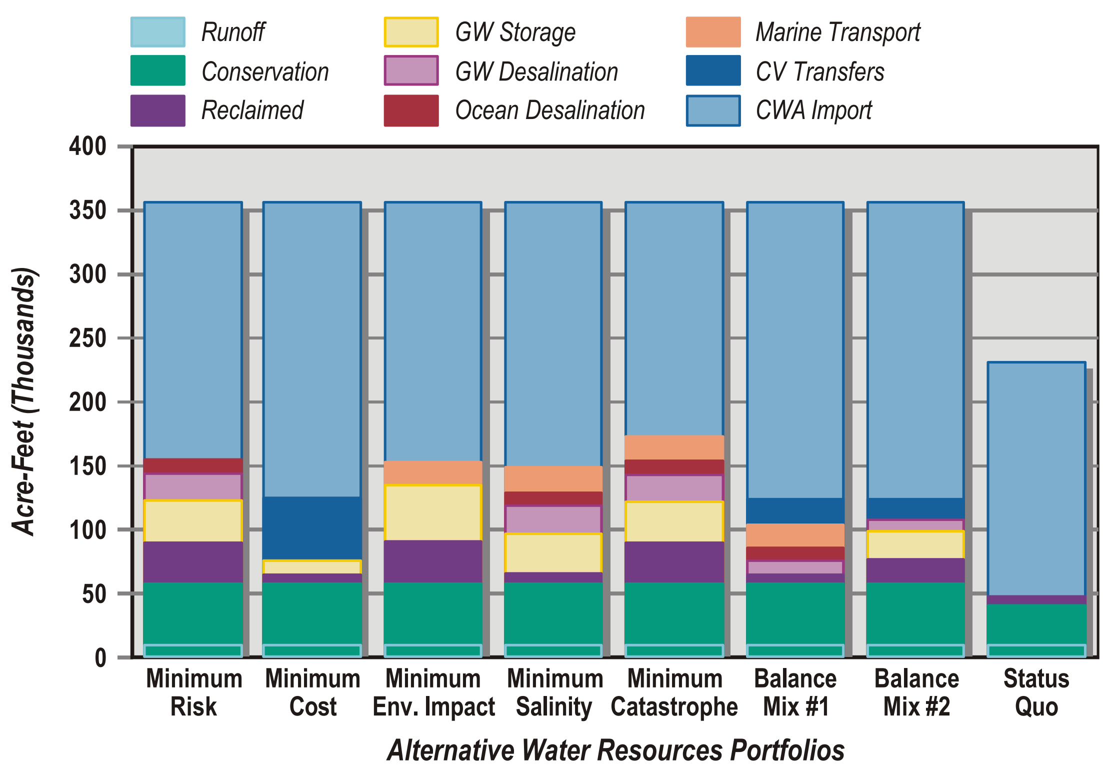
Knowing that no single water supply option could meet all of the City's objectives, water resource "portfolios" were created that combined various water supply options at different quantities into comprehensive packages. These portfolios were then tested against the performance measures. Eight alternative portfolios were developed. Some of the portfolios were designed to maximize a single objective (such as minimize cost or protect against catastrophes). This allowed the City to evaluate the trade-offs amongst the alternatives. Other portfolios represented a balanced mix (e.g., not maximizing or minimizing any one objective). A Status Quo alternative was also developed as a base case.

Evaluation of Alternatives

The City hired Camp Dresser & McKee (CDM) to develop a systems model that would be best suited for simulating alternative water resources portfolios for the next 30 years. In consultation with the City, CDM selected the generic systems simulator STELLA as the modeling platform for the City's systems model. STELLA was customized to create the San Diego Simulation (SDSIM) Model. SDSIM represents the City's physical water delivery system and simulates demands and supplies under different hydrologic and operating scenarios. Although all hydrologic scenarios were tested, the critical dry period became the most important indicator of success or failure of many of the alternatives.

Some of the evaluation criteria were easily quantifiable, such as: supply reliability (percent of time supply meets demands); cost (present value total costs); and water quality (salinity of all sources of water). Other criteria were qualitative, such as: environmental impacts and risk. A scorecard approach was used to combine both quantitative and qualitative measures into a comparable index (score from 0 to 100). A score for each objective was developed for each portfolio. An overall score was derived using the relative importance of each objective, which was determined by the CAB stakeholder process.

Figure 3 shows how each of the alternative portfolios met the critically dry period water demand in year 2030. Only the Status Quo, which did not assume any additional future supply development, was unable to meet demands reliably.



Comparing Alternative Portfolios for Year 2030 Under a Critically Dry Scenario

Generally, those portfolios designed to minimize risk or environmental impacts had the greatest amount of local supply development. In terms of reliance on imported water (either purchased directly from CWA or water transfers), the alternatives ranged from 51 to 85 percent dependent on imported supply. The Minimum Catastrophe Impact had the lowest reliance on imported water, while the Status Quo had the highest.

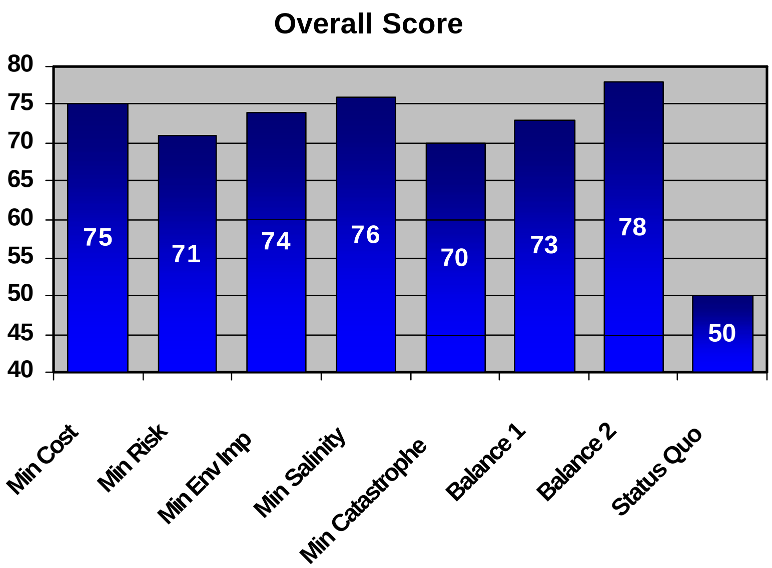


Figure 4
Overall Portfolio Score

Figure 4 presents the overall "score" for each of the portfolios. The overall score represents the weighted average of each of the objective's individual score. The three top-scoring portfolios are the Balance Mix #2, Minimum Salinity, and Minimum Cost portfolios.

The supply options for these top-scoring portfolios were then compared to find the common elements. Table 2 presents the comparison of resource options for the top-scoring portfolios.

Table 2
Common Resource Elements Among Top-Scoring Alternatives

Resource Option	Balanced Mix #2 Portfolio	Minimum Salinity Portfolio	Minimum Cost Portfolio
Conservation, Existing	◆	◆	◆
Conservation, New	◆	◆	◆
Reclamation, Existing	◆	◆	◆
Reclamation, New	◆		◆
Groundwater Storage	◆	◆	◆
Groundwater Desalination	◆	◆	
Ocean Desalination		◆	
Marine Transport		◆	
Water Transfers	◆		◆
Imported Existing	◆	◆	◆
Imported New			◆

Resources such as conservation, reclamation, groundwater storage, groundwater desalination, water transfers, and imported water were all common to at least two of the portfolios.

Recommended Water Resources Strategy

During the planning process, the importance of having a flexible and adaptive water resources strategy was recognized. Although it is critical for water plans to have long planning horizons, proposing that every element of a 30-year plan be implemented on day one is unrealistic. Therefore, it is recommended that the Long-Range Water Resources Plan be implemented in three phases in order to meet San Diego's growing demands, making course adjustments as necessary to respond to changing technology, regulations, or needs.

It is recommended that the common resource elements from the three top-scoring portfolios should be implemented by 2010 (Phase 1). Resource elements that are different among these portfolios should then be examined to determine under what conditions they would become most feasible and attractive for the City to implement.

Based on such factors as the success or failure of CALFED, emergence of a strong water transfer market, technology improvements in membrane treatment, and the outcome of the City's field investigations of local groundwater, three distinct paths or strategies could be taken and possibly implemented by 2020 (Phase 2 of the Plan). The three strategies are: (1) Treatment Strategy—assuming that technology improvements lower the cost of membrane treatment; (2) Market Strategy—assuming that a viable and strong water transfer market emerges as an outcome of CALFED; and (3) Storage Strategy—assuming that the City's field investigations in groundwater show promise in utilizing the basins for underground storage.

Once a particular strategy is chosen by the City, then Phase 3 of the Plan would implement a variety of resource options by 2030, depending on the continued success of prior resource implementation and/or achievement of planning objectives. Figure 5 presents this flexible and adaptive water management strategy.

This strategy ensures that the City can move forward with the most promising resource elements quickly, while still allowing for a "wait-and-see approach" for those options that have higher risk.

Figure 6 summarizes how the City would meet 2010 and 2030 demands under a normal and critically dry scenario.

With the implementation of the common resource elements by 2010, the City's reliance on imported water during a critically dry period would be approximately 74 percent, as compared to the 75 to 90 percent currently. By 2030, the City's reliance on imported water could be as low as 57% if most of the alternative resources options available to the City were implemented. Again, the actual implementation of resource options will be dependant on many factors, such as the success of CALFED, desalination technologies, feasibility of using local groundwater basins for storage and enhanced safe yield, and others.

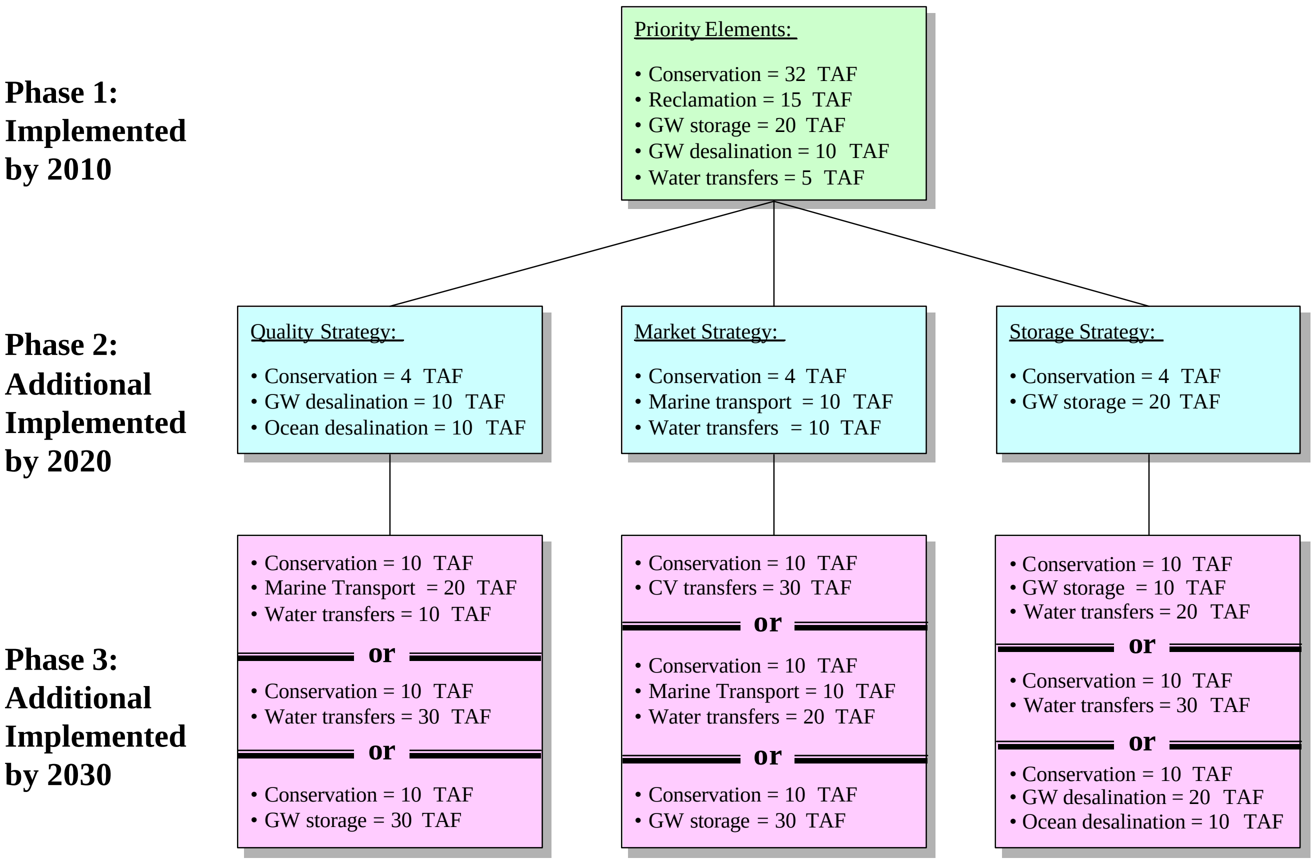
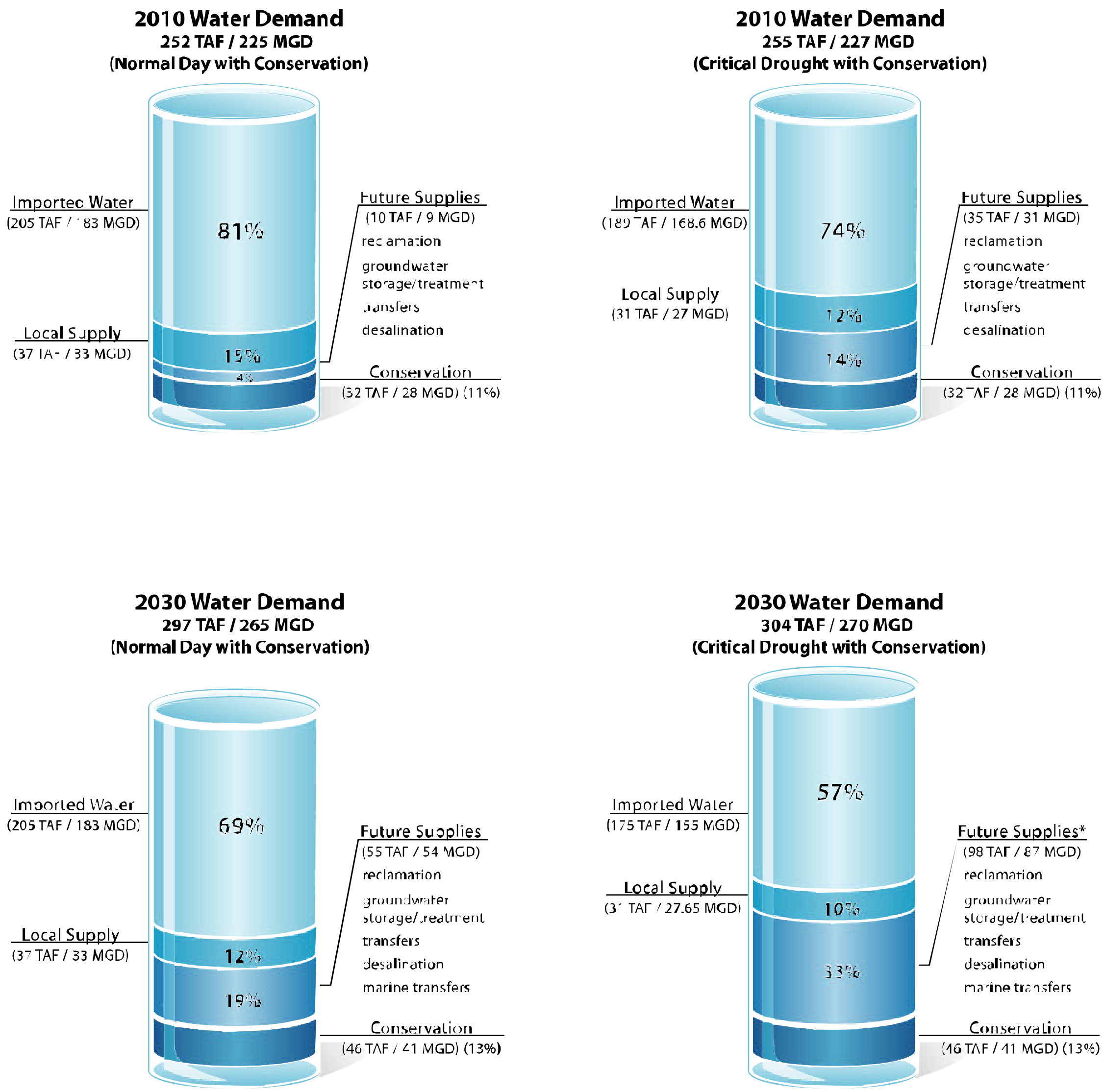


Figure 5
Flexible and Adaptive Water Resource Strategy



* Does not include 24 TAF of future reclamation and conservation.

Figure 6
City's supply mix for 2010 and 2030 for Normal day and Critical Drought
(TAF = thousand acre-feet, MGD - Million gallons per day)

Section 1
Introduction

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1.1 Background

The City of San Diego (City) has the reputation of being one of the country's most desirable places to live and conduct business because of its climate, economy, and quality of life. It is the sixth largest city in United States and the second largest in California. Although the City is located in a semi-arid coastal climate, it has successfully provided a reliable water supply to its residents for the last 100 years. The challenge for the City is to continue providing its residents with a reliable, safe drinking water supply into the future, while doing so in a cost-effective and environmentally sound manner.

Since 1996, the City's Water Department has been involved in a water supply planning process that has produced a ***Strategic Plan for Water Supply*** (City of San Diego, 1997). The focus of that plan was the development of a comprehensive capital improvements program (CIP) that identified key investments in water treatment, storage, and distribution to meet water demands through 2015. The plan also established water conservation and reclamation targets for the next 10 years. An outcome from this strategic plan was the realization that the City should become even more engaged in the planning and development of its own water supply. In the past (prior to 1996), the City had relied almost entirely on the San Diego County Water Authority (CWA) to plan for future supply.

1.2 City Profile and Institutional Setting

The population of the City is currently more than 1.2 million. The City has a young population, as reflected by the median age of 32, with two thirds of the population under 35, and only 10 percent over 65. Figure 1-1 shows the City's projected population, employment and housing.

Table 1-1 presents additional demographic data for the City. Significant growth is projected over the next 30 years, with a 48 percent increase in population, a

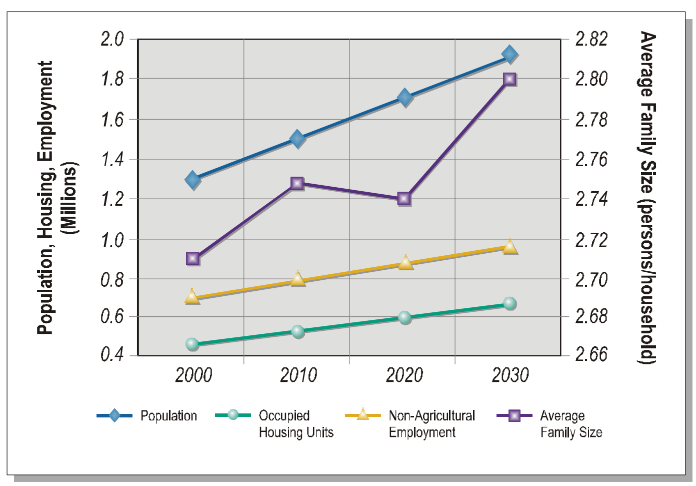

Figure 1-1
City of San Diego Demographic Projections
Source: Planning and Management Consultants Ltd., 2001

45 percent increase in occupied household units, and a 36 percent increase in employment. Family size is projected to increase from 2000 to 2030, from 2.71 to 2.80 persons per household.

Table 1-1
City of San Diego's Demographic Projections

Year	2000	2010	2020	2030	Change (2000-2030)	% Change (2000-2030)
Population	1,288,808	1,499,134	1,693,221	1,907,334	618,526	48.0%
Occupied Housing Units	459,008	527,900	597,699	665,516	206,508	45.0%
Persons per Household	2.71	2.75	2.74	2.80	0.09	3.3%
Employment	711,293	799,823	868,591	967,641	256,348	36.0%
Median Household Income	$51,265	$55,191	$57,670	$61,844	$10,579	20.6%

Source: Planning and Management Consultants Ltd., 2001. Source data provided by SANDAG.

The developed area of the City is currently 280 square miles, and is expected to grow about 10 percent in the next 30 years. As Figure 1-2 shows, the fastest growing areas of the City, in terms of percent population growth, are its northwestern (mostly residential) and southeastern (mostly industrial and commercial) communities. These areas of the City are projected to grow approximately 250 percent and 500 percent, respectively, by 2030.

The City is known worldwide as a prime tourist destination, and hosts important industries such as telecommunications, biotechnology, software, and electronics. San Diego's southern neighbor, the Mexican state of Baja California, is becoming a very important trading partner, and the Port of San Diego is helping the City emerge as a center for international trade.

Leading economic indicators reflect that the economy is strong. Financial, trade, tourism, construction, and employment figures and indices show signs of a solid and growing economy. The City's unemployment rate for 1999 was 3.2 percent, the lowest annual rate in decades. Most new jobs are among the services-producing industries. The value of all goods and services generated in San Diego County neared $87.1 billion during 1998, and San Diego's real Gross Regional Product (GRP) growth in 1999 was 3.7 percent (San Diego Regional Chamber of Commerce, 2000).

The City purchases up to 90 percent of its water from the San Diego County Water Authority (CWA). The CWA is a wholesale water agency that provided approximately 600,000 acre-feet per year (AFY) of imported water to its 23 member agencies in San Diego County in 2001. A 34-member Board of Directors governs the CWA. The City of San Diego is the largest water user within the CWA and is represented by 10 Board members. Current water deliveries to the City account for more than 35 percent of the CWA's total water sales.

The CWA, in turn, currently gets its imported water from the Metropolitan Water District of Southern California (MWD), which comprises 26 public water agencies and is the largest wholesale water agency in the nation.

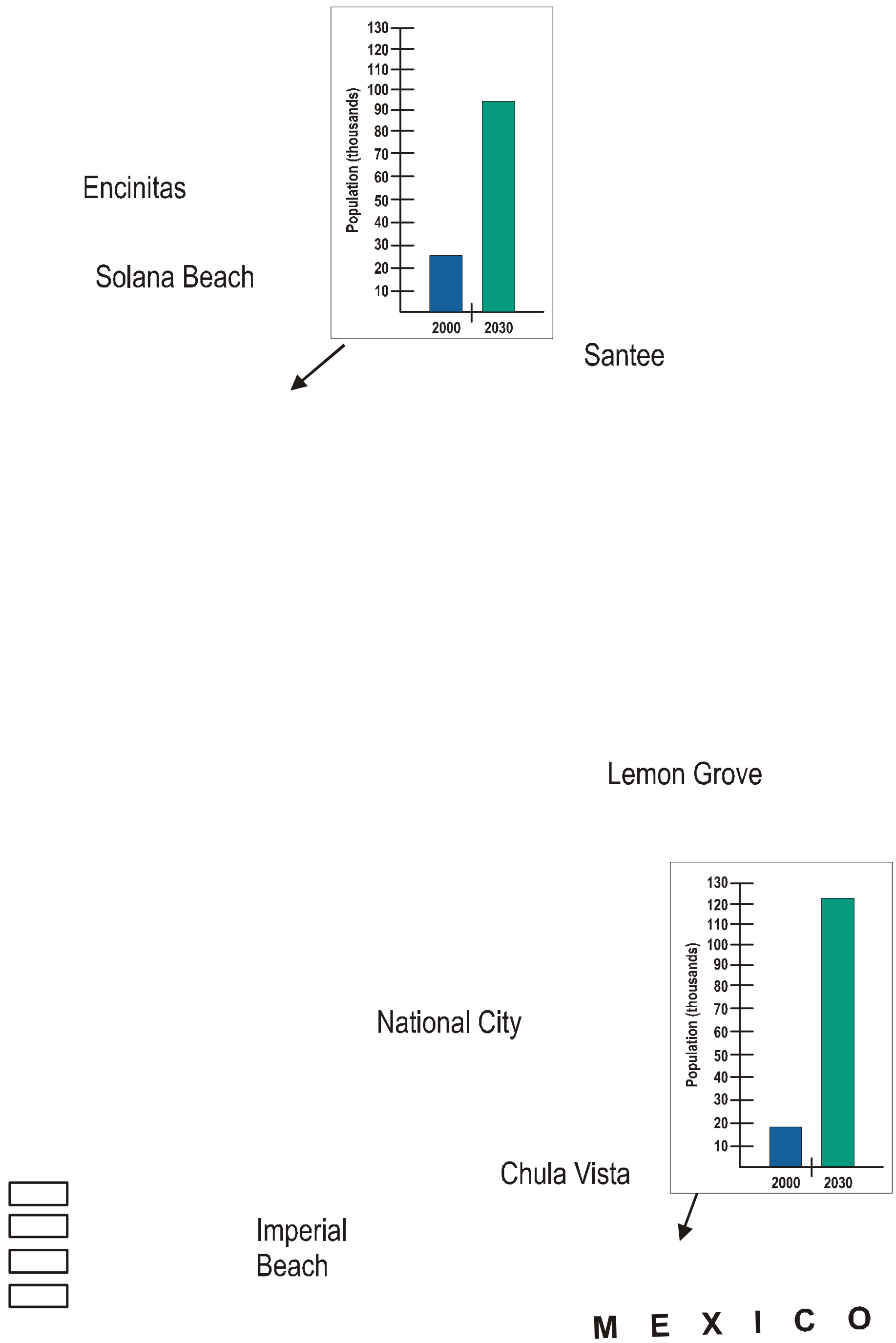

Figure 1-2
Population Growth Rate by San Diego Regions
Source: Planning and Management Consultants Ltd., 1998

The Board of Directors of MWD is composed of 37 members. The CWA, with four board members, is the largest purchaser of water among MWD's member agencies. The CWA purchases approximately 25 percent of MWD's water. However, the CWA has preferential right to about 14 percent of MWD supplies, and has about 16 percent of MWD's voting entitlement.

MWD was incorporated by the state Legislature in 1928 to build the Colorado River Aqueduct, a facility it owns and operates. MWD also imports water from northern California through the State Water Project (SWP). In 2001, MWD delivered almost 2.3 million AFY of imported water to its customers. MWD's Integrated Resources Plan has targeted increased conservation, recycling, storage, and water transfers to reduce dependence on imported water from the Colorado River and Northern California. Both CWA and MWD are actively engaged in regional planning to ensure water supply reliability to its respective customers. The agencies are pursuing storage and water transfers to augment their traditional reliance on imported water from the Colorado River and Northern California.

1.3 Need for Water Resources Plan

A reliable, high quality water supply is one of the most fundamental services supporting the City's economic prosperity. Without a reliable water supply, businesses relocate to other cities, the tourism industry suffers, and overall quality of life is negatively affected.

As described later in Section 2, San Diego's expected population and economic growth will increase water demands by almost 50 percent by 2030. Most of this increased demand will be supplied by imported water.

With such heavy reliance on imported water, the City must examine the various risk elements associated with that supply. This assessment of risk is crucial in understanding the importance of developing a water resources plan. Although imported water supplies to the City have been fairly reliable in the past, a number of factors suggest that it will become more difficult to ensure that imported water remains reliable in the future.

To understand the risk of imported supply to the City, it is important to recognize just how far water must travel before getting to San Diego. Figure 1-3 illustrates where the imported water originates, the major institutional players involved in moving the supply, and summarizes some of the major risk issues involved with the delivery of the supply to the City.

Competing demands for imported water from the SWP and Colorado River, coupled with periods of below-normal rainfall, have resulted in supply shortages over the past 30 years. This situation is only projected to worsen overtime. In addition to hydrology-based water shortages, environmental restrictions in the Bay-Delta from the implementation of the Endangered Species Act (ESA) are becoming more common, and in fact, could cause supply shortages even in wet and normal weather years.

On the Colorado River Basin, a pact to get California to live within its 4.4-million acre-foot entitlement has been initiated. Dubbed the "California 4.4 Plan", it requires that California reduces its over-use of Colorado River water over the next 10 years. The 4.4 Plan also specifies the priority of California's supply among its major user groups (Imperial Irrigation District, Palos Verdes Irrigation District, Coachella Valley Water District, MWD, City of Los Angeles, and San Diego). Although the 4.4 Plan represents significant progress in settling some long-standing disputes within California and sets the stage for a water transfer market, it creates uncertainty as to where future Colorado River supply will come from. Over time, agricultural water transfers along the Colorado River Basin will become more limited and costly. The cost and availability of energy is an additional concern for water delivered to the City through the SWP. Energy requirements are very high for pumping, particularly in the case of the SWP.

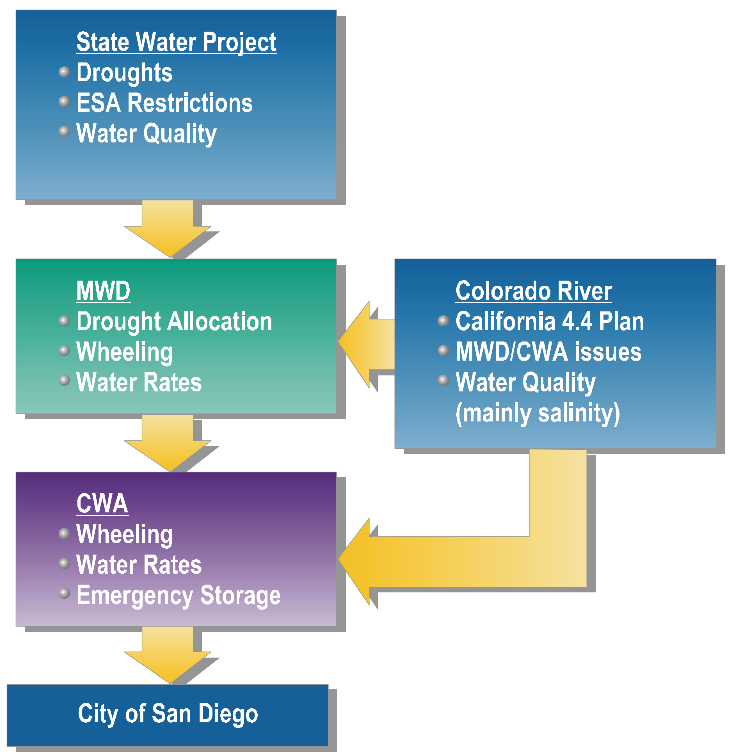

Figure 1-3
Imported Water and Risk Factors

Water quality for both the SWP and Colorado River are also of significant concern to the City, which is at the "end" of the imported water system. Water quality tends to degrade over long distances of water conveyance. Salinity is of particular concern because source water high in salinity can cause damages to residential and industrial plumbing fixtures, destroy crops, and prevent the City from using its reclaimed water to its fullest potential.

Another issue facing the City is protection against a catastrophe, such as a major earthquake. Such an event could disrupt imported water supplies for up to seven months. The CWA and City are both working towards ensuring emergency supplies to protect against catastrophes. Currently, the City does have a seven-month emergency storage supply in the event of a catastrophe

Finally, there numerous institutional issues that cause uncertainty in imported supplies. These institutional issues mainly center around MWD's rate structure, wheeling, and drought allocation. The MWD and CWA are in disagreement on many of these issues causing even further problems for the City.

Given the uncertainty in imported supplies, the City has chosen to develop a water resources plan that fully explores alternative water supply options. For some of these supply options, the City is currently investigating the feasibility for implementation, such as expanding its water reclamation and development of its local groundwater. When exploring these alternative water supplies, one important question must be answered:

> *What level of development for these alternative supplies should be pursued by the City in order to reduce its reliance on imported water?*

To answer this question, issues such as cost, risk, water quality, potential impact on the environment, and flexibility must be examined in a comprehensive and systematic fashion.

1.4 Report Outline

The organization of this report generally follows the participatory planning process that was used by the City to develop its water plan. Section 2 describes the current water resources assessment or "gap" analysis that identifies current firm water supply and future water needs in order to identify how much new water supply the City requires. Section 3 identifies feasible water supply options that the City could develop to meet its future needs. Section 4 defines the planning objectives and corresponding performance measures that will be used to evaluate alternatives, while Section 5 focuses on how supply options were combined into comprehensive resource portfolios. Section 6 summarizes the evaluation approach and model development, while Section 7 presents the evaluation results. Finally, Section 8 draws some important conclusions and makes recommendations for implementation of the ***Long-Range Water Resources Plan***.

Section 2
Water Resources Assessment

Section 2
Water Resources Assessment

A water resources assessment is the first step in determining the City's needs to continue providing its residents a reliable, safe drinking water supply into the future. This assessment includes the identification of: (1) current and projected water demand, (2) current supply situation, (3) potential shortfalls in water supply, and (4) emerging trends in the water industry that are relevant to the City.

2.1 Water Demands

Understanding current and future water demands and existing water supplies is the starting point for determining water resources investments, evaluating system capacity and capital improvements, implementing additional conservation and recycling programs, and preparing contingency plans for possible water shortages.

The City of San Diego Water Department currently operates and maintains one of the most complex municipal water supply systems in the nation, serving more than 1.2 million people and covering approximately 280 square miles of developed land. The City also delivers water outside its own incorporated boundaries, to the Cities of Del Mar, Poway, Ramona, the California American Water Company, and the San Dieguito and Santa Fe Irrigation Districts. Because water production from local sources is not sufficient for meeting consumer needs, the City relies on imported water from the CWA, which supplies as much as 90 percent of total water deliveries in some years. In 2000, the City delivered approximately 38,700 acre-feet per year (AFY) from local sources and 205,000 AFY from imported water for a total average water delivery close to 244,000 AFY (City of San Diego, 2000).

Major Assumptions for Water Demand Projections

- Water demands are projected using forecasts of population, housing, employment, and income, which are provided by San Diego Association of Governments (SANDAG)
- Demographic forecasts provided by SANDAG represent the most likely representation of growth for the City
- Water demands will continue to be greater in hot/dry weather and lower in cool/wet weather, as has occurred in the past

The residential sector in the City accounts for approximately 57 percent of the water use. Industrial use is about 3 percent, irrigation use is 14 percent, and commercial governmental and other uses constitute the remaining 26 percent of water use (City of San Diego, 2000).

In February 2001, projected water demands for the City were updated by Planning and Management Consultants, Ltd. (PMCL). These demand projections reflect the most recent information regarding conservation and demographic projections, which were provided by the San Diego Association of Governments (SANDAG). The updated water demand projections presented here differ from the City's 2000 Urban Water Management Plan (UWMP), because they were generated after the adoption and publication of the UWMP in January 2001.

When projecting future water demands, it is important to recognize that demands fluctuate year-to-year based on weather. Water demands are greater in dry-weather years than in average-weather years, due to increased landscape irrigation and other seasonal uses. Under normal weather conditions, demands are expected to increase from the current 244,000 AFY in 2000 to 252,000 AFY in 2010, and 297,000 AFY in 2030. These demands take into affect the active conservation program that the City is planning to continue. Active conservation measures are those that the City develops directly, such as ultra-low-flush toilet rebates or public education programs. Demands without conservation are expected to be 287,000 AFY in 2010 and approximately 350,000 AFY in 2030 (see Figure 2-1).

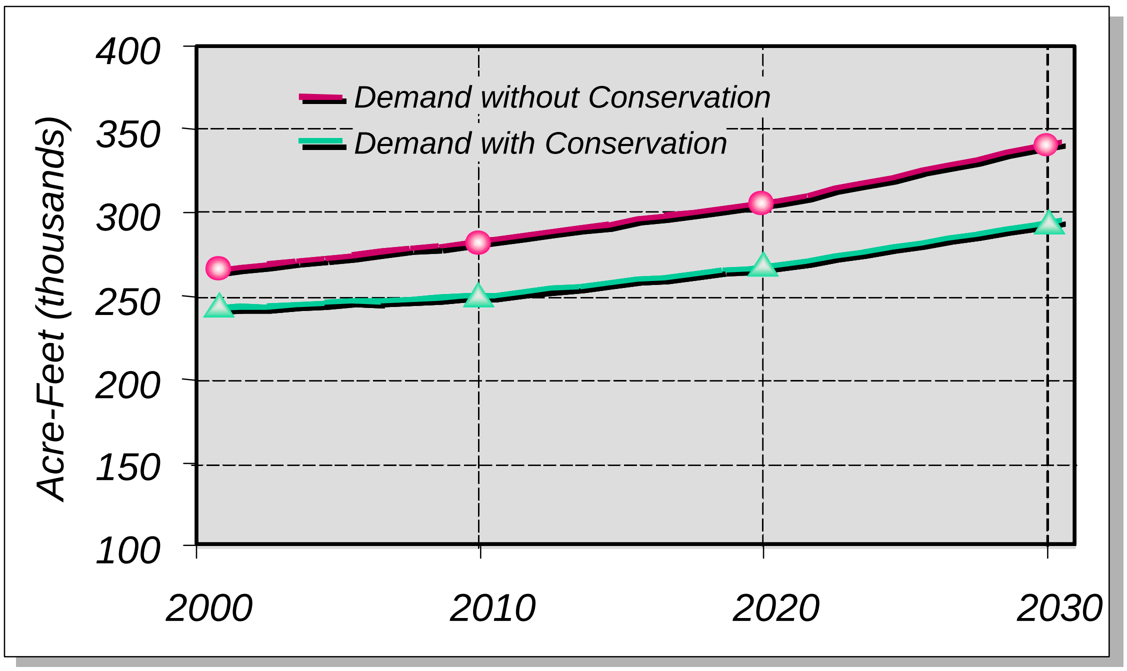

Figure 2-1
City of San Diego Normal Weather
Water Demand Projections
Source: Planning and Management Consultants, Ltd. (2001)

2.2 Existing Water Supply

Historical and current data on water supply was obtained from the City's UWMP (City of San Diego, 1995 and 2000) and the Strategic Plan for Water Supply (City of San Diego, 1998), as well as the CWA and the MWD. The City is located in a semi-arid climate and precipitation averages about 10 inches annually. There are no permanent streams, natural lakes, or prolonged precipitation periods in the region, and groundwater basins have historically provided limited supplies. Practically 100 percent of local (e.g., within San Diego County) water supply comes from surface water, stored in nine local reservoirs with more than 400,000 acre-feet of capacity.

Major Assumptions for Existing Water Supply

- City's short-term goals for conservation and reclamation will be achieved through existing levels of local supply and management
- Existing firm supplies were generated to determine the upper-end estimate of potential water short-falls, based on a critically-dry weather scenario, similar to a repeat of 1977 drought conditions
- Imported water supplies based on existing projects for MWD and CWA
- Allocation of MWD and CWA imported water to the City is based on historical need for such water (consistent with adopted policies of both agencies), rather than preferential rights (see Section 2.2.2 for more discussion on preferential rights)

To determine potential future water supply investments needed by the City, existing water supplies under critically dry weather conditions, were compared to water demands without conservation. Existing water supplies are defined as those that are already being implemented by the City. Figure 2-1 shows this comparison of existing supplies to projected demands for 2030, under a critically dry weather scenario. The drought year of 1977 was used to represent the critically dry scenario, as this year represented the worst-case supply for imported water. A more detailed discussion of hydrologic scenarios is presented in Section 6 (see Table 6-1). By 2030, there could be a shortfall in supply by as much as 122,000 AFY during a repeat of a drought.

2.2.1 Existing Local Supplies

As with water demands, water supplies can vary greatly from year-to-year due to weather and hydrology. During wet periods, abundant rainfall and runoff will lead to greater local water supply from surface reservoirs and groundwater. During dry periods, however, when rainfall and runoff is minimal, local water supply is greatly reduced. Based on historical data from 1950 to 1995 (City of San Diego, 1995), the local water supply during dry weather conditions approximately 16,000 AFY. Of this amount, less than 1 percent is from groundwater and the rest is from surface reservoirs. During normal weather conditions, local water supply can be over 52,000 AFY.

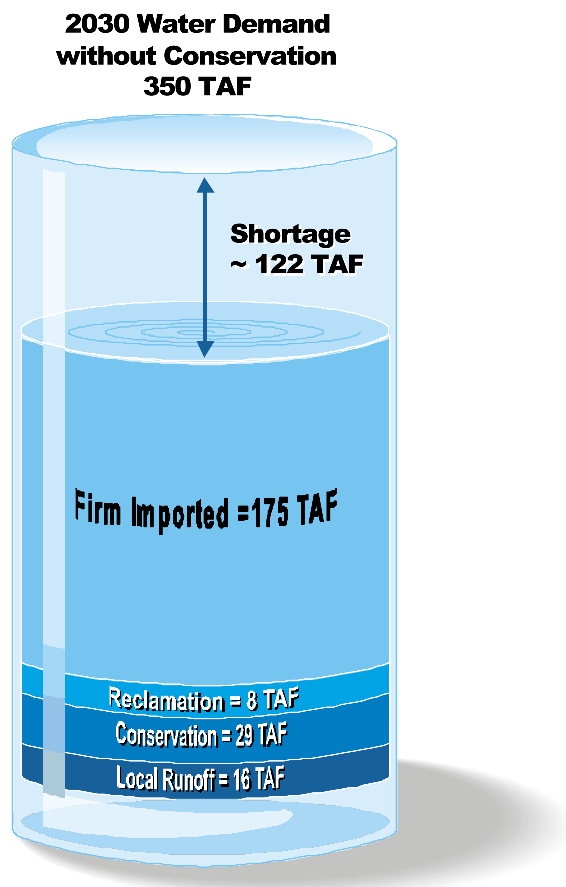

Figure 2-2
Comparing Existing Water Supplies with Projected Water Demands (2030) Under a Critically Dry Scenario (TAF = thousand acre-feet)

There are several groundwater sources throughout San Diego County, however there are challenges associated with their development. The San Diego Formation appears to be the major aquifer in the vicinity of the City, and due to its confined characteristics, it does not appear to recharge naturally at a useful rate. In addition, San Diego's four main alluvial basins contain brackish groundwater, which may require desalination before the supply could be used for potable use. Additionally, there could also be potential interjurisdictional and water rights issues regarding the City's use of the basins because they extend beyond the boundaries of the City's overlaying land. To determine the feasibility of developing these groundwater resources, the City is moving forward with an investigation, involving field studies, to determine potential safe yield, water quality and other basin characteristics.

The City is currently reclaiming approximately 4,000 AFY of water to offset the need for imported supply. This reclamation supply is serving irrigation and industrial demands. The City will be able to deliver approximately 8,000 AFY during the next two to five years, through their existing reclaimed water system—which will meet its 2003 EPA goal. The City is currently expanding its reclaimed water system to deliver additional reclaimed water in order to maximize water efficiency and improve reliability.

In addition to relying on local water supplies to meet demands, the City has an aggressive water conservation program. This conservation program includes retrofitting non-conserving toilets with ultra-low-flush fixtures, offering rebates for water-efficient washing machines, landscape conservation programs, commercial and industrial programs, and public education and information. The goal of the water conservation program is to save 26,000 AFY by 2005.

2.2.2 Existing Imported Supplies

As mentioned previously, the City obtains its imported water supplies from the CWA, which in turn purchases imported water from MWD. This imported water arrives from the Colorado River through the Colorado River Aqueduct (CRA) and from northern California through the SWP. There are many on-going issues related to these sources of imported water. They are highly susceptible to hydrological droughts and both impacted by regulatory-driven water supply restrictions, such as the Endangered Species Act. These sources of supply are also both over-subscribed, in that demand is currently more than supply. Although there are initiatives to improve the reliability of such supplies, such as CALFED and the Colorado River 4.4 Plan for California, there is great uncertainty as to the success of such programs. During normal weather years, MWD could provide as much as 1.40 million AFY from the SWP and 1.25 million AFY from the CRA—for a total of 2.65 million AFY (Metropolitan Water District, 1996). However, total imported water supply from the SWP and CRA could fall as low as 1.9 million AFY during a dry year, and 1.6 million AFY during a critically dry year.

In addition to MWD's SWP and CRA supplies, the wholesale agency has also implemented a number of water storage and transfers to supplement its imported water during dry years. These supplies include: (1) Diamond Valley Reservoir, with 800,000 acre-feet of storage capacity; (2) Semi-tropic and Arvin-Edison groundwater storage and transfer programs, with a combined storage capacity of 700,000 acre-feet;

and (3) North Las Posas groundwater storage in Ventura County, with a storage capacity of 210,000 acre-feet. These storage supplies could provide MWD with about 430,000 AFY during a dry year and 280,000 AFY during a critically dry year. When combined with the SWP and CRA supplies, MWD could provide to its member agencies about 2.1 million AFY during dry years and 1.9 million AFY during critically dry years. If a worst-case drought supply were allocated to the City of San Diego based on historical use, rather than preferential rights, then the City's existing firm imported water supply would be 175,000 AFY (as the City has historically represented about 9.5% of the total demand for MWD's water). Preferential rights calls for water to be allocated based on each of its member agencies' cumulative contribution of property taxes. If preferential rights were used as the system for imported water allocation to San Diego County, the City could receive much less firm imported water supply than 175,000 AFY. However, although preferential rights are currently in MWD's Act, the agency has never used the system to actually allocate water during severe shortages.

It should be noted that these imported supply assumptions are based on keeping the CRA full at 1.2 million AFY under all weather conditions. A large factor in keeping the CRA full is the implementation of the CWA's water conservation program with Imperial Irrigation District (IID). The ultimate supply estimated from this program is 200,000 AFY. The following California water agencies, MWD, CWA, IID, and Coachella Valley Water District have pledged to do more conservation and transfers in order to reduce California's use of the Colorado River supply to its entitlement of 4.4 million AFY. This pledge will hopefully allow California to use surplus Colorado River supply when the other basin states are not of need of their full entitlement. The CWA is also planning to develop additional water supplies, which may include Central Valley transfers, additional Colorado River Transfers, ocean desalination, and other local supplies.

2.3 Potential Shortfalls in Water Supply

The comparison of future above-normal demands and existing supplies, defined previously, is summarized in Table 2-1. This comparison indicates that a potential supply deficit of about 48,400 AFY could exist in the year 2010 during a critically dry weather year (such as a repeat of the 1991 drought). The potential supply shortage could be as much as 122,000 AFY for the year 2030. Of course, both MWD and the CWA are indicating that they will be able to meet this deficit with implementation of future programs. However, these programs will also have to serve MWD's other 25 member agencies and the CWA's other 22 member agencies. In addition, the reliability and cost of such programs is uncertain.

Table 2-1
Demand and Supply Projections for the City of San Diego
During Critically Dry Weather Conditions[1] (Acre-Feet Per Year)

Parameter	2010	2020	2030
Demand			
Above-Normal Water Demand [2]	287,000	312,000	350,000
Existing Supply			
Above-Normal Active Conservation [3]	29,000	29,000	29,000
Reclaimed Water [4]	8,000	8,000	8,000
Firm Local Surface Reservoir Supply [5]	16,000	16,000	16,000
Firm Imported Supply [6]	175,000	175,000	175,000
Total Firm Supply	228,000	228,000	228,000
Potential Supply Shortage	59,000	84,000	122,000

[1] 1977 drought conditions were used to establish upper-end estimates of potential water shortages. A complete discussion of hydrologic scenarios is presented in Section 6 (see Table 6-1).
[2] Demands without conservation during repeat of 1977 weather conditions.
[3] Projected levels of water conservation, based on existing programs.
[4] Existing reclamation potential based on current system capacity to deliver supply.
[5] Firm local surface reservoir supply during 1977 drought conditions.
[6] Firm imported supplies during 1977 drought conditions.

Source: City of San Diego Urban Water Management Plan (1995, 2000); MWD's Integrated Resources Plan (1996); PMCL M&I Water Demand Forecast (1998, 2001).

2.4 Emerging Trends in Water Industry

In the past few years several trends have emerged in the water industry that offer the City opportunities that did not exist previously. The opportunities presented by these trends emphasize the need for the City to strengthen its internal capabilities to evaluate and develop alternative water supply options.

2.4.1 Water Marketing and Wheeling

A water transfer is the voluntary sale or exchange of water from a willing seller (usually a farmer or agricultural water district) to a willing buyer (usually a city or urban water district). Although several successful water transfers have taken place in the last 10 years, water transfers often have significant political, institutional, and environmental issues that must be addressed before implementation.

One key issue affecting water transfers is the ability to deliver water through the use of facilities owned by a third party, or wheeling. Wheeling is the use of an agency's distribution system to move non-agency water between a willing seller and buyer. Currently, California law states that water agencies with excess system capacity must allow wheeling to take place in exchange for fair compensation for the use of their system. There is great debate however over what "fair" compensation means. Some believe fair compensation means paying for a share of the full capital cost of the entire system (i.e., MWD). Others believe fair compensation means paying for the incremental or operation and maintenance (O&M) cost of the system that is used specifically to move the water (i.e., CWA).

In the past three years, legislation has been proposed that is intended to open up water markets and allow wheeling to occur in a fair and equitable manner for all involved. Although the specifics differ in each of the legislative proposals, one thing is common to all of them; water agencies must open up their systems to the voluntary exchange or transfers of water between sellers and buyers. Given this new paradigm in the water industry, opportunities present themselves for water agencies like the City's Water Department. In the past, it would have been enormously difficult for the City to acquire a water transfer strictly for its own benefit. Now, just as the CWA was able to strike a deal with the Imperial Irrigation District for its own water transfer, the City has the possibility of pursuing similar types of transfers that would use MWD's and CWA's facilities for water wheeling. Section 3.7 presents a more detailed discussion about water transfers and wheeling.

2.4.2 Private Sector Emergence

Very much related to water marketing and wheeling, the emergence of the private sector will have a major impact on the water industry. The role of the private sector will no doubt continue to evolve. In most cases, private sector proposals for water supply range from selling water to which the purveyor has rights or entitlements, to brokering the sale of water with third parties. In some cases, the private sector is providing the technology to help conserve water or treat non-potable supplies to drinking water standards. Companies such as Azurix, Western Water, Cadiz, and U.S. Filter are a few of the major private sector players in California.

Some have argued that the emergence of the private sector will expand the market and allow for a greater choice in services than was once offered to water customers. Although many public agencies have expressed concern with the prospect of a water market dominated by private sector interests, the concept of public/private partnerships does look attractive to a growing number of public agencies. A public/private partnership can reduce risks to both parties and oftentimes result in a very cost-effective water supply. Often times, the private sector is willing to take greater risks with regards to future prices of water, while the public sector brings lower financing capabilities for large capital opportunities.

2.4.3 Cost-of-Service and Rate Structure Reform

Over the last few years, cost-of-service models and rate structure reform have received significant attention in Southern California. Although cost-of-service models for rate design are used by many electric, gas, and water utilities across the country, wholesale water agencies in Southern California have relied on what is typically referred to as "postage stamp" rates. A postage stamp rate structure simply divides all costs by water sold to determine a water rate that is applied uniformly to all users of the system, the same way the post office charges a uniform rate to deliver a first class letter no matter how far it travels within the United States. In the past, this model served the region well. As the water market develops however, and more choices for future supplies are introduced, the postage stamp rate may no longer allocate costs fairly with respect to services provided.

In contrast, a cost-of-service approach categorizes the various costs of the utility into services, such as supply development, treatment, transmission, distribution, and O&M. Once costs are allocated into these categories, specific rates can be developed for each level of service. Under this approach, customers that only wish to use the transmission or distribution system, for example, would only pay those costs.

Very much related to the cost-of-service debate is the rate structure reform being developed by MWD. During MWD's strategic planning process in 1999 and 2000, several rate structures were proposed by MWD's member agencies and outside interests. Although these rate structure proposals differed in specifics, there were two common themes among all of them—encourage water transfers and marketing and ensure the financial integrity of MWD and its member agencies. All of these rate structure proposals were also based on a cost-of-service approach. The MWD Board instructed its staff to take the best elements from each of the proposals and develop a hybrid model for consideration. The resulting rate structure framework was adopted by the MWD Board in April 2000.

The next step in the process is to work with the public and member agencies on issues of implementation. It is expected that this new rate structure will take effect in approximately two years. The major elements of MWD's proposed rate structure are: (1) un-bundled rates and charges; (2) member agency financial commitments; (3) pricing signals to encourage water marketing; and (4) interruptible water contracts, offering low-cost supply for storage.

Although many of the specifics have yet to be developed, the proposed rate structure framework does offer some opportunities for the City. One such opportunity is the availability of low-cost imported water for local storage.

The CWA is also examining its rate structure. Although the CWA has yet to address water supply pricing, it has identified several proposals for transportation rates. One such proposal is based more on a point-to-point pricing approach over the traditional postage-stamp approach. In a postage-stamp approach, all water users pay the same unit rate for water delivered. Point-to-point charges different users of the systems different rates depending on how much of the system they actually use—usually based on linear distance or some other proxy. The CWA and its member agencies are currently reviewing this proposal for fairness, equity, and effectiveness. Obviously, the outcome of the CWA and MWD rate structures will have an impact on the City.

2.4.4 Emerging Technologies

Technological advancements have opened the door for new water supply options that were previously considered technically unfeasible or not cost-effective. In particular, desalination technologies have improved markedly, with reduced energy requirements and increased recovery efficiencies for treating seawater or brackish groundwater. The use of membranes for removing salts and minerals from brackish groundwater and seawater is being implemented across the country to develop sources that are not available through conventional treatment.

Energy requirements for desalination technologies are greater than those for conventional treatment. The availability of power is therefore an important aspect to consider in the development and implementation of desalination projects. The City will only consider implementation of these technologies after careful evaluation of the power supply reliability, and the stability of the energy markets.

Worldwide, distillation and reverse osmosis (RO) are the most common technologies for desalination of seawater and brackish water. Distillation predominated as the preferred technology until the 1970’s, but membrane technologies such as RO have become more commercially viable since then. Distillation facilities are relatively common in the Middle East, with the largest facility in Saudi Arabia treating 143,360 AFY. No large distillation facilities exist in the U.S.

On the other hand, many RO facilities for treating brackish water have been constructed in the U.S., the largest with capacities up to 82,880 AFY (in Yuma, Arizona). The largest existing RO facility for desalination of seawater is in Malta, treating up to 5,600 AFY. Facilities for desalination of seawater also exist in California (e.g., Santa Catalina Island, and Hearst Castle) but on a much smaller scale, treating 45 to 146 AFY. RO facilities are relatively more efficient than the distillation facilities, with a yield efficiency of 35-50 percent, compared to 25-30 percent for distillation. Yield efficiency refers to how much usable water is produced for every unit of raw seawater treated.

2.4.5 CALFED and State Funding for Local Projects

CALFED, a joint program between California and the federal government, was established to help solve the water resources conflicts in the San Francisco Bay-Delta. Recently, an agreement was reached by the major stakeholders on the major components and direction for CALFED. Much of what CALFED is now calling for is a commitment by State and federal funding for conservation, water recycling, groundwater conjunctive use, and advanced water treatment processes such desalination. In addition, California’s recent voter passage of the California Water Bond 2000 (Water Bond) will provide hundreds of millions of dollars for improving supply reliability by helping local agencies develop water recycling, groundwater storage, and watershed management programs. Groundwater conjunctive use (use of groundwater basin for supply and storage of non-native water) has received considerable attention in both the CALFED process and the Water Bond, as it is regarded as a cost-effective alternative and more environmentally acceptable than constructing large surface reservoirs. State and federal funding could help to make local supply projects such as groundwater storage or expanded recycling more cost-effective for the City.

2.4.6 Conclusions and Significance to the City

All of these emerging trends have direct significance to the City. Table 2-2 summarizes the emerging trends and indicates their potential significance to the City.

Table 2-2
Emerging Trends and Significance to City of San Diego

Industry Trend	Significance to City
Water Marketing and Wheeling	▪ Opens up the possibility of City acquiring its own water supplies through water transfers and sets fair rules for wheeling such water through regional systems owned by DWR, MWD and CWA
Private Sector Emergence	▪ Expands options for future supply development ▪ Provides opportunities for public/private partnerships to share risks
Cost-of-Service and Rate Reform	▪ Costs more equitably allocated to services provided ▪ Commitment to imported water purchases (contracts) ▪ Availability of low-cost surplus water for storage
Emerging Technologies	▪ Expands options for desalination of brackish groundwater and seawater
CALFED and Funding Opportunities	▪ Provides State and federal funding for local projects such as conservation, recycling, desalination and groundwater conjunctive use, which could make local projects that were previously thought to be cost-prohibited more feasible

Section 3
New Water Supply Opportunities

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New Water Supply Opportunities

Having identified the projected need for additional supplies, the next step in developing a strategy for future supply development is the identification of new water supply opportunities. In this section, each of the supply options available to the City was identified. The information provided here should only be used in the context of developing a water resources plan and strategy. Although every attempt was made to obtain reasonable supply yield and cost data, in some cases certain estimates had to be made based on prior studies and/or professional engineering judgment. Before any supply option is actually implemented, a detailed investigation would be required. What is presented in this report for each option is an assumed level or type of development. The actual level or type of development for any of these options could be very different than what is presented here, as a result of conducting engineering feasibility studies.

3.1 Water Conservation

Every gallon of water saved though conservation becomes available as supply for another need, human or environmental. Unlike other water supply options, however, the City has somewhat limited control over conservation supply—since there are no mandates to conserve water. Without conservation mandates, the effectiveness of this option is based on consumer acceptance. Conservation which results from direct City efforts is known as “active” conservation. Conservation independent of direct City efforts is termed as “passive”; though the City may be involved indirectly, such as in support of Municipal Codes.

3.1.1 Supply Potential

Potential yield from conservation depends on user participation and on technology. The City operates an aggressive voluntary Water Conservation Program with the goals of significantly improving customer participation and installing water-saving devices. Most of the programs in the current Conservation Program are based on Best Management Practices (BMPs) recommended by the California Urban Water Conservation Council.

By 2000, conservation savings had reached 17,000 AFY, or 7 percent of 2000 demand. By 2005, current conservation programs are expected to yield 26,000 AFY, or 10 percent of expected demand. These savings are based on current projections for technology and political support. Savings will likely be a percent or two higher in dry years due to greater public awareness and participation.

Conservation programs are applicable to a wide customer base: residential, commercial, industrial, institutional and landscape. The programs include measures such as water-use surveys, retrofits of fixtures (such as toilets, showerheads, and irrigation fittings and systems), water system audits and repair, metering, financial incentives, education, waste prohibition and agency assistance. The City's programs are regularly updated to include the latest technologies. A good description of the City's conservation efforts to date can be found in the 2000 City of San Diego Urban Water Management Plan (UWMP). Figure 3-1 summarizes the expected breakdown in conservation savings for Year 2005.

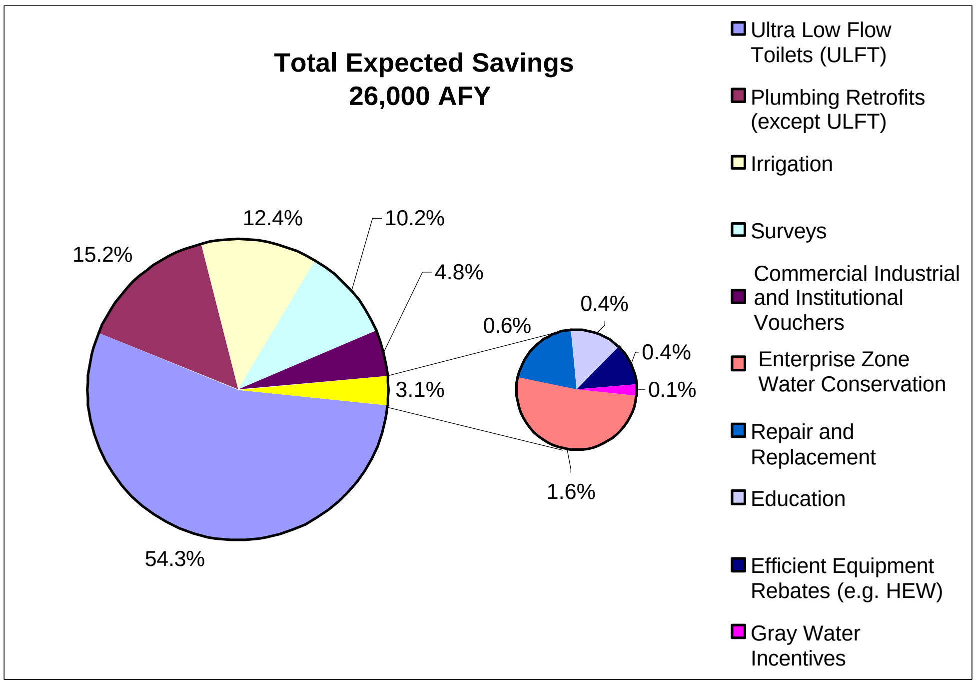


Figure 3-1
City of San Diego
Breakdown of Estimated Conservation Plan Savings for 2005

To go beyond the City's 2005 conservation goal would require more rebates and a greater emphasis on irrigation conservation. The City is exploring rebates for irrigation savings devices, working with other neighboring cities, CWA and MWD. Going significantly beyond the 2005 goal would likely require a new conservation technology, as residential plumbing retrofits will not likely produce much more savings beyond 2010—as the housing stock will be fairly efficient in terms of showerheads and toilets.

Specific conservation options for the City include expanding its plumbing retrofits, developing irrigation programs, and continuing to strengthen its public information and education program.

Toilets and Other Fixture Retrofits

The BMPs with the greatest impact to date have been the 1.6-gallon ultra-low flush toilet (ULFT) programs. With over twice the savings of a 3.5-gallon low flush toilet (LFT) (from a standard 5 gallon), ULFT's account for over half the total savings to date, and of the projected increase to 2005. It appears technically feasible to increase the ratio of replaced residential toilets from one-third to 80 percent over the next 10 years, a 150 percent increase. This could bring another 10,000+ AFY in water savings. Innovative means of increasing public participation outside of drought periods are needed and should be explored. Some ULFT brands are not very efficient and have added to public resistance. New product evaluation and an enhanced education program may be required to regain consumer confidence and increase participation.

There has been a low level of participation in ULFT and low-flow fixture replacement programs on the commercial side. Water savings for this section remain untapped. Further marketing, incentives and other means to increase participation should be explored, especially for larger users such as hotels, restaurants and places for large public gatherings.

Water use from other types of fixtures can also be reduced, or the water can be reused. The High Efficiency Clothes Washer (HEW) Rebate program encourages savings in water and electricity, but has only reached a tiny fraction of the public so far. HEWs are relatively new products, and incentives for HEWs are fairly new. With the California energy crisis and increased incentives for energy efficiency, participation in this program is expected to increase dramatically. An eye should be kept open for eligible models recently entering the market, as well as other new products. For example, a high-efficiency dishwasher is likely to appear on the market soon.

Irrigation Management

Irrigation management is the next area with high savings potential. The City is implementing further landscape incentive programs. These programs aim to identify and reduce wasteful fixtures and irrigation practices, and to date, have shown water savings of 1,600 AFY, or 10 percent of the conservation effort. By 2005, savings are expected to reach nearly 4,000 AFY or 15 percent of currently projected savings. Participation has been far from comprehensive for large irrigators (golf courses, etc.) or for common-area irrigators such as housing associations, commercial cooperatives, and public facilities such as schools and parks. Further significant savings are available.

Residential over-watering can be found throughout the City, and is largely a result of human error, forgetfulness or negligence. Technology is bringing the greatest benefits to this area. Separate meters for exterior water (or dual purpose interior/exterior, e.g., installed in new construction) can be the first line of defense, and a valuable source of information for water audits. Incentive programs for existing households, multi-family units and commercial sites may induce their incorporation. Other technological fixes include: clock timers, moisture sensors, rain sensors, flow interruption devices and sensors, and use of information from weather stations to tailor watering to evapotranspiration rates. This is an area making rapid technological improvements.

Local graywater systems could also reduce irrigation water needs. Graywater systems take untreated water used for cooking or bathing, and use it for outside landscape irrigation. There are numerous technical and health-related issues that should be addressed prior to a widespread implementation of graywater, but it could become a long-term strategy. Graywater systems require a separate plumbing discharge line for graywater sources, therefore, are easiest to install in new construction. For some existing slab homes, mainly those that have interior plumbing far from exterior walls, the cost of retrofitting can be considered prohibitive.

Public Information and Education

Water surveys are quite effective and may be used to identify the appropriate program(s) for a particular customer or customer group. They are a valuable part of the education process, and when combined with installation of water-saving devices, lead to significant savings. During droughts, a high-quality public information and education program for conservation can often mean the difference between reducing demand through voluntary means or requiring mandatory cut-backs.

3.1.2 Development Issues

The Conservation Program depends upon voluntary compliance. This raises issues beyond technical, economic or environmental feasibility. Development issues including identifying potential customers, gaining their participation, distribution of costs, low participation and political issues have made conservation more complex and somewhat more difficult to predict.

Each conservation program has its preferred target consumer group(s). For example, among residential programs, beyond ULFT and fixture replacement for all homes, more water savings are technically possible from customers who consume more water. Customers with a greater number of water using amenities, such as washing machines, dishwashers, large tubs or spas, swimming pools, and fountains are more likely to have moderate to large landscaped areas and more likely to frequently wash exteriors of houses, paths, driveways, cars and other large objects. In addition, they are more likely to entertain, with associated cooking, cleaning and sanitary usages. Education and financial incentives for efficient fixtures and reduced usage may be among the most effective way to reduce consumption by these customers.

There are also target areas. Currently water imports are greatest in the north, and local water is more available in the south. In normal and wet years, conservation will have more economic benefit in the northern part of the City, due to the reduction in imports. In dry years though, the importance of conservation in all areas of the City will become more apparent, especially in hotter areas away from the coast.

3.1.3 Summary of Supply Options

For this planning effort only two options were considered for conservation: "Existing", that is (for comparison) no further active conservation efforts beyond the 2005 levels in the UWMP, and "Greater than Existing", which assumes that continued conservation efforts will produce conservation savings according to those estimated in the PMCL water demand report (2001).

Supply Yield

If the City only implemented its existing conservation program, it is estimated that savings of about 26,000 AFY would continue through 2030. By expanding its current programs and implementing additional measures, such as providing rebates for irrigation savings devices, the City could develop another 20,000 AFY by 2030. That means that by 2030, the City would be conserving approximately 46,000 AFY of water—or over 13 percent of demand.

Estimated Cost

Conserved water is by far the least expensive supply option available to the City. The City Conservation Program Manager has determined that existing programs cost $50 per acre-foot (after receiving financial assistance from the CWA and MWD). This is one-third the cost of local supply from runoff (the least expensive water source), and less than 10 percent of most other options. For the purposes of this planning effort, future conservation programs through 2030 have been determined to cost $75 per acre-foot ($50 plus a $25 contingency). No capital improvements are required for conservation.

3.2 Water Reclamation

Water reclamation is the process by which wastewater is treated to levels suitable for reuse, offsetting demands for potable water. Reclaimed wastewater can serve non-potable demands such as irrigation and some industrial uses, and potable demands via indirect and direct reuse. For planning purposes, water reclamation is evaluated as an option to offset only non-potable demands in the City.

3.2.1 Supply Potential

Several studies were reviewed to define the potential annual supply used in this planning effort. In particular, reviews of the City's progress and potential for reclaimed supply are given in the UWMP, the City of San Diego Updated Water Reclamation Master Plan (City of San Diego, 2000) prepared by John Powell and Associates, Inc., and City of San Diego Manager's Reports.

In the year 2000, the City treated approximately 195,000 acre-feet (AF) of wastewater from the City sewer system and from 15 surrounding municipalities, according to the Point Loma Ocean Outfall Annual Monitoring Report, January-December 2000. The majority of this reclaimed water flow is not supplied to potential customers due to system constraints but rather is conveyed to the Point Loma Wastewater Treatment Plant for treatment and discharge to the Pacific Ocean.

The City entered into an Assistance Agreement with the EPA which provided 55 percent of the funding to build the North City Water Reclamation Plant (NCWRP). By 2010, NCWRP is expected to treat 26,900 AFY. The EPA grant goal is for the City to reuse 25 percent of this flow (6,700 AFY) by 2003 and 50 percent by 2010 (13,400 AFY). This equates to 4.6 percent of projected 2010 wastewater flows. Water treated at reclamation plants like NCWRP is suitable for irrigation, industrial and other non-potable uses, and in some cases may meet higher water quality standards.

In addition to NCWRP, there is another reclamation plant currently in service with a third scheduled to come on line in 2001. They are the San Pasqual Water Reclamation Plant (SPWRP), and the new South Bay Water Reclamation Plant (SBWRP). The ultimate build-out capacity for these plants, summarized in Table 3-1, is approximately 51,000 AFY. However, it is not expected that full delivery of this water will occur in the near future.

Table 3-1
Capacities of City of San Diego Reclamation Plants (AFY)

Plant	Build-out Capacity	Treated to Secondary Levels in 2000	Reclaimed Water Delivered in 2000[1]
NCRWRP	33,600	26,900	4,200
SPWRP	1,120	1,120	300
SBWRP	16,800	0	0
Totals	51,520	28,020	4,500

[1] Peter MacLaggan, 2001; using data from City of San Diego

In year 2000, about 28,000 AFY was treated by the reclamation plants and 4,500 AFY was delivered to customers. Some of the reclaimed water is sold to customers outside the City, and the City is discussing opportunities for selling reclaimed water with other cities and water districts. Since total irrigation use is 35-40 percent of potable demand (about 100,000 AFY), there are ample opportunities to develop a strong customer base.

The City's Water Reclamation Master Plan indicates that the 2003 reclamation goal of 6,700 AF will be met by a phased expansion of the existing recycled water system. Similarly, the document identified projects required to meet the City's required 50 percent reuse goals (13,400 AFY) in 2010. The main projects are three extensions to the North City service area: Black Mountain Ranch/Olivenhain Municipal Water District corridor (BMR/OMWD); State Route 56 (SR-56) corridor; and Interstate-15 corridor. These alignments were selected primarily based on the location of large irrigation users. Additionally, the SPWRP is expected to deliver 1,200 AFY for beneficial reuse within the City, by the year 2010; and the SBWRP is expected to deliver 6,700 AFY when it comes on-line. Table 3-2 presents a summary of the projected demands for the reclaimed water, based on expected customers and system improvements.

Table 3-2
Projected Reclaimed Water Usage for City of San Diego (AFY)

2000	4,500 [1]
2003	8,400
2010	14,800
2030	33,000 [2]

[1] Supplied from NCWRP and SPWRP.
[2] Supplied from NCWRP, SPWRP and SBWRP (assumes 16,800 AFY).

3.2.2 Development Issues

Distribution capacity is currently the greatest obstruction to significant water reuse. Total reclaimed deliveries in the year 2000 were 4,500 AF, less than 20 percent of current plant capacity of 28,000 AFY. Additionally, off-season storage capacity can become a limiting factor since reclaimed water that cannot be sold to customers or stored is returned to the waste stream for redundant treatment at another plant and disposed into the ocean. Currently three groundwater basins are under consideration for storage of reclaimed water, San Dieguito, Tijuana River Valley and San Pasqual.

The 16,800 AFY SBWRP is currently under construction and scheduled to be partially on line by 2002. By 2005 the entire 16,800 AFY treatment capacity is expected to be available. The City is evaluating the feasibility of marketing up to 9 mgd of reclaimed water from SBWRP (City of San Diego, 2000c). The City is currently analyzing demands of potential customers located in close proximity to the facility including the International Wastewater Treatment Plant. In addition, the Otay Water District has expressed an interest in purchasing a significant amount of production capacity, and Mexico has expressed an interest in the reclaimed water.

There are other issues related to reclamation development, including environmental and public acceptance issues, source water quality of wastewater influent, and funding assistance. Source water quality is of particular concern to the City. Source water high in salinity creates problems for wastewater and reclaimed treatment process, which adds further salt load to the effluent. Current salinity of reclaimed water for the City averages between 800 and 900 parts per million (ppm). Once salinity of reclaimed water goes beyond 1,000 ppm, its uses become greatly limited. Water this high in salinity cannot be used for irrigation, as it tends to burn vegetation. In addition, high salinity water can corrode pipes and other fixtures greatly limiting industrial uses for the water. The City has an agreement with its customers not to exceed 1,000 ppm. Therefore, it is important to the City that salinity of its source waters be managed in order to fully utilize its reclaimed water supply.

Other specific issues for City development of reclaimed water include:

- Additional direct distribution for the capacity of existing plants (within the City and exported);
- Potential for above and belowground storage. Storage could make it possible to maximize reuse of volumes treated and to extend service periods; and
- Availability and ability to distribute reclaimed water imported from surrounding communities.

As reclamation provides significant benefits to the environment, in terms of reducing reliance on imported water from the environmentally sensitive Bay-Delta, funding for reclamation has become a statewide objective. In addition to funding assistance from the CWA and MWD, CALFED and other state and federal financial assistance is available.

As stated before, there are opportunities for the City to sell reclaimed water outside of its service area, as well as opportunities to use reclaimed water to offset water demand peaks. This would help offset the City's cost for developing reclaimed water and meet the City's reuse objectives for wastewater.

3.2.3 Summary of Supply Options

For this planning effort, three supply development options were assumed. The first level (existing) simply meets EPA's 2003 goal for reclaimed water. The highest level assumes that the demand identified in Table 3-2 would be satisfied. And a mid-level assumes supply in-between the existing and highest levels of development.

Supply Yield

Although the City is only delivering about 4,500 AFY of reclaimed water, with its existing reclaimed delivery system it could meet the EPA's 2003 goal, which is a supply yield of about 8,000 AFY. A mid-level development for reclaimed water supply would add another 11,000 AFY of yield to existing levels—for a total of almost 20,000 AFY. The highest-level of development would add yet another 14,000 AFY of supply—for a total of approximately 33,000 AFY.

Cost

The total cost of reclaimed water (including O&M costs for existing treatment, capital costs for new treatment, and capital costs for distribution) are estimated to be approximately $350 per acre-feet for existing operations, and about $650 per acre-foot for new supply development. The low range cost of $350 per acre-foot represents the City Council adopted reclaimed water rate (adopted on June 19, 2001), based on a 10-year cost-of-service study taking capital and operating expenses into account. This rate was based on the net present value of all costs, divided by anticipated deliveries.

3.3 Ocean Desalination

Desalination is the process whereby dissolved minerals (salts and others) are removed from seawater or brackish groundwater. Historically, desalination technology was focused on removal of salts from seawater and used in other countries where no other solutions were feasible. Given other alternatives, the cost of desalination in the United States was considered too high. However, because of new technologies, desalination is being examined by coastal water agencies around the country. Desalination offers improved water quality (low in salinity), and can help the City protect itself against droughts and earthquakes. Figure 3-2 illustrates desalination for three different applications: (1) seawater; (2) filtered seawater; and (3) brackish groundwater. All three situations could be applicable to the City. Although the technologies are similar for all three applications, the cost varies significantly as the higher the mineral or salt content, the higher the treatment cost. In all cases, however, substantial energy requirements are needed. Desalination as it pertains to removing salts and other minerals from brackish groundwater is discussed later in Section 3.4.

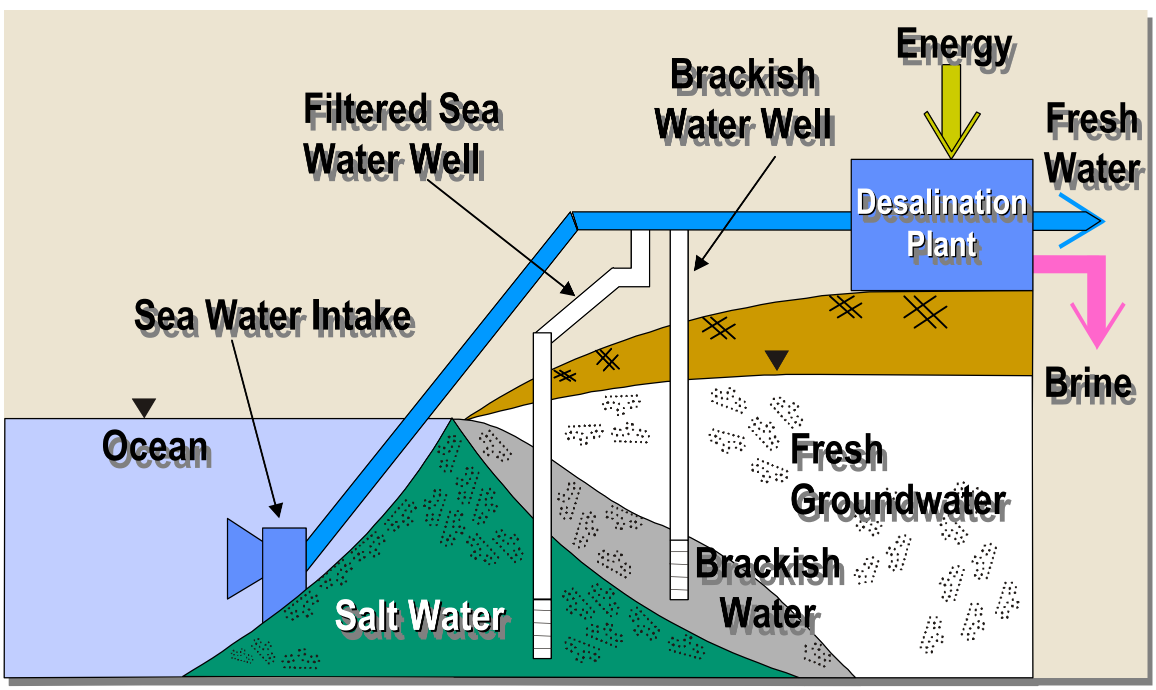


Figure 3-2
Desalination Applications

3.3.1 Supply Potential

Although seawater is a seemingly unlimited resource, the high cost of developing this supply tends to restrict the total capacity developed. Issues such as siting, energy availability, environmental impacts, and the distribution costs needed to move the water from treatment to delivery all impose constraints on how much seawater can be treated. Most seawater desalination plants in the United States are not very large, under 5 million gallons per day (mgd).

In determining the site location for seawater desalination facility in San Diego, the most critical issues are: (1) how much land space is required; (2) is the land a current City asset; and (3) are there existing infrastructure assets that can be used to transport water and power to and from the site. The most economical approach for siting a seawater desalination facility is to locate the plant on coastal property adjacent to an existing power plant or municipal site. A power plant site, if sufficient land is available, provides many benefits including available thermal energy to support desalination processes and existing intake and discharge facilities. Advantages associated with existing municipal sites are avoiding the need to purchase costly coastal land assets, and the availability of existing infrastructure such as power and possibly intake and/or discharge facilities.

The April 1991 South Bay Combined Power/Seawater Desalination Facility Feasibility Study by San Diego County Water Authority determined that the South Bay Power Plant Site could accommodate a 460-megawatt (MW) power facility and a 50,000 AFY desalination plant.

3.3.2 Development Issues

Capacity requirements, appropriate process technology, siting, environmental impacts, regulations, ownership, and schedule requirements comprise the primary categories of development issues.

Capacity

The high costs related to developing a desalination project restrict the total capacity of the plant. Using low-pressure steam from a power plant can offset the energy costs associated with the process technology. However, the amount of available steam can be a critical factor in limiting the capacity of these facilities. Other factors that can affect seawater desalination capacity include: size of intake and discharge facilities, if existing facilities are to be used to reduce costs, quantity of brine disposal and potential environmental impacts; and limits set for any power cost reductions that may be negotiated with a power utility.

The overall capacity can be augmented if opportunities exist to blend higher quality product water with lower quality water that produces a blend that meets drinking water standards. If the lower quality water is only problematic with regards to aesthetic water quality (Total Dissolved Solids, chlorides, sodium, iron, manganese, etc.), it may be possible to produce an acceptable quality water by using high quality desalination product and untreated or minimally treated lower quality water (e.g., brackish groundwater). This will increase the overall capacity and reduce the unit cost.

Desalination capacity needs will be determined by the City's overall future supply mix, which may combine supplies from existing water treatment plants with other alternative supplies such as reclaimed water and groundwater. Relative to developing a desalination program, capacity is one determining factor in the selection of a process technology.

Appropriate Process Technology

The appropriate process technology relates to the type of water being desalinated, the quality of water being treated, the level of desalination desired, and whether the facility is to be combined with a power plant. Both thermal and membrane processes can be used with seawater, and be beneficially located with a power plant. Ultimately, the unit cost to treat the selected source water and the proven reliability of a process are the primary factors influencing the selection of an appropriate technology.

Siting

Desalination plant candidate sites should be evaluated based on the following:

- Availability of land and/or existing infrastructure,
- Proximity to other groundwater sources for blending opportunities,
- Feedwater quality,
- Product water quality use and delivery facilities, and
- Availability and proximity to a power plant if to involve combined used.

Land and Infrastructure Availability

The key issues are (1) the amount of land space required, (2) the value of the land to the City, (3) the availability of the land to be purchased or leased, and (4) the existence of infrastructure that can be used to transport water and power to and from the site.

The most economical approach for siting a seawater desalination facility is to locate the plant on an existing power plant or municipal site. Advantages associated with locating the facility on these existing facility sites are avoiding the need to purchase costly coastal land assets, and the availability of existing infrastructure such as power and possibly intake and/or discharge facilities. There may also be benefits such as reduced power costs by establishing a relationship with the power generating entity.

Space requirements will increase if power generation facilities must be built alongside seawater desalination facilities. However, these costs can be shared with a combined use facility. Availability of coastal property for constructing new facilities is very restricted in the San Diego County area.

Blending Opportunities

Opportunities exist to reduce the unit cost of desalination if high quality desalinated water can be blended with brackish groundwater to generate a product that falls within the recommended potable water standards or standards appropriate for the intended use. Since the South Bay location is above the San Diego Formation, a confined aquifer, the opportunity to develop a groundwater desalination project in conjunction with the ocean desalination project is extremely valuable.

Another option to consider with seawater desalination is a hybrid facility consisting of both thermal and membrane desalination. The distillation process produces water free of minerals, approximately 1 mg/l TDS. An RO facility could be designed to produce water that exceeds drinking water standards for minerals and then be blended with the distillate to meet the standards. There may be economic advantages of using the hybrid approach.

Product Water Quality and Delivery

Product water quality must meet the criteria established for the intended use of the water. This includes criteria for potable water or reclaimed water. The state has established water quality criteria as well as watershed and aquifer protection criteria for drinking water supplies. Currently, the State is developing criteria that can be applied to treatment of open seawater. It is not clear how watershed protection criteria and microbial treatment criteria will be established for these waters at this time.

Consideration of how water will be conveyed to the end users and how much pumping is required are important factors to consider when siting desalination facilities. The intended end use is also an important consideration relative to the level of treatment required. Desalination of seawater requires locating a treatment plant along the coastline at a hydraulic gradeline of sea level. Most likely, seawater desalination facilities will be located to supplement water supply to the lowest pressure zones in the distribution system.

Seawater desalination facilities must be located on the coast due to low product yield, which requires feedwater flows two to three times that of the treated water produced. The high cost of conveyance makes it impractical to locate their facilities inland. Consideration must be given to the existing distribution system infrastructure and if piping of sufficient size exists to convey the new product water from the new site to its intended users.

The City may also want to consider whether locating a new desalination facility can improve water supply redundancy in service areas where redundancy may not exist or be limited. Potential areas for consideration include Point Loma and Pacific Beach.

Power Supply

Seawater desalination involves power intensive processes that require significant sources of thermal and/or electrical energy. Whenever possible, these facilities should be sited near a power plant with excess thermal energy. Thermal energy can be used to heat the feedwater to improve product yield and overall efficiency. Steam driven motors may also be considered. It should be noted that any desalination facility that is designed to depend on thermal energy from a power plant can only be operated when the power plant is generating electricity.

Other opportunities may exist to reduce overall power costs. The design should consider selection of materials and powered equipment to optimize life cycle costs – capital, operation (including power) and maintenance costs. Advancements in technology are constantly being pursued to reduce energy requirements for desalination facilities and to improve the recovery of excess waste energy.

The City should also try to identify opportunities to lock in lower power costs for an extended period by negotiating with a power supplier. Opportunities exist to obtain more favorable rates whenever an existing power generating facility seeks to renew or expand its license to generate power or when a new power plant is proposed. The regulatory process for approving an expansion of a power plant might be more favorable if a desalination plant is coupled with the proposed power project. The City may be able to barter certain credits such as air credits, or establish a public beneficial use relationship that expedites or increases the favorability of the licensing process for the power facility. Reduced power costs could be used to support new seawater desalination facilities and/or minimize costs at existing City facilities.

Environmental Impacts

Environmental impacts associated with desalination plants can be separated into two main categories: construction-related impacts (temporary) and operational impacts (long-term, permanent). Efforts to control these impacts can affect both process technology and site selections. Examples of construction impacts include: marine habitats, public access and recreation, commercial fishing and navigation, seafloor ecology, view obstructions, noise, and others.

Operational impacts are long-term in nature. The most significant impacts are likely to include: energy use, air quality, and marine environment impacts. Desalination plants require large amounts of energy. The overall impact can be reduced if exhaust steam from a thermal power plant can be applied to satisfy a portion of the energy requirements.

Production of additional energy to power desalination plants will increase air emissions. Potential air quality mitigation measures include a preference for reduced energy use and use of alternative non-polluting energy sources.

Constituents in the desalination plant's waste discharge must be considered with regard to potential marine environment impacts. Waste discharge constituents depend on the process technology, intake water quality, and product water quality. Many marine environment impacts can be mitigated via dilution if desalination wastewater is combined with discharge cooling water from a power plant or discharge from a wastewater plant. Marine resource impacts may also occur as a result of desalination plant intake. When species collide with intake screens, impingement results in loss of marine species. Species may also be carried into the plant with the intake water.

Proper siting of intake and outfall facilities can mitigate some of the marine resource impacts of ocean desalination. Removal of hazardous constituents in the brine waste stream prior to discharge can also greatly reduce environmental impacts.

Regulatory/Permitting

The following agencies are likely to have permit jurisdiction over the construction and operation of a desalination plant:

- California Department of Health Services, Drinking Water Branch - responsible for permitting all public water supply facilities
- California Coastal Commission – If the City does not have a fully certified Local Coastal Program (LCP), a coastal development permit will be required; approval of such a permit will require a CEQA document (Negative Declaration or EIR). A permit may be required in any case, if the project is in state waters, on land up to the mean high tide line, or on lands subject to the public trust
- State Lands Commission – if the project will be located in the SLC's jurisdiction, the project owner must obtain a lease or permit from the SLC to do so
- Regional Water Quality Control Board – proposed discharges must be authorized in an NPDES permit
- U.S. Army Corps of Engineers – permits under the Rivers & Harbors Act of 1899 and Section 404 of the Clean Water Act

3.3.3 Summary of Supply Options

For planning purposes, it was assumed that an 8.9 mgd seawater desalination plant (located at the South Bay site) would be an appropriate sized facility given the above-mentioned development issues. This option would provide 10,000 AFY of supply to the Otay Service Area (the area south of Chula Vista extending to the U.S.-Mexico border). It is assumed that the fastest that this supply option could be available to the City would be 2011.

Cost of Supply

Based on typical life-cycle costs of similar RO ocean desalination plants, the estimated capital cost for an 8.9 mgd plant is approximately $57.2 million, while the total O&M costs are approximately $8.1 million. O&M costs include fixed costs (i.e., maintenance and repair, and labor costs), estimated to be 3 percent of the capital costs, and variable costs (i.e., power costs). Therefore, the fixed O&M cost is estimated to be approximately $1.7 million per year, while the variable O&M cost is estimated to be $638 per acre-foot.

Additional costs are required for conveyance facilities to deliver the source water to the plant and the treated water from the plant to the existing City distribution system. Based on a planning-level cost analysis, the capital cost for the additional infrastructure is estimated to be $5 million, while the O&M costs are estimated to be $0.5 million per year.

Therefore, the total estimated cost of an 8.9 mgd ocean desalination plant, including the distribution costs to deliver the treated water to the City's customers is approximately $1,400 per acre-foot.

3.4 Groundwater Desalination and Conjunctive Use Storage

Groundwater resources maybe one of the most promising local supply opportunities for the City. There are eight major groundwater basins that are of interest to the City for supply development (see Figure 3-3):

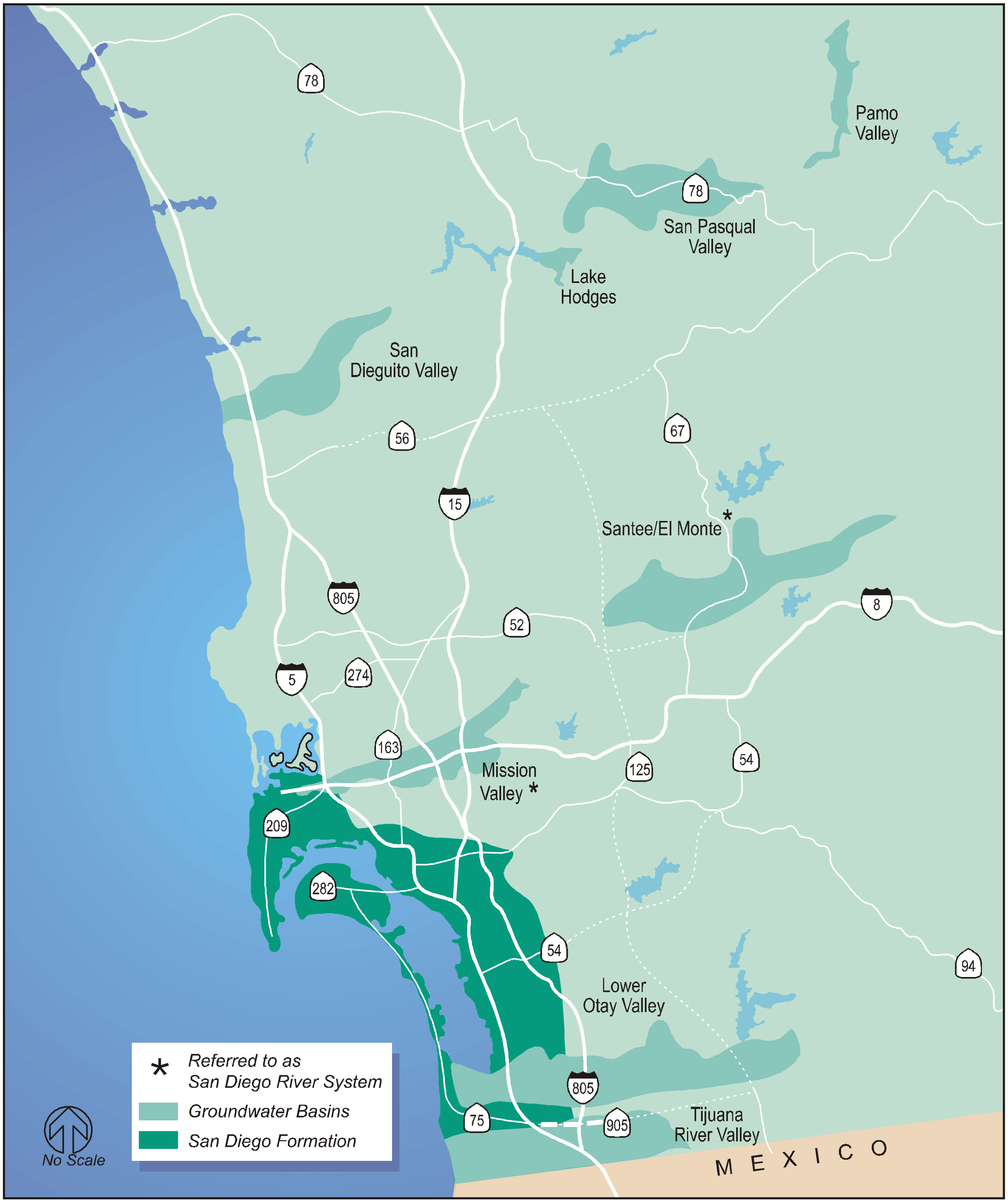
- San Pasqual Valley Basin
- San Dieguito Valley Basin
- Santa Maria Basin
- Mission Valley Basin*
- Santee/El Monte Basin*
- Middle Sweetwater River Basin
- Lower Sweetwater River Basin
- Tijuana River Valley Basin
- San Diego Formation Aquifer

** Typically referred to as San Diego River System*

San Pasqual Valley, Santa Maria, Santee/El Monte (part of San Diego River System), and Middle Sweetwater River are alluvial inland basins. Alluvial inland basins are hydraulically isolated from the ocean and have limited areas where natural outflow takes place. These basins are ideal for storage and maintaining safe yield.

San Dieguito Valley, Mission Valley (part of San Diego River System), Lower Sweetwater River, and Tijuana Valley are alluvial shoreline basins. Alluvial shoreline basins likely have hydraulic interaction with the ocean and, therefore, management options would likely be needed to address this factor.

San Diego Formation appears to be a confined aquifer system, which has a much greater aerial extent. It is also likely to have hydraulic interaction with the ocean.



Map shows relative locations of basins only. Not to scale.

Figure 3-3
Major San Diego Groundwater Basins

In 1983 and 1985, the USGS published reports summarizing data collection for many of these groundwater basins. A subsequent report prepared by Boyle Engineering Corporation (1995), summarized the USGS studies. Much of the safe yield and water quality data is over two-decades old and it is likely that conditions have changed.

The City is currently investigating five of the groundwater basins to determine their feasibility for development. The City sees these basins as a local asset and a way to improve its water supply. The City is completing a master plan for groundwater development, and is moving ahead with field studies for the San Diego River System, San Dieguito Valley, San Pasqual Valley, Lower Tijuana River Valley, and San Diego Formation. Field studies, through drilling exploratory wells, will be used to determine safe yield (inflow and outflows), water quality, and other basin characteristics.

3.4.1 Supply Potential

For planning purposes, the supply potential for these basins was based on the Boyle Engineering Corporation (1995) report. However, it should be noted that actual supply yield and cost could be significantly different, based on the outcome of the City's investigation and field study.

There are two types of supply that these groundwater basins could provide: (1) safe yield production, providing a yearly supply; and (2) conjunctive use storage of imported and/or reclaimed water, providing a dry year supply.

Groundwater Desalination (safe yield production)

Based on prior reports, it is likely that safe yield production from these basins would require treatment (desalination). Similar to ocean desalination, groundwater desalination is the process whereby dissolved minerals are removed from saline or brackish groundwater (see Figure 3-2 in Section 3.3).

The most likely development range of safe yield supply from these basins is 6,000 to 20,000 AFY. It is assumed that natural recharge is sufficient for this range of safe yield. The safe yield, with treatment, could be used for both potable and non-potable purposes, as well as for average annual and peak demands.

Depending on which basin(s) are developed, the cost for groundwater desalination could involve the following components:

- Desalination treatment facility
- Brine disposal lines
- Groundwater production wells
- Interconnection facilities to move groundwater supply to City's water delivery system (e.g., pump stations, pipelines, etc.)

A planning-level cost analysis indicates that groundwater desalination could range from $650 to $1,200 per acre-foot, depending on level of treatment, pumping, and location of basin relative to the City's water delivery system.

Groundwater Conjunctive Storage (dry year production)

Another potential benefit of these groundwater basins is conjunctive use storage. Conjunctive use storage is the process by which non-native water supply is artificially recharged into the basin to produce a supply yield. Whereas safe yield supply requires that natural runoff and rainfall replenish the groundwater, conjunctive use storage can offer increased supply where little or no natural replenishment is available. Conjunctive use storage of the groundwater basins can essentially operate like an underground surface reservoir. There are four possible ways for the City to store non-native water in the groundwater basins for storage:

- Treated water injected into the groundwater basins through injection wells
- Untreated water percolated into the groundwater basins through natural or man-made spreading basins
- Reclaimed water injected into the groundwater basins through injection wells
- Reclaimed water percolated into the groundwater basins through natural or man-made spreading basins

It should be noted that the use of reclaimed water for groundwater storage would limit the supply production for non-potable uses only. The City would not store reclaimed water in groundwater basins used for potable demand.

Table 3-3 summarizes the potential for groundwater conjunctive use storage for three basins. These estimates were generated using the Boyle Engineering Corporation (1995) report. There may be additional storage potential in the other basins, which will be determined through the City's field investigations.

Table 3-3
Groundwater Conjunctive Use Storage Potential for Three Groundwater Basins

Groundwater Basin	Maximum Storage (AF)	Recoverable Storage – Supply Yield (AFY)	Artificial Recharge (AFY)
San Pasqual Basin	60,000	20,000	29,000
San Diego River System	70,000	18,000	26,000
San Diego Formation	200,000	10,000	14,000
Total	330,000	48,000	69,000

Costs for groundwater conjunctive use storage, depending on the source of stored water (e.g., imported vs. reclaimed) and need for treatment, may involve the following components:

- Groundwater production and/or injection wells
- Pre or post treatment (filtration, purification)
- Spreading basins
- Interconnection facilities to move groundwater supply to City's water delivery system
- Cost of imported and/or reclaimed water.

A planning-level cost analysis indicates that groundwater conjunctive use storage could range from $550 to $700 per acre-foot, depending pumping, need for treatment, source of replenishment water, and distance of basin relative to City's water deliver system.

3.4.2 Development Issues

There are numerous issues that should be evaluated when considering the development of groundwater resources. Groundwater desalination development issues will be similar to those discussed in Section 3.3.2. However, the following are several other development issues specific to groundwater:

- Interjurisdictional and water rights issues
- Potential impacts to groundwater basins (overdraft, subsidence)
- Outflows of groundwater storage supply (losses)
- Water quality of native groundwater
- Seawater intrusion
- Estimation of safe yield
- Regulatory permitting for possible storage of reclaimed water

3.5 Marine Transport

Marine transport is a relatively new concept for water supply in California. Proposals range from hauling fresh water from as far away as Alaska, carried by either pulling large plastic bags behind ships or retrofitting oilrigs to carry water instead of oil.

3.5.1 Supply Potential

The marine transport option of water supply proposes the use of marine conveyance to import water from the North Pacific Coast of North America to the City of San Diego. In April 1997, the Natural Resources Corporation (NRC) proposed to deliver up to 20,000 acre-ft/yr of potable water to the City. Since the US Oil Pollution Act of 1990 (OPA 90) banned the use of single hull vessels for oil transportation, NRC planned to convert old single hull oil vessels into bulk water carriers.

Similarly, in September 2000, World Water, SA (WW) presented a similar proposal to deliver 20,000 acre-ft/yr of potable water for 20 years to the City by 2004 at the prevailing imported treated water rate of CWA. However, WW declared that the application of converted tankers was economically infeasible and politically unacceptable. WW proposed the bulk trans-ocean transport of water stored in bags and continues to develop new and/or improved conveyance technologies.

Conveyance facilities would be required to deliver the water from the bulk water carrier to the existing City delivery system. Since the tankers are too big to enter San Diego's harbor, a mooring system would be constructed offshore and the water would be pumped through a force main to "tie-in" to the City's existing distribution system. Per the City's request, the selected "tie-in" location would be the North City pressure zone, located in the Miramar Service Area. However, in order to optimize the distribution system, the supply would contribute to both the Miramar and Alvarado Service Areas.

The cost of this option includes two main components: (1) the purchase of the supply from third party seller; and (2) the infrastructure costs needed to move the supply from point of delivery to the City's water delivery system.

NRC proposed that the cost of this option would be between $400 and $700 per acre-foot, not to exceed the CWA untreated water rate. Based on a planning-level cost analysis, the capital costs to move the water supply to the City's delivery system was estimated to be $13.2 million. The overall cost of this option, including the price for the water and infrastructure to move the water is estimated to be about $730 per acre-foot.

3.5.2 Development Issues

The environmental impacts associated with marine transport would be minimal. The water would come from the North Pacific Coast where there is more water than people and the environment need. The typical rainfall is 300-400 inches per year with the lowest recorded annual rainfall over the past 50 years of more than 100 inches. The vessel emission control system would ensure air quality control, and the loading and unloading infrastructure would be constructed in compliance with all environmental laws and regulations.

Current emergency storage requirements are based on the interruption of imported water supplies due to earthquakes. However, the bulk water carriers would not be subject to damage from seismic activity. In addition, WW proposes that the bags may be used as a storage reserve when necessary (i.e., seismic emergencies or the need for storage capacity). Marine transport would be a reliable external source of high quality drinking water even in the event of an earthquake.

The water supply option of marine transport is considered to be controversial due to the uncertainty of political and public support. Multiple state and federal permits or contracts are required to obtain the water rights to buy the water from the North Pacific. In addition, the public has significant influence on political issues, and public perception is always a concern when exploring exotic sources of potable water. The idea of replacing oil with potable water in the tankers raises the question of water quality. However, the Environmental Protection Agency requires that the ships' oil storage bunkers be sandblasted and re-lined, and that all piping be replaced before conveying potable water.

The quality of the source water is highly potable with TDS levels on the order of 10 mg/l. Currently, the imported water from the Colorado River has TDS levels that often exceed 550 mg/l. Therefore, blending the marine transported water with the current supply would (1) reduce the need for softening by the operator and the consumer, (2) reduce the levels of contaminants, sodium, and chlorides, (3) reduce effluent treatment required to meet National Pollutant Discharge Elimination System (NPDES) permit regulations, and (4) increase the service life of the distribution system since the water would be less chemically active.

Although marine transport is proposed to cost the same as the current imported water rate, this does not include the costs associated with the infrastructure necessary to develop the option. The total costs (i.e., water costs and infrastructure costs) were used in the decision model to determine the economic feasibility. In addition, there may be costs associated with the need to improve the existing distribution system in order to support the marine transported supply.

3.6 Water Transfers

Water transfers are agreements in which water supplies are transferred from the original point of origin or control, to a new place of use. They can be a viable option to augment the City's current water supplies. Transfers can offer flexibility and help ensure that the State's water resources are used efficiently. However, a myriad of rules surround transfers in California, and thus it is crucial to consult with the regulatory agencies, affected parties, and environmental experts at the very start of the planning process. Early consultation can help identify and resolve controversial issues, and expedite the approval of the transfer.

Water transfers vary significantly in volume, duration, and complexity. Five basic types of water transfers include:

- Spot transfers: one-time purchases, i.e., during drought years

- Option transfers: buyers purchase a certain amount of water any time during the life of the agreement, paying costs only in those years in which water is needed.

- Core transfers: multi-year contracts that make a specific amount of water available to the purchaser annually; the purchaser incurs costs whether or not the water is needed.

- Storage transfers: allow purchasers to place water into storage for future delivery.

- Water exchanges: allow selling and purchasing agencies to exchange water from one source to another.

3.6.1 Supply Potential

The City of San Diego's three primary sources of possible future water transfer agreements are (1) Central Valley; (2) Colorado River; and (3) North of Delta . Water purchased from these sources would be stored and/or transferred in facilities owned by one of the agencies described in Section 3.7.

Central Valley Opportunities

More than half of California's agricultural water use is in the Central Valley region. The California Aqueduct, which conveys water from north to south through the Central Valley, could be used as a transport mechanism for voluntary transfers to San Diego. In addition to the California Aqueduct, Central Valley transfers could use parts of the federal Central Valley Project (CVP) system to transport water. It is estimated that potential future marketing arrangements from the Central Valley to the South Coast region could approach 200,000 AFY. Marketing arrangements can range from option agreements, storage programs and purchases of water through drought water banks or other similar spot markets (CDWR 1998). Generally, the water quality of Central Valley transfers is good. The cost of Central Valley transfers generally ranges from $50 to $200 per acre-foot depending on hydrology (dry year transfers generally cost more).

Colorado River Transfers and Groundwater Banking Opportunities

Colorado River transfer and banking opportunities may include additional transfers with Imperial Irrigation District and Palos Verdes Irrigation District, canal-lining projects for the All American and Coachella canals, groundwater storage in Cadiz, and participation in the Arizona Water Bank. Estimated potential future marketing arrangements from the Colorado River Region could generate approximately 250,000 AFY, from inter/intra state transfers and water conservation programs (CDWR 1998). The water quality of Colorado River transfers is high in salinity. The typical cost for such transfers ranges from $150 to $300 per acre-foot. Although opportunities exist for transfers along the Colorado River, it is unlikely that such options will increase the City's supply for water. This is because the MWD and CWA have first right of refusal for such transfers and it is anticipated that they will exercise their rights to keep the Colorado River Aqueduct full.

North of the Delta

Although water supply north of the Delta is plentiful, operating restrictions in the Delta related to water exports and water transfers are comprehensive and complicated. For water transfers across the Delta, the physical location of existing pumping plants on the SWP are not ideal for either the water users or fish and wildlife. Pumping at critical times or increased exports could negatively impact the environment or third parties. In general, the same restrictions and uncertainties that face imported supplies from Northern California will affect North of Delta transfers, as these transfers would need to be transported through the environmentally fragile Bay-Delta. The CVP, SWP and other affected agencies have implemented the Operations Group to advise the agencies on how to adaptively manage the Delta within these constraints. Although capacity and regulatory monitoring systems are in place, across-delta transfers are not yet considered viable opportunities in the near future. The water quality of North of Delta transfers is good to excellent. The cost of such transfers typically has ranged from $20 to $100 per acre-foot, however, few agriculture to urban transfers have taken place. North of Delta transfers may be an economical way to reduce the City's cost of imported water, but would carry significant risks for dry year supply reliability.

3.6.2 Development Issues

Water transfers depend upon existing storage and distribution systems. The systems San Diego would be dependent upon for moving transfers are the Central Valley Project (CVP), SWP, MWD's Colorado River Aqueduct and internal distribution system, and CWA's San Diego Aqueducts. In addition to delivery issues, transfers involve complex legal, operational, and financial transactions.

Central Valley Water Project and State Water Project Systems

Figure 3-4 shows the major California water supply and delivery systems that could be utilized in some fashion for the City's water transfers. To move North of Delta and Central Valley transfers, both the CVP and SWP systems would be needed. The CVP, operated by the United States Bureau of Reclamation (USBR), is the largest water storage and delivery system in California. The CVP delivers about 7 million acre-feet (MAF) annually for agricultural, urban, and wildlife refuge use. Most of the CVP's deliveries are to agricultural users. CVP water transport system includes reservoirs located in Northern California and the Sierras; and the CVP aqueduct extends from Tracy south of the Delta to the southern end of the San Joaquin Valley.

Currently, there is no direct tie-in from the CVP to MWD's distribution system (which would need to be used to transport water to the City). Therefore, in order to deliver transferred water to San Diego, SWP facilities would also be needed. SWP facilities include 20 dams, 662 miles of aqueduct and 26 power and pumping facilities. Maximum capacity of the California Aqueduct is 7.5 million AFY at the Delta and 3.2 million AFY at the Edmonton pumping plant, which delivers water over the Tehachapi's to the South Coast Region (MWD) system.

Figure 3-4

California's Major Water Supply and Delivery Systems that May Be Needed for Water Transfers

The ability of both the CVP and SWP to fulfill their contractor's water supply requests depends on rainfall, snow pack, runoff, pumping capacity and regulatory constraints on pumping operation.

Both the SWP and the CVP require water transfer permits be filed before a transfer can take place. These regulatory requirements are in place to insure that water transfers do not negatively impact third parties or the environment. Approvals may be subject to mitigation requirements, which add expenses that adversely affect transaction costs. Additionally, SWP, CVP and other conveyance system owners require various contractual agreements and impose fees for the use of the facilities.

Colorado River Aqueduct and MWD Distribution System

The Colorado River has an average annual unimpaired flow of about 15 million AFY. There is currently over 60 million acre-feet of surface storage on the Colorado River. Water is made available to California parties via releases from Lake Mead (Hoover Dam), which is controlled by the United States Bureau of Reclamation (Bureau). Lake Havasu (Parker Dam) lies approximately 60 miles below Lake Mead, and is the point of diversion for both Southern California urban users and Arizona (via the Central Arizona project). Colorado River water to MWD and CWA must currently travel through the Colorado River Aqueduct, which is owned and operated by MWD. The aqueduct is 242 miles long and has a design capacity of 1.3 million AFY. Water from the Colorado River Aqueduct enters MWD's distribution system in Lake Mathews and Diamond Valley Lake (see Figure 3-4). From these reservoirs, Colorado River water can be sent to virtually all of MWD's member agencies.

San Diego County Water Authority System

The CWA delivers imported water to its member agencies via the San Diego Aqueducts, which contain five, large-diameter pipelines. Delivery points from the MWD system are located approximately six miles south of the Riverside/San Diego County line (see Figure 3-4).

As noted above, the City has no conveyance facilities to independently transfer water from distant sources. Thus, the City would have to enter into separate wheeling agreements with MWD and CWA to transport water from those sources. CWA's total system capacity is approximately 900,000 AFY. Thus far, the most water CWA has delivered was 647,000 AFY (in 1990).

MWD and CWA Wheeling

Wheeling is the use of someone else's water delivery system to move your own water supply (e.g., a water transfer). California law requires that any water system with excess capacity shall make that capacity available for wheeling. The law also states that fair compensation shall be paid to use that system's capacity. The intent of the law was to facilitate and encourage water marketing. However, there are many unresolved issues regarding wheeling. They include: (1) definition for fair compensation; (2) addressing the possible water quality or operational impacts of wheeling; and (3) how the wheeling charge is levied, postage stamp or point-to-point.

Water entities such as MWD and the CWA have yet to finalize contractual aspects associated with wheeling water. MWD has, in the past, posted a wheeling charge of approximately $140 per acre-foot. This rate does not include power, which could be between $60 to $90 per acre-foot. MWD is currently engaged in a rate structure update which could alter its wheeling charge.

At the time of the original posting, CWA and others challenged MWD's wheeling rate. CWA's main contention was the fact that MWD's wheeling rate is system or postage stamp based, rather than point-to-point. However, the court has upheld the postage stamp rationale behind MWD's wheeling rates.

CWA has never entered into a wheeling agreement with its member agencies, so no precedent is available as clear guidance. For planning purposes, the City can reasonably assume that water delivery costs for transferred water will be the same as imported delivery rates for supplies CWA delivers to the City, approximately $90 per acre-foot.

Legal Aspects

Several aspects of water transfers present formidable but surmountable obstacles. The complexity of water law, the relative newness of a privatized water market and the physical restrictions of existing water delivery infrastructure must be addressed.

Transferable water can become available via one of the following means:

- Storage of surplus water during wet or normal years
- Permanent sale or lease of a water entitlement
- Groundwater substitution by water rights owner in-lieu of surface water supplies
- Agricultural conservation

Water transfer requirements differ widely depending on:

- Capacity for storage of surplus water during "wet" and "normal" years;
- The type of water right involved (riparian or appropriative);
- The source of the water involved (surface, ground, or recycled water);
- The use intended for the transferred water (direct diversion or storage);
- Where, when and how far the water is moved (area of origin laws, Bay-Delta restrictions, and other environmental regulations);
- Availability of capacity in the transmission lines

The contractual duration of the transfer (short-term or spot transfers vs. long-term supply or drought contingency plans);

- Requirements to avoid harm to other legal users of water (SWRCB 1999); and
- Regulatory requirements primarily concerned with potential harm to downstream users, fish and wildlife, and third parties.

Numerous transactions are required to be concurrently executed to accomplish securing the water source, providing for storage at the source (if any), securing a wheeling agreement, and providing for storage at the receiving end (if needed). Each transaction involves contractual agreements, and completion of regulatory compliance documents, including environmental review and permitting.

3.6.3 Supply Options

For this planning study, it was assumed that the most likely water transfer opportunities for the City would be from the Central Valley. Although the City may pursue North of Delta and Colorado River transfers, Central Valley transfers offer the most promise as a reliable, good quality and cost-effective water supply. As stated before, approximately 200,000 AFY of water transfer opportunities exist for southern California in the Central Valley. How these transfers would be specifically allocated to buyers in Southern California is uncertain. It is assumed that roughly 30 percent of the total available amount of Central Valley transfers for Southern California could be made available to San Diego County. This estimate was based on the County's historic use for imported water.

Of the different types of water transfers described earlier, "option-type" transfers present the best balance between reliability and cost. In an option agreement, the buyer agrees to pay a certain amount of fixed costs every year for the "right" to call on the transfer water. Then, when the transfer water is actually needed, the buyer pays the remaining costs on a unit-cost basis.

Another major component of a water transfer to the City is wheeling. The City will need to pay both MWD sand CWA for the delivery of the transferred water. Wheeling costs are currently being debated in both the courts and legislature. For the purposes of planning, it was assumed that wheeling charges for both MWD and CWA would total $230 per acre-foot. There would also likely be environmental fees associated with the transfer itself, which have ranged from $20-$50 per acre-foot.

Three levels of option transfers were assumed for the City. The first level represents 10,000 AFY of ultimate supply. The fixed cost for this level is estimated to be $4.2 million. The purchase price for the actual transfer supply is estimated to be $150 per acre-foot. Level 2 represents 20,000 AFY of ultimate supply at a purchase price of $175 per acre-foot. Because this represents a yield double that of the first level, the fixed costs are assumed to be greater, estimated at $7.5 million. Finally, the third level of transfers has an ultimate supply of 30,000 AFY at a purchase price of $200 per acre-foot. Because this level is greater than the previous level, the fixed costs are assumed to be greater, estimated at $10.8 million. For all these transfer levels transaction costs of $230 per acre-foot for wheeling and $30 per acre-foot for environmental fees would be added.

3.7 Additional Imported Supply

As stated in Section 1, both the CWA and MWD are actively pursuing ways to improve supply reliability. However, unlike many of the other supply options discussed in this document, the specific alternatives and assumptions surrounding those alternatives for future imported water are not well documented.

The CALFED program, for example, is very complex; and after almost six years in planning and development, CALFED is still as much a mystery in terms of the specific water supply benefits as when it was conceived back in 1995. Other potential programs CWA and MWD are pursuing include additional water banking and transfers in the Central Valley and groundwater conjunctive use storage in southern California.

For planning purposes, it was assumed that an additional 24,000 AFY of imported supply could be made available to the City if CWA/MWD were successful in their efforts. This number was based on securing an additional 300,000 AFY of dry year supply for the entire Southern California region, as identified in MWD's Integrated Resources Plan. The marginal cost for this supply was estimated to be $300 per acre-foot. When MWD delivery changes are added, the total cost of new imported supply are estimated to be about $600 per acre-foot for untreated water and $680 per acre-foot for treated water.

The main development issues associated with this supply relate to how it will be allocated to the City during a drought. In addition, if MWD has to rely on CALFED to help meet this 300,000 AFY goal for dry year supply, the costs could be significantly higher. Other uncertainties relate to MWD keeping its existing SWP and CRA supplies in tact. Both supply sources have become increasingly more uncertain due to regulatory restrictions and increased competition for water supply. It is plausible that MWD will have to aggressively pursue water transfers just to keep its existing supply levels from falling—leaving fewer options for actual new supply.

3.8 Summary of Supply Options

Table 3-4 summarizes the supply options available to the City, both in terms of production and unit cost.

Table 3-4
Summary of Supply Options for City of San Diego

Supply Option	Existing Supply (AFY)	Range in Potential Supply (AFY)	Range in Unit-Cost ($/AF)[1]
Water Conservation	21,000	42,000 (by 2030)	$50 - $75
Water Reclamation	8,000 [2]	33,000	$300 - $600
Groundwater Desalination (Safe Yield Supply)	0	6,000 – 20,000	$650 - $1,200
Groundwater Storage (Dry Year Supply)	0	10,000 – 48,000	$550 - $700
Ocean Desalination	0	10,000	~ $1,400
Marine Transport	0	20,000	~ $700
Central Valley Water Transfers (Dry Year Supply)	0	10,000 – 60,000	$500 - $580 (untreated)
Imported Supply from CWA/MWD (Firm Dry Year Supply)	175,000 [3]	200,000	$430 - $600 (untreated)

[1] Range in unit cost reflects cost of existing supplies and ranges of potential cost for new supplies.
[2] Although the City is currently delivering about 4,000 AFY of reclaimed water, it has the system capacity to deliver 8,000 AFY without the need for additional facilities.
[3] The City can get as much as 260,000 AFY from imported water during normal and wet years. However, in a repeat of a critically dry event, such as 1977, the estimated firm imported supply will be 175,000 AFY. This estimate assumes imported water will be allocated based on need, rather than preferential rights.

Section 4
Objectives and Performance Measures

Section 4
Objectives and Performance Measures

4.1 Defining Planning Objectives

The essential first step in any decision-making process is to define objectives. Objectives define the process and establish the goal of the organization for the specific program or plan or project. In the context of developing a water resources plan, objectives represent the goals for that plan and indicate the reasons "why" the plan is being developed.

Involving major stakeholders in the development of planning objectives is highly recommended. This involvement can greatly increase community acceptance and support for the plan.

In order to respond to the public's concerns and gain better understanding of the major issues that are important to the public, the City's Water Department appointed a Citizen's Advisory Board (CAB). CAB members represent a variety of community interests and groups, such as:

- San Diego Association of Realtors
- San Diego County Apartment Association
- San Diego Chamber of Commerce
- Building Industry Association
- San Diego Taxpayer's Association
- American Society of Landscape Architects
- San Diego County Water Authority Board
- San Diego State University Graduate School of Public Health
- League of Women Voters
- Sierra Club

The Department elected to involve the CAB in the development of its ***Long-Range Water Resources Plan***, to provide a forum for discussion of water supply issues and a means for incorporating community values in planning-level decision making. The Department's approach for involving CAB members in this planning effort was to devote a portion of each semi-monthly CAB meeting to informative presentations, discussion, and participation.

To help gain a better understanding of the major water supply issues from the community at large, each CAB member was interviewed. Questions ranged from what should be the mission of the City's Water Department in terms of supply planning, to what types of risk exist for supply development and reliance on imported water.

The results from these interviews helped define the planning process and were the basis for the initial generation of planning objectives. At subsequent CAB meetings, these initial objectives were refined. In the end, the CAB and water department staff agreed upon seven primary planning objectives for the ***Long-Range Water Resources Plan***, these being:

- **Ensure Supply Reliability** – ensuring that water demands are met under all hydrological conditions.
- **Minimize Cost** – minimizing the overall costs to consumers for the development, treatment, and delivery of high quality water.
- **Minimize Risk** – minimizing the risk of developing new supplies, as well as protecting existing supplies from regulatory/political/institutional threats.
- **Maximize Flexibility** – maximizing those supply investments that can adapt to changes in future water demands.
- **Minimize Impacts on Environment** – minimizing the impacts to the local and Bay-Delta environments due to development and operations of water supplies.
- **Protect Against Catastrophes** – ensuring that water demands are met during catastrophes, such as earthquakes.
- **Minimize Salinity** – minimizing the TDS of water supply to end-users.

To help determine the relative importance of these objectives, two approaches were used. Both approaches utilized the CAB members as well as key management staff from the City's Water Department.

The first approach, called paired comparisons, asks each participant to determine which objective is more important. Each objective is paired with another, until all possible pairs are compared. A tally is kept indicating which objective is rated as most important and are the basis for determining the relative weights. Individual phone interviews for each CAB member were conducted for this approach.

The second approach, called dot budgeting, gives each participant a budget (12 dots). Participants place (spend) these dots on any of the objectives they feel are important. The only rule is that participants cannot place more than four dots on any one objective. The total dots for each objective are tallied and used to establish the relative weights. This approach was conducted in a group setting, rather than one on one interviews.

Both approaches have their advantages and disadvantages, which is why both were used to help solicit relative importance. At a subsequent CAB meeting, the results of both approaches were discussed. For some objectives, both approaches yielded comparable results. However, for others there was wide discrepancy between the approaches. CAB members even offered possible reasons for why the two methods yielded different results. Through an interactive and facilitated discussion process involving the CAB members, an agreed upon weighting was arrived at. Table 4-1 summarizes the results of this weighting exercise.

Table 4-1
Weighting Objectives for Relative Importance

Objective	Paired Comparison Approach	Dot Budget Approach	Agreed Upon
Ensure Supply Reliability	25%	28%	28%
Minimize Cost	13%	21%	18%
Minimize Risk	12%	17%	15%
Maximize Flexibility	12%	12%	12%
Minimize Impacts on Environment	18%	6%	10%
Protect Against Catastrophes	13%	9%	10%
Minimize Salinity	7%	6%	7%

4.2 Developing Performance Measures

Once objectives are defined, the next step in the decision-making process is to develop performance measures or predictive indicators, which are used to determine whether the objective is being achieved. There are several important properties of performance measures:

- **Distinctive**: Performance measures should distinguish between one alternative and another.
- **Measurable**: Performance measures should be measured either quantifiably or qualitatively.
- **Non-Redundant**: Performance measures should not be redundant with one another.
- **Understandable**: Performance measures should be easy to communicate.
- **Concise**: Performance measures should be kept to manageable numbers.

Together objectives and performance measures serve as evaluation criteria by which alternatives can be compared.

For each objective, a performance measure (or several measures) were developed. These performance measures were used as the basis for evaluation of alternatives, which is discussed in Sections 6 and 7.

Some performance measures were quantitative indices, meaning their values are derived from real data or modeled calculations. Other performance measures were qualitative indices, meaning their values were generated from expert opinion.

As with the objectives, the CAB reviewed these performance measures and offered suggestions and clarification. Figure 4-1 summarizes the objectives and performance measures.

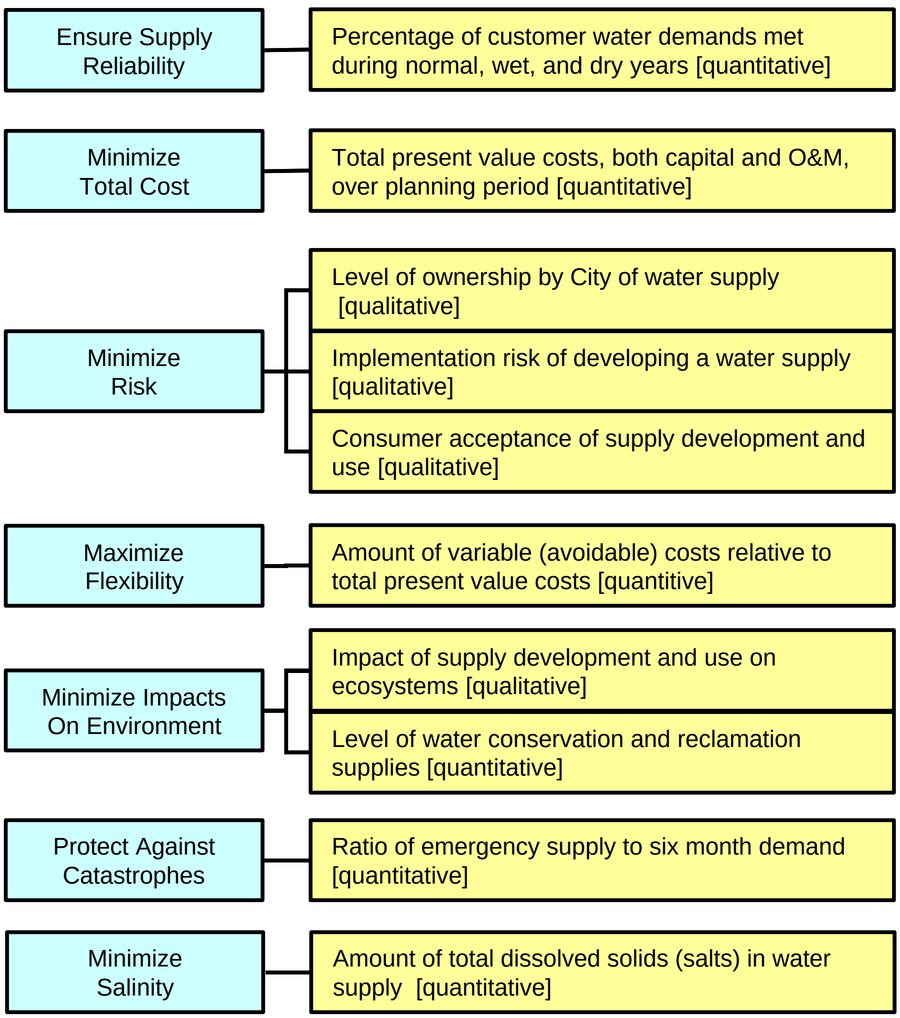


Figure 4-1
Objectives and Performance Measures

Section 5
Developing Water Resources Portfolios

Section 5
New Water Supply Opportunities

5.1 The Need for Portfolios

No individual supply source is sufficient for meeting San Diego's needs in the future. Rather, use of a variety of sources, among those summarized in Section 3, is necessary in order to provide sufficient, reliable water supply for the City. However, because of the interplay between water supplies, simply selecting supply options and adding up their total amounts to meet demands will not adequately address planning needs. Storage and source water quality of supplies are two issues that complicate the dynamic relationships between supply and demand.

The interrelationships between individual water supply options (both existing and new) require that the entire water system be examined in a comprehensive fashion. The first step in modeling the water system is to develop comprehensive alternatives that represent combinations of supply options. These alternatives are then analyzed and compared according to their overall performance in meeting the City's objectives. Just as stocks and bonds may be pulled together to maximize gain and minimize risk as part of a successful investment strategy, so too can water supply options be combined very effectively into comprehensive water resource portfolios.

5.2 Development Approach

Developing portfolios, combining individual supply options into comprehensive packages can sometimes be challenging. Developing thematic portfolios is well suited for systems modeling that is based more on descriptive, rather than prescriptive goals. Section 6 discuses the modeling and evaluation approach in detail. Thematic portfolios can be constructed to represent certain policy or operational preferences, which can then be tested using a systems model. There are several approaches to developing thematic portfolios.

Policy-based themes represent one approach to developing alternatives that seek to test broad policy questions or operational preferences, such as:

- What would happen if the City maximized all its local supplies before using imported water to meet demands?
- What would happen if the City aggressively relied on the market and storage to meet demands?

The use of policy-based thematic portfolios are beneficial for establishing the outer boundaries of the "search space" of which all possible alternatives fall in. By establishing the boundaries of this search space, decision-makers can then more quickly identify preferred alternatives. Figure 5-1 illustrates how broad-based thematic portfolios can be used to establish the boundaries of the search space.

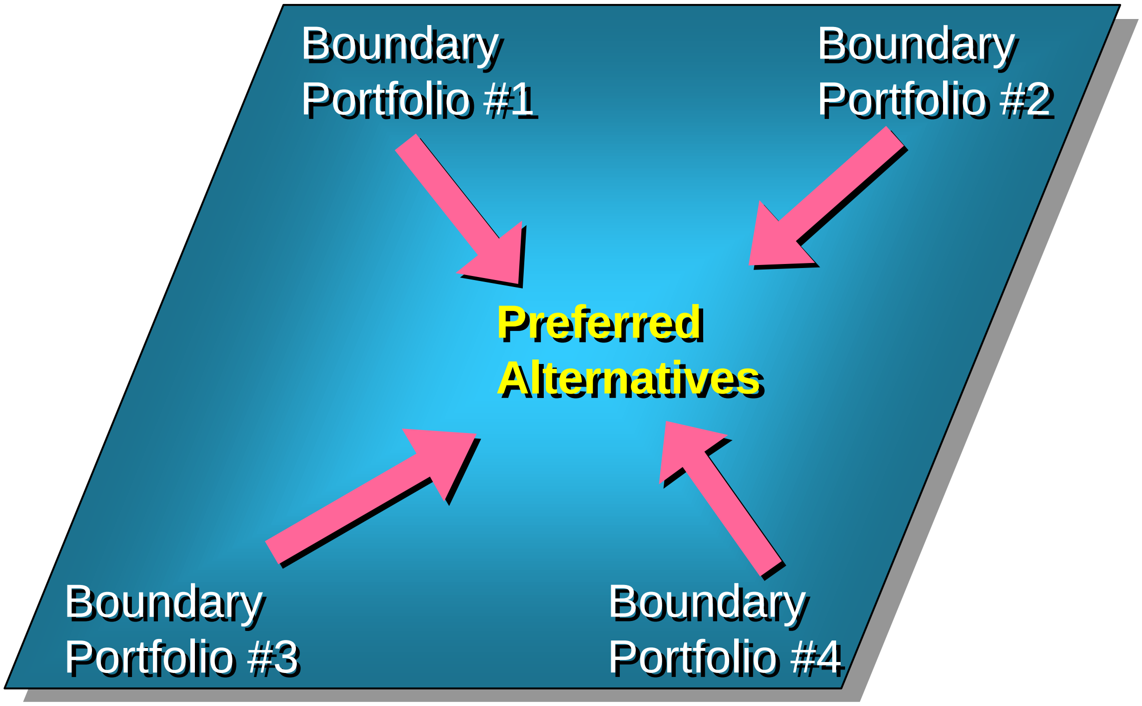


Figure 5-1
Use of Thematic Portfolios to Establish Boundaries for Selecting Preferred Alternatives

Another approach to developing thematic portfolios is the use of incremental analysis. It involves using the planning objectives as the basis for creating alternative portfolios. In this case, portfolios are constructed minimizing or maximizing stated objectives. The main benefit of this approach is that trade-offs between objectives can be easily evaluated by comparing the portfolios. For example, the trade-off between increasing supply reliability and cost can be tested using incremental-based portfolios.

The incremental approach to portfolio building involves a more rigorous process, by which objectives are specified first, and then supply options are incrementally added to the portfolio in order to maximize the objective. For example, if the objective was to minimize cost, then individual supply options would be added to the portfolio in ascending cost until the target demand was met. The problem with incremental analysis is that it is static in nature and does not allow for the interplay between supply options. This is why a systems model approach, which will be discussed in Section 6, is required. However, even with this limitation, incremental analysis can be a useful way to construct portfolios.

The following example illustrates how a portfolio can be constructed to minimize cost (one of the primary objectives of the City):

Step 1: Establish target water demand. The target demand represents the year 2030 water demand under dry weather conditions.

Step 2: Rank supply options in terms of their unit cost. The unit cost simply takes annualized capital and O&M costs and divides by the annual supply yield.

Step 3: Incrementally add supply options one by one, in ascending unit cost, until target water demand is achieved.

Step 4: Select supply options that are to the left of the target demand for the portfolio in order to minimize cost.

The following represents the supply options, showing the dry year supply yield and estimated unit-cost ($/AF):

Supply Option	Yield (AF)	Cost ($/AF)
Conservation Existing	27,051	50
Conservation New	14,725	75
Local Runoff	20,000	125
Reclamation Existing	7,600	134
Reclamation New Option 1	11,200	608
Reclamation New Option 2	13,500	644
GW Storage Option 1	20,000	650
GW Storage Option 2	18,000	655
GW Storage Option 3	10,000	500
GW Desalination Option 1	6,000	1190
GW Desalination Option 2	5,000	1175
GW Desalination Option 3	10,000	700
Ocean Desalination	10,000	1420
Marine Transport	20,000	792
CV Transfers Option 1	5,000	480
CV Transfers Option 2	10,000	500
CV Transfers Option 3	15,000	520
Imported Supply Existing	195,000	455
Imported Supply New	32,500	630

Supply options range from $50/AF to over $1,400/AF. Supply yields range from 5,000 AF to 195,000 AF. In incremental analysis these supply options would be ranked in terms of their unit-cost (from lowest to highest). Each supply option would be added, lowest cost first, then second lowest, and so on. Each supply option's yield would then be cumulated until the target demand was achieved. Those supply options to the left of the demand target would be selected.

Figure 5-2 illustrates the incremental approach to developing a portfolio that seeks to minimize overall cost.

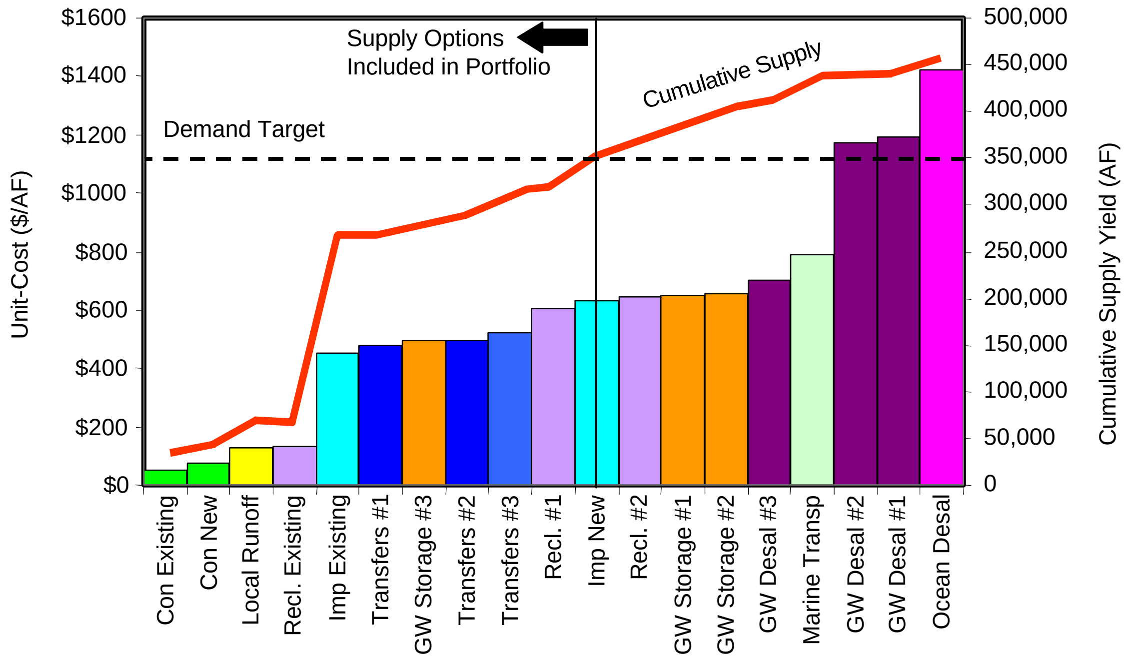


Figure 5-2
Use of Incremental Analysis to
Develop Minimum Cost Portfolio

5.3 Water Resources Portfolios for San Diego

Based on the incremental analysis approach, portfolios were constructed to achieve the following objectives: cost, risk, flexibility, environmental impact, catastrophe protection, and salinity. A portfolio to maximize supply reliability was not constructed since all portfolios were designed to meet demands under all hydrological conditions. In addition, two balanced portfolios were constructed in order to test the hypothesis that the overall best performing portfolio would be one that did not seek to maximize any one objective. Finally, a status quo portfolio was created to test the City's base case (or no action alternative). The following describes each portfolio and indicates the amount of non-imported supply that each alternative includes. Imported water will be used to meet any remaining demands after, and only after all other supply options for each portfolio are used. The actual supply yields for any of these portfolios will be determined using the systems model (described in Section 6), under a variety of hydrologic scenarios.

5.3.1 Minimum Cost Portfolio/Maximum Flexibility

This portfolio seeks to minimize the overall present value cost. It was constructed by incrementally adding the least-cost supply option, using a simple unit cost. The minimized cost portfolio also maximized flexibility. Table 5-1 summarizes the options included in this portfolio.

5.3.2 Minimum Risk Portfolio

This portfolio seeks to minimize the overall risk. Risk has three elements: level of City control over the resource, consumer acceptance, and implementation risk. Supply options were added to the portfolio that would minimize the weighted average of these three risk elements. Table 5-1 summarizes the options included in this portfolio.

5.3.3 Minimum Environmental Impact

This portfolio seeks to minimize the cumulative environmental impact to the local and Bay-Delta ecosystems. Supply options were incrementally added to the portfolio in terms of their environmental impact. Table 5-1 summarizes the options included in this portfolio.

5.3.4 Minimum Catastrophe Impact

This portfolio seeks to maximize the protection against catastrophes such as an earthquake, which could disrupt imported supplies for up to six months. Supply options that would give the greatest protection against disruption of imported supplies were added to the portfolio. Table 5-1 summarizes the options included in this portfolio.

5.3.5 Minimum Salinity

This portfolio seeks to minimize the overall salinity in the City's water supply. Supply options that have the lowest levels of salinity were added to the portfolio. Table 5-1 summarizes the options included in this portfolio.

5.3.6 Balanced Mix 1: Water Quality Focus

This portfolio seeks to balance objectives, with the focus of reducing salinity. Table 5-1 summarizes the options included in this portfolio.

5.3.7 Balanced Mix 2: Storage Focus

This portfolio seeks to balance objectives, with the focus of increasing storage. Table 5-1 summarizes the options included in this portfolio.

5.3.8 Status Quo

This portfolio seeks represents the City's base case, or no action alternative. Only existing levels of non-imported water were included. It is expected that this portfolio will not achieve many of the objectives that the City determined important in the planning process. The imported supply assumptions for this portfolio are discussed in Section 2.2.2. Table 5-1 summarizes the options included in this portfolio.

5.3.9 Summary of Portfolios

Table 5-1 summarizes the options included in each portfolio.

Table 5-1

Summary of Resources Portfolios

Portfolio	Local Runoff	Conservation	Reclamation	GW Storage	GW Desalination	Ocean Desalination	CWA/MWD Imported	CV Transfers	Marine Transport
Minimize Cost	Yes (15,000 AFY*)	High (42,000 AFY*)	Medium (19,000 AFY)	1 Option (10,000 AFY*)	None	No	New	3 options (60,000 AFY*)	No
Minimize Risk	Yes (15,000 AFY*)	High (42,000 AFY*)	High (32,000 AFY)	3 Options (48,000 AFY*)	3 Options (21,000 AFY)	Yes (10,000 AFY)	Existing	None	No
Minimize Environmental Impacts	Yes (15,000 AFY*)	High (42,000 AFY*)	High (32,000 AFY)	3 Options (48,000 AFY*)	None	No	Existing	None	Yes (20,000 AFY)
Minimize Salinity	Yes (15,000 AFY*)	High (42,000 AFY*)	Low (8,000 AFY)	3 Options (48,000 AFY*)	3 Options (21,000 AFY)	Yes (10,000 AFY)	Existing	None	Yes (20,000 AFY)
Minimize Catastrophe Impacts	Yes (15,000 AFY*)	High (42,000 AFY*)	High (32,000 AFY)	3 Options (48,000 AFY*)	3 Options (21,000 AFY)	Yes (10,000 AFY)	Existing	None	Yes (20,000 AFY)
Balanced Mix #1, water quality	Yes (15,000 AFY*)	High (42,000 AFY*)	Low (8,000 AFY)	None	1 Option (10,000 AFY)	Yes (10,000 AFY)	New	3 options (60,000 AFY*)	Yes (20,000 AFY)
Balanced Mix #2, storage	Yes (15,000 AFY*)	High (42,000 AFY*)	Medium (19,000 AFY)	2 Options (35,000 AFY*)	1 Option (10,000 AFY)	No	Existing	2 options (30,000 AFY*)	No
Status quo	Yes (15,000 AFY*)	Low (30,000 AFY*)	Low (8,000 AFY)	None	None	No	Existing	None	No

* Dry year yield

Section 6
Developing Evaluation Approach and Systems Model

Section 6
Developing Evaluation Approach and Systems Model

6.1 General Approach

Section 4 summarized the City's planning objectives and corresponding performance measures. Together they represent the "why are we doing this" aspect of the planning process. Section 3 and Section 5 presented water supply options that were then combined to form water resource portfolios. These supply options and alternative portfolios represent the "how will we accomplish this" aspect of the planning process. Where these two aspects converge, a model is needed to facilitate the evaluation and decision-making process (see Figure 6-1).

Models help decision makers compare and contrast alternatives in a systematic and reproducible manner. Because of the dynamic and complex nature of the City's water supply system, evaluating alternatives without a model would be very difficult. It is important however, to recognize that models are only tools that help in the decision-making process. It is also important to recognize that there are different types of models, and choosing the correct model depends on the answers to a number of important questions:

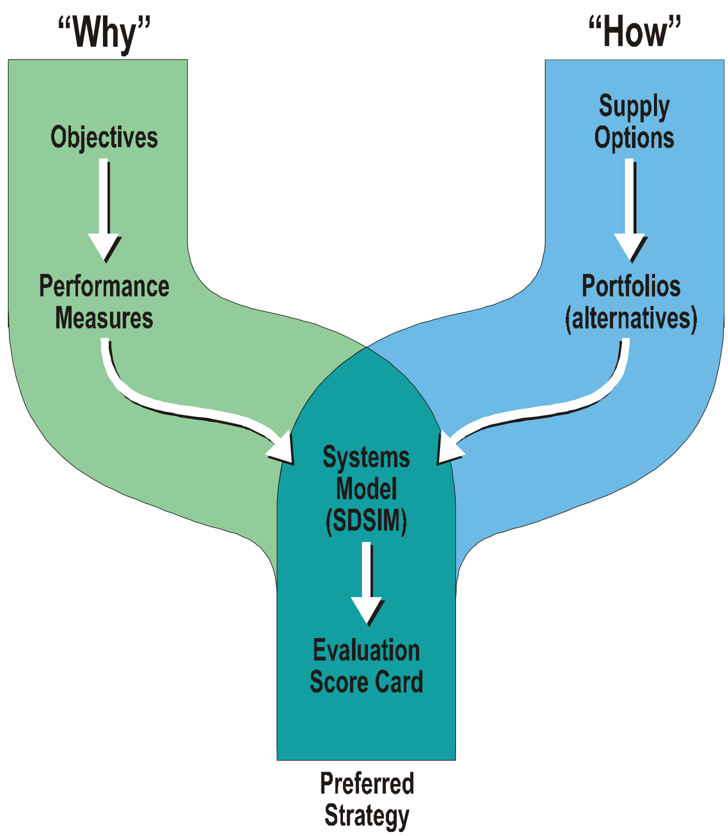


Figure 6-1
Evaluation Approach Road Map

- Is the problem long-term or short-term?
- Is the problem policy related or operational?
- Is the problem dynamic in nature?
- Are stakeholders involved in the process for solving the problem?

6.2 Developing a Systems Model for San Diego

6.2.1 Selecting from Different Types of Models

Models can be classified in several ways, depending on their characteristics: static or dynamic, stochastic or deterministic, physical or conceptual. One of the most useful classifications, however, divides models into optimization and simulation.

Optimization models are prescriptive. Optimization delineates the actions needed in order to obtain the best results or outcome according to a specific objective or set of objectives. They do not describe how the system will respond after making a particular set of decisions. The outcome of the optimization model prescribes the best way to accomplish a goal by using three main elements: an objective function that specifies the goal to accomplish, a set of decision variables, and a set of constraints. Optimization works best for a specific and well-defined problem, such as: what is the best way to operate a surface reservoir, given the objective of providing the maximum water supply and the constraints of local runoff and dedicated storage for emergency purposes?

Simulation models are descriptive. Their outcome is a description of the system's response to a set actions or decisions. They represent the physical system and the decision-making process, and are good tools for analyzing "what if" scenarios.

While optimization models are very useful for situations in which the maximum or minimum values of an objective can be well determined (i.e., when the "best" outcome can be easily defined), they are less useful in foresight and policy formation, where understanding the response of the system is more important than knowing the optimum outcome. Simulation models, on the other hand, are better suited for systems that are relatively more dynamic, and present feedback relationships.

Based on the nature of the City's water supplies, the need to explore other supply options, and the desire of the City's Water Department to expand its role in securing additional supplies, a simulation model was determined to be best suited for evaluating alternatives. In addition, it was determined that dynamic simulation (components vary over time) was preferred over static simulation (only represents a snapshot in time).

The City hired Camp Dresser & McKee (CDM) to develop a systems model that would be best suited for simulating alternative water resources portfolios for the next 30 years. CDM reviewed several modeling environments, including Microsoft Excel. In consultation with the City, CDM selected the generic systems simulator STELLA, developed by High Performance Systems, Inc, as the modeling platform for the City's systems model. This modeling platform was selected because of its flexible and relatively simple programming environment. In addition, the STELLA software was selected because it provides graphical interfaces that create an engaging virtual environment, increasing the ability of technical staff to share their understating of the system with decision-makers and stakeholders. CDM customized STELLA to create the San Diego Simulation (SDSIM) Model.

6.2.2 Modeling Objectives

The SDSIM Model was developed to: (1) represent the physical water delivery system for the City; (2) simulate the operations of existing and future water supplies under different hydrological conditions in order to meet current and projected demands; and (3) provide the performance measurements for the stated planning objectives as identified in Section 4.

The model development process included: (1) depicting the City's water supply system, including reservoirs, major conveyance, and treatment capacity; (2) defining the water supply options to include in the model; (3) defining the outputs required; (4) identifying the general relationships between the water supply options and the components within a each option; (5) developing a conceptual model; (5) collecting data and defining the response functions; (6) programming, and (7) performing a testing protocol.

The planning horizon for the systems model is the year 2030, and the simulation time step is specified as one year. Therefore, all of the variables are annualized and in units of acre-feet per year.

6.2.3 Physical System

City of San Diego Water Supply System – Service Area Scale

The City of San Diego Water Department divides its overall service area into three service areas: Miramar Service Area (MSA), including all the north area of the City; the Alvarado Service Area (ASA), from approximately the Mission Bay and Mission Valley area and Interstate 8, south to the limits with National City; and the Otay Service Area (OSA) serving the area south of Chula Vista to the U.S.-Mexico border (see Figure 6-2).

Each service area is relatively independent from the others in terms of the treated water distribution systems, although some interconnectivity exists. Raw imported water and treated imported water can be delivered to each of the service areas, through the CWA aqueducts. Each service area has a water treatment plant: the Miramar Treatment Plant (MTP), the Otay Treatment Plant (OTP), and the Alvarado Treatment Plant (ATP), which treat raw imported water and local runoff from the City's reservoirs.

Local reservoirs include Sutherland, San Vicente and El Capitan supplying raw water to the Alvarado Treatment Plant; Morena, Barret and Lower Otay, supplying raw water to the Otay Treatment Plant; and two small lakes, Miramar Lake and Lake Murray, located next to the Miramar Treatment Plant and Alvarado Treatment Plant, respectively. Lake Hodges is also a reservoir the City could use in the future, but it is currently not connected to the City's system.

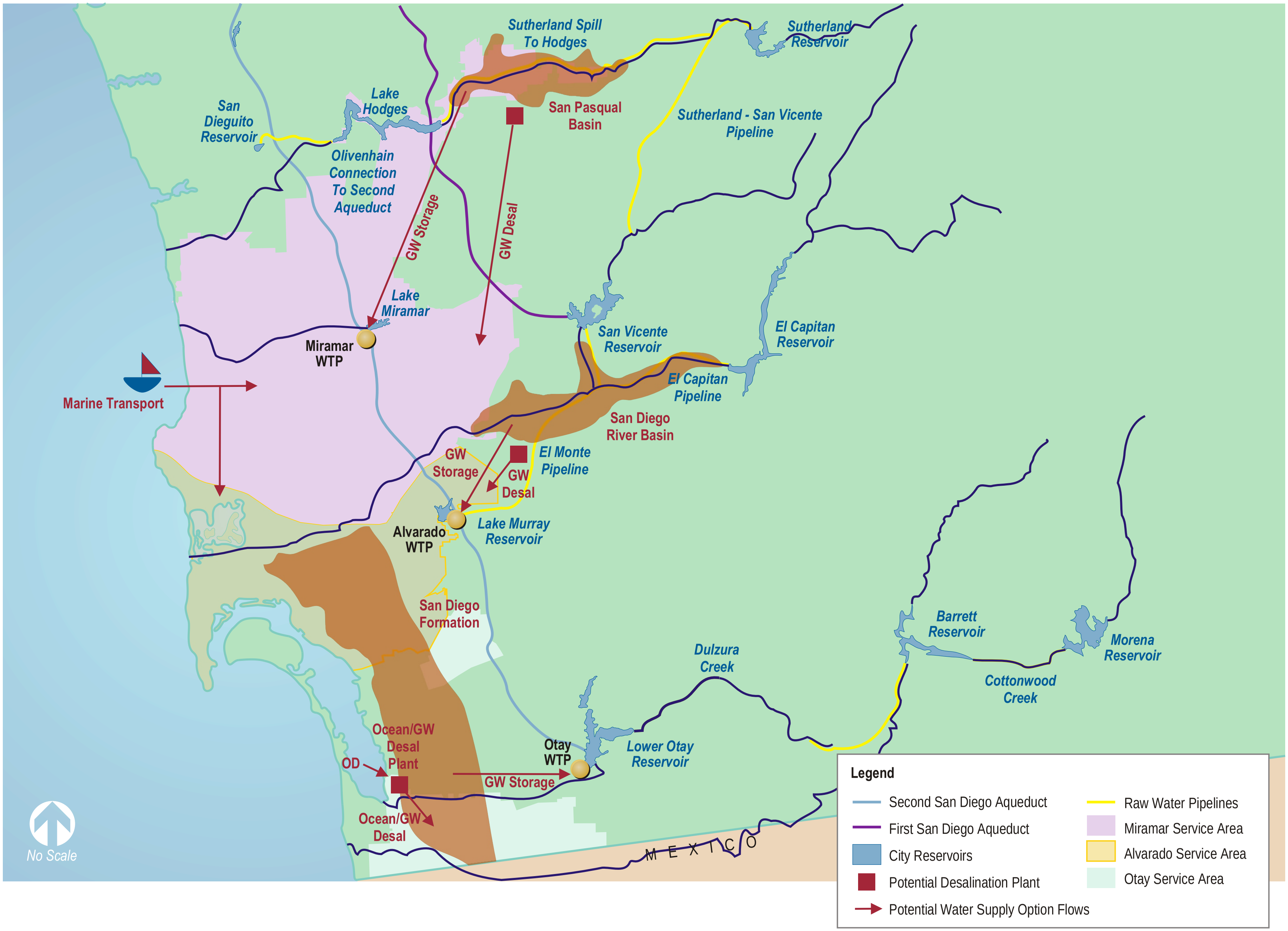


Figure 6-2
Existing Water Supply System and Potential New Water Supply Options

The City's reservoirs are connected through a series of pipelines and streams. Sutherland is upstream of San Vicente, and the reservoirs are connected through a pipeline. Similarly, the El Monte pipeline connects San Vicente to the Alvarado Treatment Plant, and the El Capital pipeline connects the El Capitan Reservoir to the El Monte Pipeline, upstream of the Alvarado Treatment Plant. In the Otay system, the Morena Reservoir feeds the Barret Reservoir through the Cottonwood Creek, and Barret is connected to Lower Otay through the Dulzura Conduit.

To accomplish the geographic representation of the City's sources and facilities in the SDSIM Model, the system was divided into the City's three service areas. The model did not go beyond the service area scale (i.e., the distribution system was not included in the SDSIM Model). Demands and supply were analyzed at the service-area scale, and the imported water system, the CWA aqueducts, were represented as sources of raw and treated water to each one of the service areas, to mimic the actual system operation.

Reservoirs, pipelines, creeks and treatment plants were represented in the model using the elements of the systems dynamics software:

- Stocks: used to represent elements that can accumulate over time
- Flows: used to represent elements that feed or drain stocks, and elements that can be represented as rates
- Converters: used to establish more detailed mathematical relationships between stocks and flows, introducing constants or exogenous variables (variables that are not affected by the model and serve as inputs)

In general, the SDSIM Model used stocks to represent the City's reservoirs and groundwater basins, as they are essentially (or could be) used for storing water and releasing water to satisfy demand. Flows were used to represent pipelines, streams, wells and treatment plants (including desalination plants), because these elements are relevant to the system in terms of the volumes of water that they handle per unit of time (i.e., millions of gallons treated per day, cubic feet of water conveyed per second, etc.). Flows, however, were needed in the model to represent a great variety of water flows intrinsic to the system, not related to the City's facilities. Examples of such flows are the water losses in conveying water from one reservoir to another through a creek, and the evaporative losses at a reservoir.

Figure 6-3 shows a screen capture of the SDSIM Model, with the representation of the El Capitan Reservoir system.

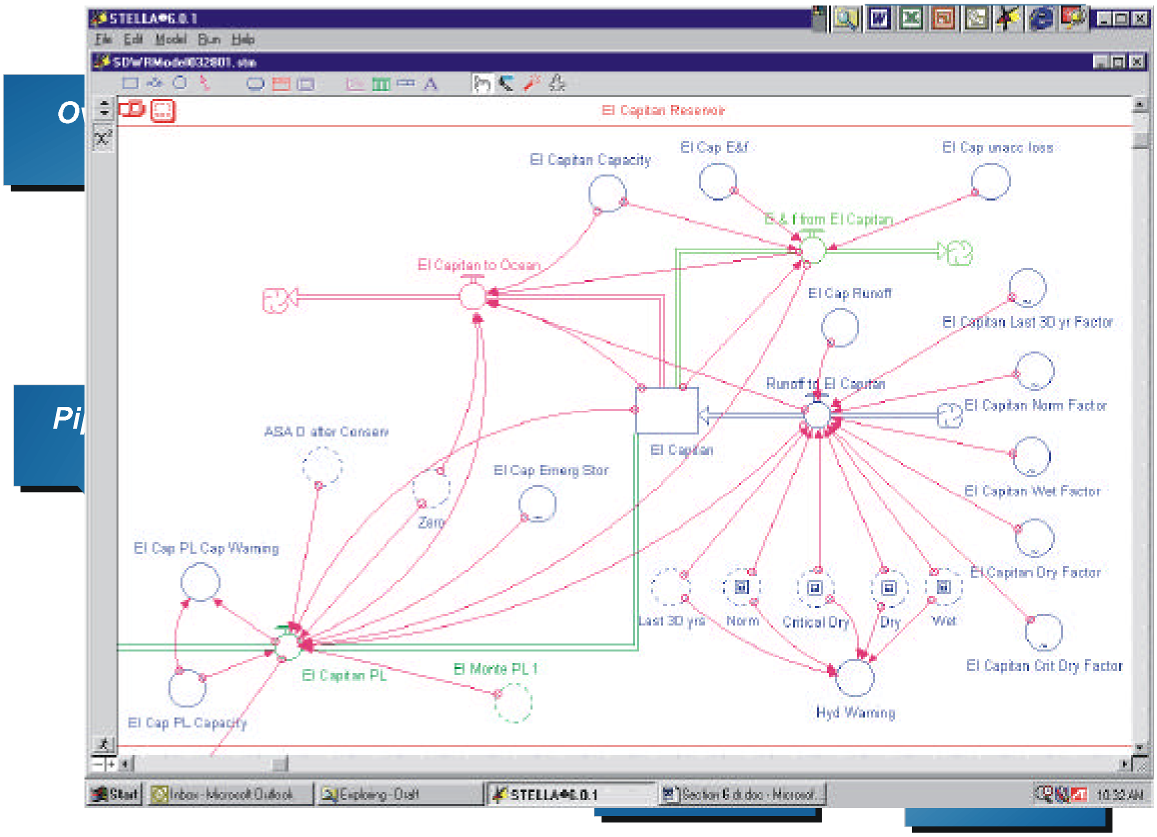


Figure 6-3
Model Representation of a Reservoir

As Figure 6-3 shows, stocks are elements with several inflows and outflows, that in some cases represent actual facilities (such as El Capitan Pipeline), natural flows (runoff or overflows to a stream), or water losses that exist in the real system, but are "invisible" flows in the sense that they are not conveyed in a natural stream or pipeline.

Surface Reservoir Operations

The SDSIM Model assumes that the City will continue to maximize the supply yield from its surface reservoirs, as it is one of the lowest-cost supply options available. The water entering the reservoir by natural runoff was modeled as a function of the type of hydrology year (wet, normal, dry, or critically dry). Each year in a simulation has a given amount of runoff, depending on the hydrology (see Section 6.2.5 for a further discussion on the hydrology and weather aspects of the model).

Reservoir capacity was determined from City records, and the total capacity was divided into dead storage, emergency storage, and available storage for supply yield. Dead storage was also obtained from City's records for each reservoir. Emergency storage is required to meet the City's emergency storage policy. The emergency storage City Council Policy 400-4 establishes that enough water must remain in storage for emergency conditions, to be able to meet a demand equal to six tenths of a year. The City's water demand projections were used to estimate the required emergency storage for every year from 2001 to 2030. Available storage for supply, therefore, represents the difference between total capacity (constant), dead storage (constant) and emergency storage (variable over time).

In addition to emergency storage and dead storage, the available storage was corrected for losses due to evaporation and infiltration. These losses were specific for each reservoir and based on the City's historical records. A function was estimated that allowed the model to calculate evaporative losses every year, as a function of the water level in the reservoir.

The model calculated reservoir storage for every year during the simulation, and used a mass balance to determine spillover based on inflows, outflows, and the capacity of the reservoir. The main outflow for the City's reservoirs was the actual draft as a function of demand in a given service area. Given the annual nature of the model, reservoir optimization routines were not needed. However, the City does have rule curves for monthly reservoir operations that do reflect optimization goals and take into consideration seasonal variability in demands, runoff, and recreational needs.

Another constraint for the use of water from city reservoirs was the capacity of the pipeline conveying the surface water to the treatment plant. The model established the capacity of the conveyance as a constraint, and kept track of the times that the capacity of the pipe was the limiting factor for local runoff use. An analysis for the optimization of the pipe capacity was not performed, however, because all of the flows in the model were annualized, and no seasonal or peak demands and drafts were incorporated into the model.

Miramar Reservoir and Lake Hodges were assumed to be in-line with the Miramar Water Treatment Plant. Because Lake Hodges in not currently connected to the treatment plant, a management decision variable was included to turn the option "on" or "off, " which allows the analyst to incorporate water from Lake Hodges into the resource mix, however account for the costs of connecting the reservoir into the system, and estimate the salinity impacts. Sutherland, San Vicente, Murray and El Capitan reservoirs were assumed to be in-line with the Alvarado Treatment Plant, Morena, Barret, and Lower Otay reservoirs were assumed to be in-line with the Otay Treatment Plant.

6.2.4 Water Supply Options

The overall operational assumption for the model is that local supply options meet only local demand in the specific service area of the City. Remaining supply needs

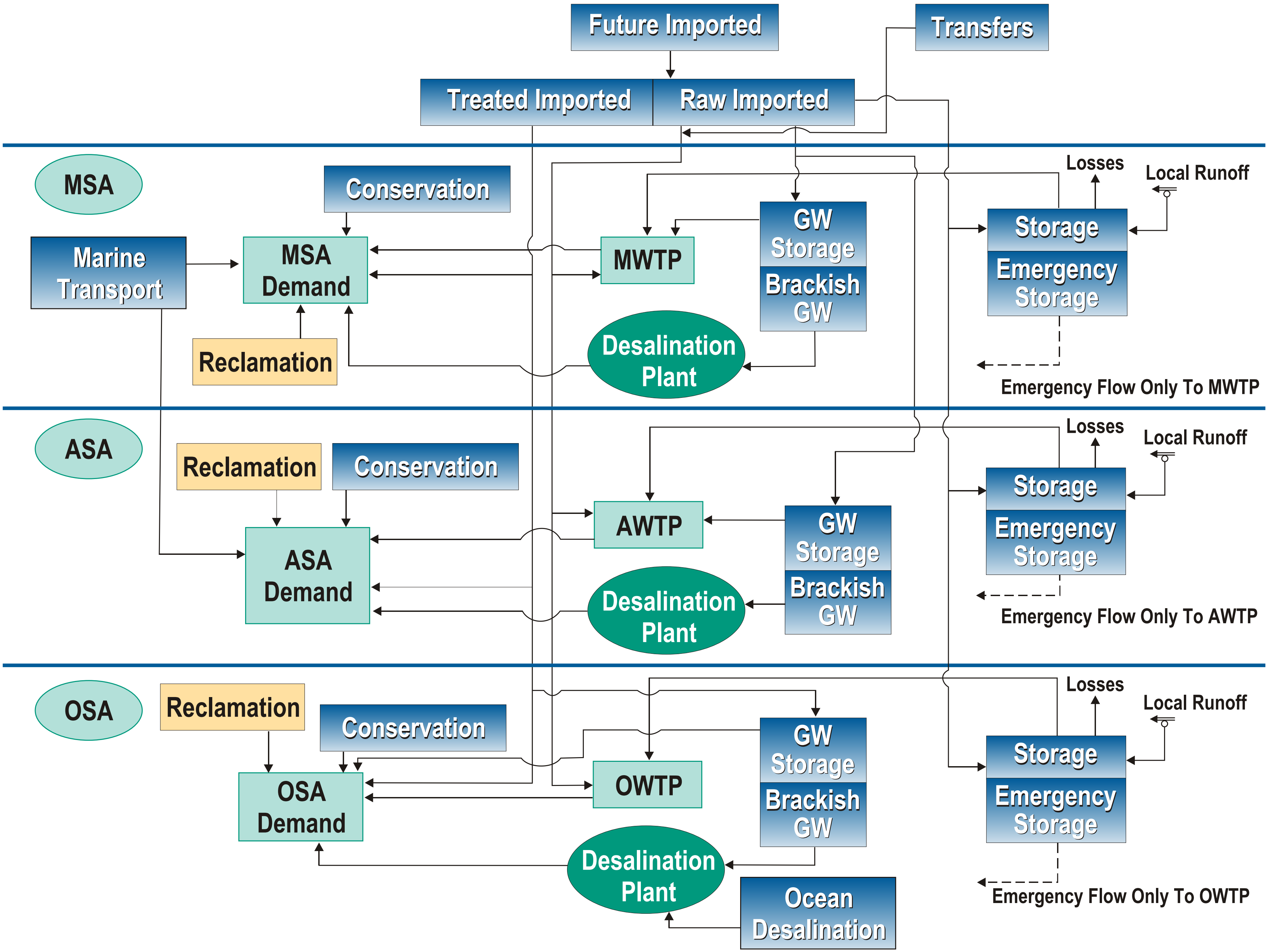


Figure 6-4 Model Flow Chart

after local supplies are utilized are met by imported water, distributed to minimize remaining supply deficits. Figure 6-2 illustrates the location of the water supply options in the City's system. Water supply flows in the model followed the conceptual representation depicted in Figure 6-4.

Priorities for the Use of Water Supply Options

In order to supply each service area demand with a sufficient, and not excessive, demand, priorities were set to establish an order in which each supply is utilized. The following is the priority order in which the supplies are developed:

- Conservation
- Local reservoir
- Reclamation
- Groundwater desalination
- Ocean desalination
- Marine transport
- Firm/existing imported water
- Groundwater storage
- Water transfers
- Future imported water

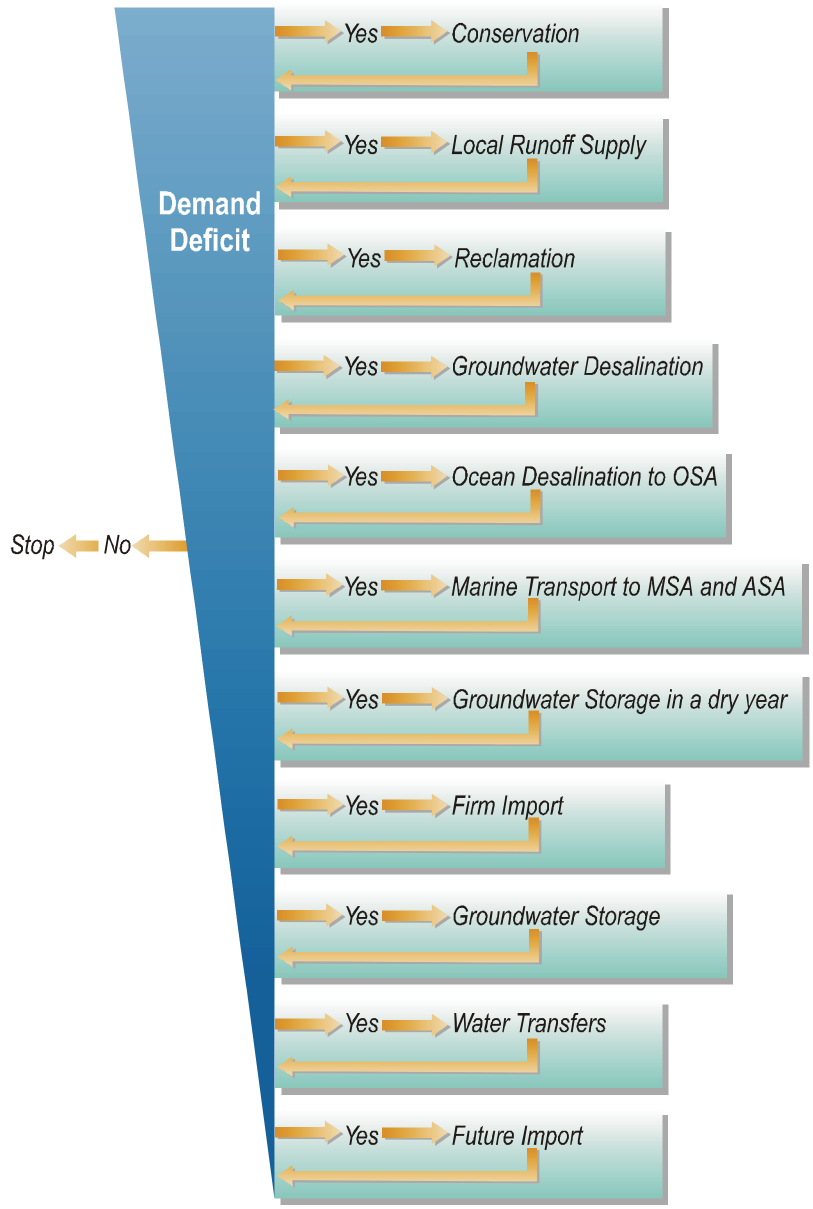


Figure 6-5
Water Supply Priorities Used in the Model

The priorities for the use of water supply options were mainly based on the marginal operating cost of water, with the assumption that once all the options are in place (i.e., capital investments have been made to establish a water supply option), the marginal operating cost of water dictates the decision on whether or not the supply is used in a specific year. In addition to the marginal cost rule, the type of supply was a factor for prioritization. Supplies can be categorized generally as core and dry year. Core supplies are basically used each and every year, whereas dry year supplies are used only during dry years. Figure 6-5 illustrates the water supply priorities programmed in the model.

6.2.5 Hydrology and Weather

Modeling hydrology requires addressing several difficulties. One of the most common problems in modeling a water supply and delivery system is the use of averages for the representation of inherently probabilistic variables, such as precipitation. Another hurdle to be overcome is that what typically drives water demands upward (warm, dry weather), also drives supply downward. Finally, hydrology in northern California and Colorado River basin (where the City's imported supplies originates) is not always correlated to hydrology in San Diego County (where local runoff originates). To avoid these problems, simulations of water demand and various supplies were modeled using historical hydrology records from 1922 to 1998, indexed sequentially for all points of origin of the City's water supply. These records were used to generate demand and supply factors that were applied to long-term averages in order to estimate the variability in demand and supply under different hydrological conditions.

Weather factors for water demand were obtained from the MWD, which developed them statistically for their long-term planning efforts. These demand factors were shared with and reviewed by the CWA in previous studies. These factors were applied to "normal" weather water demand projections developed for the City by PMCL (see Section 2). These same factors were also applied to water conservation, as dry weather not only affects demand, but also how much conservation occurs.

Imported water from the CWA and MWD is one of the most variable supplies. This variation is mainly due to hydrology in northern California. The imported water from the Colorado River is tempered by the massive storage of the system, which is over 10 times the storage on the SWP. Again, weather factors for imported water were obtained by MWD.

In addition to demand and imported water, local runoff was also modeled using historical hydrology. Local runoff records to each reservoir were used as input to the model, based on the year sequence corresponding to each hydrology. A runoff factor was applied to the average runoff for the period 1922 to 1998, resulting in the actual runoff observed in a given year. Thus, if a simulation included hydrology conditions for the years 1947, 1948, and 1949, all reservoirs were applied factors that resulted in a runoff equal to the recorded runoff for those specific years. Figure 6-6 shows actual runoff records from Morena Reservoir from 1922 to 1998, as an example of the data used for every reservoir in the SDSIM Model.

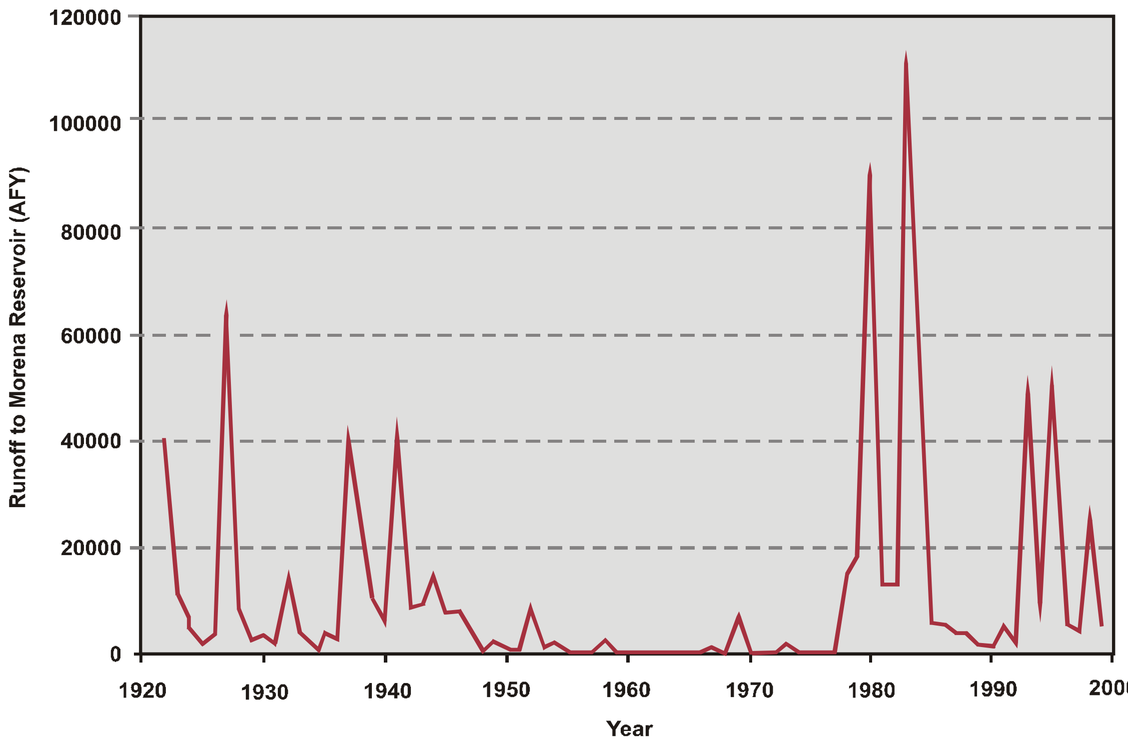


Figure 6-6
Actual Runoff Records for Morena Reservoir

For the purposes of modeling and evaluation, four 30-year hydrologic traces were developed: (1) critically dry; (2) dry; (3) normal; and (4) wet. These four traces represented the most likely weather scenarios that the City could face. To determine the specific hydrologic years that went into each of these 30-year traces, cumulative water shortage/surplus were generated. The cumulative shortage/surplus was generated by comparing the water demand, with existing conservation and reclamation, to local runoff and imported supplies for each hydrological year from 1922 to 1998. Those 30-year sequences with the highest cumulative supply shortage represented the critically dry hydrologies. It should be noted that not all the years included in the critically dry hydrology trace were dry, just that the cumulative sequence produced the greatest overall shortage. It should also be noted that a critically dry year does not necessarily mean water demands were at an all time high or that all sources of supply were at an all time low. However, it does imply that the overall supply deficit was greatest.

Hydrological sequences that produced cumulative shortages not as great as the critically dry trace were used to represent the dry hydrologies. The normal year hydrologies were developed using the statistical mean, while the wet sequence was developed by selecting the traces that had the greatest cumulative surplus. Table 6-1 presents the selection of the representative hydrologies used in the SDSIM Model.

Table 6-1
Selected Traces for Four Represented Hydrologic Scenarios

Hydrologic Scenario	Hydrologic Years Included in Trace	30-Year Cumulative Shortage/Surplus	Probability of Occurrence
Critically Dry	1948-1977	-690,000 AF	8%
Dry	1939-1968	-165,000 AF	19%
Normal	1923-1952	+239,000 AF	44%
Wet	1992-1998/ 1922-1944[1]	+690,000 AF	29%

[1] Trace starts with 1992-1998, then wraps around and begins again using 1922-1944 data.

6.2.6 Performance Measures

As a result of stakeholder and water department staff interviews, the following seven broad objectives were developed to analyze each portfolio.

- Supply Reliability
- Flexibility
- Salinity
- Catastrophe Protection
- Environmental Impact
- Risk
- Minimize Costs

From these objectives, performance measures were developed. The performance measures are numerical values needed for the decision-making process; therefore, the model was programmed to provide output for these performance measures.

Supply Reliability

Supply reliability was measured by taking the total usable supply in a given year under a given hydrological scenario and comparing it to the total demand. The ratio of percent of supply to demand became the output for measuring how well an alternative portfolio did in terms of meeting the Supply Reliability Objective.

Cost

Capital costs and O&M costs for each supply option were included in the model. Both capital and O&M costs were escalated by an inflation rate of 3 percent per year. In addition, the present values (PV) of the costs were calculated for the 30-year period at a discount rate of 6 percent. For the capital costs, the assumption was made that the capital investment would be financed at 6 percent interest rate, equal to the discount rate used for the PV estimates. O&M costs were separated into fixed and variable O&M costs. Fixed O&M costs were considered unavoidable and included maintenance, repair, and labor costs; and, variable O&M costs included mainly power costs and chemicals, which were considered avoidable. Water conservation costs were modeled as variable costs, and the costs of CWA water purchases were also variable. The percent of variable costs to the total costs became the output for measuring how accommodating an alternative portfolio was in terms of avoiding costs if the supply was not needed, and how well the portfolio met the Flexibility Objective.

Flexibility

The quantification of flexibility was based on the costs of the portfolio. The ratio of PV of variable costs (which could be avoided if conditions change) to the total PV of the portfolio was estimated, and that was assumed to be an indication of how easily a portfolio could avoid costs if conditions changed in the future. A high ratio indicated high flexibility. The rationale for this performance measure that investments in infrastructure requiring very high fixed costs may preclude taking advantage of new opportunities in the future.

Salinity

The water quality assessment is based on the concentration of total dissolved solids (TDS) estimated for each water supply source. TDS concentrations for each option, excluding water conservation, were determined based on historic records and/or projected water quality of options currently not in place (i.e., desalination, marine transport, etc.). A mass-balance of supplies was programmed into the model in order to track the total salinity for each alternative portfolio. By multiplying the water supply's TDS concentration by the water supply yield, a TDS load is calculated and totaled for the entire San Diego supply. The total TDS load is then divided by the total San Diego supply yield to obtain an overall TDS concentration for the each simulation. The following equation represents the formula used to convert TDS concentration to TDS load, including unit conversions:

*TDS Load (mg/year) = Supply Yield (AFY) * 1,233,246 (L/AF) * TDS Conc. (mg/L)* [1]

Catastrophe Protection

A separate analysis was performed for emergency conditions representing a major earthquake in the region. This PM essentially evaluated the same aspect as the supply reliability PM, doing it in this case for a simulated period equal to six tenths of a year (based on the City's emergency supply policy, see Section 6.3.3). The general approach to quantify this performance measure was to identify the sources that would not be available during an earthquake scenario, eliminate those sources from the simulation, make the emergency storage available for supply, and determine the reliability of the portfolio, measured over six tenths of a year. For a detailed discussion on the emergency simulation see Section 6.3.3.

Environmental Impact

The assessment of the negative environmental impact caused by the development and use of each water supply option was quantitatively analyzed by means of qualitative

[1] mg/year = milligram per year; L/AF = liter per acre-foot; mg/L = milligram per liter

factors developed by expert judgment. Table 6-2 indicates the factors assigned to each water supply option.

Table 6-2 Environmental Impact Factors	
Water Supply Option	**Environmental Impact Factor (5: no impact) (1: highest impact)**
Existing Conservation	5
Additional Conservation	5
Local Runoff	4
Existing Reclamation	5
Level 1 Reclamation	5
Level 2 Reclamation	5
Option 1 GW Storage	4
Option 2 GW Storage	4
Option 3 GW Storage	4
Option 1 GW Desalination	3
Option 2 GW Desalination	3
Option 3 GW Desalination	3
Ocean Desalination	2
Marine Transport	3
Level 1 Water Transfers	4
Level 2 Water Transfers	4
Level 3 Water Transfers	3
Firm Imported Water	3
Future Imported Water	1

A total score for each portfolio was generated based on multiplying each supply option's water yield (acre-feet per year) by the numeric factor.

Risk

There are three components of the risk evaluation: level of ownership, level of consumer acceptance, and level of implementation risk. The level of ownership is the assessment of City ownership of the water supply option. The level of consumer acceptance is the assessment of how well consumers will accept and/or implement the supply option. The level of implementation risk is the assessment of the difficulty in developing the supply option. Similar to environmental impact, risk is quantitatively analyzed by means of qualitative factors developed by expert judgment. In the case of level of ownership, experts used as a guideline, three basic situations: (1) options for which the City would have direct control, such as reclamation; (2) options for which a contract exists but the actual deliveries depend on other parties, such as water transfers; and (3) options for which no control or contract exists, such as imported supply. Table 6-3 indicates the factors assigned to each water supply option. A total score for each component was generated by multiplying each supply's water yield by the numeric factor. A weighted average of the three components became the output for measuring how uncertain an alternative portfolio was in terms of the overall Risk Objective.

Table 6-3
Risk Evaluation Factors

Water Supply Option	Level of Ownership (5: completely owned) (1: no ownership)	Level of Consumer Acceptance (5: highest degree of acceptance) (1: lowest degree)	Level of Implementation Risk (5: lowest risk) (1: highest risk)
Existing Conservation	4	4	4
Additional Conservation	4	4	4
Local Runoff	5	5	5
Existing Reclamation	5	3	4
Level 1 Reclamation	5	3	4
Level 2 Reclamation	5	3	4
Option 1 GW Storage	4	4	4
Option 2 GW Storage	4	4	4
Option 3 GW Storage	4	4	4
Option 1 GW Desal	5	4	3
Option 2 GW Desal	5	4	3
Option 3 GW Desal	5	4	3
Ocean Desalination	5	3	3
Marine Transport	3	2	1
Level 1 Water Transfers	3	4	2
Level 2 Water Transfers	3	4	2
Level 3 Water Transfers	3	3	1
Firm Imported Water	1	3	4
Future Imported Water	1	2	1

6.2.7 Quality Control

Model development was subject to quality control process. All data used in the model was obtained from information developed or compiled by technical staff, and was reviewed by senior staff. The overall model structure and the modeling approach were discussed with the City in various work sessions and reviewed by an internal technical committee.

The model was subject to a detailed review for flow and stock magnitudes and dynamics, mass conservation, dimensionality, and response under extreme input conditions. The model used explicit representation of units in every equation, forcing unit consistency. In addition, the hydrology record for the past 30 years was used to validate the output for the use of local reservoir water, obtaining a mean error (mean over the 30-year simulation) on the order of ±3 percent of supply.

Frequent and effective communication with City staff was established to guarantee that any model reprogramming and all of the assumptions for developing the most important response functions were consistent with existing information about the system and congruent with the modeling objectives. The conceptual nature of the model provided opportunity for validating most of the response functions using simple spreadsheets.

6.3 Simulation Process

6.3.1 Management Decisions and Options

The input process for the SDSIM Model is facilitated by the use of a graphical interface based on switches that set the hydrology and turn options on and off. Figure 6-7 shows the graphical management panel developed for the systems model.

Figure 6-7
SDSIM Model Management Panel

As Figure 6-7 shows, the following options were included in the model in addition to local reservoir water, which was used in the model by default with no associated management decisions:

- Conservation: existing conservation (included in all simulations by default) and additional conservation efforts
- Reclamation: existing levels, and two additional levels that can be implemented independently
- Groundwater desalination: as three independent options

- Ocean desalination: only one level of ocean desalination
- Marine transport: only one level of marine transport
- Firm/existing imported water: on by default for every simulation, but allowing the model allows for the evaluation of scenarios without imported supply
- Groundwater storage: as three independent options
- Water transfers: three options that can be added to the simulation independently
- Future imported water: increasing the levels of imported water that can be purchased (at higher costs and risks)

To run the model, the user switches on desired water supply options for the portfolio by clicking on the appropriate buttons (the green square in the middle of the switch indicates that the option is on). The desired hydrology must be selected before running the simulation because results can vary significantly depending on the hydrologic conditions.

Each project alternative or "portfolio" was represented by a unique set of inputs to the model, which were entered in to the model through the management panel. The Dynamic Data Exchange features of the STELLA software were used to develop a spreadsheet-based output file that could be updated automatically at the end of each simulation. The output file was then used to develop the alternative scorecards for analysis of the impacts of each portfolio comparatively. The output file was designed in close communication with the developers of the decision-making model (score card analysis), and it served as the primary and direct input file for that model, with no intermediate steps for data conversion involved.

In addition to the main inputs included in the management panel, the model was programmed to provide easy manipulation of certain variables for sensitivity analysis. Input variables were programmed for: (1) reducing costs of groundwater storage, reclamation and groundwater desalination to account for potential cost-sharing opportunities; (2) increasing energy costs; (3) reducing the availability of imported supplies and transfers; and, (4) reducing the capital costs of groundwater and ocean desalination to account for improvements in desalination technology.

6.3.2 Model Operation

Once the water supply options, levels of implementation and hydrology are selected, the model computes demands, supplies, storage operations, costs, TDS mass balance, and the other performance measures for every annual time-step. Data from the model database is used for inputs to the model. The yields from the different sources in the database (described in Section 3), however, are used as maximum yields, allowing the model to calculate the actual annual yield based on the combination of factors involved in each simulation. Table 6-4 shows an example of some of the model outputs for a part (5 years) of a simulation.

Table 6-4
Example of Some of the Model Outputs for a Part (5 Years) of a Simulation

Parameter (AFY)	2018	2019	2020	2021	2022
Type of Year (model input)	**Dry**	**Normal**	**Wet**	**Dry**	**Wet**
Demand	297,572	299,475	299,029	322,615	300,897
Conservation	12,576	13,666	14,851	17,222	17,167
Local Runoff	9,126	21,286	30,988	9,452	48,952
Reclamation	14,600	14,600	14,600	14,600	14,600
Ocean Desalination	10,000	10,000	10,000	10,000	10,000
Imported Supply	228,982	218,208	207,728	232,386	190,968
Groundwater Storage	53,863	43,513	68,445	96,445	84,831
Flow out of Groundwater Storage to Demand	10,350	0	0	11,614	0
Total Supply	297,572	299,475	299,029	322,615	300,897

As shown in Table 6-4, the model computes each one of the variables at each time step, and uses the end-of-year values as inputs to the following year (as seen in the groundwater storage row, where the flow out of groundwater storage is subtracted from the storage of the next year. Table 6-4 shows a very simplified version of the model output, with only very few elements included. The SDSIM Model provides output both by service area and aggregated, and includes values for each one of the possible yields under each portfolio as well as performance measures, costs, and variables used as intermediate steps for the calculation of performance measures.

6.3.3 Emergency Scenario Simulation Process

Under City Council Policy 400-4, the City of San Diego is required to have available at all times a substantial emergency storage reserve, equal to a six-tenths of the annual demand for the entire city. The purpose of the emergency storage reserve is to maintain water service in the event of a prolonged outage of the imported water system due to an earthquake, flood, or other catastrophe.

In order to evaluate the performance of each portfolio of options in the event of a catastrophe, an emergency scenario was developed to determine the supply reliability. The emergency scenario, representing a major earthquake, was simulated by eliminating the imported supply and water transfers options. This emergency scenario represents a case in which the CWA aqueducts are off-line for a period equal to six-tenths of a year, during peak months.

The dry hydrology condition was used in the emergency simulation to represent conservative conditions. Thus, the simulation of each portfolio was run without imported supply or water transfers under the dry hydrology in order to obtain the following output:

- Reservoir Storage
- Groundwater Basin Storage
- Total San Diego Demand
- Total San Diego Conservation

More than these four variables are needed for the calculation of the reliability under emergency conditions. However, other variables required (such as desalination yields, reclamation yields, marine transport yields) are exogenous variables (i.e., not affected by the model), whereas the reservoir and groundwater storage are calculated by the model for each simulation year. Demand and conservation are also calculated by the model depending on projected averages and the hydrology selected.

Beginning-of-year storage for every year was obtained from the model runs and the reservoir supply was computed based on available water and capacity constraints. The supply availability is limited by the pipeline capacities conveying the water to the treatment plants for six-tenths of the year; therefore, the reservoir storage was compared to the six-tenths of the year pipeline capacity in order to determine the reservoir supply. Similarly, the groundwater basin supply is limited by the production well capacities pumping the water from the basins for six-tenths of the year; therefore the groundwater basin storage was compared to the six-tenths of the year production well capacity in order to determine the groundwater basin supply.

The total supply available for the emergency storage reserve includes the reservoir supply, the groundwater basin supply, and six-tenths of the annual supply options included in the portfolio (desalination, marine transport, etc.). Demand and supply was computed in this way for every year from 2001 to 2030, and the performance of a portfolio was evaluated based on the ratio of the total supply to the total San Diego demand for an emergency period occurring in any given year. An average performance measure was calculated for each portfolio.

6.4 Use of Score Card to Evaluate Alternatives

Often the most difficult aspect of the evaluation process is how to compare alternatives using a standardized approach. For example, how does one compare two portfolios when the criteria are costs and supply reliability? Reliability, as measured by the percent of demand met by supply, is a totally different metric than present value cost. Comparing alternatives is further complicated when both quantitative and qualitative measurements are introduced.

In an attempt to standardize all of the performance measures, a scorecard approach was used. For each planning objective, a score of 0 to 100 was generated, with 100 being the best. Both quantitative and qualitative measurements were converted into these standardized scores. Once standardized, scores for each objective could then be weighted, according to the stakeholder preferences summarized in Section 4.

Two quantitative measurements, Supply Reliability (measured as the percent of demand met by supply) and Flexibility (measured as the percent of variable cost to total costs) did not have to be converted because their raw model output was already in the form of a percentage. All other measures were first calculated in raw form, then converted using the minimum/maximum alternative technique.

The minimum/maximum alternative technique involves looking at the raw model output for all alternatives, then identifying the minimum and maximum values, and comparing those values to the alternative in question. For example:

Assume that there are 5 alternatives and their raw model output (the larger the number the better) is as follows:

Alternative 1 = 50
Alternative 2 = 10
Alternative 3 = 140
Alternative 4 = 35
Alternative 5 = 70

To put these on a standard score from 1-100, the following formula would be used:

$$\left[(AlternativeScore - MinScore) \div (MaxScore - MinScore)\right] \text{ x } 100$$

Where:

AlternativeScore =	the raw model output for the alternative in question
MaxScore =	the maximum raw model output for all alternatives
MinScore =	the minimum raw model output for all alternatives

So, for this example, the standardized score for Alternative 5 would be:

$$[(70\text{-}10) \div (140\text{-}10)] \text{ x } 100 = 46$$

Section 7 summarizes the evaluation results of the alternatives and the development of standardized scores for each portfolio.

Section 7
Evaluation of Alternatives

Section 7
Evaluation of Alternatives

As discussed in Section 6, a systems model was developed to help measure performance and compare alternative portfolios. While some of the performance measures were qualitative in nature, much of the performance was quantitative and modeled on a continuous scale. The three major continuous-scaled variables modeled were supply reliability, cost, and water quality (salinity). In the end, all of the output from the SDSIM Model (both qualitative and quantitative) was converted into standard, comparable scores. However, the raw output for supply reliability, cost and salinity can provide some detailed insights that overall scores may miss.

7.1 Water Supply and Storage Evaluations

All of the water resource portfolios were designed to achieve 100 percent supply reliability under all hydrological scenarios. The results of the SDSIM Model concluded that essentially all but the Status Quo portfolio achieved this goal. The Status Quo was developed to test the City's no action alternative, so it is not surprising that it did not achieve the reliability goal. During extreme shortage years in the model simulation, the Status Quo's supply reliability fell as low as 65 percent. During the critically dry hydrology scenario, the Status Quo failed to meet demands in 19 out of 30 years.

Although the other portfolios achieved the reliability target, they did so in very different ways. To help illustrate this, a static snapshot of the simulation was used to compare how alternatives "stack" up in terms of meeting water demand in year 2030. The snapshot was based on a critically dry year that was preceded by other dry years in the simulation. This event could be similar to what occurred at the end of 1991, one of California's most severe droughts. Figure 7-1 presents this snapshot of supply for each of the alternative portfolios.

Each portfolio maximized, to the extent possible, local runoff. However, because this was a critically dry year, local runoff was significantly lower than average conditions. Local runoff for this scenario is estimated at 10,000 AFY. Conservation was maximized for all alternatives, except the Status Quo. Conservation represents the cheapest supply alternative when financial incentives from the CWA and MWD are accounted for. Reclaimed water varies between alternatives, with alternatives focusing on cost and water quality only implementing current levels of production. Six out of the eight portfolios relied on groundwater storage to help meet reliability, while five portfolios implemented groundwater desalination. Ocean desalination was implemented in four portfolios. Marine transport was also implemented in four portfolios, although not necessarily the same as was ocean desalination. Central Valley transfers were implemented in three portfolios.

Generally, those portfolios designed to minimize risk or environmental impacts had the greatest amount of local supply development. In terms of reliance on imported water (either purchased directly from CWA or water transfers), the alternatives ranged from 51 to 85 percent dependent on imported supply. The Minimum Catastrophe Impact had the lowest reliance on imported water, while the Status Quo had the highest.

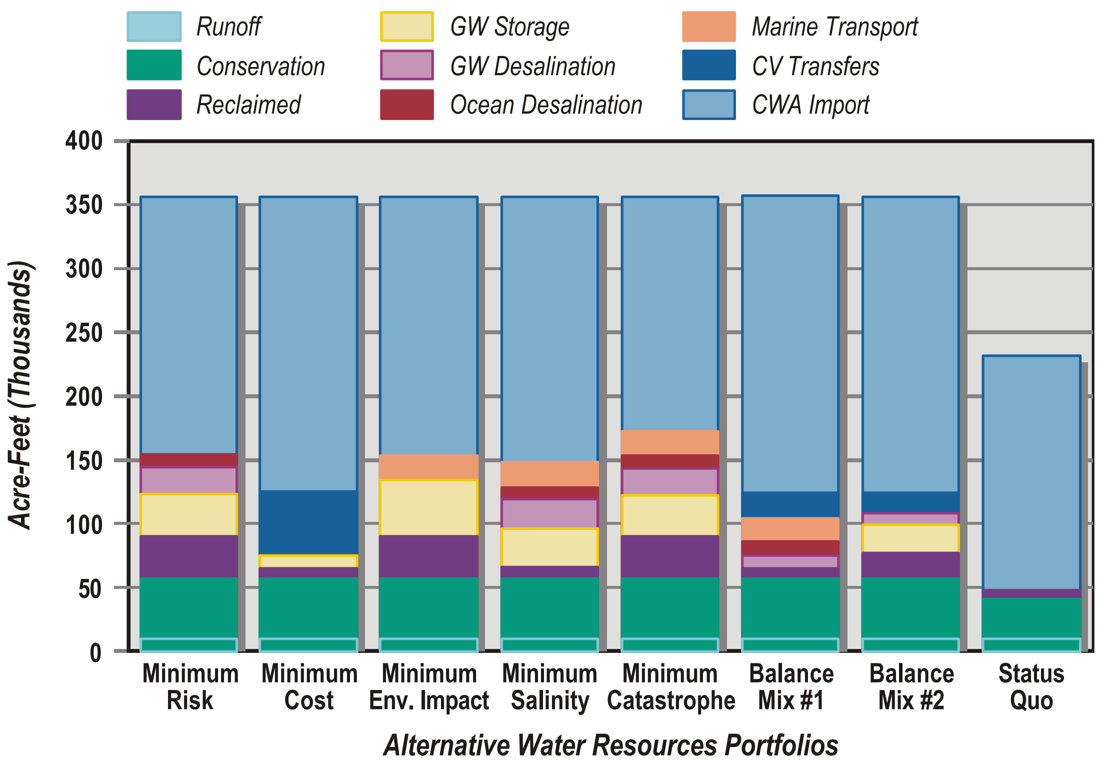


Figure 7-1
Comparing Alternative Portfolios
for Year 2030 Under a Critically Dry Scenario

In addition to the static snapshot, it is also important to look at how supplies were utilized in a dynamic sense. Figure 7-2 illustrates a hydrology sequence using the historical record of 1933 to 1952 mapped onto the projection of 2010 to 2030. This record represents a typical "normal" hydrologic scenario. Three core supplies were examined for this scenario: reclamation, ocean desalination, and groundwater desalination. The sequence illustrates how reclaimed water is almost always utilized. This is because reclaimed facilities are in areas which demand for additional water beyond local runoff is not as variable. However, during very wet weather conditions, some parts of the City get all their water from local runoff. In these years, ocean and groundwater desalination are not used. A way to improve the utilization of these supplies under these wet years would be to pipe the desalination water to other parts of the City's service area. However, that would add significant costs to what are already higher-cost supply options. Figure 7-3 illustrates groundwater storage operations for a dry hydrology. The figure shows puts into, takes from, and ending storage levels.

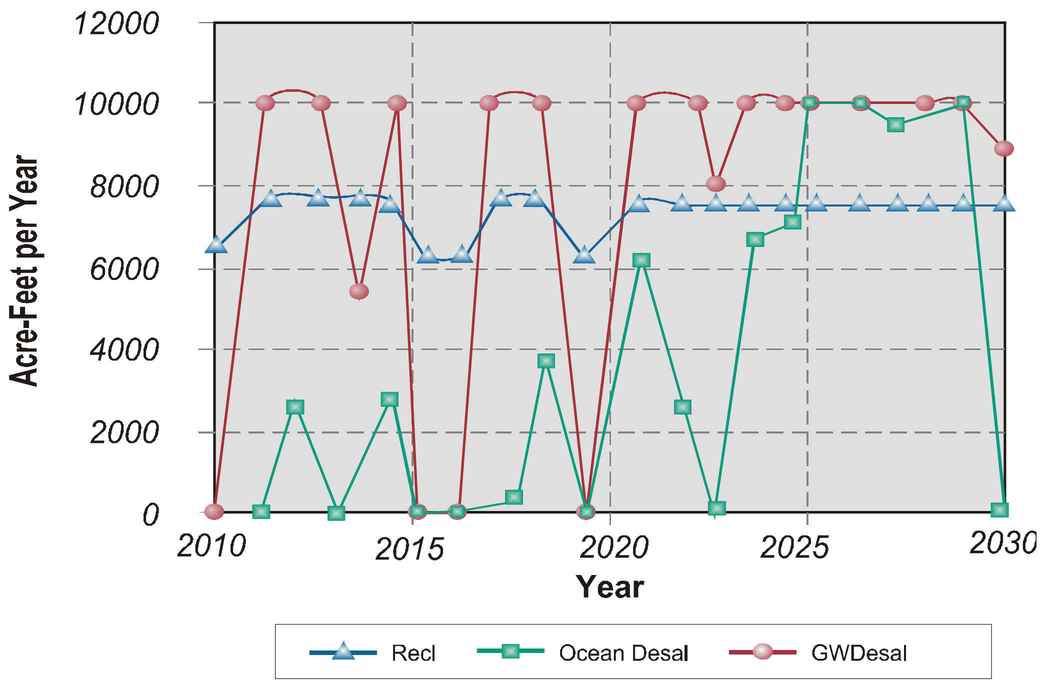


Figure 7-2
Example of Water Supply Option Yields Over Time

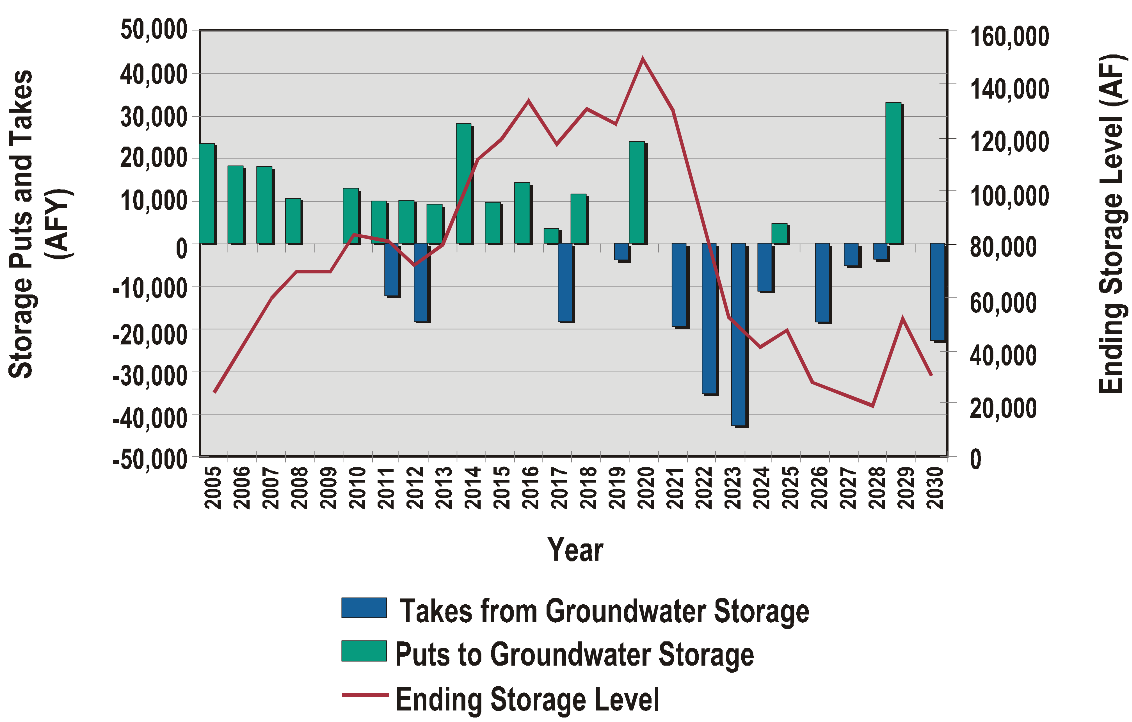


Figure 7-3
Simulation of Groundwater Storage for Dry Hydrology

7.2 Cost Evaluations

For each alternative portfolio, the capital, fixed O&M and variable O&M costs were evaluated and brought back to present value dollars using a 3 percent escalation rate and 6 percent discount rate. The costs included this analysis only reflect the additional capital and fixed O&M cost for additional water supply, as well as the current and future variable costs for water supply. What are not included are costs for existing capital debt for the City. These costs were not included, as they will not discriminate between alternatives.

Portfolios varied significantly in their total present value costs. Alternatives ranged from $1.79 billion to $2.74 billion (see Figure 7-4). The Minimum Cost Portfolio had the lowest overall cost as it relied most heavily on lower-cost imported water. The Minimum Catastrophe Impact Portfolio had the highest cost as it contained the most redundancy for protection against earthquakes.

In addition to comparing the total cost, the amount of variable costs to the total cost was examined. The percent of variable cost is a good indication of how flexible a certain alternative is to changing conditions. Those portfolios that have high variable costs (or low fixed costs) can more easily adapt financially if changes in demand occur. The Minimum Cost Portfolio also had the greatest percent of variable cost, as it relied more on water that was simply purchased on demand.

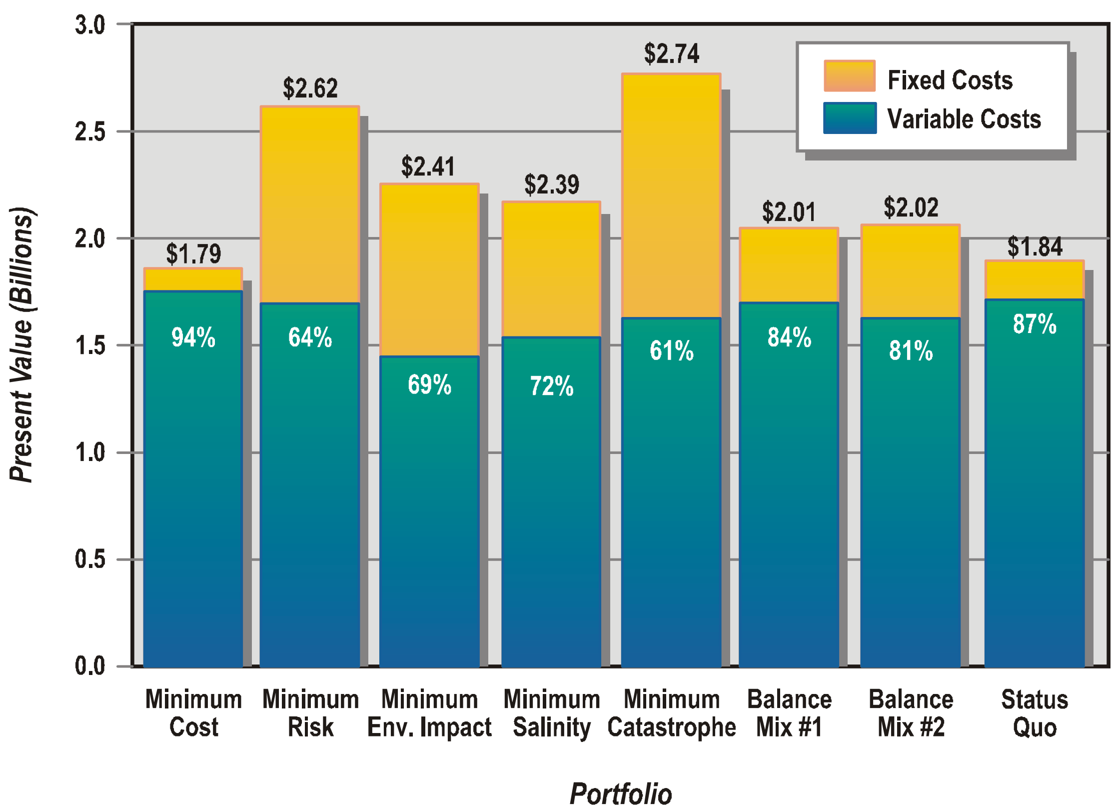


Figure 7-4
Total 30-Year Present Value Cost

7.3 Water Quality Evaluations

The SDSIM Model calculated salinity for each portfolio and for every year in the planning horizon, as described in Section 6. Figure 7-5 presents salinity estimates for all scenarios, averaged over the 30-year period and the four hydrologies.

This evaluation found a correlation between imported water use and salinity. Other sources affect the total salinity of the water delivered as well, but imported water has the largest impact. Generally, those portfolios having desalination (ocean and groundwater), groundwater storage, and marine transport had much lower salinity than those alternatives without such supplies. Figure 7-6 presents the correlation between imported water and salinity.

Another clear correlation was found between weather and salinity. Wet years resulted in lower TDS concentration levels for all portfolios mainly because of the low-salinity of local runoff and the fact that during wet years the salinity of imported water is much lower.

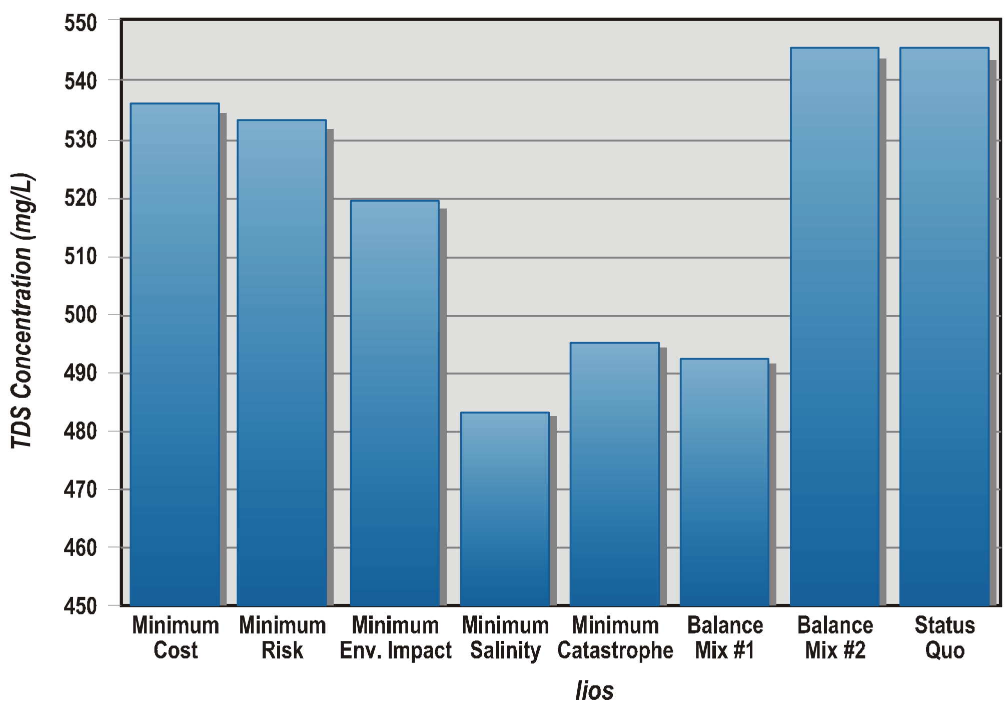


Figure 7-5
Average Salinity Concentrations

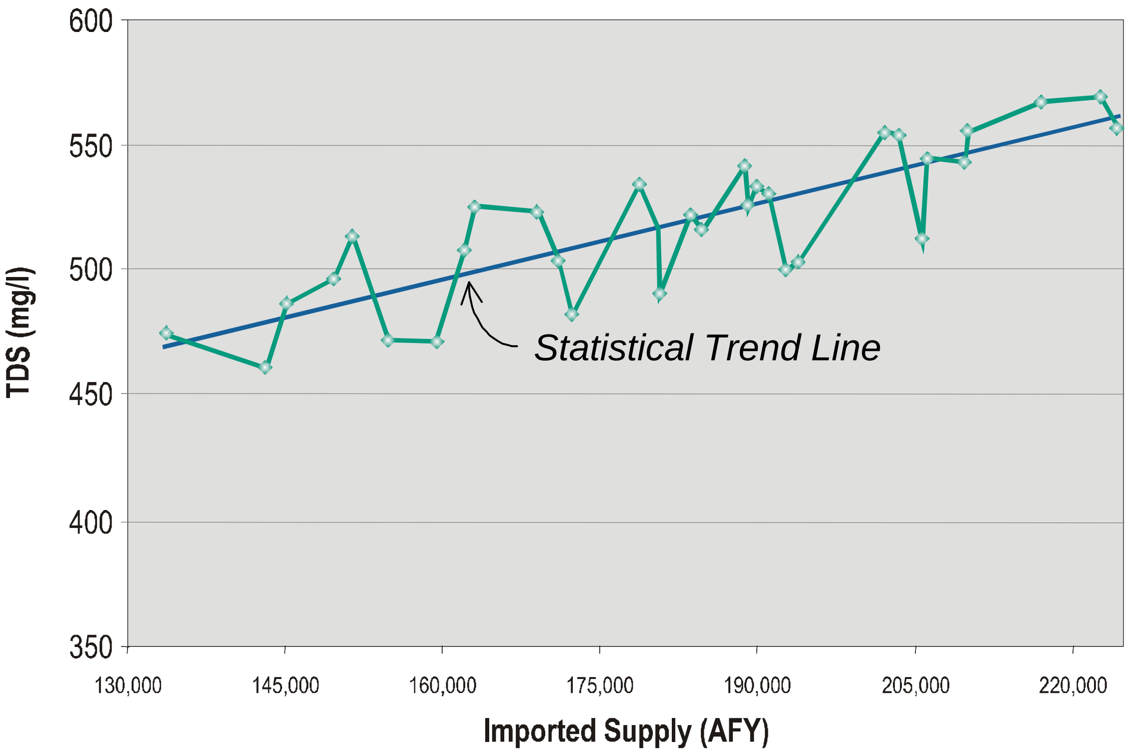


Figure 7-6
Correlation Between Imported Water Purchases and Average Salinity

7.4 Simulation of Catastrophe

The simulation of an emergency condition was described in Section 6. The purpose of this simulation was to evaluate the response of the portfolios, in terms of supply reliability, under an earthquake scenario. It is expected that a major earthquake in the region would cause major damage to the CWA aqueducts, limiting (or eliminating) the ability to import water. Such a scenario, as modeled by the SDSIM Model, would also eliminate water transfers as a source of supply. Local supplies, reclamation, ocean and groundwater desalination, groundwater storage, and marine transport are assumed to be immune from this type of catastrophe. These local supplies would augment the emergency storage in the City's surface reservoirs to meet demand.

Results indicate that all of the portfolios could meet the City's policy for emergency supply (See Section 6.3). However, when planning for such a catastrophic event, having redundancy in supplies is important. Redundancy was measured by taking the ratio of total available emergency supplies to the target demand (six tenths of the year). The higher the ratio, the more protection the alternative portfolio provides against a catastrophe. Figure 7-7 presents this reliability factor for each portfolio.

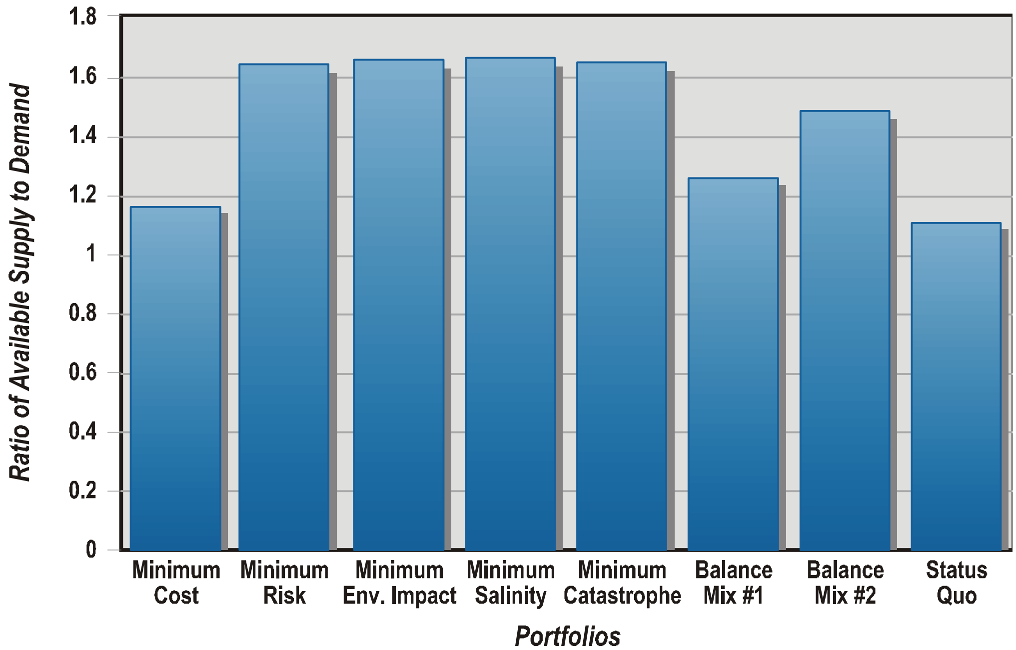


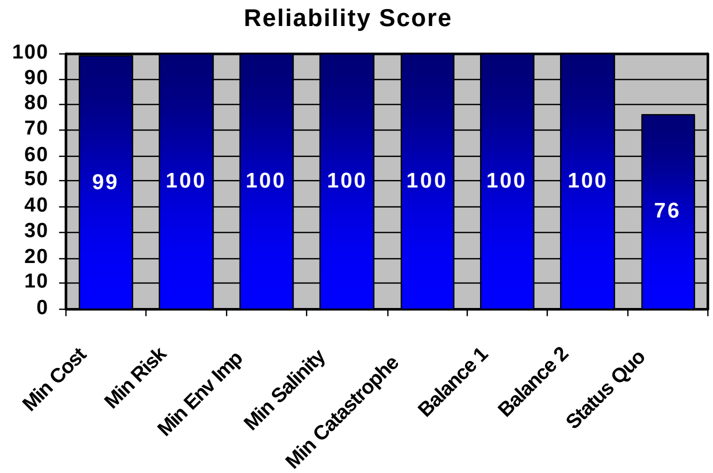
Figure 7-7
Ratio of Emergency Supplies to Demands Under Simulation of Catastrophe

7.5 Score Card Results

As mentioned in Section 6, it was necessary to convert the raw output from the SDSIM Model into standard metrics to allow easy comparisons of alternative water resource portfolios. To accomplish this, a scorecard approach was used. For each objective and for each portfolio, a score of 0 to 100 was given (with 100 being the best score). Some of the model output was easily converted into this score, since the measurement was already calculated in terms of percentage (e.g., supply reliability or flexibility). However, most of the model output had to be converted into scores based on the min/max approach discussed in Section 6.

7.5.1 Ensure Supply Reliability

The performance measurement for ensuring supply reliability was the percent of water demand achieved in any given year and for any given hydrology. The final SDSIM Model output averaged across all years to obtain an average reliability measurement. Since this measurement was already output as a percentage, there was no need to convert it into a standard score. All of the portfolios were designed to meet water demands 100 percent of the time, with the exception of the Status Quo Portfolio (the no action alternative). All of the portfolios achieved this reliability target except the Minimum Cost Portfolio, which experienced water shortages of about 3 percent under dry weather conditions. When averaged with normal and wet years (during which this portfolio achieved 100 percent reliability), the overall average score was 99 percent.



7.5.2 Minimize Cost

The performance measurement for minimizing cost was the total present value cost over the 30-year planning period. Costs were estimated for capital, fixed and variable O&M, and supply development or purchase. To create a standard score, the following formula was used:

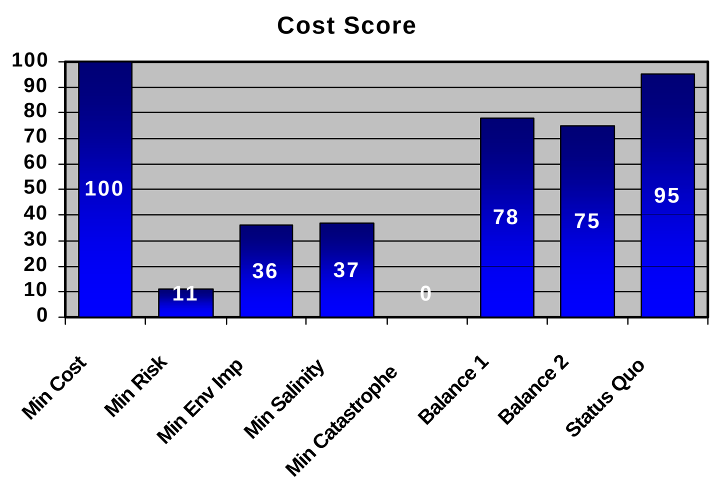
$$\left[(AlternativeScore - MaxScore) \div (MinScore - MaxScore)\right] \text{ x } 100$$

Where: $AlternativeScore$ = PV cost of alternative in question

$MaxScore$ = Maximum PV cost of all alternatives

$MinScore$ = Minimum PV cost of all alternatives

As designed, the Minimum Cost Portfolio had the highest score. This was due to its heavy reliance on imported water and transfers, which have the lowest projected costs. The Status Quo Portfolio actually had lower costs, but for comparison, costs associated with shortages were included. To account for the costs unreliability, the cumulative demand that was not met over the 30-year period was multiplied by the marginal cost of water supply (estimated to be about $1,300/AF). On average, the Status Quo's cumulative 30-year supply shortage was estimated to be 181,000 AF. Therefore, the cost of being unreliable for the Status Quo Portfolio is estimated to be $230 million. This cost was added to the total PV cost to obtain the



adjusted total cost. The highest cost alternative was the Minimum Catastrophe Impact Portfolio, which was heavily reliant on expensive water supply options such as ocean desalination, groundwater desalination, and marine transport. Generally, those portfolios that were more reliant on local supply options had the greatest costs.

7.5.3 Minimize Risk

For San Diego risk has three components: (1) level of City ownership in supply; (2) implementation risk for developing the supply; and (3) consumer acceptance. The qualitative indices for these components were presented in Section 6. These indices for each supply option were multiplied by their respective cumulative supply yield for each component of risk. To create a uniform score, the following formula was used:

$$\left[(AlternativeScore - MinScore) \div (MaxScore - MinScore)\right] \text{ x } 100$$

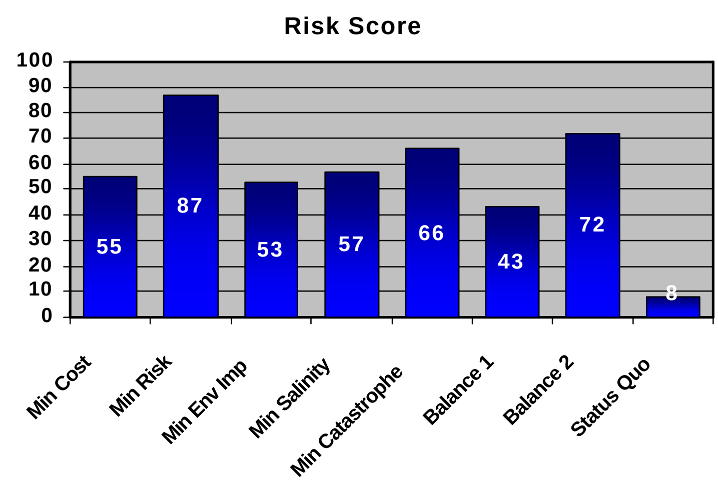
Where:

AlternativeScore = the multiplication of risk index times supply yield for the alternative in question

MaxScore = the maximum of the risk index times supply yield

MinScore = the minimum of the risk index times supply yield

After each component of risk was calculated, a weighted risk score was obtained using the following weights:

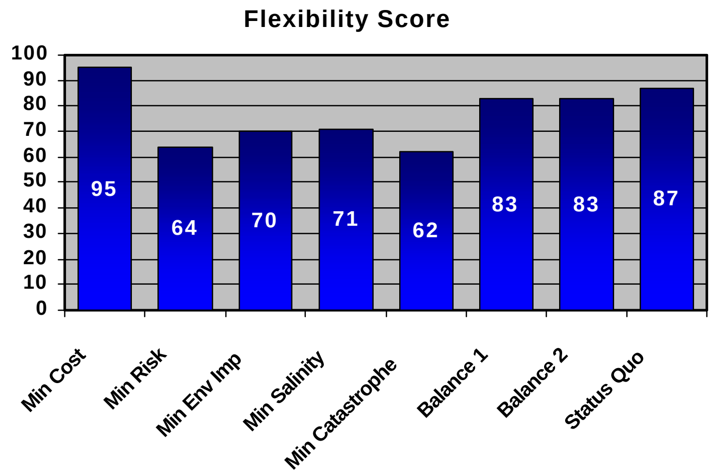


Level of City ownership = 50%
Implementation risk = 30%
Consumer acceptance = 20%

As designed, the Minimum Risk Portfolio had the highest score. This was due to its heavy reliance on lower risk supplies, such as conservation, reclamation, groundwater storage, and ocean and groundwater desalination. The Balance Mix #2 Portfolio, with its storage focus, had the next highest score. The Status Quo had the lowest overall risk score, due to its continued heavy reliance on imported water. Generally, those portfolios that relied heavily on imported water, water transfers, or marine transport scored lower than alternatives that relied more on proven technologies such as reclamation and groundwater storage. Desalination options, while scoring low in terms of implementation risk, balanced out because of the City ownership and consumer acceptance factors.

7.5.4 Maximize Flexibility

Flexibility was measured by taking the ratio of PV variable costs (which could be avoided if future conditions change) to the PV total costs. The higher the ratio, the better the score. Because this measurement was already scaled from 0 to 100 percent, a min/max formula to convert the model output was not required.



The Minimum Cost Portfolio also had the highest flexibility score. This was due to its heavy reliance on imported water and water transfers which do not have large fixed costs. Fixed costs can be troublesome if future conditions change, because they cannot be avoided (much like a fixed mortgage payment). The Minimum Catastrophe Impact Portfolio had the lowest variable cost, as it relied on heavily capital intensive supply options such as ocean desalination, reclamation, and groundwater storage. Generally, portfolios with greater reliance on imported water and transfers scored higher for this performance measure.

7.5.5 Minimize Environmental Impact

For each supply option, an index was applied to account for its impact on the local and Bay-Delta ecosystems (see Section 6 for summary of index). The index was then multiplied by the supply yield for each supply option. To create a uniform score, the following formula was used:

$$\left[(AlternativeScore - MinScore) \div (MaxScore - MinScore)\right] \text{ x } 100$$

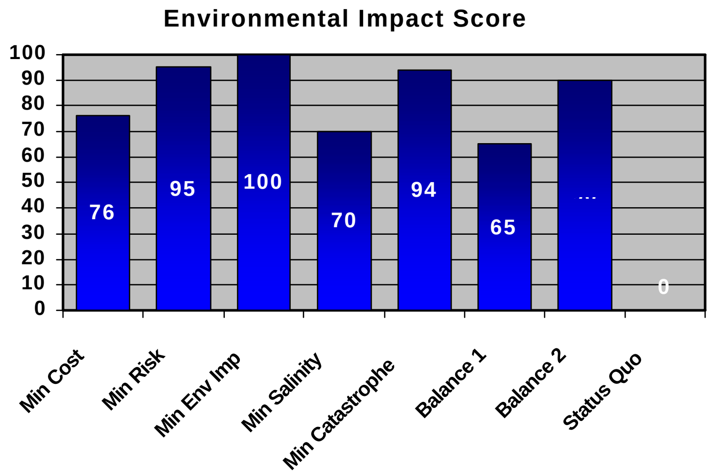
Where:

AlternativeScore = the multiplication of environmental impact index times supply yield for the alternative in question

MaxScore = the maximum of the environmental impact index times supply yield

MinScore = the minimum of the environmental impact index times supply yield

As designed, the Minimum Environmental Impact Portfolio had the highest score. This was due to its heavy reliance on supplies, such as conservation, reclamation, and groundwater storage. In general, those portfolios with heavy reliance on local supplies and marine transport scored well for this performance measure. The Status Quo had the lowest overall risk score, due to its continued heavy reliance on imported water. Portfolios with heavy reliance on desalination and water transfers did not score as highly as others, as these options can have significant impacts to the environment.



7.5.6 Protect Against Catastrophes

The results of the earthquake simulation demonstrated the effectiveness of the City's emergency supplies in meeting demands for seven months. In addition to the emergency storage, all supply options that are local and do not require the use of San Diego Feeders numbers 1 and 2 also will help ensure supply reliability during a catastrophe. The measurement for this performance measure was the ratio of supplies that would be available during a catastrophe to the six-month demand. To create a uniform score, the following formula was used:

$$\left[(AlternativeScore - MinScore) \div (MaxScore - MinScore)\right] \times 100$$

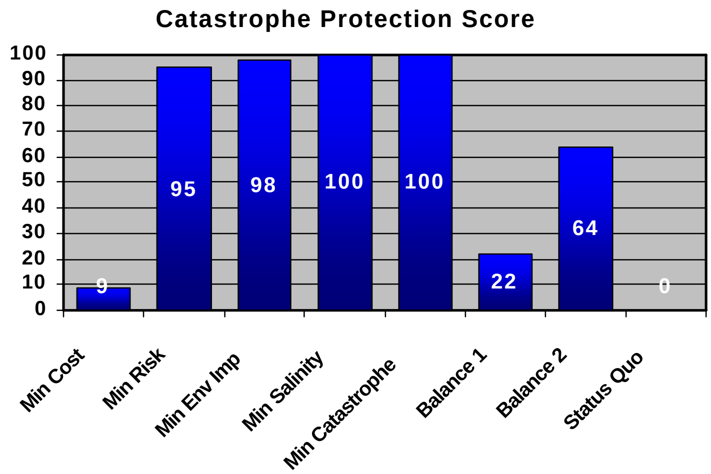
Where:

AlternativeScore = the ratio of emergency supply to 6 month demand for the alternative in question

MaxScore = the maximum of the ratio of emergency supply to 6 month demand

MinScore = the minimum of the ratio of emergency supply to 6 month demand

As designed, the Minimum Catastrophe Impact Portfolio had the highest score. This was due to its heavy reliance on local supplies such as reclamation, desalination, marine transport, which are less vulnerable to an earthquake. In a major earthquake, it is likely that CWA's imported aqueducts will be disrupted for some time. The Minimum Salinity Portfolio also scored 100, as it relied heavily on similar local supplies. In general, those portfolios with heavy reliance on imported water and transfers scored the lowest.



7.5.7 Minimize Salinity

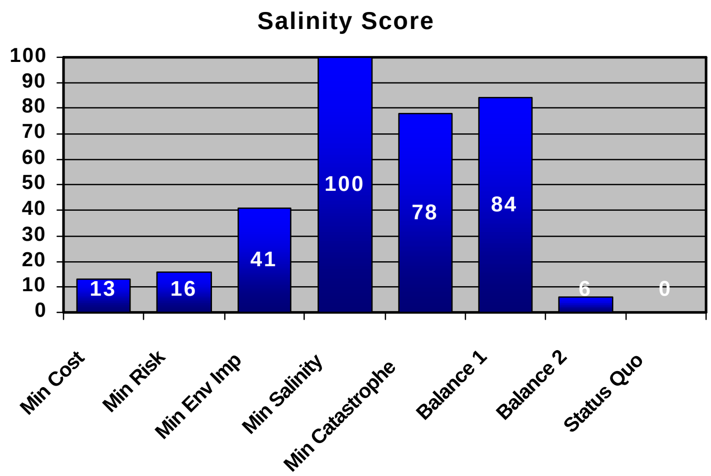
Salinity of the City's water effluent after leaving the treatment and reclaimed systems was measured on a mass-balance basis. Salinity was estimated in parts per million (ppm) for each supply option. The total mass-balance of salinity was then calculated. To create a uniform score, the following formula was used:

$$\left[(AlternativeScore - MinScore) \div (MaxScore - MinScore)\right] \text{ x } 100$$

Where:

$AlternativeScore$ =	the total average salinity (in ppm) for the alternative in question
$MaxScore$ =	the maximum of the total average salinity (in ppm)
$MinScore$ =	the minimum of the total average salinity (in ppm)

As designed, the Minimum Salinity Portfolio had the highest score. This was due to its heavy reliance on supplies with low salinity, such as desalination, marine transport and water transfers. The Minimum Catastrophe Impact Portfolio also scored high for this performance



measure due to the use of lower-salinity local supplies. Those portfolios with heavy reliance on high TDS imported water and reclaimed water did not score as well. The lowest scoring portfolio was the Status Quo, as it has the heaviest reliance on imported water. The Balanced Mix #2 Portfolio also scored poorly because of its reliance on reclaimed water, without balancing it out with reliance on desalination. The Balanced Mix #1, with its water quality focus, showed its strength in reducing the salinity of the City's water supply.

7.5.8 Overall Score

An overall score for each portfolio was generated using the weightings for each objective as discussed in Section 4. Because there are many trade-offs between the seven planning objectives, it was expected that the total overall scores would converge. Some of the more interesting trade-offs involved were: cost vs. risk; protection against catastrophes vs. flexibility; and minimize salinity vs. minimize environmental impact. Figure 7-8 illustrates these trade-offs.

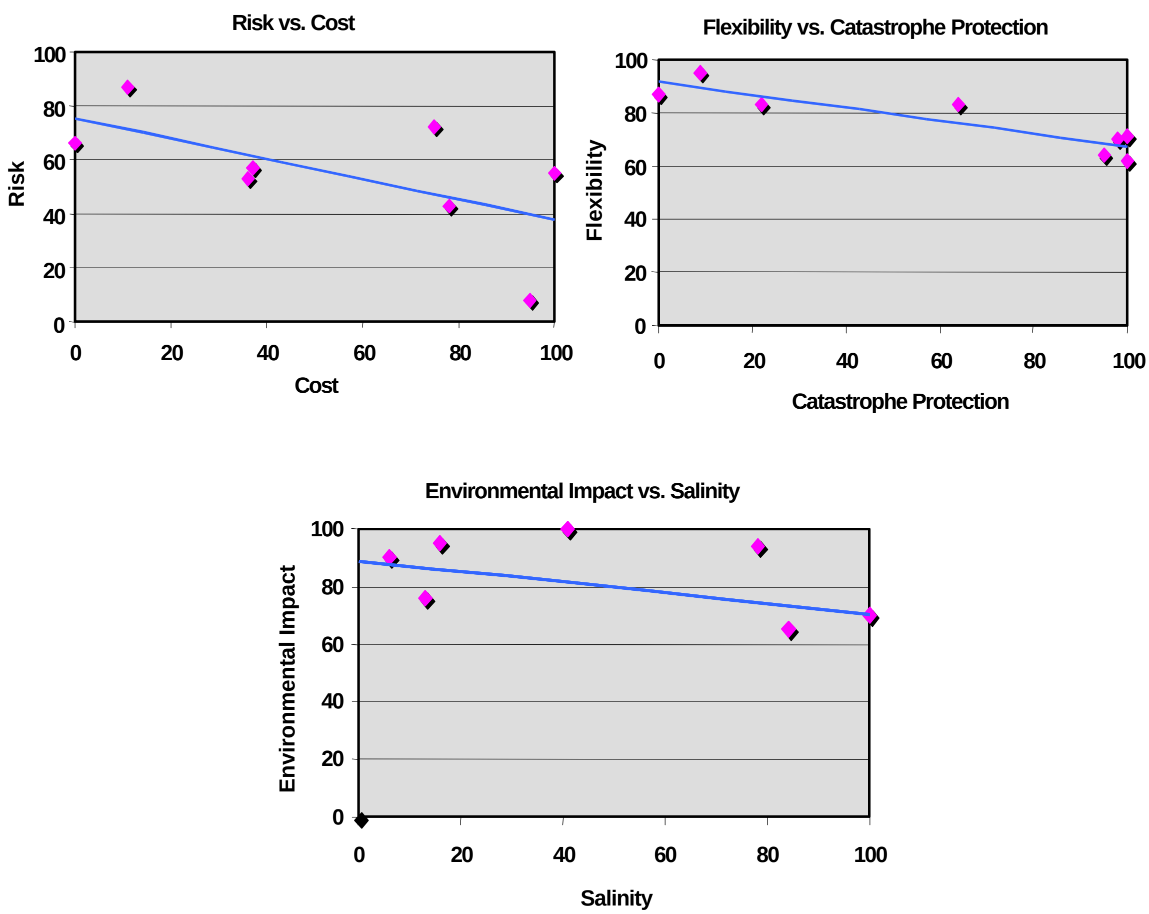


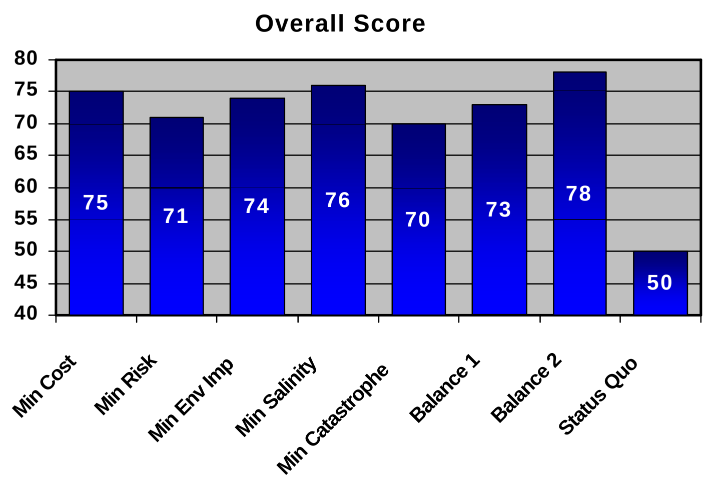
Figure 7-8
Trade-Offs Between Key Objectives

Generally those portfolios that have lower costs have higher risks. This is a classic water supply trade-off, to get a risk "free" supply, an agency must typically invest in higher-cost supply options.

An analysis of catastrophe protection vs. flexibility indicates that the more flexible portfolios are ones that generally offer lower protection against catastrophes. This is due to the fact that protection against catastrophes often involves capital-intensive projects.

Finally, the trade-offs between minimizing salinity and protecting the environment indicate that there are generally more impacts to the environment as salinity is reduced. This is due to the fact that desalination options generally have significant impacts to the environment, in terms of brine disposal and energy use.

These trade-offs illustrate the complexity of providing a reliable, safe water supply in a highly regulated arena. And because of this difficulty, it is essential that decision-support tools be used to help identify these trade-offs so that proper planning can take place.



The overall scores illustrate how these trade-offs balance each other out. Only the Status Quo Portfolio scored 50 or below, while the other portfolios scored 70 or above. The overall best scoring portfolio was the Balanced Mix #2 Portfolio, with its focus on storage. The next highest scoring alternative was the Minimum Salinity Portfolio, followed by the Minimum Cost Portfolio.

Given the uncertainity in technology, price of imported water, and availability of state/federal funding for local projects, it would be unwise to simply select the highest scoring alternative as the basis for a 30-year water resources plan. It is more appropriate to examine which resource elements are common among all of the high-scoring portfolios, and pursue them first. As time advances and factors such as changing technology, water markets, CALFED, and others unfold, decisions can be made on implementation of non-common elements.

This flexible and adaptable resource strategy blends two importants tactics: (1) beginning implementation of the plan with favorable options; and (2) keeping all options open without locking into anything that could become very costly or inefficient should conditions change. Table 7-1 summarizes the resources that are common to the top-scoring alternatives.

Table 7-1
Common Resource Elements Among Top-Scoring Alternatives

Resource Option	Balanced Mix #2 Portfolio	Minimum Salinity Portfolio	Minimum Cost Portfolio
Conservation, Existing	◆	◆	◆
Conservation, New	◆	◆	◆
Reclamation, Existing	◆	◆	◆
Reclamation, New	◆		◆
Groundwater Storage	◆	◆	◆
Groundwater Desalination	◆	◆	
Ocean Desalination		◆	
Marine Transport		◆	
Water Transfers	◆		◆
Imported Existing	◆	◆	◆
Imported New			◆

Section 8 presents a plan for implementation of the common elements and an approach for implementation of other options thereafter.

Section 8
Conclusions and Recommendations

Section 8
Conclusions and Recommendations

8.1 Implementation of the Water Resources Plan

During the planning process, the importance of having a flexible and adaptive water resources strategy was recognized. Although it is critical for water plans to have extended planning horizons, proposing that every element of a 30-year plan be implemented on day one is unrealistic. Therefore, it is recommended that the Water Resources Plan be implemented in three phases in order to meet San Diego's growing demands, making course adjustments as necessary to respond to changing technology, regulations, or needs. The three phases are 2010, 2020 and 2030.

Summary of Recommendations

- Common resources from 3 top-scoring portfolios implemented by 2010
- By 2010, City's reliance on imported water during a critical drought is expected to be 74%, as compared to 75-90% currently
- Success or failure of CALFED, water marketing, desalination technology, and the City's groundwater field investigation will dictate implementation of remaining resource elements in 2020 and 2030

The evaluations summarized in Section 7 compared eight alternative water supply portfolios. The alternative portfolios were compared using a set of evaluation criteria, which were based upon the seven planning objectives developed by the City and its stakeholders.

The three top-scoring portfolios were: (1) Balanced Mix #2, with a storage focus; (2) Minimum Salinity Impacts; and (2) Minimum Cost. These three portfolios were then compared to identify common resource elements. Those elements that were common to all three portfolios are recommended to be implemented by 2010 (Phase 1 of the Plan).

Resource elements that were different among the top-scoring portfolios were then examined to determine under what conditions would they become most feasible and attractive for the City to implement.

Based on such factors as the success or failure of CALFED, emergence of a strong water transfer market, technology improvements in membrane treatment, and the outcome of the City's field investigations of local groundwater, three distinct paths or strategies could be taken and possibly implemented by 2020 (Phase 2 of the Plan).

The three strategies are: (1) Treatment Strategy—assuming that technology improvements lower the cost of membrane treatment; (2) Market Strategy—assuming that a viable and strong water transfer market emerges as a possible outcome of CALFED; and (3) Storage Strategy—assuming that the City's field investigations in groundwater show promise in utilizing the basins for underground storage.

Once a particular strategy is chosen by the City, then Phase 3 of the Plan would implement a variety of resource options by 2030, depending on the continued success of prior resource implementation and/or achievement of planning objectives.

This flexible and adaptive water management strategy ensures that the City can move forward with the most promising resource elements quickly, while still allowing for a "wait-and-see approach" for those options that have higher risk.

Figure 8-1 presents this adaptive resources strategy, identifying resource targets that should be implemented in each phase.

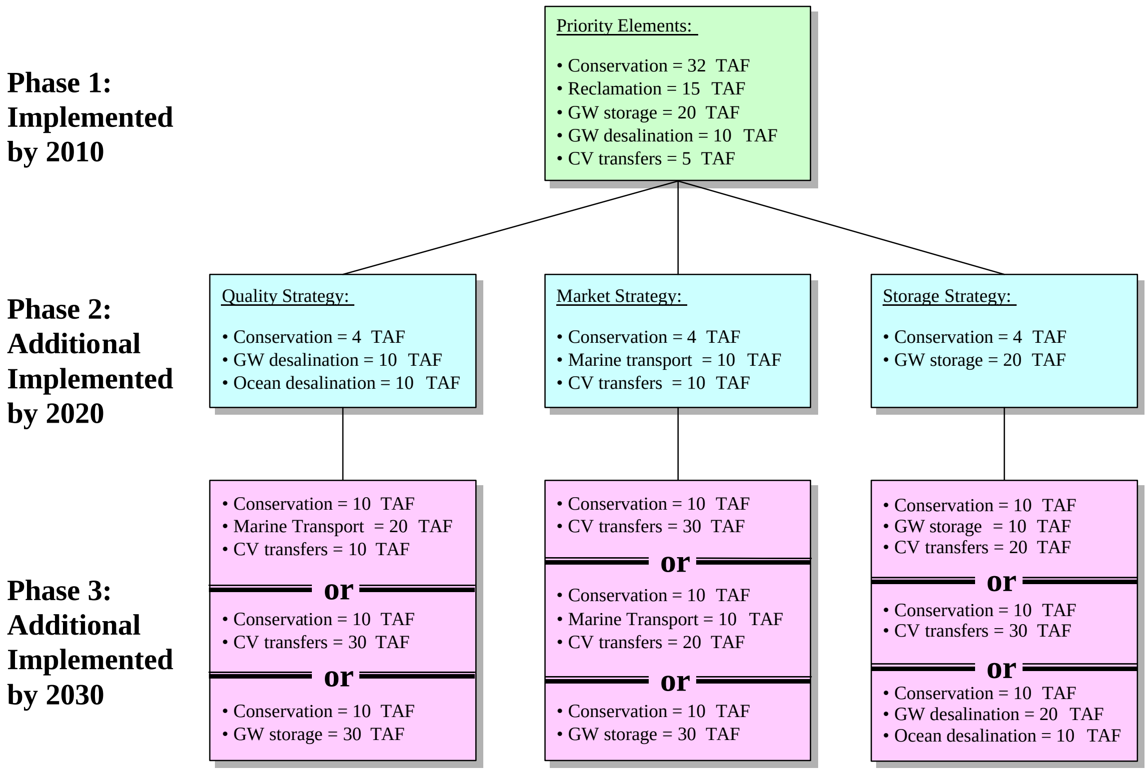


Figure 8-1
Recommended Resources Strategy
and Corresponding Supply Development Targets
(TAF = thousand acre-feet)

The first phase, called priority elements, include conservation, reclamation, groundwater storage and desalination, and Central Valley water transfers. Based on anticipated water demands, it is recommended that the priority elements (resources) be implemented by 2010. A special note should be made regarding reclamation. The listed target for reclamation reflects the water supply that is needed for the City. The City may wish to develop reclamation beyond this target to sell to potential customers outside of the City. In fact, the City has identified such customers and determined their willingness to pay for reclaimed water. Reclaimed supply development beyond the resource targets presented here would be beneficial to the City in meeting its goals for reuse. Figure 8-2 summarizes how the priority resource elements will meet the City's projected water demand in year 2010, under a repeat of critically dry weather conditions.

The next phase, which should be implemented by 2020, reflects the three strategies discussed previously. The "triggers" for determining which strategy the City should pursue are:

- Technology Improvements – Could make desalination options more cost-effective.
- Funding Assistance – Could make groundwater programs more cost-effective.
- CALFED Outcome – The outcome (success or failure) could affect the market for water transfers.
- Groundwater Rights – Securing groundwater rights and successfully dealing with other institutional issues regarding the groundwater basins would make it easier to implement groundwater storage and desalination.
- Marine Transport Proposals – Receiving more substantial and detailed proposals for marine transport that specify contract price and terms would allow the City to better evaluate the potential of this option.

The third phase, which should be implemented by 2030, reflects additional choices that the City could pursue. The success of the City's 2020 resource implementation will, to a large extent, influence the choice it makes for implementation by 2030.

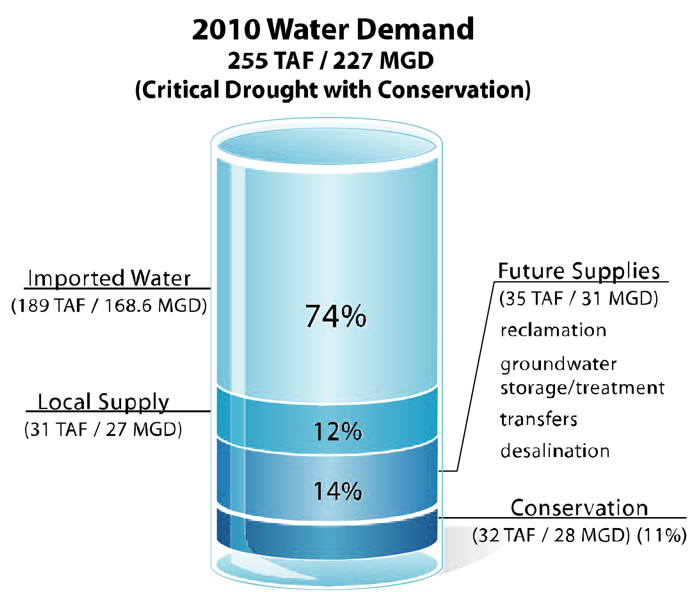


Figure 8-2
How Priority Resource Elements Meet Projected Demands in 2010

With this adaptive water resources strategy, the City can balance the need to move forward and implement a plan with the advantage of keeping its options open. As the ***Long-Range Water Resources Plan*** is implemented in phases, the City will learn which supply options merit expanding and which should be deferred in-lieu of more effective alternatives.

8.2 Implications for City's 10-year CIP

By implementing the recommended water resources strategy, the City could reduce its reliance of imported water from the current 75-90 percent to about 74 percent by 2010. This reduced reliance on imported water could have an impact on the City's existing 10-year Capital Improvements Program (CIP). Therefore, a review of the major CIP projects was conducted to see if there was any potential conflict from the implementation of the ***Long-Range Water Resources Plan***.

The following categories of projects were reviewed:

- Water treatment plants
- Transmission pipelines
- Water main replacements
- Pump stations
- Treated water reservoirs
- Reclaimed water lines

The review of these projects indicated that none of the water supply-related projects in the CIP were affected by the implementation of the ***Long-Range Water Resources Plan***. However, as the ***Long-Range Water Resources Plan*** is implemented, the City should continually review and update its CIP to ensure that the infrastructure is appropriate to meet the City's reliability and water quality objectives.

8.3 Implications for City's Water Supply and Institutional Relationships

With the implementation of this ***Long-Range Water Resources Plan***, the City will be taking significant steps towards increased independence and control of its water resources. It is important to identify the implications that this recommended plan will have in terms of water supply and institutional relationships with the CWA and MWD.

8.3.1 Water Supply Development

As the City develops additional conservation and reclamation, it will likely rely more heavily on financial assistance from CWA, MWD, and other sources of funding, such as CALFED. It is therefore important that the City continue to support regional stewardship programs that help develop local resources and conservation.

For its groundwater storage and desalination supply development, the City should seek CALFED funding for feasibility studies, pilot projects, and co-funding for capital investments. The City should also seek to resolve other outstanding issues regarding groundwater development, including water right ownership, water quality and subsidence concerns.

Finally, if the City plans to negotiate and secure its own water transfers, the City should work with the CWA and MWD to establish fair wheeling charges. Currently, the CWA and MWD disagree on how wheeling charges should be calculated. The City will become more involved in the process to apply pressure to these two regional providers to find common ground on wheeling and help water transfers into San Diego County become a possibility.

8.3.2 Water Rate Structure

Both the CWA and MWD are developing new rate structures. Currently, both CWA and MWD bundle their water rates into a single, simple rate for supply, transmission, and delivery. Both agencies also charge their member agencies based on a postage stamp basis. MWD has identified the need to un-bundle its rates and charges into supply, transmission, delivery, power and treatment. However, MWD still contends that these charges should be applied uniformly across its service area (i.e., in a postage stamp manner). CWA, on the other hand, maintains that some form of rate structure based on distance water travels to its pipes is more equitable. The issues of supply contracts and imported water allocation during severe droughts are also being discussed in the context of these rate structure revisions.

The outcome of the CWA and MWD rate structure revisions will no doubt have an effect on the City. The greatest potential implication to the City is the application of pricing based on distance traveled. The CWA maintains that if this form of pricing were implemented by MWD, it would save considerable money in the years to come. However, the application of pricing based on distance the water travels by the CWA could significantly increase the City's overall imported water cost.

Compatibility between CWA and MWD is also a concern. If the MWD rate structure is designed to accomplish some key objectives and the CWA rate structure contradicts it, the City may not receive the anticipated benefits. Of most importance to the City is the establishment of a fair rate structure that recognizes its past investments, allowing water transfers to take place, and a drought allocation plan that is based on "need" rather than MWD's preferential rights. Again, the City may wish to open dialogs between both CWA and MWD with regard to rate structure issues.

8.3.3 Institutional Relationships

As the City develops alternative supplies, it is important to recognize that importing water will continue to be key to providing a reliable water supply. To this end, the City should continue to support regional efforts toward ensuring that imported water is reliable, cost-effective, and of high quality. Continuing to support the CWA's efforts to maintain, and even expand, imported water to San Diego County is in the best interest of the City. Supporting a regional approach for imported water should not preclude the City from becoming more active in statewide water supply issues. It is in the best interest of the City to become more engaged in the Bay-Delta, CALFED, and the Colorado River. Being more of a partner with CWA should be the goal in improving imported supplies. Further, the City should explore other mutually beneficial partnering opportunities with the CWA for developing local supplies, such as ocean and groundwater desalination. Such partnerships could substantially improve the success of supply development.

8.4 Recommended Next Steps

With the implementation of this water plan, the City will be taking significant steps to becoming more independent and in control of its water resources. It is important, therefore, for the City to update its current CIP to reflect the recommendations in this plan, and at a minimum, to identify specific supply projects that will meet the resource targets identified in the first phase of this plan. Specific recommendations include:

- Update City's CIP to account for water supply projects that are necessary to achieve the specified resource targets of the ***Long-Range Water Resources Plan***, and to incorporate the City's recent seismic vulnerability study.

- Evaluate the City's surface reservoirs for possible re-operation and/or expansion to meet its drought/seasonal storage needs.

- Update the City's ***Strategic Plan for Water Supply*** to merge the elements of the ***Long-Range Water Resources Plan*** and CIP.

Section 9
References

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References

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Appendix A

(R-2003-657)

RESOLUTION NUMBER R- 297484

ADOPTED ON DEC 0 9 2002

WHEREAS, on August 12, 1997, the City Council adopted the *Strategic Plan for Water Supply (Strategic Plan)* that included a water resources strategy to meet future water demands through 2015, identified a nine-year Capital Improvements Program (CIP) to upgrade, replace and expand key water system facilities, and approved a rate increase to fund the initial years of the CIP; and

WHEREAS, by the year 2030, San Diego's population and economic growth is projected to increase water demands by almost 50 percent over 2002 levels; and

WHEREAS, a long-range water resources plan is necessary to define a flexible strategy for the next 30 years and develop evaluation tools for continued water resources planning; and

WHEREAS, the Water Department, together with its consultant and the Citizen's Advisory Board, have developed a long-range water resources plan;

NOW, THEREFORE, BE IT RESOLVED, that the Council hereby adopts the City of San Diego Long-Range Water Resources Plan (2002-2030) as set forth in the document on file in the office of the City Clerk as Document No. RR - 297484

APPROVED: CASEY GWINN, City Attorney

By Catherine Bradley
Catherine Bradley
Deputy City Attorney

CB:cbs
11/8/02
Or. Dept: Water
R-2003-657