A Simulation–Optimization Model for Water-Resources Management, Santa Barbara, California

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CONTENTS

Abstract 1
Introduction 2
    Purpose and Scope 2
    Previous Studies 2
Description of the Study Area 3
    Location and General Features 3
    Available Water Resources 5
        Background 5
        Ground Water 5
            Santa Barbara Ground-Water Basin 5
                Storage Unit I Subbasin 5
                Storage Unit III Subbasin 5
            Foothill Ground-Water Basin 7
        Surface Water 7
        Imported Water 7
        Desalinated Water 7
        Reclaimed Water 7
Numerical Models 7
    MODFLOW 7
    Santa Ynez River Hydrologic Model 9
Problem Formulation 9
    Model Objective — Minimize Cost 9
    Water-Supply-Capacity Constraints 11
        Surface-Water-Supply Constraints 11
        Ground-Water-Supply Constraints 11
        Head Constraints 11
        Demand Constraints 11
        Temporal Balance Constraints 12
    Solution of the Simulation-Optimization Model 12
Results and Discussion 13
    Basic Assumptions 13
    Base Case—Average Monthly Releases 13
        Nonlinear Effects 18
            Formulation 18
            Nonlinear Results 20
        Sensitivity Analysis 20
            Reduce Allowable Carryover 20
            Reduce Demand 21
            Vary Head Constraints 22
                First Scenario 23
                Second Scenario 24
            Constrain Desalination-Plant Capacity to Zero 24
            Carryover State Water Project (SWP) Water 25
    Current Monthly Gibraltar Diversion Distribution 28
        Sensitivity Analysis 30
            State Water Project (SWP) Carryover 30
            Zero Desalination Capacity with State Water Project Carryover 30
    Proposed Monthly Gibraltar Reservoir Diversion Distribution 30

Cachuma Reservoir Variable Monthly Water Deliveries 31
Actual Monthly Gibraltar Reservoir Diversion Distribution 31
Proposed Monthly Gibraltar Reservoir Diversion Distribution 33
Summary 34
References Cited 35
Appendix: Tables A1–A31 37

FIGURES

1. Map showing location and general features of the Santa Barbara and the Foothill ground-water basins, Santa Barbara, California 4
2. Hydrogeologic section of the Foothill and the Santa Barbara ground-water basins, Santa Barbara, California 6
3. Map showing MODFLOW model grid for the study area, Santa Barbara, California 8
4–51. Graphs showing:
4. Monthly varying demand and actual, proposed, and average Gibraltar Reservoir distributions, Santa Barbara, California 12
5. Optimal surface-water, ground-water, and total deliveries for the base-case simulation, months 1–60, Santa Barbara, California 14
6. Optimal surface-water deliveries from all sources for the base-case simulation, months 1–60, Santa Barbara, California 14
7. Optimal ground-water deliveries from coastal Storage Unit I wells for the base-case simulation, months 1–60, Santa Barbara, California 14
8. Optimal ground-water deliveries from inland Storage Unit I wells for the base-case simulation, months 1–60, Santa Barbara, California 14
9. Optimal ground-water deliveries from the Foothill basin wells for the base-case simulation, months 1–60, Santa Barbara, California 17
10. Simulated December 1990 water-level altitudes in model layers 1 and 2 for the base-case simulation, Santa Barbara, California 19
11. Change in surface-water, ground-water, and total deliveries after model nonlinear iteration no. 2, months 1–60, Santa Barbara, California 20
12. Optimal surface-water deliveries from all sources for the Cachuma Reservoir carryover sensitivity simulation, months 1–60, Santa Barbara, California 21
13. Optimal ground-water deliveries from coastal Storage Unit I wells for the Cachuma Reservoir carryover sensitivity simulation, months 1–60, Santa Barbara, California 21
14. Optimal ground-water deliveries from inland Storage Unit I wells for the Cachuma Reservoir carryover sensitivity simulation, months 1–60, Santa Barbara, California 21
15. Optimal ground-water deliveries from the Foothill basin wells for the Cachuma Reservoir carryover sensitivity simulation, months 1–60, Santa Barbara, California 21
16. Optimal surface-water deliveries from all sources for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California 22
17. Optimal ground-water deliveries from coastal Storage Unit I wells for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California 22
18. Optimal ground-water deliveries from inland Storage Unit I wells for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California 23
19. Optimal ground-water deliveries from the Foothill basin wells for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California 23
20. Optimal surface-water deliveries from all sources for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California 23
21. Optimal ground-water deliveries from coastal Storage Unit I wells for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California 23
22. Optimal ground-water deliveries from inland Storage Unit I wells for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California 24
23. Optimal ground-water deliveries from the Foothill basin wells for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California 25
24. Optimal surface-water deliveries from all sources for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California 25

25. Optimal ground-water deliveries from coastal Storage Unit I wells for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California 25
26. Optimal ground-water deliveries from inland Storage Unit I wells for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California 25
27. Optimal ground-water deliveries from the Foothill basin wells for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California 26
28. Optimal surface-water deliveries from all sources for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California 26
29. Optimal ground-water deliveries from coastal Storage Unit I wells for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California 26
30. Optimal ground-water deliveries from inland Storage Unit I wells for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California 27
31. Optimal ground-water deliveries from the Foothill basin wells for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California 27
32. Optimal surface-water deliveries from all sources for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 27
33. Optimal ground-water deliveries from coastal Storage Unit I wells for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 27
34. Optimal ground-water deliveries from inland Storage Unit I wells for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara. California 28
35. Optimal ground-water deliveries from the Foothill basin wells for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara. California 28
36. Optimal surface-water deliveries from all sources for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 28
37. Optimal ground-water deliveries from coastal Storage Unit I wells for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 28
38. Optimal ground-water deliveries from inland Storage Unit I wells for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 29
39. Optimal ground-water deliveries from the Foothill basin wells for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 29
40. Optimal surface-water deliveries from all sources for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 29
41. Optimal ground-water deliveries from coastal Storage Unit I wells for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 29
42. Optimal ground-water deliveries from inland Storage Unit I wells for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 30
43. Optimal ground-water deliveries from the Foothill basin wells for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months, 1–60, Santa Barbara, California 30
44. Optimal surface-water deliveries from all sources for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 32
45. Optimal ground-water deliveries from coastal Storage Unit I wells for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 32
46. Optimal ground-water deliveries from inland Storage Unit I wells for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 32
47. Optimal ground-water deliveries from the Foothill basin wells for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California 32

48. Optimal surface-water deliveries from all sources for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California ... 33
49. Optimal ground-water deliveries from coastal Storage Unit I for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California ... 33
50. Optimal ground-water deliveries from inland Storage Unit I for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California ... 33
51. Optimal ground-water deliveries from the Foothill basin wells for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California ... 33

TABLES

1. Sources, quantities, and unit costs of available surface water for the base-case simulation, years 1–5, Santa Barbara, California ... 10
2. Total capacities, distribution of pumping between the upper and the lower systems, and unit costs for the base-case simulation, Santa Barbara, California ... 10
3. Maximum allowable cumulative Cachuma Reservoir carryover, years 1–5, Santa Barbara, California ... 14
4. Optimal surface-water and ground-water deliveries for the base-case simulation, months 1–60, Santa Barbara, California ... 15
5. Summary of water-delivery costs for all simulations, Santa Barbara, California ... 17
6. Optimal cumulative annual Cachuma Reservoir carryover and delivered carryover for the base-case simulation, years 1–5, Santa Barbara, California ... 18
7. Average monthly pumping, pumping capacity, and percentage of pumping capacity utilized for Storage Unit I and for the Foothill basin for the base-case simulation, years 1–5, Santa Barbara, California ... 18
8. Optimal cumulative annual Cachuma Reservoir carryover and delivered carryover for the sensitivity of the base case to Cachuma Reservoir carryover simulation, Santa Barbara, California ... 22
9. Hydraulic-head values at constraint locations, Santa Barbara, California ... 24
10. Maximum allowable cumulative State Water Project (SWP) carryover, years 1–5, Santa Barbara, California ... 26
11. Optimal cumulative annual State Water Project (SWP) carryover and delivered SWP carryover, years 1–5, Santa Barbara, California ... 27

CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATIONS, AND ACRONYMS

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per day (acre-ft/d)	0.01427	cubic meter second
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per month [$(ft^3/s)/mo$]		
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	259.0	hectare

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Altitude, as used in this report, refers to distance above or below sea level.

Abbreviations and acronyms

LINDO	A proprietary linear programming problem solver (Schrage, 1991)
MODFLOW	A finite-difference ground-water flow model (McDonald and Harbaugh, 1988)
MODMAN	A proprietary optimization problem assembler (Greenwald, 1993)
SBHS	Santa Barbara High School (well)
SUTRA	A density-dependent ground-water flow and transport model (Voss, 1984)
SWP	(California) State Water Project
SYRHM	Santa Ynez River Hydrologic Model. Developed by the Santa Barbara County Water Agency
USGS	U.S. Geological Survey

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By Tracy Nishikawa

ABSTRACT

In times of drought, the local water supplies of the city of Santa Barbara, California, are insufficient to satisfy water demand. In response, the city has built a seawater desalination plant and gained access to imported water in 1997. Of primary concern to the city is delivering water from the various sources at a minimum cost while satisfying water demand and controlling seawater intrusion that might result from the overpumping of ground water.

A simulation-optimization model has been developed for the optimal management of Santa Barbara's water resources. The objective is to minimize the cost of water supply while satisfying various physical and institutional constraints such as meeting water demand, maintaining minimum hydraulic heads at selected sites, and not exceeding water-delivery or pumping capacities. The model is formulated as a linear programming problem with monthly management periods and a total planning horizon of 5 years. The decision variables are water deliveries from surface water (Gibraltar Reservoir, Cachuma Reservoir, Cachuma Reservoir cumulative annual carryover, Mission Tunnel, State Water Project, and desalinated seawater) and ground water (13 production wells). The state variables are hydraulic heads. Basic assumptions for all simulations are that (1) the cost of water varies with source but is fixed over time, and (2) only existing or planned city wells are considered; that is, the construction of new wells is not allowed.

The drought of 1947–51 is Santa Barbara's worst drought on record, and simulated surface-water supplies for this period were used as a basis for testing optimal management of current water resources under drought conditions. Assumptions that were made for this base case include a head constraint equal to sea level at the coastal nodes; Cachuma Reservoir carryover of 3,000 acre-feet per year, with a maximum carryover of 8,277 acre-feet; a maximum annual demand of 15,000 acre-feet; and average monthly capacities for the Cachuma and the Gibraltar Reservoirs. The base-case results indicate that water demands can be met, with little water required from the most expensive water source (desalinated seawater), at a total cost of $5.56 million over the 5-year planning horizon. The simulation model has drains, which operate as nonlinear functions of heads and could affect the model solutions. However, numerical tests show that the drains have little effect on the optimal solution.

Sensitivity analyses on the base case yield the following results: If allowable Cachuma Reservoir carryover is decreased by about 50 percent, then costs increase by about 14 percent; if the peak demand is decreased by 7 percent, then costs will decrease by about 14 percent; if the head constraints are loosened to –30 feet, then the costs decrease by about 18 percent; if the heads are constrained such that a zero hydraulic gradient condition occurs at the ocean boundary, then the optimization problem does not have a solution; if the capacity of the desalination plant is constrained to zero acre-feet, then the cost increases by about 2 percent; and if the carryover of State Water Project water is implemented, then the cost decreases by about 0.5 percent.

Four additional monthly diversion distribution scenarios for the reservoirs were tested: average monthly Cachuma Reservoir deliveries with the actual (scenario 1) and proposed (scenario 2) monthly distributions of Gibraltar Reservoir water, and variable monthly Cachuma Reservoir deliveries with the actual (scenario 3) and proposed (scenario 4) monthly distributions of Gibraltar Reservoir water. Scenario 1 resulted in a total cost of about $7.55 million, scenario 2 resulted in a total cost of about $5.07 million, and scenarios 3 and 4 resulted in a total cost of about $4.53 million.

Sensitivities of the scenarios 1 and 2 to desalination-plant capacity and State Water Project water carryover were tested. The scenario 1 sensitivity analysis indicated that incorporating State Water Project water carryover decreased the cost by about 0.1 percent and that constraining the desalination plant capacity to zero in combination with State Water Project water carryover was infeasible. The scenario 2 sensitivity analysis indicated that the optimal solution was insensitive to State Water Project water carryover or desalination plant capacity. Scenarios 3 and 4 did not require desalinated or State Water Project water and, therefore, sensitivity analyses were not performed.

INTRODUCTION

During non-drought years, the city of Santa Barbara obtains an adequate water supply from local surface-water reservoirs supplemented by local ground water. However, during times of drought these local surface-water supplies are insufficient to meet demand. In addition, Santa Barbara is aware that the overpumping of ground water to compensate for any surface-water shortfalls may induce seawater intrusion, other water-quality problems, and excessive drawdown in sensitive areas. In response, Santa Barbara has built a seawater desalination plant and gained access to imported water in 1997. This report documents the development of a simulation-optimization model for the management of the water resources available to Santa Barbara. The model identifies a least-cost water-supply alternative that satisfies specific physical and institutional constraints.

Purpose and Scope

In 1993, Santa Barbara entered into a cooperative study with the U.S. Geological Survey (USGS) to develop a simulation-optimization model for the management of its water resources during Santa Barbara's design drought. The purpose of this report is to describe the development and application of this model. Key issues are (1) to provide the least-cost water supply, (2) control seawater intrusion, and (3) meet water demands. The scope of this study includes developing a simulation-optimization model and using the model to optimally manage available water resources under a variety of management scenarios.

Previous Studies

Many researchers have addressed the application of simulation-optimization models to the management of ground-water systems [Reichard (1995) gives a thorough review]. This review will focus on the application of simulation-optimization models that also address, in some manner, the control of seawater intrusion.

Shamir and others (1984) considered the optimal annual operation of a coastal aquifer in Israel using a multiple-objective linear programming model. Ground-water hydraulics were addressed using a multi-cell model in which seawater intrusion was simulated using "coastal cells" that contained all the seawater intrusion. The decision variables were annual pumpage and (or) recharge quantities. Four competing objective functions were identified and a trade-off procedure was used to identify the most desirable solution. For their example problem, the authors found that the problem was tightly constrained for the existing wells and hydraulic system. As a result, tradeoffs were few and a final solution was selected after one round of optimizations.

Willis and Finney (1988) formulated a seawater-intrusion management model for a coastal aquifer in Taiwan using a sharp-interface model. The decision variables were pumpage and (or) recharge. The objective was expressed as a weighted sum of seawater intrusion, water supply, and recharge objectives. They solved the optimization problem using quadratic programming in combination with the influence-coefficient method and the reduced-gradient method in conjunction with a quasi-Newton algorithm. Their work showed that: (1) both solution algorithms resulted in stable and reliable solutions; (2) for their application, the response surface was relatively flat, yielding nonunique solutions; and (3) the solutions were sensitive to choice of starting solution because only local optima, caused by nonlinear hydraulics, could be assured.

Finney and others (1992) developed a simulation-optimization model for the control of seawater intrusion in a multiple aquifer system in Indonesia. The simulation model was a quasi-three-dimensional sharp-interface seawater-intrusion model. The decision variables were the location and magnitude of ground-water pumping and recharge. The objective was to minimize the squared volume of seawater intrusion. Their results indicated that a redistribution of pumping and recharge from historical policies could result in a decrease in the total squared saltwater volume.

Reichard (1995), unlike the previous researchers, included the delivery of surface water as a decision variable. He considered a simulation-optimization model for the management of surface- and ground-water resources in a coastal aquifer in southern California. The ground-water flow system was modeled as two layers (upper and lower aquifer systems), and the available surface water was treated as a stochastic process. The simulation model was MODFLOW (McDonald and Harbaugh, 1988), and therefore seawater intrusion was not addressed explicitly. Seawater intrusion was addressed by using equivalent freshwater heads as a boundary condition. Three different objectives were tested and the optimization problem was solved using a linear programming package. Reichard's results indicate that the control of seawater intrusion would require significant reductions in water use or the importation of significant volumes of water. The model results also indicate the importance of ground-water recharge and the redistribution of water for the control of seawater intrusion.

Nishikawa and Reichard (1996) evaluated the efficacy of the decision rules derived from Reichard's (1995) simulation-optimization model to control seawater intrusion using Monte Carlo analysis and the density-dependent flow and solute transport model, SUTRA (Voss, 1984). Nishikawa and Reichard (1996) found that the simulation-optimization model generally yields strategies that control seawater intrusion; however, seawater intrusion can be controlled more effectively in the upper system than in the lower.

This study is similar to those of Reichard (1995) and Nishikawa and Reichard (1996) in that MODFLOW was used as the simulation model and equivalent freshwater hydraulic heads were used at the coastal boundary. In this study, however, the objective is to minimize the cost of water delivery during Santa Barbara's design drought, and operation of the city's reservoirs is addressed.

DESCRIPTION OF THE STUDY AREA

Location and General Features

The city of Santa Barbara obtains its ground-water supplies from the Santa Barbara and the Foothill ground-water basins, which are on the south coast of Santa Barbara County about 120 mi northwest of Los Angeles (fig. 1). The basins are bounded on the north by foothills of the Santa Ynez Mountains, on the west by the Goleta and the Hope Ranch ground-water basins, on the south by the Pacific Ocean, and on the east by the Montecito ground-water basin. Hydrologically, the Santa Barbara ground-water basin is divided into two subbasins—Storage Unit I and Storage Unit III—by the Mesa Fault (Freckleton, 1989). The area of principal concern for this study consists of the Santa Barbara and the Foothill ground-water basins and encompasses about 14 mi^2.

The Santa Barbara area has a Mediterranean-type climate of warm, dry summers and mild winters. The area has distinct wet and dry seasons, with 95 percent of the precipitation falling between November and March. The mean annual precipitation at the lower altitudes of the Santa Barbara area for the period 1868–1990 is 17.81 in. (National Oceanic and Atmospheric Administration). Nearly all ground-water recharge and nearly all surface-water flow in the Santa Barbara area are derived directly from precipitation that falls on the area.

The Santa Barbara ground-water basin is drained by Sycamore, Mission, and San Roque Creeks and Arroyo Burro. The Foothill ground-water basin is drained by Cieneguitas, Atascadero, and Hospital Creeks. All these streams are intermittent in their lower reaches, where they lose water by seepage as they flow over the unconsolidated deposits of the basins.

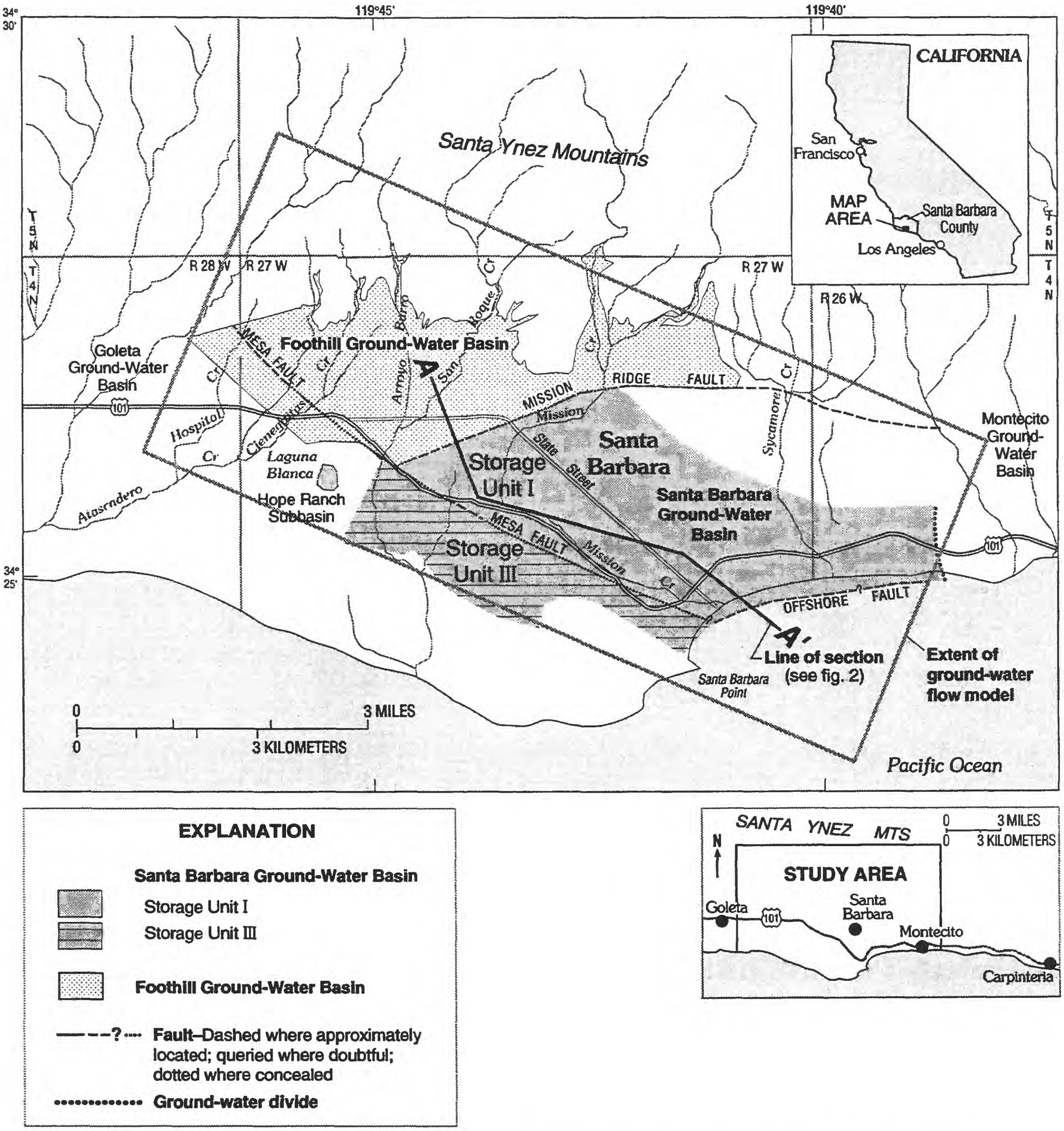

Figure 1. Location and general features of the Santa Barbara and the Foothill ground-water basins, Santa Barbara, California.

Available Water Resources

Background

In the 1800's, ground water supplied all the water to the city of Santa Barbara and outlying homes and estates; however, the supply became inadequate for the expanding population and other sources of water had to be identified. Following extreme water shortages in 1889, a local water company purchased several reservoir sites in the Santa Ynez River basin. Santa Barbara constructed the Mission Tunnel to convey water from the Santa Ynez River through the Santa Ynez Mountains. Later, in 1913–22, Santa Barbara constructed the Gibraltar Dam and Reservoir, which also is connected to the Mission Tunnel. In 1948, Congress authorized the construction of the 210,000 acre-ft Cachuma Reservoir and the Tecolote Tunnel (completed in the early 1950's) through the Santa Ynez Mountains to Santa Barbara area communities.

In recent years, the Santa Ynez River has been the predominant source of water supply, and ground water has supplied less than 20 percent of the total demand. An additional source of water supply is a seawater desalination plant that was completed in 1991 in response to an extended drought in southern California. The plant is capable of producing 7,500 acre-ft/yr, of which about 3,000 acre-ft is allocated to Santa Barbara. This water is very expensive to produce and is therefore considered a reserve water supply for use only during water-deficient years. Santa Barbara was connected to a pipeline that delivers water supplied from the California State Water Project (SWP) in 1997.

Ground Water

Santa Barbara Ground-Water Basin

On the basis of data from geophysical and geologic logs of selected wells, Martin (1984) subdivided the unconsolidated deposits underlying the Santa Barbara ground-water basin into five main zones: (1) the shallow zone, (2) the upper producing zone, (3) the middle zone, (4) the lower producing zone, and (5) the deep zone (fig. 2). The upper and lower producing zones are the two main water-bearing zones tapped by wells in the Santa Barbara area (fig. 2). The shallow and the upper producing zones are contained within the alluvium and terrace deposits of Holocene age, and the middle, the lower producing, and the deep zones are part of the Santa Barbara Formation of Pleistocene and Pliocene age (Martin and Berenbrock, 1986).

A brief description of the hydrology and hydrogeology of the Santa Barbara ground-water basin follows. A detailed description is given by Martin and Berenbrock (1986) and Freckleton and others (1998).

Storage Unit I Subbasin

In Storage Unit I, the shallow and the middle zones confine the upper and the lower producing zones, respectively. The deep zone separates the lower producing zone from the consolidated rocks in most of Storage Unit I.

The upper producing zone near the base of the alluvium consists of medium to coarse sand and some fine gravel (Martin, 1984). This zone is distinct and continuous throughout most of Storage Unit I and ranges in thickness from less than 10 ft south of the Mission Ridge Fault to about 50 ft beneath the city of Santa Barbara.

The lower producing zone, near the base of the Santa Barbara Formation, consists of medium to coarse sand, and fine gravel and shell fragments. In Storage Unit I, the lower producing zone ranges in thickness from less than 10 ft near the contact with the consolidated rocks on the northeastern side to more than 200 ft beneath the city of Santa Barbara. The lower producing zone is the main source of water to wells in the Santa Barbara ground-water basin (Martin, 1984). A detailed description of the hydrology and hydrogeology of the Storage Unit I subbasin is given by Martin and Berenbrock (1986).

Storage Unit III Subbasin

In Storage Unit III, the shallow zone confines the upper producing zone; the middle zone is not present in this subbasin. The deep zone separates the lower producing zone from the consolidated rocks in most of Storage Unit III.

The upper producing zone near the base of the alluvium consists of medium to coarse sand and some fine gravel (Martin, 1984, p. 5). This zone is distinct and continuous throughout the inland part of Storage Unit III and ranges in thickness from 40 ft to 60 ft.

The lower producing zone, near the base of the Santa Barbara Formation, is present only in the inland part of the subbasin and consists of medium to coarse sand and fine gravel and shell fragments (Freckleton, 1989). In Storage Unit III, the lower producing zone ranges in thickness from about 20 ft to 100 ft. The lower producing zone is the main source of water to wells in Storage Unit III (Freckleton and others, 1998).

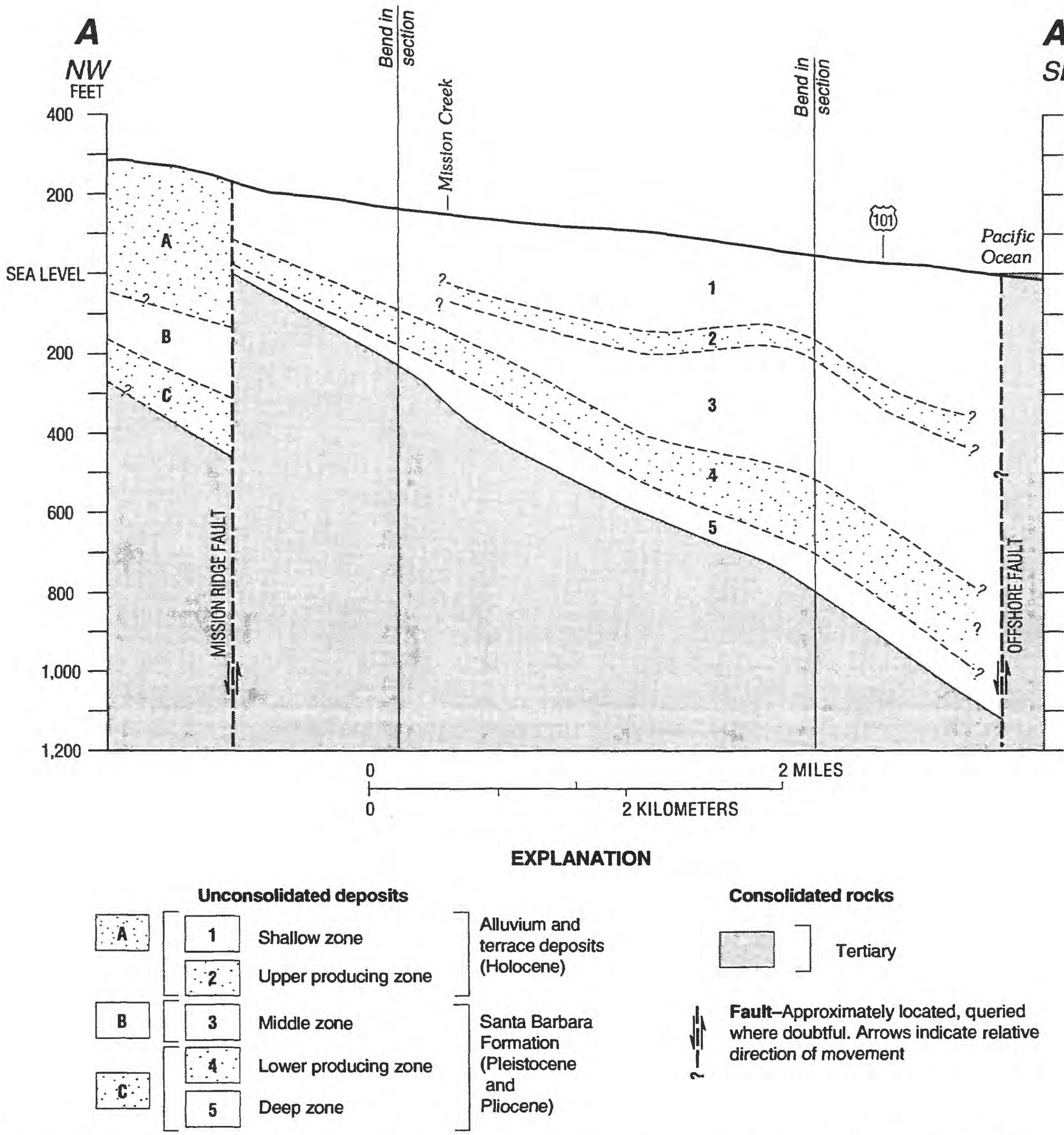

Figure 2. Hydrogeologic section of the Foothill and the Santa Barbara ground-water basins, Santa Barbara, California.

Foothill Ground-Water Basin

The Foothill ground-water basin is distinct hydrogeologically from the Santa Barbara ground-water basin. In the Foothill basin, there are two permeable zones: the first consists of alluvium and terrace deposits (undifferentiated), and the second is the Santa Barbara Formation (Freckleton, 1989). The alluvium and the Santa Barbara Formation are separated by a confining layer throughout most of the basin (fig. 2).

The alluvium consists of gravel, sand, silt, and clay (Freckleton, 1989). This zone is as much as 400 ft thick in the eastern part of the basin.

The Santa Barbara Formation, which consists of marine sand, silt, and clay, has a maximum thickness of about 400 ft. This formation is the main source of water to wells in the Foothill basin (Freckleton, 1989). A detailed description of the hydrology and hydrogeology of the Foothill ground-water basin is given by Freckleton (1989).

Surface Water

As noted earlier, the primary source of surface water to Santa Barbara comes from the nearby Santa Ynez River and the two reservoirs, the Gibraltar and the Cachuma. The Gibraltar Reservoir, which is owned and operated by Santa Barbara, was constructed between 1913 and 1922 and the height of the dam was increased in 1949. Santa Barbara is entitled to a maximum water delivery from the Gibraltar Reservoir of 8,000 acre-ft/yr. The Gibraltar Reservoir water is transported to Santa Barbara by means of the Mission Tunnel, a hard-rock tunnel through the Santa Ynez Mountains. Infiltration of ground water into the tunnel is an additional source of water to the city.

The Cachuma Reservoir is owned and operated by the U.S. Bureau of Reclamation and construction was completed in 1956. Santa Barbara is entitled to a maximum water delivery from the Cachuma Reservoir of 8,277 acre-ft/yr. The Cachuma Reservoir water is transported through the Santa Ynez Mountains to Santa Barbara by means of the concrete-lined Tecolote Tunnel. It is assumed that there is no infiltration into this tunnel.

Imported Water

Santa Barbara is a participant in the California State Water Project (SWP) and receives SWP water by means of the 102-mi Coastal Branch of the State Aqueduct and the 42-mi Santa Ynez Extension, which ends at Lake Cachuma. Construction of the extension was completed in 1997. Santa Barbara is entitled to 3,000 acre-ft/yr, subject to availability. The SWP water is delivered from the Cachuma Reservoir through the Tecolote Tunnel along with non-SWP Cachuma Reservoir water.

Desalinated Water

Santa Barbara contracted for the construction of a reverse-osmosis seawater desalination facility as an emergency water supply during the drought year of 1990. Santa Barbara is entitled to about 3,000 acre-ft/yr. Water from this facility has since been incorporated into Santa Barbara's long-term supply plan to reduce demand shortages owing to depleted surface supplies during drought.

Reclaimed Water

Reclaimed water is tertiary-treated wastewater that is used only to irrigate parks, schools, golf courses, and other landscaped areas. The reclaimed water is distributed using a separate pipeline system; the maximum capacity of the system is 1,200 acre-ft/yr and current demand is about 800 acre-ft/yr. The delivery of reclaimed water is fixed and is not addressed explicitly in the simulation-optimization model.

NUMERICAL MODELS

MODFLOW

The numerical simulation model used in this study is MODFLOW, a finite-difference ground-water flow model (McDonald and Harbaugh, 1988). A detailed explanation regarding the theoretical development and numerical implementation of MODFLOW is presented by McDonald and Harbaugh (1988).

The ground-water flow model simulates the ground-water hydraulics in Storage Unit I and Storage Unit III of the Santa Barbara ground-water basin and in the Foothill ground-water basin (fig. 1). The model has two layers, which generally simulate the upper and lower producing zones, that are separated by an intermediate confining layer. The layers are assumed to be continuous within their active areas (that is, there is no "pinching out" of layers). The horizontal dimensions of the model cells are 1,000 ft by 1,000 ft (fig. 3). A

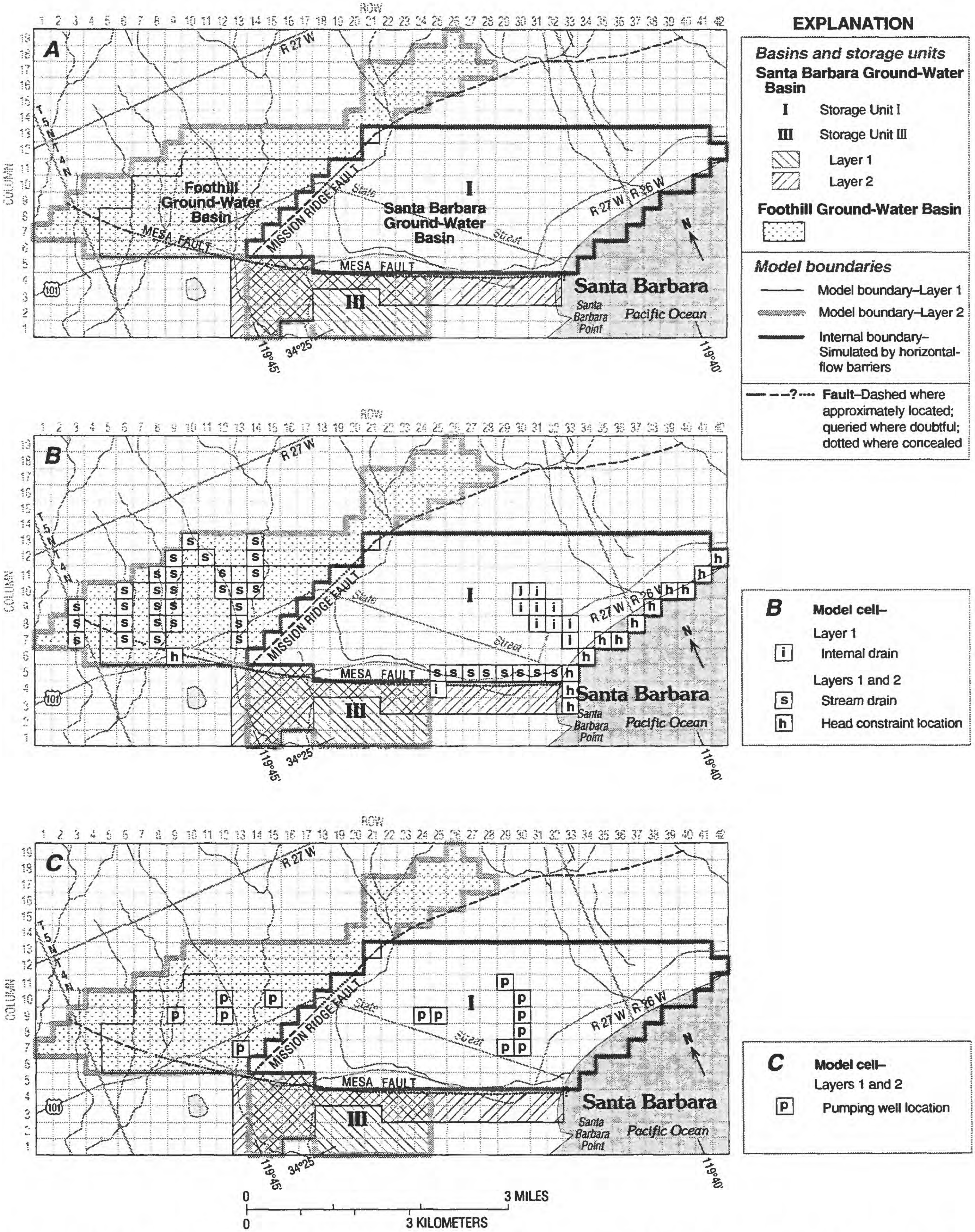

Figure 3. MODFLOW model grid for the study area, Santa Barbara, California. ***A,*** MODFLOW model grid. ***B,*** Drain and head constraint locations, ***C,*** Pumping well locations.

detailed description of the numerical model of Storage Unit I, Storage Unit III, and the Foothill basin is presented by Freckleton and others (1998). Note that MODFLOW simulates only ground-water flow and cannot simulate density-dependent solute transport, such as seawater intrusion.

Santa Ynez River Hydrologic Model

The Santa Ynez River Hydrologic Model (SYRHM), which was developed by the Santa Barbara County Water Agency, is a proprietary model that simulates the hydrologic system (including streamflow, reservoirs, tunnels, and ground-water aquifers) in the Santa Ynez River basin (John Ahlroth, Santa Barbara County Water Agency, written commun., 1996). The model incorporates operational guidelines and water-rights agreements that govern the distribution and use of the basin's water resources. The model typically simulates historical data from 1929 to current conditions. Input data include precipitation, evapotranspiration, streamflow into each reservoir, and tunnel flow. Output includes water deliveries from the Gibraltar and the Cachuma Reservoirs, the Mission Tunnel infiltration, and the State Water Project. Santa Barbara provided the USGS with the simulated results for the drought of 1947–51 for use in the simulation-optimization modeling.

PROBLEM FORMULATION

In the Santa Barbara area, the primary management issues during a drought are minimizing the cost of water supply over a 5-year management horizon while satisfying water demand and controlling seawater intrusion. The optimization model was formulated as a linear programming problem with the objective of minimizing the cost of water supply subject to: (1) water-supply capacity constraints; (2) maximum and minimum heads along the coast; (3) constraints maintaining pumping distributions between the upper and the lower producing zones as defined in the original simulation model of Freckleton and others (1998) and recharge distributions for Mission Creek; and (4) satisfying water-supply demands. The decision variables are the monthly amounts of water (in cubic feet per second) supplied from surface water (including desalinated water and SWP water), ground water from 13 production wells (see fig. 3 for locations), and the Cachuma Reservoir carryover [the volume of water stored in one year for use in the following year(s)]. Carryover is addressed in the temporal mass-balance constraints that are discussed below. No carryover is allowed in the Gibraltar Reservoir. Note that all deliveries are treated in the model as nonpositive values.

In this model, the decision variables (Q_{ij} = flow rate from source j in time step i) are the monthly amounts of water (in cubic feet per second) supplied from surface water (including desalinated water and SWP water), ground water from 13 production wells (see fig. 3 for locations), and the Cachuma Reservoir carryover.

Model Objective — Minimize Cost

The objective of the optimization model is to minimize total monthly costs of water deliveries (units of dollars per month) for a 5-year management period. The objective function has the form:

$$\text{min cost} = min\sum_{i}\sum_{j} C_j \times Q_{ij},$$

where:

C_j = unit cost for source j [\$/(ft^3/s)/mo] [that is, (cost/cubic foot per second)/month] and
Q_{ij} = flow rate from source j in time step i.

The unit costs of water (cost per acre-foot) for the various sources were supplied by Santa Barbara (Steven Mack, Public Works Department, city of Santa Barbara, written commun., 1995). Note that the costs provided by Santa Barbara assume no relation between the cost of pumping and the pumping lift. The costs were converted and are shown as [\$/(ft^3/s)/mo] in tables 1 and 2. Because drought conditions were assumed, the unit cost for SWP water was assumed to equal \$460/acre-ft, which is the maximum cost for this water source under drought conditions as provided by Mack (written commun., 1995). The cost coefficients for the Lincolnwood #1 and #2 wells were set at \$461/acre-ft (\$1/acre-ft greater than the cost of SWP water) to reflect that using these wells for water supply is less desirable because of local community concerns than using SWP water (Mack, written commun., 1996). The cost coefficients for the Ortega and the Vera Cruz wells reflect greater treatment costs than for other wells. It should be noted that Santa Barbara does not incur a cost when carryover is stored; any cost to Santa Barbara is reflected in the volume of delivered Cachuma Reservoir water at $60/acre-ft.

Note that neither the well-construction costs of the proposed wells (SBHS [Santa Barbara High School], Church, and Franciscan) nor any startup costs for the desalination plant were included in the cost coefficients; only the variable portion of the operational costs are addressed. A typical production well costs about $150,000 (Steven Mack, written commun., 1996); if one assumes that this cost will be amortized over 30 years at a discount rate of 5 percent, the annual cost is about $9,660. As will be demonstrated later in this report, this cost is small in comparison with the operating expenses estimated by the optimization model.

Table 1. Sources, quantities, and unit costs of available surface water for the base-case simulation, years 1–5, Santa Barbara, California

[unit cost: $/($ft^3$/s)/mo, cost per cubic foot per second per month; $/acre-ft, cost per acre-foot]

Source	Quantity available, in cubic feet per second					Unit cost	
	Year 1	Year 2	Year 3	Year 4	Year 5	$/($ft^3$/s)/mo	$/acre-ft
Cachuma Reservoir	11.425	11.425	11.076	10.250	9.305	$3,622	$60
Gibraltar Reservoir	6.902	6.902	1.928	3.864	0	$3,622	$60
Mission Tunnel	1.169	.905	.759	.727	.690	$3,622	$60
State Water Project	2.071	2.236	2.071	2.071	1.242	$27,770	$460
Desalination plant	4.141	4.141	4.141	4.141	4.141	$66,047	$1,100

Table 2. Total capacities, distribution of pumping between the upper and the lower systems, and unit costs for the base-case simulation, Santa Barbara, California

[ft^3/s, cubic foot per second. unit cost: $/($ft^3$/s)/mo, cost per cubic foot per second per month; $/acre-ft, cost per acre-foot]

City production well (local name)	Modeled well location (row, column)	Total capacity (ft^3/s)	Distribution of pumping between systems, in percent (upper–lower)	Unit cost	
				$/($ft^3$/s)/mo	$/acre-ft
Lincolnwood #1 ...	(12,10)	0.2761	50 – 50	$27,831	$461
Lincolnwood #2 ...	(12,10)	.2761	50 – 50	27,831	461
Los Robles	(9,9)	.6902	0 – 100	5,433	90
Hope Avenue	(13,7)	.5521	10 – 90	6,037	100
Ortega[1]	(30,9) (30,10)	1.5184	10 – 90	7,135	118
Corporation[2]	(30,8) (30,9)	1.2424	30 – 70	4,025	67
Vera Cruz	(30,7)	1.7944	5 – 95	6,965	115
City Hall	(29,7)	1.3803	10 – 90	3,924	65
Alameda	(25,9)	.8972	20 – 80	4,876	81
Chupparosa	(15,10)	.3451	50 – 50	7,848	130
Santa Barbara High School	(29,11)	.8282	30 – 70	4,528	75
Church	(24,9)	.8282	20 – 80	4,528	75
Franciscan	(12,9)	.3451	50 – 50	7,848	130

[1]For modeling purposes, the pumping of the Ortega well was divided evenly between two model nodes: (30,9) and (30,10).

[2]For modeling purposes, the pumping of the Corporation well was divided evenly between two model nodes: (30,8) and (30,9).

Water-Supply-Capacity Constraints

Typical water-supply-capacity constraints are that surface-water deliveries must be less than the available water as simulated by the SYRHM or that pumpage from a given well must be less than the capacity of the pump. The capacity constraints have the general form:

$$Q_{ij} \geq Q_{max}, \tag{1}$$

where Q_{ij} is the water delivered in time step i from source j and Q_{max} is the capacity of source j. The constraint is formulated as a greater than or equal equation because, as stated earlier, deliveries (Q) are treated as nonpositive values in the model.

Surface-Water-Supply Constraints

Santa Barbara supplied SYRHM estimates (given in table 1) of the available surface-water supplies during the design drought of 1947–51 on an annual basis (Mack, written commun., 1996). In the optimization model, Santa Barbara's maximum available Cachuma Reservoir water was arbitrarily set at 20,000 acre-ft/yr (27.607 ft^3/s) to allow for water deliveries greater than the maximum values simulated by the SYRHM; the amount of carryover will define the actual volume of water delivered to the city. The time-varying nature of the available surface water was incorporated into the optimization model as capacity constraints; however, it was assumed that Cachuma Reservoir water available in any one year was divided equally among the 12 months of that year. This assumption is made initially for the Gibraltar Reservoir; however, monthly varying distributions are tested later.

Ground-Water-Supply Constraints

The locations of the 10 existing and 3 proposed ground-water production wells to be operated by Santa Barbara are shown in figure 3 and the modeled well locations are given in table 2. Note that the 13 wells are modeled as 15 wells as in the simulation model of Martin (1984). Specifically, the Ortega and the Corporation wells are located on the boundary between two model cells; therefore, Martin (1984) divided the pumping rate of each well between the two adjacent model cells.

Well capacities were provided by Santa Barbara (Steven Mack, written commun., 1996). The proposed SBHS, Church, and Franciscan wells were added to the model of Freckleton and others (1998) at model nodes (29,11), (24,9), and (12,9), respectively (fig. 3). The distribution of pumping from the upper and the lower producing zones by the existing wells given by Freckleton and others (1998) was used, and the distributions for the proposed wells were assumed to be the same as those at existing nearby wells (table 2). In addition, it was assumed that well pumping capacities do not change over time.

Head Constraints

Hydraulic heads are constrained at the coastal boundary nodes and at a well operated by the La Cumbre Mutual Water Company (fig. 3). (The La Cumbre well is a production well and it is not addressed in the optimization problem.) The hydraulic-head constraints have the general form:

$$h_{min} \leq h_j \leq h_{max}, \tag{2}$$

where h_{min} and h_{max} are the minimum and maximum allowable heads, respectively, at control node j, and h_j is the head at control node j.

Hydraulic-head constraints were placed along the coastal boundary of the flow model to simulate the control of seawater intrusion in Storage Units I and III. The minimum heads are set initially to zero feet (sea level) and the maximum heads are approximately the local land-surface altitude. Although the minimum heads are set initially to sea level, this constraint still allows a landward gradient to occur because of the greater density of seawater and, therefore, allows some unknown amount of seawater intrusion to occur. The sensitivity of the optimal solution to this constraint is tested in the Sensitivity Analysis section of this report.

Demand Constraints

The demand constraints have the following general form:

$$\sum_i \sum_j Q_{ij} = D_i, \tag{3}$$

where D_i is the demand in month i.

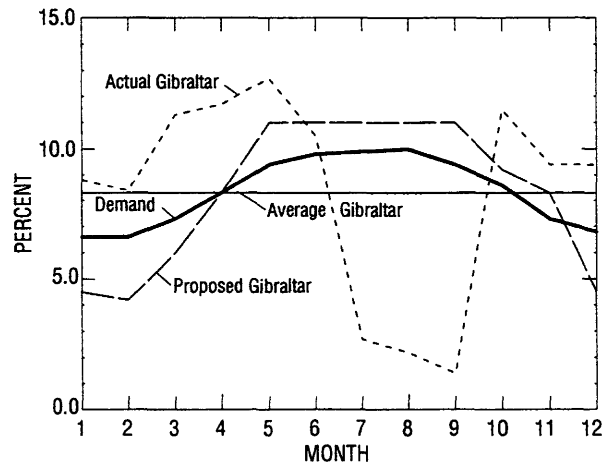

Figure 4. Monthly varying demand and actual, proposed, and average Gibraltar Reservoir diversion distributions, Santa Barbara, California.

Within a given year, water demand varies seasonally; for example, lower demand during the winter and higher demand during the summer. Also, seasonal demand varies with total demand. However, in this study, a typical monthly demand distribution is used (fig. 4) (Steven Mack, written commun., 1996).

Temporal Balance Constraints

Recall that carryover is defined as the volume of water stored in a year for use in the following year(s). The temporal balance constraints address the Cachuma Reservoir carryover in the simulation-optimization model. In the first year, the constraint has the following form:

$$Q^i_{cr} - \overline{Q^1_{co}} \geq \overline{Q^1_{max}}, \qquad (4)$$

where Q^i_{cr} is the water delivered to Santa Barbara from the Cachuma Reservoir in month i (i = 1 to 12), $\overline{Q^1_{co}}$ is the monthly average cumulative carryover in year 1, and $\overline{Q^1_{max}}$ is the maximum water available from the Cachuma Reservoir in year 1 on an average monthly basis as predicted by the SYRHM. Equation 4 above states that for year 1 only, the delivered Cachuma Reservoir water minus water carried over that year must be greater than or equal to the maximum water available to Santa Barbara from the Cachuma Reservoir. Note that the constraints are "greater than or equal to" because, as defined within the model, water delivery (either from surface water or ground water) is nonpositive.

The constraint has the following general form for years 2 through 5 (months 13–60):

$$Q^i_{cr} - \overline{Q^t_{co}} + \overline{Q^{t-1}_{co}} \geq Q^i_{max}, \qquad (5)$$

where Q^i_{cr} is the water delivered to Santa Barbara from the Cachuma Reservoir in month i (i = 13 to 60), $\overline{Q^t_{co}}$ is the monthly average Cachuma Reservoir carryover in year t (t = 2 to 5), $\overline{Q^{t-1}_{co}}$ is the average monthly carryover in the previous year, and Q^i_{max} is the maximum available water from the Cachuma Reservoir in month i as predicted by the SYRHM. Equation 5 above states that delivered Cachuma Reservoir water minus water carried over in the current year plus the water carried over from the previous year must be greater than or equal to the maximum water available to Santa Barbara from the Cachuma Reservoir.

Solution of the Simulation-Optimization Model

MODMAN (Greenwald, 1993) generates the input file in the Mathematical Programming System format required by many optimization software packages. MODMAN uses MODFLOW to generate response coefficients that are used to estimate the heads that would result from a particular pumping pattern. By use of response coefficients, it is implicitly assumed that the ground-water system responds linearly to pumping and recharge stresses. Gorelick and others (1993) present a thorough discussion of response coefficients. The resulting decision variables within the flow model are pumping and (or) recharge, and the state variables are the heads and (or) drawdowns.

LINDO (Schrage, 1991), a proprietary linear programming problem solver, can solve linear programming problems, linear mixed-integer programming problems, and quadratic programming problems. LINDO was used in this study because MODMAN can read LINDO output for the post-processing of the optimal solutions.

RESULTS AND DISCUSSION

Five operating scenarios for the release schedules of water from the Cachuma and the Gibraltar Reservoirs were tested: (1) average monthly releases from both reservoirs (the base case), (2) current monthly diversion distribution from the Gibraltar Reservoir and average monthly releases from the Cachuma Reservoir, (3) proposed monthly diversion distribution from the Gibraltar Reservoir and average monthly releases from the Cachuma Reservoir, (4) current monthly diversion distribution from the Gibraltar Reservoir and variable monthly releases from the Cachuma Reservoir, and (5) proposed monthly diversion distribution from the Gibraltar Reservoir (fig. 4) and variable monthly releases from the Cachuma Reservoir. The use of variable releases from the Cachuma Reservoir allows the monthly water deliveries to vary within a year such that the total water delivered within that year is less than or equal to the maximum annual volume of water available. In addition, the sensitivity of the base case to Cachuma Reservoir carryover, demand, coastal head constraints, and SWP carryover were tested.

For compactness, the optimal pumping results are presented for Storage Unit I and the Foothill ground-water basin. The Foothill basin wells include the Lincolnwood #1, the Lincolnwood #2, the Los Robles, the Hope Avenue, the Chupparosa, and the Franciscan wells. In addition, the Storage Unit I wells have been arbitrarily divided into two groups: coastal (the Ortega, the Corporation, the Vera Cruz, and the City Hall wells) and inland (the Alameda, the SBHS, and the Church wells). The average pumpage for all Storage Unit I wells is presented with the coastal and inland results.

Basic Assumptions

The initial conditions for all simulations, including the sensitivity analyses, are the simulated 1986 heads. The 1986 heads are representative of the long-term, average conditions in Storage Units I and III (Freckleton and others, 1998). However, the 1986 heads may be higher than the long-term average in the Foothill basin, where it is difficult to determine an average because of the short data record in the basin (Freckleton and others, 1998). For the purposes of this report, it is assumed that the 1986 heads reflect the long-term average and can be used as the initial conditions for the Foothill basin.

The surface-water supply conditions for the drought of 1947–51, Santa Barbara's design drought, were used for all simulations. Santa Barbara used the SYRHM to estimate the water deliveries from the Gibraltar Reservoir, the Cachuma Reservoir, the Mission Tunnel, and the SWP.

Additional assumptions are that the cost of water varies with source but is fixed over time, and only existing or planned city wells are considered; that is, the construction of new wells is not allowed.

In this study, a 5-year design drought was assumed; however, the duration and return period of droughts are uncertain. These uncertainties can affect the optimal water-delivery policies and the extent of seawater intrusion. To address drought uncertainty, within the context of the simulation-optimization model, stochastic hydrology methods are needed.

Base Case—Average Monthly Releases

In the base case, the minimum allowable freshwater head constraints at the seawater boundary were set at zero feet (sea level) in both the upper and the lower producing zones for the entire simulation period (see fig. 3 for constraint locations).

The annual demand was set to 13,500 acre-ft in year 1 and increased 500 acre-ft for each of the subsequent 3 years to a maximum annual demand of 15,000 acre-ft in year 4 (Steven Mack, written commun., 1996). The annual demand was decreased to 14,000 acre-ft in year 5 to reflect the implementation of water-conservation measures (Mack, written commun., 1996). Recall that the total annual demand includes 800 acre-ft/yr supplied by reclaimed water; therefore, the demand constraint is the total annual demand minus water supplied by reclaimed water.

The maximum annual carryover is 3,000 acre-ft and the total maximum carryover is 8,277 acre-ft (Santa Barbara's maximum annual allocation of Cachuma Reservoir water); that is, the maximum carryover is 3,000 acre-ft in year 1; 6,000 acre-ft in year 2; and 8,277 acre-ft in years 3 to 5 (see table 3).

The optimal water deliveries for the base case are summarized in figure 5 and table 4. The water sources are shown graphically in figures 6 to 9 and are tabulated in tables A1 to A3. The cost of delivering water over the 5-year design period is $5.56 million. The costs of this and all additional simulations presented in this report are summarized in table 5.

Table 3. Maximum allowable cumulative Cachuma Reservoir carryover, years 1–5, Santa Barbara, California

Year	Maximum allowable Cachuma Reservoir carryover (acre-feet per year)	(cubic feet per second)
1	3,000	4.141
2	6,000	8.282
3	8,277	11.425
4	8,277	11.425
5	8,277	11.425

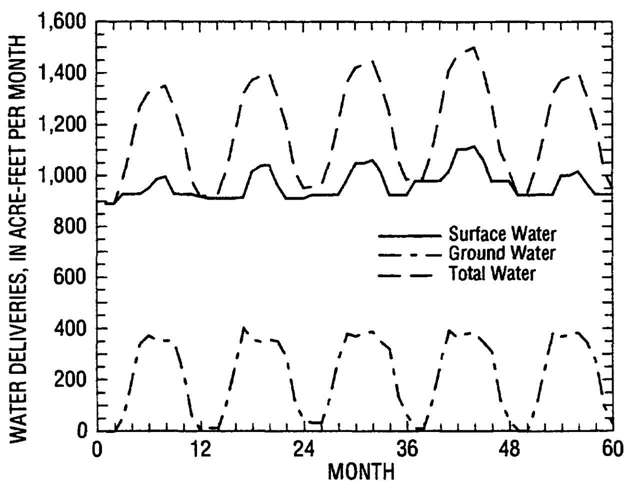

Figure 5. Optimal surface-water, ground-water, and total deliveries for the base-case simulation, months 1–60, Santa Barbara, California.

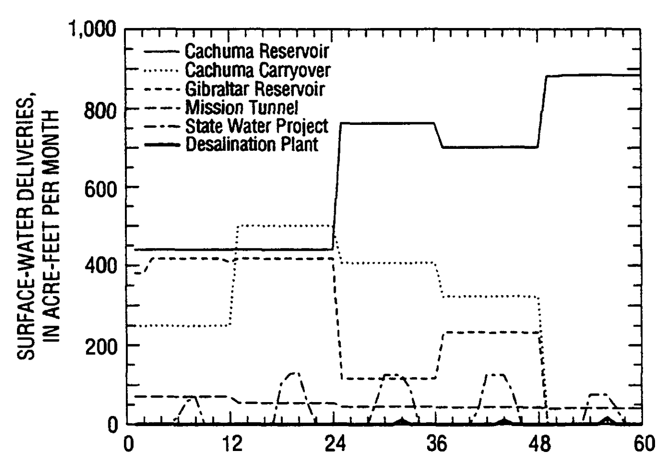

Figure 6. Optimal surface-water deliveries from all sources for the base-case simulation, months 1–60, Santa Barbara, California.

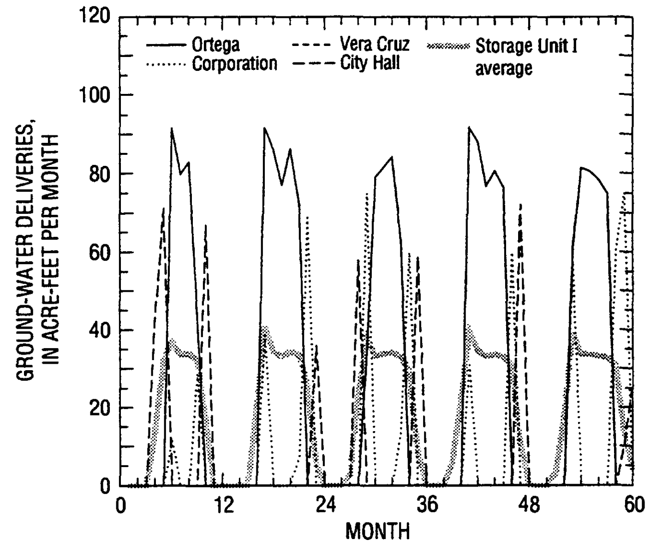

Figure 7. Optimal ground-water deliveries from coastal Storage Unit I wells for the base-case simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Vera Cruz well.)

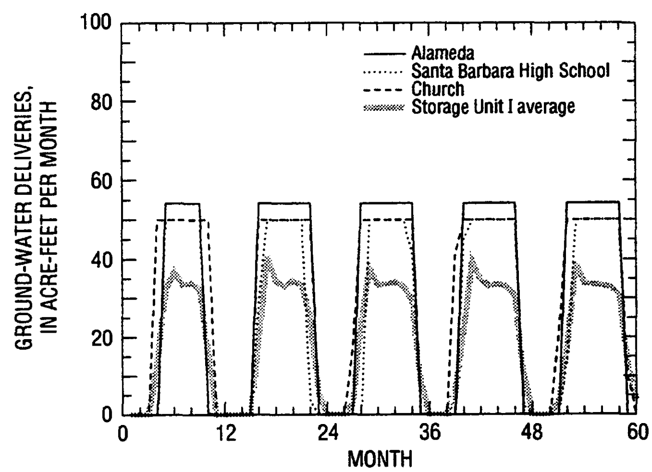

Figure 8. Optimal ground-water deliveries from inland Storage Unit I wells for the base-case simulation, months 1–60, Santa Barbara, California.

The total volume of water available to Santa Barbara from the Gibraltar Reservoir and the Mission Tunnel is used in this simulation (fig. 6) because of the low cost of this water. Deliveries from Cachuma Reservoir vary with the amount of carryover and total water available as specified by the SYRHM (fig. 6). SWP water is required during the summer months to meet the higher demands and is at its maximum allocation during those months (fig. 6). Desalinated water is required only in the final 3 years to help meet the peak summer demand (fig. 6); however, the quantities are very small and because of the desalination plant startup expenses the cost to deliver these small quantities may be prohibitive.

Table 4. Optimal surface-water and ground-water deliveries for the base-case simulation, months 1–60, Santa Barbara, California

Month	Surface-water total	Ground-water total	Surface water and ground water, combined total	
	(acre-feet per month)		(acre-feet per month)	(cubic feet per second)
1	891.029	0.000	891.029	14.759
2	891.029	.000	891.029	14.759
3	927.011	58.500	985.511	16.324
4	927.011	193.492	1,120.502	18.560
5	927.011	342.007	1,269.017	21.020
6	949.162	373.828	1,322.990	21.914
7	985.988	350.525	1,336.513	22.138
8	996.384	353.592	1,,349.976	22.361
9	927.011	342.007	1,269.017	21.020
10	927.011	234.002	1,161.012	19.231
11	927.011	58.500	985.511	16.324
12	918.015	.000	918.015	15.206
13	911.072	12.920	923.992	15.305
14	911.072	12.920	923.992	15.305
15	911.072	110.903	1,021.976	16.928
16	911.072	250.906	1,161.978	19.247
17	915.027	400.960	1,315.987	21.798
18	1,015.192	356.820	1,372.012	22.726
19	1,038.252	347.767	1,386.018	22.958
20	1,042.739	357.285	1,400.024	23.190
21	965.824	350.163	1,315.987	21.798
22	911.072	292.924	1,203.997	19.943
23	911.072	110.903	1,021.976	16.928
24	911.072	40.932	952.005	15.769
25	924.786	32.229	957.015	15.852
26	924.786	32.229	957.015	15.852
27	924.786	133.715	1,058.500	17.533
28	924.786	278.728	1,203.514	19.935
29	982.938	380.079	1,363.016	22.577
30	1,049.816	371.157	1,420.973	23.537

Table 4. Optimal surface-water and ground-water deliveries for the base-case simulation, months 1–60, Santa Barbara, California (Continued)

Month	Surface-water total	Ground-water total	Surface water and ground water, combined total	
	(acre-feet per month)		(acre-feet per month)	(cubic feet per second)
31	1,049.816	385.707	1,435.523	23.778
32	1,061.709	388.303	1,450.012	24.018
33	1,015.294	347.722	1,363.016	22.577
34	924.786	322.196	1,246.982	20.655
35	924.786	133.715	1,058.500	17.533
36	924.786	61.208	985.994	16.332
37	979.073	10.906	989.979	16.398
38	979.073	10.906	989.979	16.398
39	979.073	115.953	1,095.026	18.138
40	979.073	265.917	1,244.990	20.622
41	1,016.673	393.313	1,409.986	23.355
42	1,104.103	365.893	1,469.996	24.349
43	1,104.103	380.925	1,485.028	24.598
44	1,115.280	384.721	1,500.000	24.846
45	1,062.746	347.240	1,409.986	23.355
46	979.073	310.954	1,290.027	21.368
47	979.073	115.953	1,095.026	18.138
48	979.073	40.911	1,019.984	16.895
49	923.992	.000	923.992	15.305
50	923.992	.000	923.992	15.305
51	926.436	95.539	1,021.975	16.928
52	926.436	235.541	1,161.978	19.247
53	926.436	389.550	1,315.987	21.798
54	1,001.418	370.593	1,372.012	22.726
55	1,001.418	384.600	1,386.018	22.958
56	1,017.502	382.522	1,400.024	23.190
57	970.302	345.685	1,315.987	21.798
58	926.436	277.560	1,203.997	19.943
59	926.436	95.539	1,021.975	16.928
60	926.436	25.568	952.004	15.769

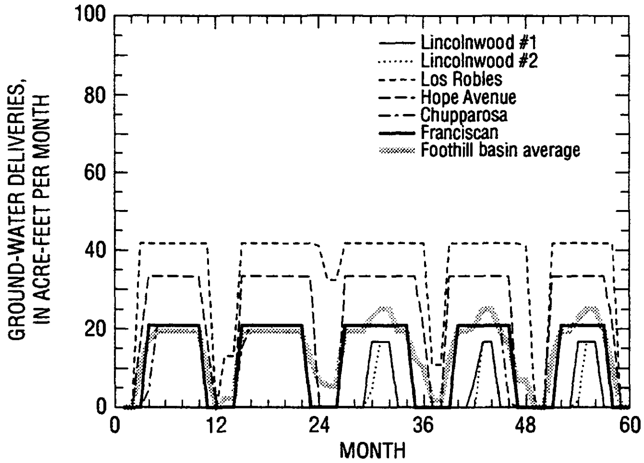

Figure 9. Optimal ground-water deliveries from the Foothill basin wells for the base-case simulation, months 1–60, Santa Barbara, California.

Table 5. Summary of water-delivery costs for all simulations, Santa Barbara, California

Simulation	Total cost (millions of dollars)
Base case	5.56
Sensitivity to maximum cumulative carryover	6.34
Sensitivity to peak annual demand	4.87
Sensitivity to 30 feet below sea level head constraint at coast	4.53
Sensitivity to zero desalination-plant capacity	5.66
Sensitivity to allowing SWP carryover	5.53
Current monthly Gibraltar Reservoir diversion distribution	7.55
Proposed monthly Gibraltar Reservoir diversion distribution	5.07
Cachuma Reservoir variable monthly water deliveries with current monthly Gibraltar Reservoir diversion distribution	4.53
Cachuma Reservoir variable monthly water deliveries with proposed monthly Gibraltar Reservoir diversion distribution	4.53

The optimal cumulative carryover is shown in figure 6 and summarized in table 6. In years 1 and 2, 3,000 acre-ft/yr is stored. This stored water (6,000 acre-ft) is then used (delivered) in years 3, 4, and 5 (1,126; 997; and 3,876 acre-ft/yr, respectively) with no carryover available for use in year 6. Note that no carryover for use in year 6 is a result of the model not a constraint, that is, all the cheapest water (surface water including carryover) was used in year 5 of a 5 year planning horizon.

In general, ground-water pumping is intermittent; most of the pumping occurs in the summer months (figs. 7 to 9). Of the coastal wells in Storage Unit I (Vera Cruz, Ortega, Corporation, and City Hall), there is no pumping from the Vera Cruz, pumping from the Ortega takes place over the summer months, and pumping from the Corporation and the City Hall wells brackets the summer months (fig. 7). This pumping pattern is a result of the wells' proximity to the coastal boundary nodes (seawater-intrusion constraint locations); increased pumping can cause the head constraints at these nodes to be violated. Of the inland wells in Storage Unit I (Alameda, SBHS, and Church), most of the pumping takes place in the summer months; little pumping occurs in the winter months (fig. 8). Of the Foothill basin wells, the Los Robles well is pumped almost continuously for the simulation period because pumping this well does not affect the coastal boundary hydraulic-head constraints (fig. 9). There is relatively little pumping at the Lincolnwood wells (fig. 9) because of the high cost of water ($461/ acre-ft).

The average monthly pumpage for each group of wells is given in table 7. In general, less water is pumped from the coastal Storage Unit I wells than from the other groups of wells. The coastal Storage Unit I wells pump at about 3 percent of their average pumping capacities, and the other groups of wells pump from about 10 to 15 percent of their average pumping capacities (table 7). This further illustrates that pumping in the coastal area is constrained by the minimum head requirements at the coast (zero feet).

Over the 5-year management period the total volume of water pumped from Storage Unit I was about 8,000 acre-ft, and the total capacity of these wells was about 30,750 acre-ft. This indicates that adding additional wells to the system would not provide additional water with little or no impact on the coastal heads because the 8,000 acre-ft is the maximum volume of water that can be pumped from the system without violating these head constraints. In addition, if additional water could be extracted, the existing wells would provide this water because the wells are not pumping at capacity.

Table 6. Optimal cumulative annual Cachuma Reservoir carryover and delivered carryover for the base-case simulation, years 1–5, Santa Barbara, California

Year	Cumulative annual carryover[1] (rounded)		Delivered carryover (rounded)	
	cubic feet per second	acre-feet per year	cubic feet per second	acre-feet per year
1	4.141	3,000.0	0.00	0.00
2	8.282	6,000.0	.00	.00
3	6.727	4,873.461	1.555	1,126.540
4	5.350	3,875.876	1.377	997.585
5	.00	.00	5.35	3,875.876

[1]Assumes a maximum annual carryover of 3,000 acre-feet and a maximum accumulated volume of 8,277 acre-feet.

Table 7. Average monthly pumping, pumping capacity, and percentage of pumping capacity utilized for Storage Unit I and for the Foothill basin for the base-case simulation, years 1–5, Santa Barbara, California

Year	Average Storage Unit I coastal pumping	Storage Unit I coastal pumping capacity	Storage Unit I coastal pumping capacity utilized	Average Storage Unit I inland pumping	Storage Unit I inland pumping capacity	Storage Unit I inland pumping capacity utilized	Average Foothill basin pumping	Foothill basin pumping capacity	Foothill basin pumping capacity utilized
	(acre-feet per month)		(percent)	(acre-feet per month)		(percent)	(acre-feet per month)		(percent)
1	10.789	358.330	3.011	22.848	154.170	14.820	13.387	150.000	8.925
2	11.742	358.330	3.277	23.960	154.170	15.542	19.012	150.000	12.675
3	12.654	358.330	3.531	25.081	154.170	16.269	20.756	150.000	13.838
4	12.002	358.330	3.349	26.457	154.170	17.161	22.842	150.000	15.228
5	12.614	358.330	3.520	25.849	154.170	16.766	23.907	150.000	15.938

The resulting simulated water levels for model layers 1 and 2 are shown in figure 10. Depressions in the water levels are evident in both model layers owing to pumping from the SBHS and the Alameda wells (nodes (29,11) and (25,9) in fig. 3, respectively). The drawdown located in the southern part of the Foothill basin is caused by a drain in the model (Freckleton and others, 1998). However, the water levels along the coastal boundary are at least equal to zero feet.

Nonlinear Effects

Formulation

The Santa Barbara area MODFLOW model contains drain nodes near the coast (fig. 3). The flow through these nodes is a nonlinear function of head (see McDonald and Harbaugh, 1988; Greenwald, 1993), and these nonlinearities violate the basic assumption that allows the use of linear programming techniques to solve the optimization problem. In order to incorporate the effects of these nonlinearities, an iterative approach is used (see Greenwald, 1993; Danskin and Freckleton, 1992). Ideally, as the number of iterations increases, the change in water deliveries and objective function caused by the nonlinearities should diminish (converge).

To apply this iterative solution, the optimization problem first must be reformulated. The optimal water deliveries and carryover values are treated as fixed variables and the changes in delivery and carryover caused by the nonlinear nature of the problem are the decision variables; that is, instead of the following general water-capacity constraint:

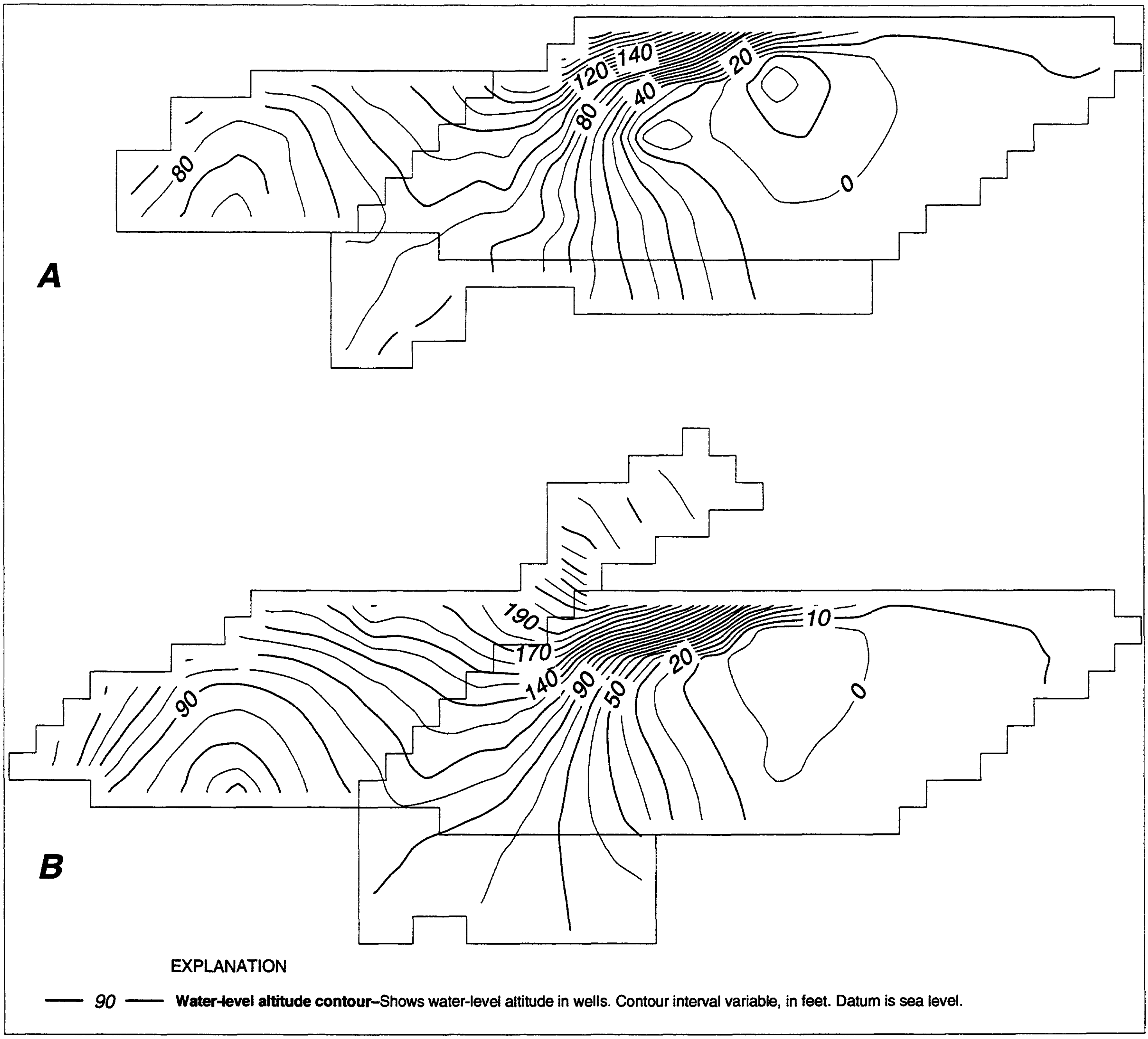

Figure 10. Simulated December 1990 water-level altitudes in model layers 1 and 2 for the base-case simulation, Santa Barbara, California.

$$0 \geq Q_{del} \geq Q_{max}, \tag{6}$$

where Q_{del} is the water delivered and Q_{max} is the maximum capacity of the source the constraint is reformulated as:

$$0 \geq Q_{del}^* + \Delta Q_{del} \geq Q_{max}, \tag{7}$$

where Q_{del}^* is the optimal delivery and ΔQ_{del} is the change in water delivery caused by the nonlinearity. Equation 7 is reformulated as:

$$-Q_{del}^* \geq \Delta Q_{del} \geq Q_{max} - Q_{del}^* . \tag{8}$$

The demand constraints are similarly reformulated as:

$$\sum \Delta Q_{del} = D - \sum Q_{del}^*, \tag{9}$$

where D is demand. The temporal carryover constraints are reformulated as:

$$\Delta Q_{del} - \overline{\Delta Q_{co}}^{t} + \overline{\Delta Q_{co}}^{t-1} \geq Q_{max}$$

$$-Q_{del}^* + \overline{Q_{co}}^{t\,*} - \overline{Q_{co}}^{t-1*} . \tag{10}$$

Again, the new decision variables are ΔQ_{del} and $\Delta \overline{Q_{co}}$, adding 2,165 new decision variables to the problem.

This iterative approach is a numerical method that yields a solution that reflects more accurately the nonlinear ground-water hydraulic effects caused by the drains than does the original formulation. As will be shown below, the nonlinearities are not significant.

Nonlinear Results

The nonlinear optimization problem converged in two iterations. After the first iteration the objective value decreased $44,000 and after the second iteration the objective value increased $762—for a net change of about 0.8 percent from the original objective value of $5.56 million.

The combined effect of the changes in surface-water and ground-water deliveries after iteration 2 (fig. 11) is to offset each other; the total change is approximately zero. The final-iteration water levels for layers 1 and 2 are very similar to the base-case water levels (fig. 10).

The nonlinear iterations are considered to have converged because the changes in objective function, water deliveries, and water levels are small. In addition, the effects of the nonlinearities seem to be small; therefore, the sensitivity analyses discussed below do not include the iterative solution described above.

Sensitivity Analysis

Six sensitivity analyses were performed to test the sensitivity of the simulation-optimization model results to choice of (1) maximum cumulative carryover, (2) peak annual demand, (3) ocean-boundary constraint head values, (4) desalination-plant capacity, (5) SWP water carryover, and (6) the assumption of average monthly deliveries from the Cachuma Reservoir. Only the fourth, fifth, and sixth analyses are discussed in detail.

Reduce Allowable Carryover

In this simulation, allowable annual carryover is reduced to 1,500 acre-ft, with a stored maximum carryover of 4,500 acre-ft/yr. The resulting water deliveries are shown in figures 12 to 15 and Appendix tables A4 to A6. The optimal cumulative carryover is shown in

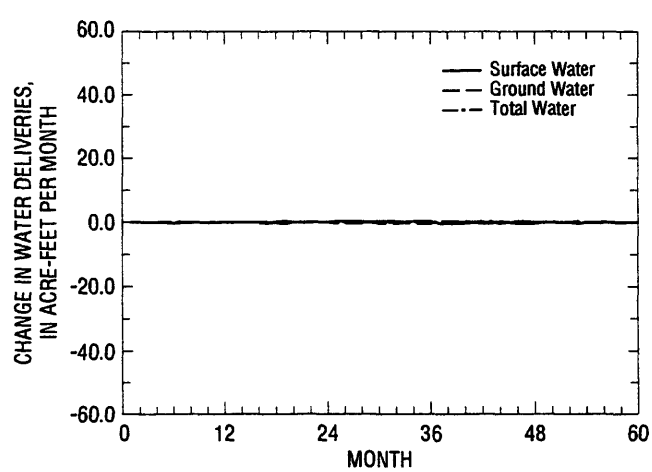

Figure 11. Change in surface-water, ground-water, and total deliveries after model nonlinear iteration no. 2, months 1–60, Santa Barbara, California.

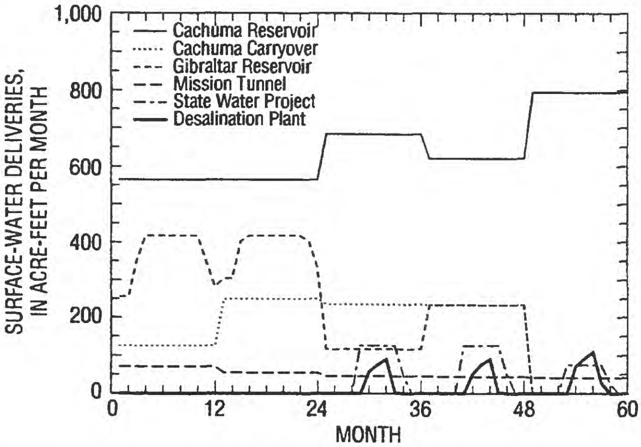

Figure 12. Optimal surface-water deliveries from all sources for the Cachuma Reservoir carryover sensitivity simulation, months 1–60, Santa Barbara, California.

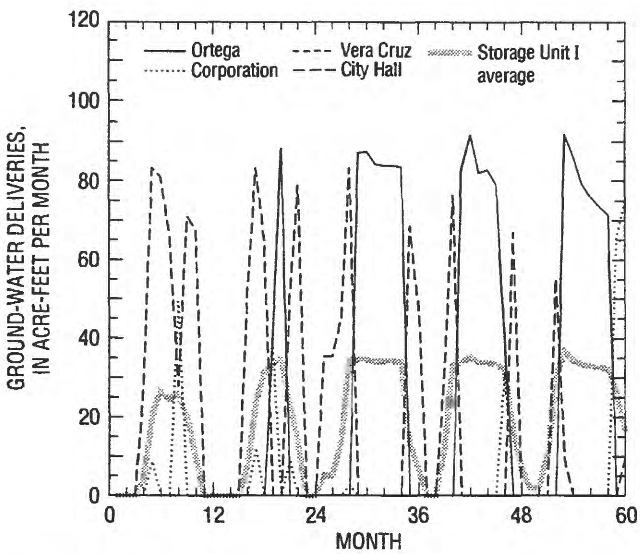

Figure 13. Optimal ground-water deliveries from coastal Storage Unit I wells for the Cachuma Reservoir carryonver sensitivity simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Vera Cruz well.)

figure 12 and table 8. The minimum cost for water delivery is $6.34 million, indicating that if the amount of carryover is halved the increased cost of water delivery over the 5-year simulation period is approximately $800,000; that is, the benefit from the additional carryover is about $533/acre-ft. The total volume of surface water delivered is about 240 acre-ft less than in the base case; this difference is compensated by additional pumping of ground water.

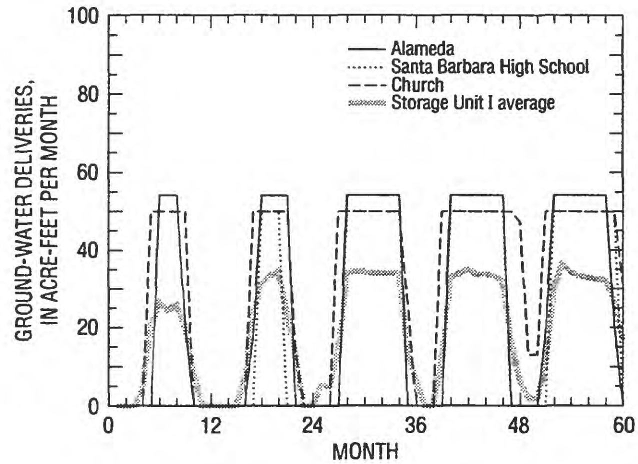

Figure 14. Optimal ground-water deliveries from inland Storage Unit I wells for the Cachuma Reservoir carryover sensitivity simulation, months 1–60, Santa Barbara, California.

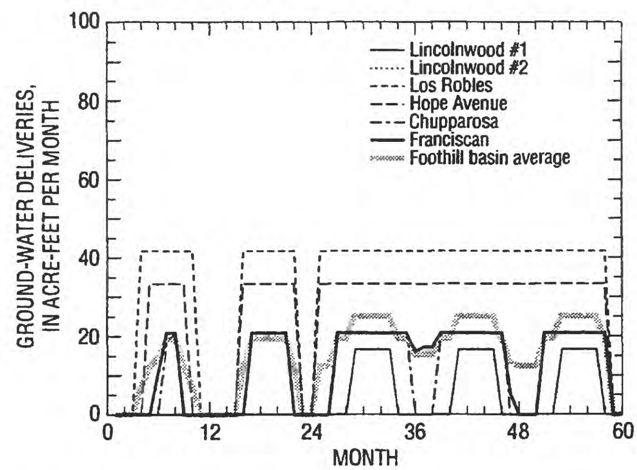

Figure 15. Optimal ground-water deliveries from the Foothill basin wells for the Cachuma Reservoir carryover sensitivity simulation, months 1–60, Santa Barbara, California (Note: Delivery values from the Lincolnwood #1 and #2 wells overlap.)

Reduce Demand

In this simulation, the maximum annual demand is reduced to 14,000 acre-ft in year 4 with a minimum demand of 13,500 acre-ft in years 1 and 5. The demand increases at a rate of about 167 acre-ft/yr in years 2, 3, and 4. Recall that in the base case the initial demand was 13,500 acre-ft/yr, with a maximum demand of 15,000 acre-ft in year 4 and a final demand of 14,000 acre-ft in year 5. The total volume difference between this simulation and the base case is 3,000 acre-ft. The resulting water deliveries are shown in figures 16 to 19 and Appendix tables A7 to A9. The minimum cost of water delivery is $4.87 million, indicating that a decrease in peak annual demand of 7 percent can result in a cost savings of about $800,000 (about 15 percent) over the 5-year simulation period. Surface-water deliveries for this simulation were about 1,135 acre-ft less than for the base case; therefore, the balance was saved by reductions in ground-water pumpage.

Vary Head Constraints

Recall that in the base case the minimum hydraulic head was set at an altitude of zero feet. In this sensitivity analysis, two scenarios are tested: (1) constraining the hydraulic heads at the coastal boundary to be greater than or equal to an altitude of −30 ft, and (2) constraining the hydraulic heads at the coastal boundary such that the hydraulic gradient at this boundary is zero. The first scenario probably will allow a greater amount of seawater intrusion than will

Table 8. Optimal cumulative annual Cachuma Reservoir carryover and delivered carryover for the sensitivity of the base case to Cachuma Reservoir carryover simulation, Santa Barbara, California

Year	Cumulative annual carryover[1]		Delivered carryover	
	cubic feet per second	acre-feet per year	cubic feet per second	acre-feet per year
1	2.071	1,500.000	0.000	0.000
2	4.142	3,000.000	.000	.000
3	3.841	2,782.789	.301	218.063
4	5.353	3,877.905	.000	.000
5	.000	.000	5.353	3,877.905

[1]Assumes a maximum annual carryover of 1,500 acre-feet and a maximum accumulated volume of 4,500 acre-feet.

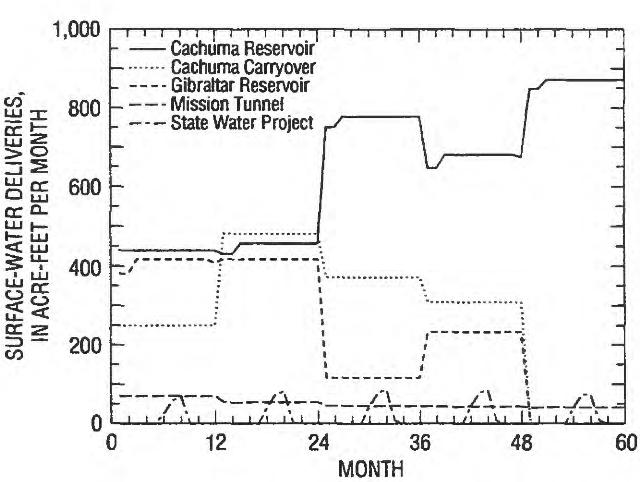

Figure 16. Optimal surface-water deliveries from all sources for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California.

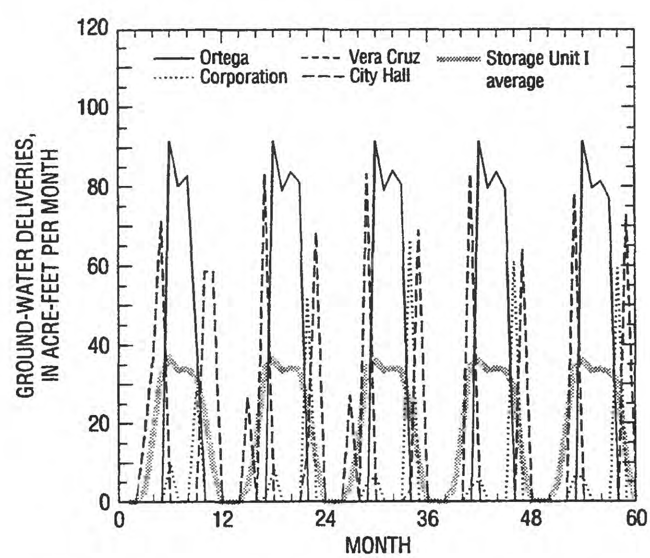

Figure 17. Optimal ground-water deliveries from coastal Storage Unit I wells for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Vera Cruz well.)

the base case constraint of zero feet, and the second scenario will allow little or no seawater intrusion because of the zero gradient at the coast.

First Scenario

The optimal water deliveries for this scenario (hydraulic head at coastal boundary constrained to an altitude of greater than or equal to −30 ft) are shown in figures 20 to 23 and Appendix tables A10 to A12. The cost of water delivery over the 5-year design period is $4.53 million, indicating that if Santa Barbara is willing to accept a greater amount of seawater intrusion than in the base case, it will realize a cost savings of about $1 million over the 5-year drought period.

The optimal pumping patterns for this sensitivity analysis are presented in figures 21 to 23. The greatest differences in pumping from the base case are: (1) in the coastal Storage Unit I wells, there is pumping from the Vera Cruz well because the lower head constraint allows pumping from this well without violating the constraint; (2) pumping from the City Hall well is increased and is almost continuous over the study period; and (3) pumping from the Ortega and the Corporation well has been decreased (fig. 21).

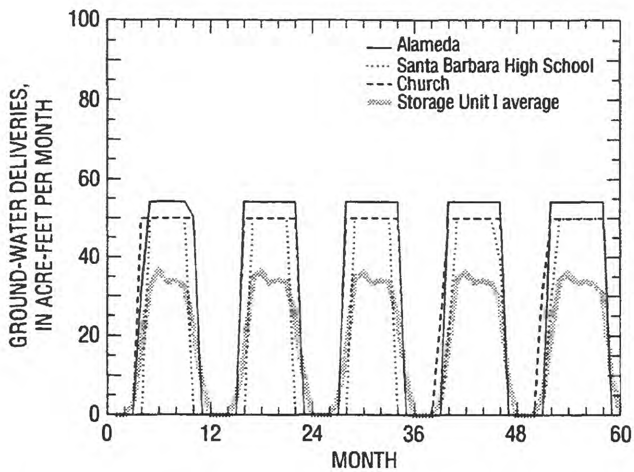

Figure 18. Optimal ground-water deliveries from inland Storage Unit I wells for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California.

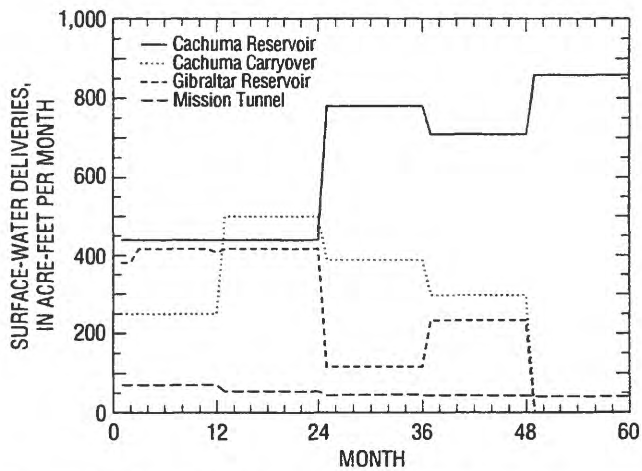

Figure 20. Optimal surface-water deliveries from all sources for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California.

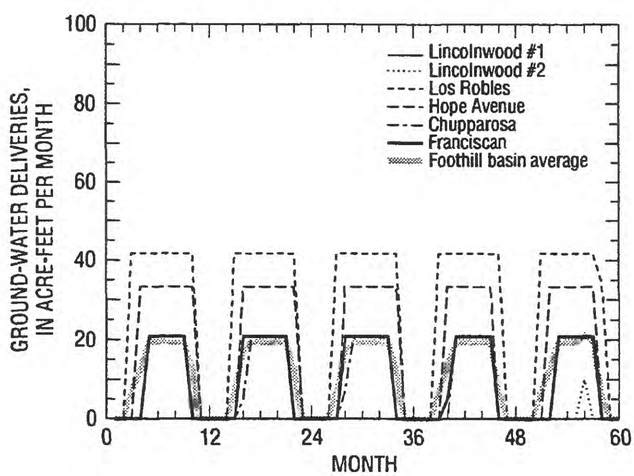

Figure 19. Optimal ground-water deliveries from the Foothill basin wells for the reduced-demand sensitivity simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Lincolnwood #1 well.)

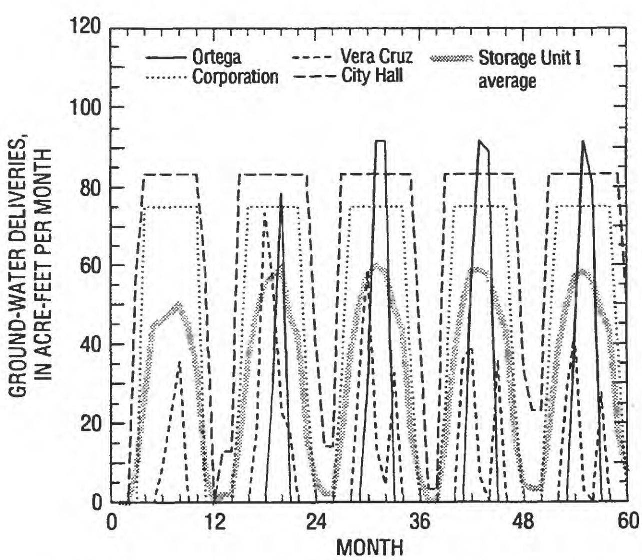

Figure 21. Optimal ground-water deliveries from coastal Storage Unit I wells for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California.

Second Scenario

In this scenario, the heads at the coastal boundary are constrained to be greater than or equal to the equivalent freshwater heads as specified in the general-head boundary conditions of the MODFLOW model. The heads required for zero gradient and the constraint locations are presented in table 9. This scenario resulted in an infeasible solution of the optimization problem; even with no pumping, the head constraints could not be met. All the coastal boundary constraints were infeasible in the first few months, but by month 58 only two constraints remained infeasible. The greatest difference in the first few months was about 11 ft; that is, the minimum head was set at about 21 ft and the simulated head was about 10 ft. In month 58 the greatest difference was about 0.06 ft.

Constrain Desalination-Plant Capacity to Zero

As noted in the base-case results, the optimal water delivery from the desalination plant was small (about 39 acre-ft over 5 years). In this sensitivity analysis, the capacity of the desalination plant is constrained to zero to test whether an optimal solution exists and to estimate the change in cost caused by removing this water source.

The optimization problem is feasible at a cost of $5.66 million over the 5-year management period; this is an increase of about $0.1 million (2 percent) over the base-case cost. The results are shown in figures 24 to 27 and Appendix tables A13 to A15.

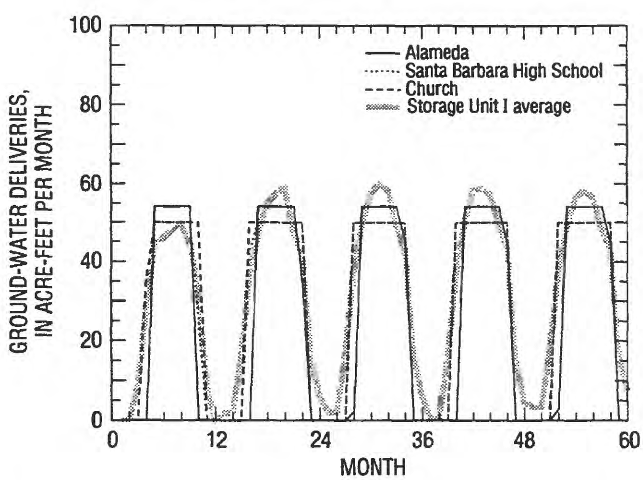

Figure 22. Optimal ground-water deliveries from inland Storage Unit I wells for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California (Note: Delivery values for the Santa Barbara High School and Church wells are very similar.)

Desalinated water is not required in this simulation because the capacity of the desalinated-water plant is constrained to zero. However, SWP water deliveries are increased over the base case and, as in the base case, this water is required only during the peak-demand summer months (fig. 24). Deliveries from the other sources of surface water are unchanged. The total volume of delivered surface water in this simulation is 58,019 acre-ft, which is slightly greater than in the base case (57,835 acre-ft).

The distribution of pumping (figs. 25 to 27) is virtually the same as in the base case; that is, intermittent pumping near the coast and more continuous pumping inland. However, pumping is greater than in the base case at the Lincolnwood wells but less than the base case at most of the other wells. Overall, the total volume of pumped water in this simulation is

Table 9. Hydraulic-head values at constraint locations, Santa Barbara, California

Constraint location (layer, column, row)	Hydraulic head (feet)
1,32,3	0.0
1,32,4	.0
1,33,5	10.8
1,34,6	9.6
1,35,7	8.4
1,36,7	8.4
1,37,8	7.8
1,38,9	7.2
1,39,10	5.6
1,40,10	5.6
1,41,11	5.4
1,42,12	4.8
2,33,5	21.6
2,34,6	19.2
2,35,7	16.8
2,36,7	16.8
2,37,8	15.6
2,38,9	14.4
2,39,10	13.8
2,40,10	13.8
2,41,11	13.2
2,42,12	9.6

12,981 acre-ft, which is less than in the base case (13,165 acre-ft).

Carryover State Water Project (SWP) Water

In this simulation, SWP water is allowed to be carried over with the Cachuma Reservoir carryover. Such a policy could be implemented by Santa Barbara because SWP water is delivered to the Cachuma Reservoir (allowing storage) and delivered to Santa Barbara by means of the Tecolote Tunnel. The formulation of the optimization problem is the same as that for the Cachuma Reservoir carryover and adds five new decision variables to the formulation. The maximum allowable cumulative carryover for years 1 to 5 according to Mack (oral commun., 1996) is presented in table 10. Note that the maximum value of 3,000 acre-ft/yr is the maximum allocation of SWP water anticipated by Santa Barbara.

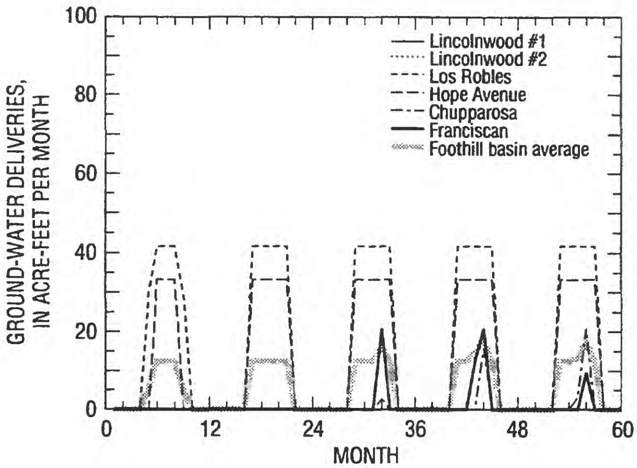

Figure 23. Optimal ground-water deliveries from the Foothill basin wells for the 30 feet below sea level head-constraint sensitivity simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Lincolnwood #1 and #2 wells.)

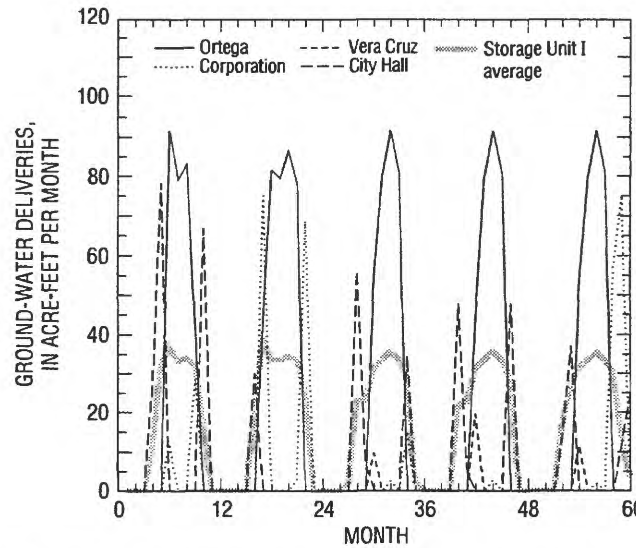

Figure 25. Optimal ground-water deliveries from coastal Storage Unit I wells for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California.

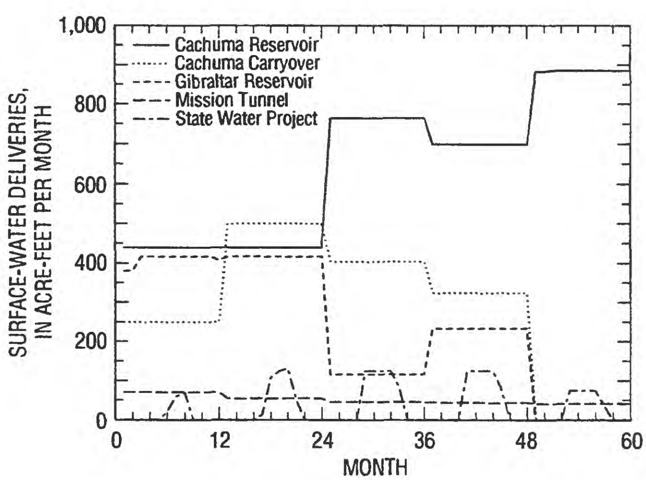

Figure 24. Optimal surface-water deliveries from all sources for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California.

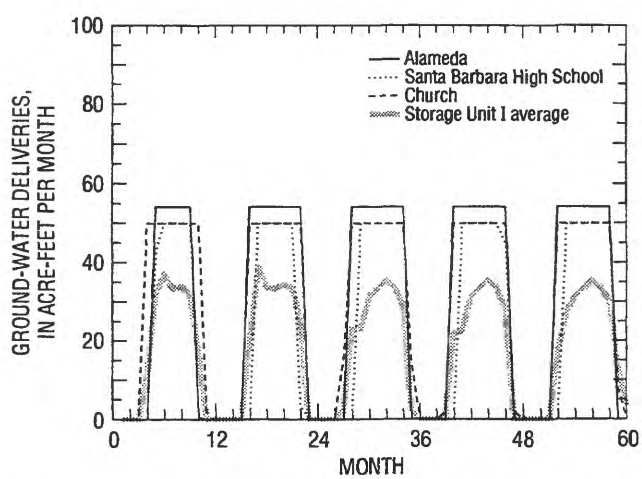

Figure 26. Optimal ground-water deliveries from inland Storage Unit I wells for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California.

The optimal water deliveries are shown in figures 28 to 31 and Appendix tables A16 to A18. The optimal cumulative carryover values are presented in table 11. The cost of delivering water is about $5.53 million, a cost savings of about $0.03 million in comparison with the base case.

In this simulation, desalinated water is not required and total SWP water deliveries are greater than in the base case. The total volume of surface water delivered in this simulation is 57,959 acre-ft, which is greater than the volume in the base case (57,835 acre-ft).

The general pattern of ground-water deliveries is the same as in the base case; that is, intermittent pumping in Storage Unit I and more continuous pumping in the Foothill basin (figs. 29 to 31). However, the total volume of water delivered from Storage Unit I in this simulation (8,256 acre-ft) is greater than in the base case (7,983 acre-ft), and the volume delivered from the Foothill basin (4,787 acre-ft) is less than in the base case.

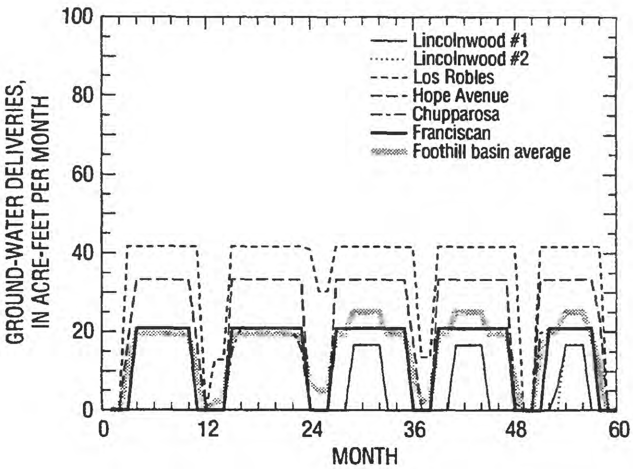

Figure 27. Optimal ground-water deliveries from the Foothill basin wells for the zero desalination capacity sensitivity simulation, months 1–60, Santa Barbara, California (Note: Delivery values for the Chupparosa and Franciscan wells are very similar.)

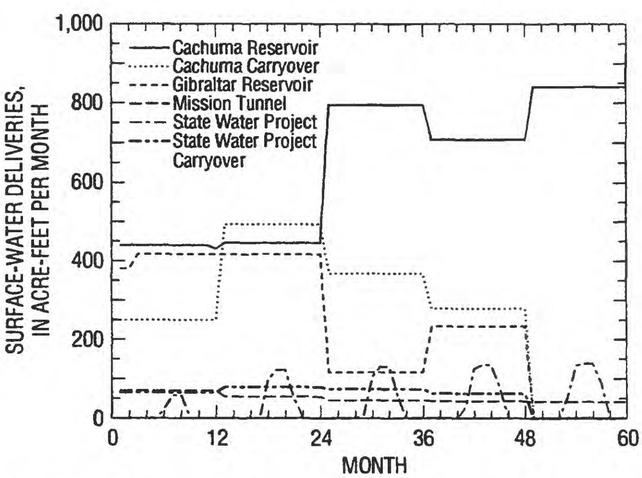

Figure 28. Optimal surface-water deliveries from all sources for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California.

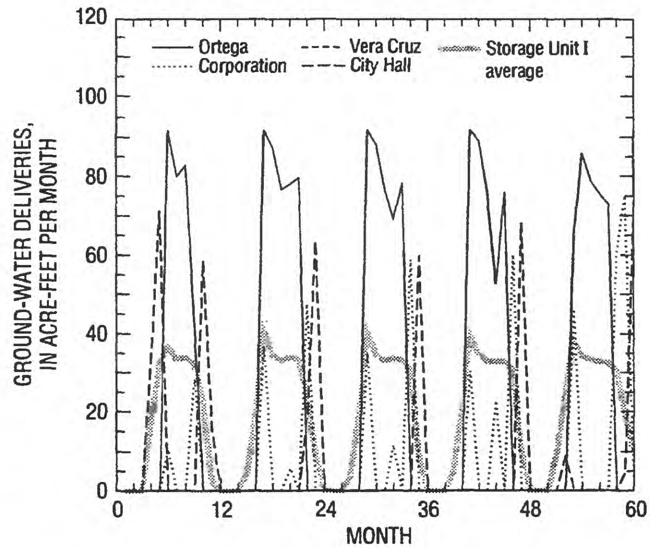

Figure 29. Optimal ground-water deliveries from coastal Storage Unit I wells for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Vera Cruz well.)

Table 10. Maximum allowable cumulative State Water Project (SWP) carryover, years 1–5, Santa Barbara, California

Year	Maximum allowable SWP carry over, in acre-feet per year	Maximum allowable SWP carry over, in cubic feet per second
1	1,500	2.071
2	3,000	4.141
3	3,000	4.141
4	3,000	4.141
5	3,000	4.141

Table 11. Optimal cumulative annual State Water Project (SWP) carryover and delivered SWP carryover, years 1–5, Santa Barbara, California

Year	Cumulative annual SWP carryover		Delivered SWP carryover	
	cubic feet per second	acre-feet per year	cubic feet per second	acre-feet per year
1	1.097	794.737	0.000	0.000
2	1.314	952.194	.000	.000
3	1.218	882.509	.096	69.549
4	1.047	758.249	.172	124.608
5	.000	.000	1.047	758.249

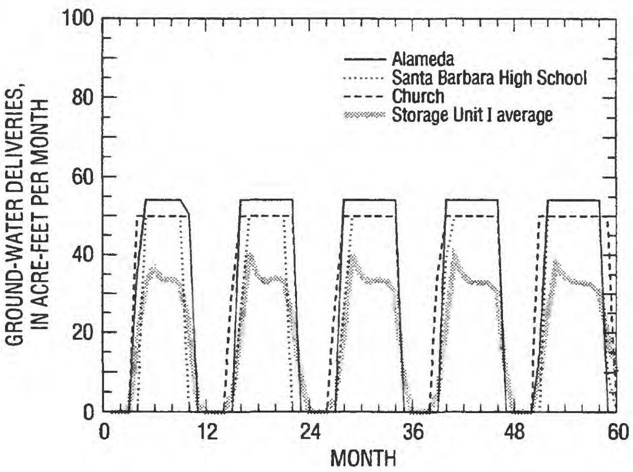

Figure 30. Optimal ground-water deliveries from inland Storage Unit I wells for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California

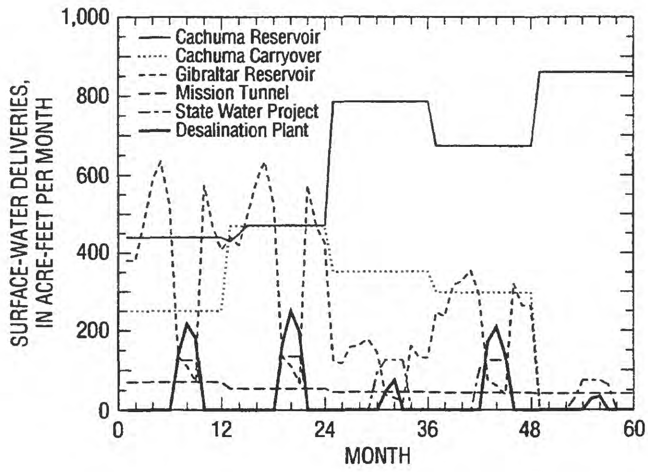

Figure 32. Optimal surface-water deliveries from all sources for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

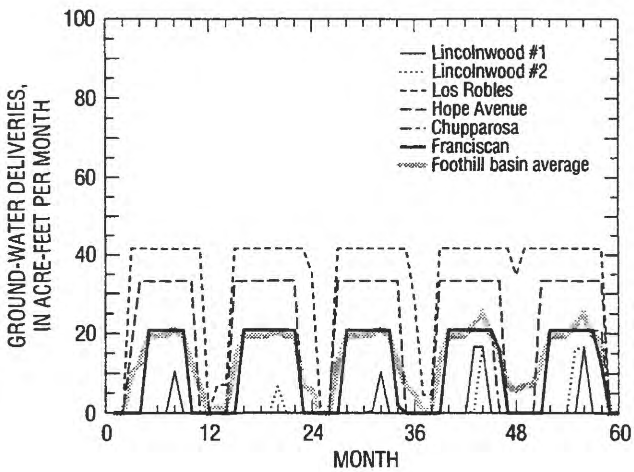

Figure 31. Optimal ground-water deliveries from the Foothill basin wells for the State Water Project carryover sensitivity simulation, months 1–60, Santa Barbara, California.

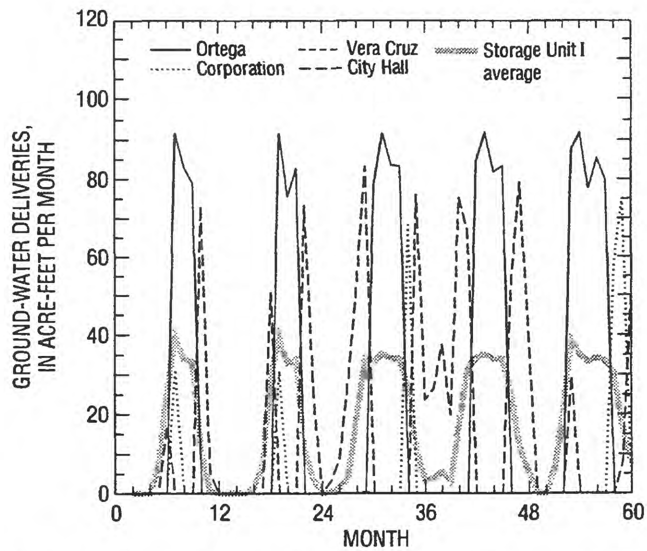

Figure 33. Optimal ground-water deliveries from coastal Storage Unit I wells for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Vera Cruz well.)

Current Monthly Gibraltar Diversion Distribution

In the base case, equal average monthly Gibraltar Reservoir capacities were used. In this scenario, the actual monthly diversion percentages of Gibraltar Reservoir water are used (fig. 4). Note the very low percentage of water available in the late summer months.

The results for this scenario are shown in figures 32 to 35 and Appendix tables A19 to A21. The cost of delivering water over the 5-year design period is $7.55 million, which is 36 percent greater than the cost in the base case.

The total volume of delivered Gibraltar Reservoir water is greater in the base case than the volume in this scenario because of the inappropriate timing of

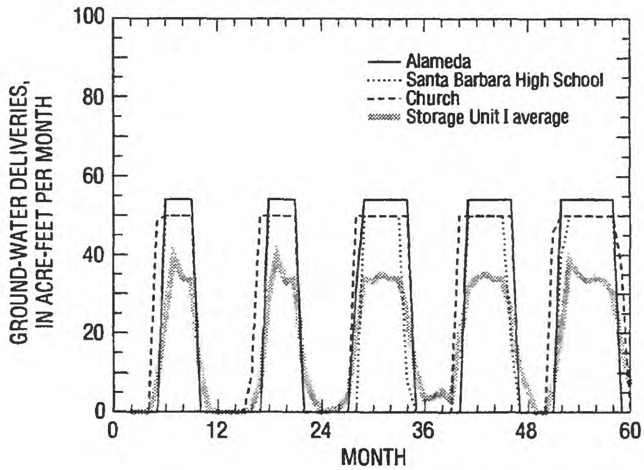

Figure 34. Optimal ground-water deliveries from inland Storage Unit I wells for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara. California.

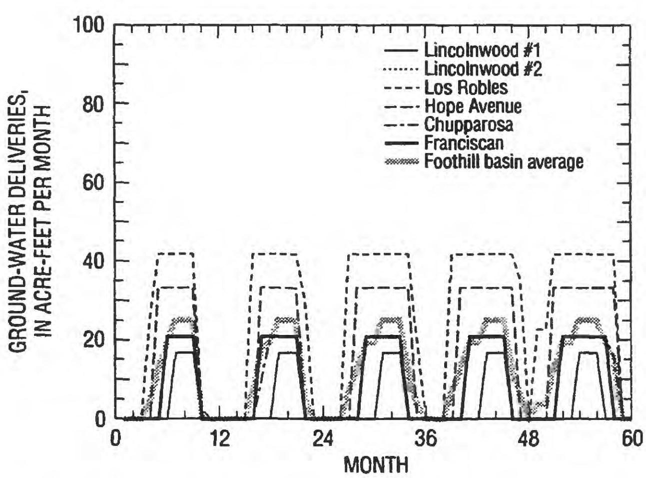

Figure 35. Optimal ground-water deliveries from the Foothill basin wells for the current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara. California (Note: Delivery values for the Lincolnwood #1 and #2 wells and from the Chupparosa and Franciscan wells are very similar.)

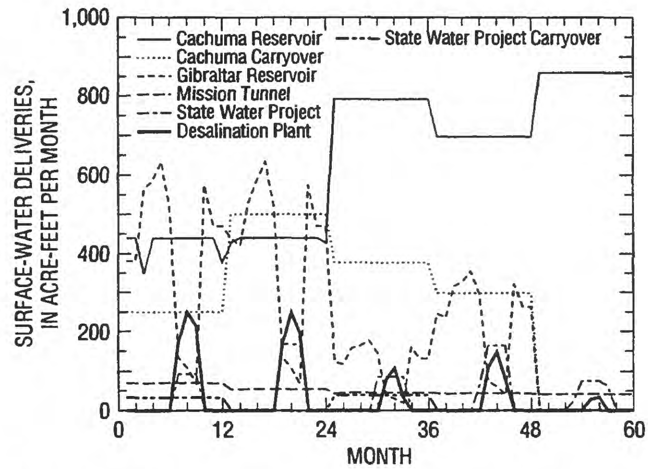

Figure 36. Optimal surface-water deliveries from all sources for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

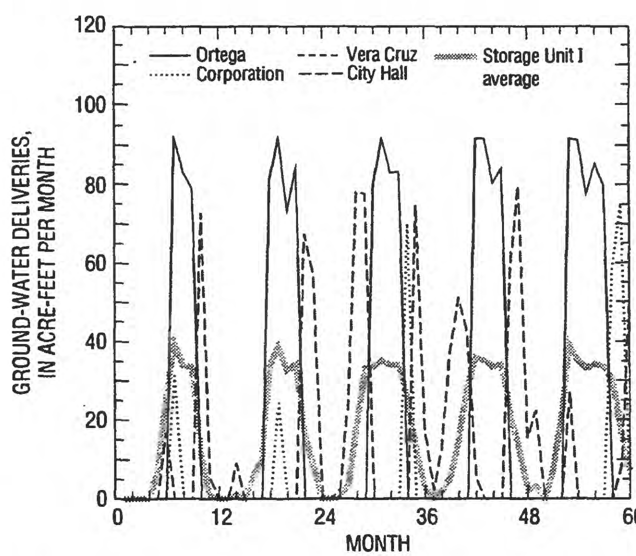

Figure 37. Optimal ground-water deliveries from coastal Storage Unit I wells for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Vera Cruz well.)

diversions throughout a year. For example, 9.4 percent of the annual demand occurs in month 9, when only 1.4 percent of the Gibraltar Reservoir capacity is available. To compensate for this mistiming, greater volumes of SWP and desalinated water are required in the summer months.

The optimal pumping patterns for this scenario are shown in figures 33 to 35. Considering the coastal Storage Unit I wells, the City Hall well is pumped more continuously and at a greater total volume than in the base case. However, the total volumes pumped from these wells are approximately equal (2,870 acre-ft for the base case and 2,876 acre-ft for this scenario). Considering the inland Storage Unit I wells, the total volume pumped from all the wells (4,401 acre-ft) is less than in the base case (5,113 acre-ft). Considering the

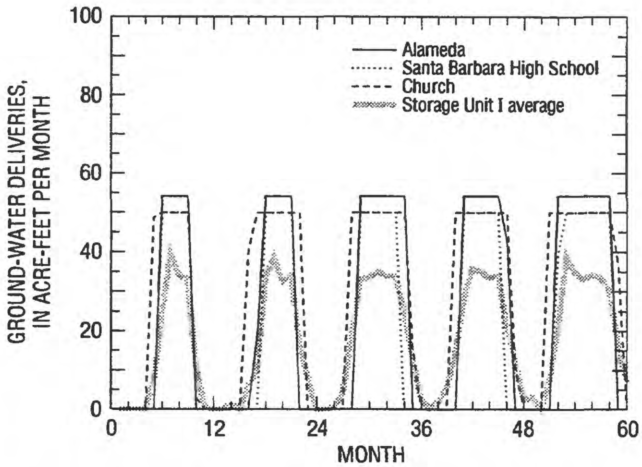

Figure 38. Optimal ground-water deliveries from inland Storage Unit I wells for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

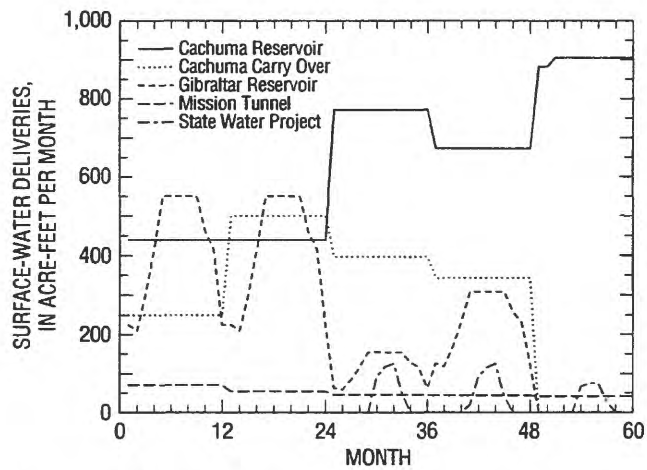

Figure 40. Optimal surface-water deliveries from all sources for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

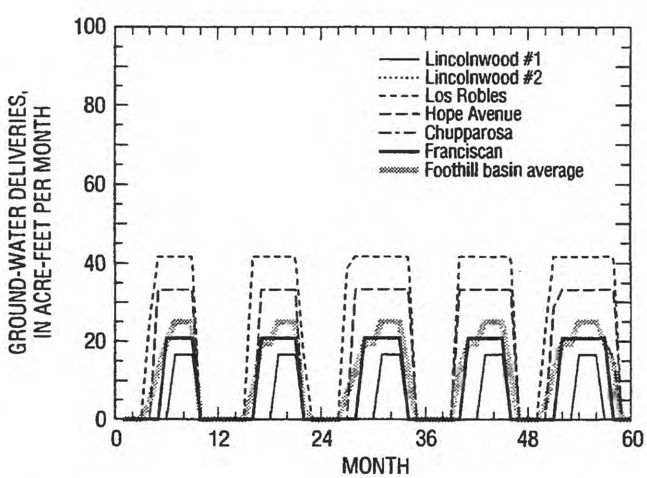

Figure 39. Optimal ground-water deliveries from the Foothill basin wells for the State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: Delivery values for the Lincolnwood #1 and #2 wells and from the Chupparosa and Franciscan wells are very similar.)

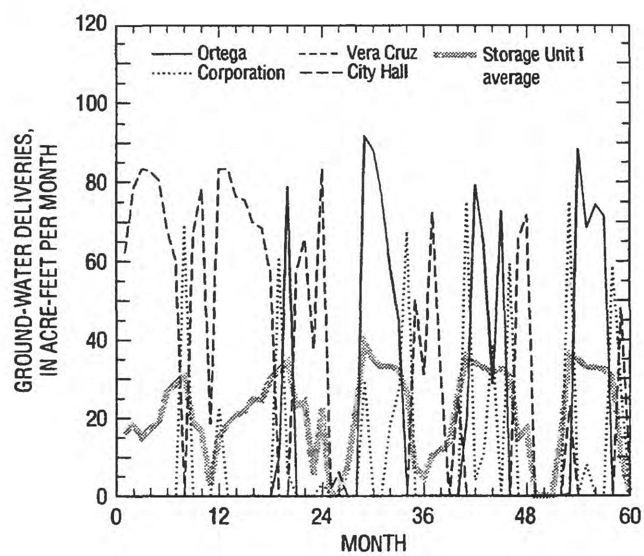

Figure 41. Optimal ground-water deliveries from coastal Storage Unit I wells for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Vera Cruz well.)

Foothill basin wells, the pumping patterns are more intermittent than in the base case, and the total volume of water pumped is 4,230 acre-ft, which is less than in the base case (5,182 acre-ft).

Sensitivity Analysis

Two sensitivity analyses are performed using the current monthly Gibraltar Reservoir diversion percentages scenario: (1) implementing SWP carryover, and (2) combining zero desalination-plant capacity with SWP carryover. In this scenario, it is assumed that the sensitivity to choice of Cachuma Reservoir carryover, maximum annual demand, and coastal head constraint is similar to that of the base case.

State Water Project (SWP) Carryover

SWP carryover is implemented in the same manner as is the base case (table 10). The results are shown in figures 36 to 39 and Appendix tables A22 to A24. The cost of delivering water with SWP carryover is about $7.54 million, a cost savings of about $0.01 million (0.1 percent) in comparison with the current-Gibraltar Reservoir-distributions scenario without SWP carryover.

SWP water is stored in years 1 and 3 and then used entirely in years 2 and 4; however, the total volume of water delivered (1,997 acre-ft) is less in this scenario than in the previous scenario (2,043 acre-ft) (fig. 36). All other surface-water deliveries are relatively unchanged from the previous scenario.

There is little difference in pumping pattern or volumes of water pumped between this scenario and the previous scenario.

Zero Desalination Capacity with State Water Project Carryover

In this analysis, the capacity of the desalination plant is constrained to zero, and SWP water is allowed to be carried over in order to reduce costs. This optimization problem is infeasible, indicating that desalinated water is required if the current monthly Gibraltar Reservoir percentages are used.

Proposed Monthly Gibraltar Reservoir Diversion Distribution

In this scenario, the proposed monthly diversion of Gibraltar Reservoir water is implemented (fig. 4). The water is more appropriately distributed in this scenario in comparison with the actual percentages; for example, in month 9, 11 percent of the water is available, in comparison with an actual value of 1.4 percent

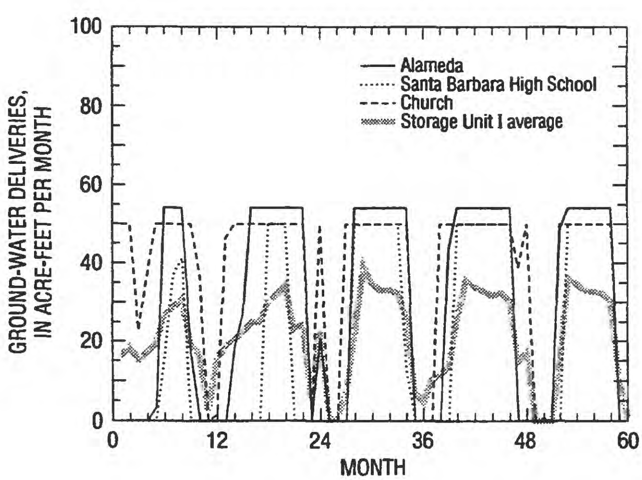

Figure 42. Optimal ground-water deliveries from inland Storage Unit I wells for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

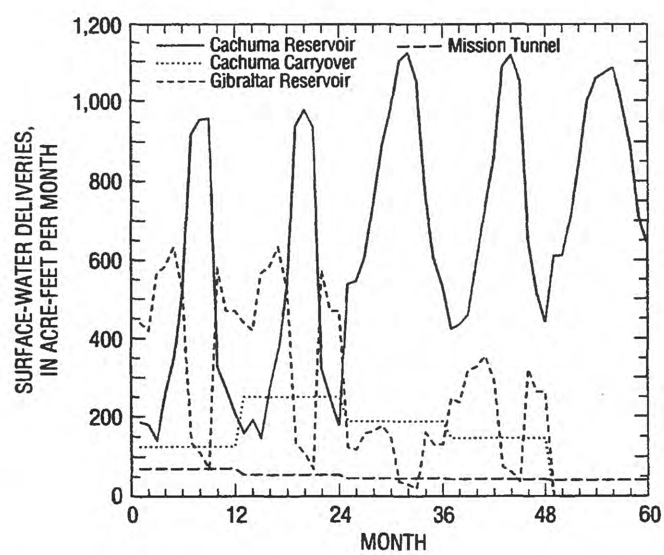

Figure 43. Optimal ground-water deliveries from the Foothill basin wells for the proposed monthly Gibraltar Reservoir diversion percentages simulation, months, 1–60, Santa Barbara, California.

(fig. 4). The results are shown in figures 40 to 43 and Appendix tables A25 to A27. The total cost of water delivery is $5.07 million, which is 9 percent less than in the base case.

This distribution allows more Gibraltar Reservoir water to be used (14,196 acre-ft) than does the base case (14,115 acre-ft) because more water is available in the high-demand summer months. As in the base case, SWP water is required in the last 3 years to help meet peak summer demand; however, the total volume of 1,018 acre-ft is less in this scenario than in the base case (1,861 acre-ft). Desalinated water is not required in this scenario.

Considering the coastal Storage Unit I wells, the Ortega well is not required in the first year and is required for fewer months thereafter than in the base case. The total volume of water pumped from these wells in this scenario is 3,545 acre-ft, which is greater than in the base case (2,870 acre-ft). Considering the inland Storage Unit I wells, the Church well is pumped more continuously in this scenario than in the base case, and the total volume of water pumped from this well (2,284 acre-ft) is greater than in the base case (1,840 acre-ft). Considering the Foothill wells, the Los Robles and the Hope Avenue wells are pumped almost continuously and the total volume of water pumped from both wells is greater in this scenario (2,333 acre-ft and 1,679 acre-ft, respectively) than in the base case (2,069 acre-ft and 1,407 acre-ft, respectively).

Cachuma Reservoir Variable Monthly Water Deliveries

In the base case, it was assumed that average monthly deliveries from the Cachuma and the Gibraltar Reservoirs were used. In the following simulations, the monthly deliveries from the Cachuma Reservoir are allowed to vary with demand and with water deliveries from the Gibraltar Reservoir. Two scenarios based on the Gibraltar Reservoir release schedules are tested: (1) using the current, actual, monthly diversion distribution and (2) the proposed monthly diversion distribution for Gibraltar Reservoir (fig. 4).

These simulations require that the capacity and temporal balance constraints be reformulated. The capacity constraints are reformulated as (recall that water deliveries are nonpositive values in the model):

$$\sum_i Q^i_{cr} \geq Q^t_{max}, \tag{11}$$

where Q^i_{cr} is the water delivered in time step i from the Cachuma Reservoir, and Q^t_{max} is the maximum capacity of the Cachuma Reservoir in year t.

The reformulated temporal balance constraint for the first year is:

$$\sum_i Q^i_{cr} - 12\overline{Q^1_{co}} \geq Q^1_{max}. \tag{12}$$

Equation 12 states that the sum of delivered Cachuma Reservoir water minus the sum of water carried over in year 1 must be greater than or equal to the maximum water available in year 1.

The reformulated temporal balance constraint for years 2 through 5 is:

$$\sum_i Q^i_{cr} - 12\overline{Q^t_{co}} + 12\overline{Q^{t-1}_{co}} \geq Q^t_{max}. \tag{13}$$

Equation 13 states that the sum of delivered Cachuma Reservoir water within a year minus the sum of water carried over in the current year (year t) plus the sum of water carried from the previous year (t-1) must be greater than the maximum water available in year t. Note that the above reformulations decrease the number of constraints from 3,300 to 3,245 because of the simplification of the capacity constraints and temporal balance constraints.

Actual Monthly Gibraltar Reservoir Diversion Distribution

In this scenario, the monthly deliveries from the Cachuma Reservoir are allowed to vary and the actual monthly diversion percentages of Gibraltar Reservoir water are used (fig. 4). The results for this scenario are shown in figures 44 to 47 and Appendix tables A28 to A30. The cost of delivering water over the 5-year design period is $4.53 million, which is more than 18 percent less than the cost in the base case ($5.56 million).

The Cachuma Reservoir deliveries are much more variable than in the base case and are out of phase with the Gibraltar Reservoir deliveries (fig. 44). The total volume of water delivered from the Cachuma and the Gibraltar Reservoirs is approximately equal to the base case; however, the timing of the deliveries is such that no SWP or desalinated water is required. Cachuma Reservoir carryover is stored in the first 2 years and used over the last 3 years.

The optimal pumping patterns for this scenario are shown in figures 45 to 47. Considering the coastal Storage Unit I wells, the Ortega and the Vera Cruz wells are not pumped and the other wells are pumped variably during the first 17 months; the Corporation well is pumped continuously after the first 12 months (fig. 45). The total volume of water pumped from these

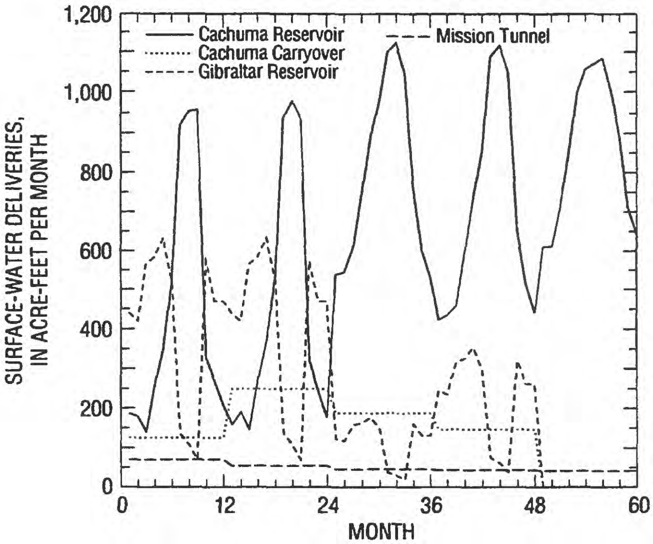

Figure 44. Optimal surface-water deliveries from all sources for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

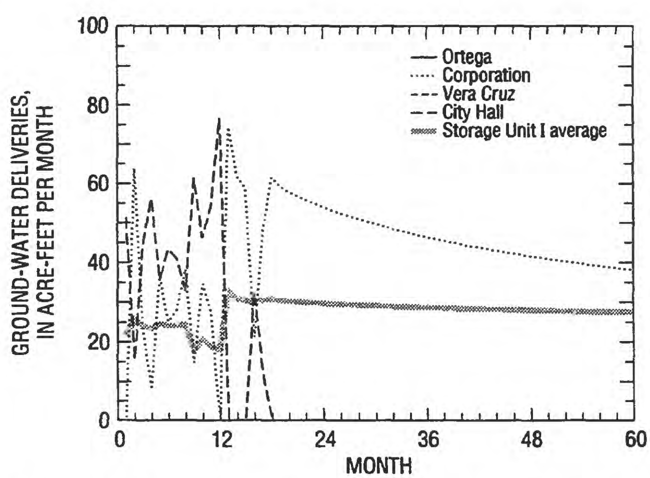

Figure 45. Optimal ground-water deliveries from coastal Storage Unit I for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Ortega and Vera Cruz wells.)

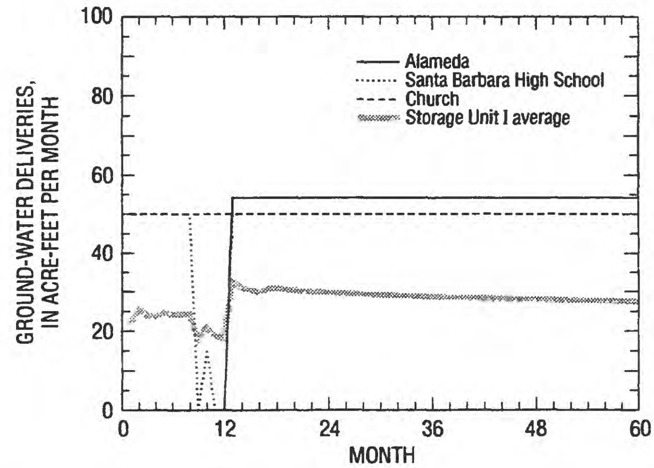

Figure 46. Optimal ground-water deliveries from inland Storage Unit I wells for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

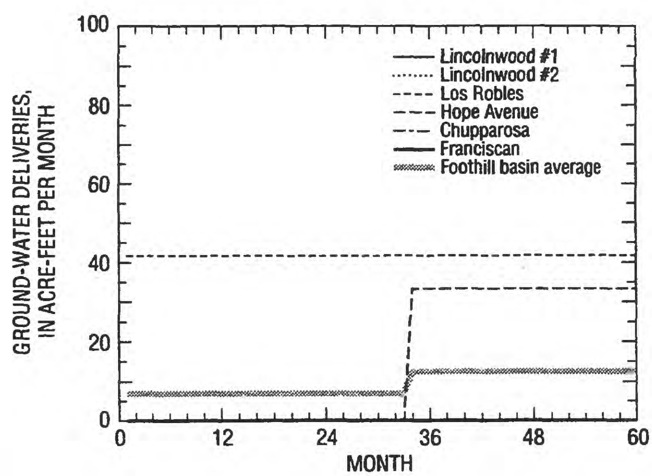

Figure 47. Optimal ground-water deliveries from the Foothill basin wells for the variable Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Lincolnwood #1, #2, Chupparosa, and Franciscan wells.)

wells is greater in this scenario than in the base case (2,870 acre-ft in the base case and 3,166 acre-ft in this scenario). Considering the inland Storage Unit I wells, pumping is variable in the first year and becomes continuous for years 2 to 5 (fig. 46). The total volume of water pumped from these wells (8,413 acre-ft) is greater than in the base case (5,113 acre-ft). Considering the Foothill basin wells, water is pumped from the Los Robles and the Hope Avenue wells only, and these wells are pumped more nearly continuously than in the base case. The total volume of water pumped from these wells (3,400 acre-ft) is less than in the base case (5,182 acre-ft).

Proposed Monthly Gibraltar Reservoir Diversion Distribution

In this scenario, the monthly deliveries from the Cachuma Reservoir are allowed to vary, and the pro-

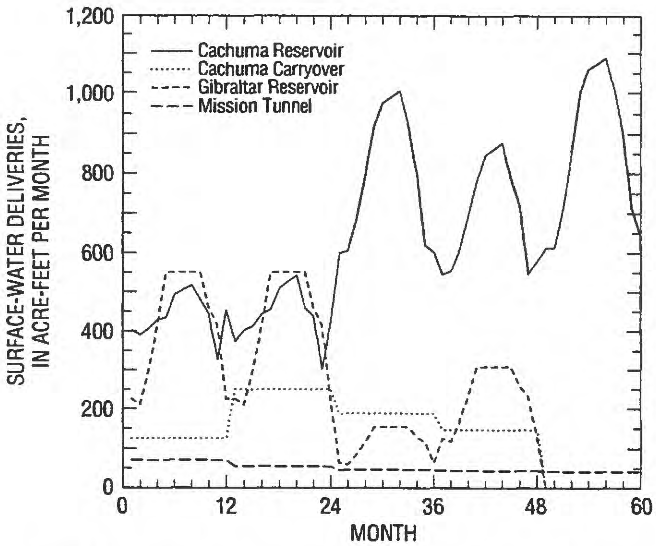

Figure 48. Optimal surface-water deliveries from all sources for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

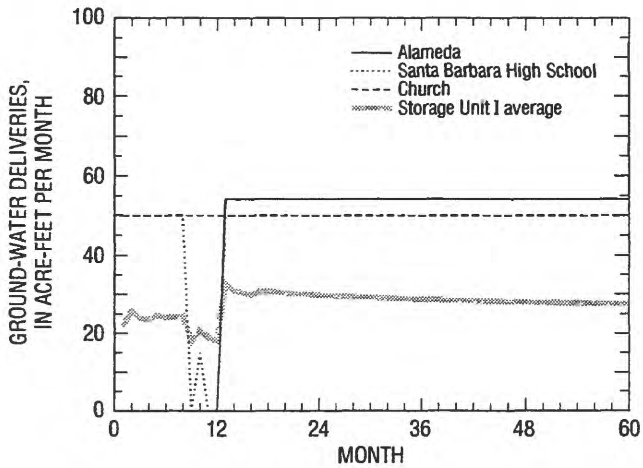

Figure 50. Optimal ground-water deliveries from inland Storage Unit I for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California.

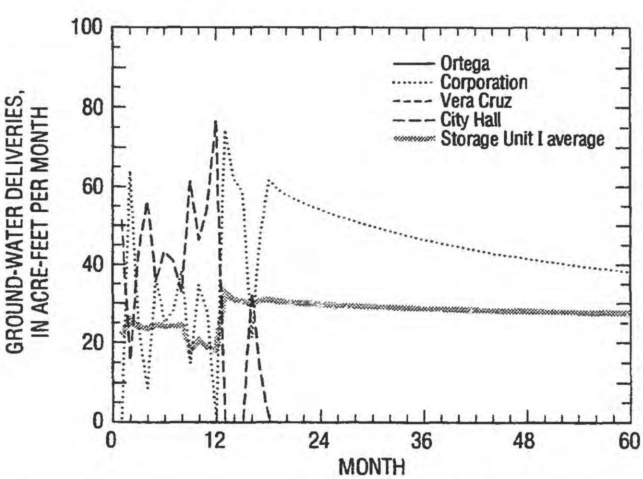

Figure 49. Optimal ground-water deliveries from coastal Storage Unit I for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Ortega and Vera Cruz wells.)

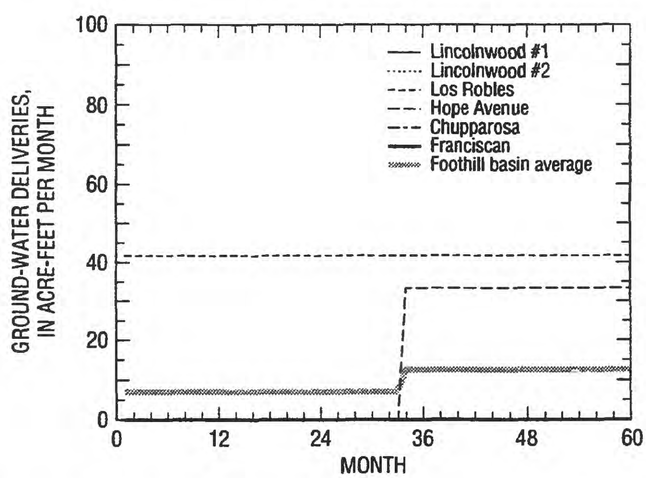

Figure 51. Optimal ground-water deliveries from the Foothill basin wells for the variable Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages simulation, months 1–60, Santa Barbara, California (Note: No pumping from the Ortega and Vera Cruz wells.)

posed monthly diversion percentages of Gibraltar Reservoir water are used (fig. 4). The results for this scenario are shown in figures 48 to 51, and (the optimal surface-water deliveries only) in Appendix table A31. The cost of delivering water over the 5-year design period is $4.53 million, which is equal to the cost of the previous scenario and more than 18 percent less than the cost in the base case ($5.56 million).

The total volume of delivered Cachuma Reservoir water is equal to the volume in the previous scenario and approximately equal to that in the base case; however, there is less variability in the first 2 years because of the distribution of the Gibraltar Reservoir deliveries. In the last 3 years, the deliveries increase in variability but the variability is not as great as in the previous scenario (see fig. 44).

The optimal pumping patterns for this scenario are shown in figures 49 to 51. Note that the pumping patterns for the Storage Unit I and Foothill basin wells are the same in this scenario as in the previous scenario. This would indicate that if the Cachuma Reservoir deliveries are allowed to vary with demand and with the Gibraltar Reservoir deliveries, then this variability will compensate for the Gibraltar Reservoir delivery schedules and result in an alternative delivery schedule for surface water and ground water that is lower in cost than in the base case. In fact, this cost ($4.53 million) is less than the cost from the reduced-demand sensitivity analysis of the base case ($4.87 million).

SUMMARY

A simulation-optimization model for the management of water resources by the city of Santa Barbara under drought conditions has been developed. Santa Barbara is concerned with the cost of water supply sufficient to meet its water demands during a drought and to control seawater intrusion. The objective of the model is to minimize the cost of water supply over a 5-year planning horizon subject to capacity constraints, head constraints for controlling seawater intrusion, and demand constraints. The problem is formulated as a linear programming problem with monthly management periods and a total planning horizon of 5 years. The decision variables are surface-water deliveries from the Gibraltar Reservoir, the Cachuma Reservoir, the Cachuma Reservoir cumulative annual carryover, the Mission Tunnel, and the State Water Project; desalinated seawater; and ground-water deliveries from 13 production wells. The state variables are the hydraulic heads.

The simulation model is based on MODFLOW, a finite-difference ground-water flow model. Using MODFLOW introduces two potential limitations: (1) seawater intrusion is not addressed explicitly and (2) drain nodes are nonlinear functions of head. The first limitation requires that a density-dependent flow and transport model be used to test whether the optimal solutions resulting from the simulation-optimization model control seawater intrusion; this limitation is not addressed in this report. The second limitation requires an iterative solution scheme to ascertain the extent to which the optimal solution is affected by the nonlinearities in the hydraulic system.

The base-case results indicate that all constraints can be satisfied optimally at a minimum cost of about $5.56 million over 5 years. The most expensive water source (desalinated water) has a low utilization, and the high startup costs of the plant (which are not incorporated in the model) may prevent the desalination plant from being cost effective. Base-case results further indicate that Santa Barbara's water resources can be managed such that desalination-plant water may not be required to meet water demands. The maximum capacity of the cheapest water (reservoir water) is used in all optimal-simulation results. The inland wells are pumped almost continuously and the coastal wells are pumped intermittently.

The iterative solutions converged in two iterations with little change in objective value (0.8 percent) and water deliveries. These results indicate that the nonlinearities are not significant to the problem solution.

Sensitivity analyses showed the effects of several system variables on the cost of delivering water over the 5-year management horizon. Specifically, the analyses showed that:

- If the allowable Cachuma Reservoir carryover is decreased by about 50 percent, then costs increase by about 14 percent.
- If the peak demand is decreased by 7 percent, then costs will decrease by about 14 percent.
- If the head constraints are loosened to –30 ft, then the costs decrease by about 18 percent.
- If the heads are constrained such that a zero hydraulic gradient condition occurs at the ocean bound-

ary, then the optimization problem does not have a solution.

- If the capacity of the desalination plant is set equal to zero, then the cost increases by about \$0.1 million.
- If SWP carryover is incorporated into the optimization model, then desalinated water is not required and the total cost of water supply is \$5.53 million.

It was assumed for the base case that the average monthly capacities of the Cachuma and the Gibraltar Reservoirs are used. In addition, four other scenarios were tested: average monthly Cachuma Reservoir deliveries with the actual (scenario 1) and proposed (scenario 2) monthly distributions of Gibraltar Reservoir water, and variable monthly Cachuma Reservoir deliveries with the actual (scenario 3) and proposed (scenario 4) monthly distributions of Gibraltar Reservoir water. The actual distribution of Gibraltar Reservoir water was characterized by low water availability in the summer and the proposed distribution was characterized by peak water availability in the summer. Using average monthly Cachuma Reservoir deliveries with the actual monthly distributions resulted in a higher objective value (36 percent greater than in the base case), which was caused primarily by the large volume of desalinated water. Implementing SWP carryover had little effect, and constraining the desalination-plant capacity to zero was infeasible. Using average monthly Cachuma Reservoir deliveries with the proposed monthly distributions resulted in an objective value that was 9 percent lower than in the base case. This scenario was not sensitive to choice of SWP carryover or desalinated-plant capacity.

When the delivery schedule for Cachuma Reservoir water was allowed to vary on a monthly basis, the total cost of water delivery over the 5-year management period was 18 percent less than in the base case regardless of the delivery schedule of Gibraltar Reservoir water. In both scenarios, SWP and desalinated water were not required and pumping was fairly continuous over time.

In this study, a 5-year design drought was assumed; however, the duration and the return period of droughts are uncertain. These uncertainties can affect the optimal water-delivery policies and the extent of seawater intrusion. To address drought uncertainty, within the context of the simulation-optimization model, stochastic hydrology methods are needed. In addition, the zero-hydraulic-gradient sensitivity analysis was infeasible—suggesting that an optimal solution at the end of the management period may be reached by "ramping" up the coastal head constraint over time to a zero-hydraulic-gradient condition.

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APPENDIX:
Tables A1–A31

Table A1. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Base case

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	380.705	439.749	70.575	0.000	0.000
2	380.705	439.749	70.575	.000	.000
3	416.687	439.749	70.575	.000	.000
4	416.687	439.749	70.575	.000	.000
5	416.687	439.749	70.575	.000	.000
6	416.687	439.749	70.575	22.152	.000
7	416.687	439.749	70.575	58.977	.000
8	416.687	439.749	70.575	69.374	.000
9	416.687	439.749	70.575	.000	.000
10	416.687	439.749	70.575	.000	.000
11	416.687	439.749	70.575	.000	.000
12	407.691	439.749	70.575	.000	.000
13	416.687	439.749	54.637	.000	.000
14	416.687	439.749	54.637	.000	.000
15	416.687	439.749	54.637	.000	.000
16	416.687	439.749	54.637	.000	.000
17	416.687	439.749	54.637	3.954	.000
18	416.687	439.749	54.637	104.120	.000
19	416.687	439.749	54.637	127.179	.000
20	416.687	439.749	54.637	131.667	.000
21	416.687	439.749	54.637	54.752	.000
22	416.687	439.749	54.637	.000	.000
23	416.687	439.749	54.637	.000	.000
24	416.687	439.749	54.637	.000	.000
25	116.397	762.567	45.822	.000	.000
26	116.397	762.567	45.822	.000	.000
27	116.397	762.567	45.822	.000	.000
28	116.397	762.567	45.822	.000	.000
29	116.397	762.567	45.822	58.152	.000
30	116.397	762.567	45.822	125.030	.000
31	116.397	762.567	45.822	125.030	.000

Table A1. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Base case—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	116.397	762.567	45.822	125.030	11.893
33	116.397	762.567	45.822	90.508	.000
34	116.397	762.567	45.822	.000	.000
35	116.397	762.567	45.822	.000	.000
36	116.397	762.567	45.822	.000	.000
37	233.277	701.905	43.890	.000	.000
38	233.277	701.905	43.890	.000	.000
39	233.277	701.905	43.890	.000	.000
40	233.277	701.905	43.890	.000	.000
41	233.277	701.905	43.890	37.600	.000
42	233.277	701.905	43.890	125.030	.000
43	233.277	701.905	43.890	125.030	.000
44	233.277	701.905	43.890	125.030	11.177
45	233.277	701.905	43.890	83.673	.000
46	233.277	701.905	43.890	.000	.000
47	233.277	701.905	43.890	.000	.000
48	233.277	701.905	43.890	.000	.000
49	.000	882.335	41.657	.000	.000
50	.000	882.335	41.657	.000	.000
51	.000	884.780	41.657	.000	.000
52	.000	884.780	41.657	.000	.000
53	.000	884.780	41.657	.000	.000
54	.000	884.780	41.657	74.982	.000
55	.000	884.780	41.657	74.982	.000
56	.000	884.780	41.657	74.982	16.084
57	.000	884.780	41.657	43.866	.000
58	.000	884.780	41.657	.000	.000
59	.000	884.780	41.657	.000	.000
60	.000	884.780	41.657	.000	.000
Total............	14,115.615	38,740.107	3,078.967	1,861.100	39.154

Table A2. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Base case

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	43.113	.000	.000	49.988
5	.000	.000	.000	71.192	54.154	49.999	49.988
6	91.645	11.368	.000	.000	54.154	49.999	49.988
7	79.710	.000	.000	.000	54.154	49.999	49.988
8	82.777	.000	.000	.000	54.154	49.999	49.988
9	42.706	28.486	.000	.000	54.154	49.999	49.988
10	.000	.000	.000	66.856	.483	.000	49.988
11	.000	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	54.154	30.089	49.988
17	91.645	38.501	.000	.000	54.154	49.999	49.988
18	86.005	.000	.000	.000	54.154	49.999	49.988
19	76.952	.000	.000	.000	54.154	49.999	49.988
20	86.316	.154	.000	.000	54.154	49.999	49.988
21	71.897	7.451	.000	.000	54.154	49.999	49.988
22	.000	68.788	.000	.000	54.154	3.320	49.988
23	.000	.000	.000	35.909	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000	.000
27	.000	.000	.000	.000	.000	.000	17.040
28	.000	.000	.000	57.912	54.154	.000	49.988
29	34.261	75.002	.000	.000	54.154	49.999	49.988
30	79.096	.000	.000	.000	54.154	49.999	49.988
31	81.542	.000	.000	.000	54.154	49.999	49.988

Table A2. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Base case—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	84.138	0.000	0.000	0.000	54.154	49.999	49.988
33	63.234	13.673	.000	.000	54.154	49.999	49.988
34	.000	59.816	.000	.000	54.154	41.563	49.988
35	.000	.000	.000	58.721	.000	.000	.000
36	.000	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000	.000
39	.000	.000	.000	.000	.000	.000	40.959
40	.000	.000	.000	.000	54.154	45.100	49.988
41	91.645	30.853	.000	.000	54.154	49.999	49.988
42	87.990	.000	.000	.000	54.154	49.999	49.988
43	76.761	.000	.000	.000	54.154	49.999	49.988
44	80.556	.000	.000	.000	54.154	49.999	49.988
45	76.425	.000	.000	.000	54.154	49.999	49.988
46	.000	59.776	.000	.000	54.154	49.999	49.988
47	.000	.000	.000	72.096	.000	.000	2.188
48	.000	.000	.000	.000	.000	.000	.000
49	.000	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	.000	.000	20.545
52	.000	.000	.000	.000	54.154	14.725	49.988
53	61.421	57.315	.000	.000	54.154	49.999	49.988
54	81.409	.000	.000	.000	54.154	49.999	49.988
55	80.435	.000	.000	.000	54.154	49.999	49.988
56	78.358	.000	.000	.000	54.154	49.999	49.988
57	74.870	.000	.000	.000	54.154	49.999	49.988
58	.000	60.530	.000	.000	54.154	49.999	49.988
59	.000	75.002	.000	10.586	.000	.000	9.951
60	.000	0.000	.000	25.568	.000	.000	.000
Total............	1,841.793	586.716	.000	441.952	1,787.551	1,484.764	1,840.261

Table A3. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Base case

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	41.669	16.832	.000	.000
4	.000	.000	41.669	33.325	4.556	20.840
5	.000	.000	41.669	33.325	20.840	20.840
6	.000	.000	41.669	33.325	20.840	20.840
7	.000	.000	41.669	33.325	20.840	20.840
8	.000	.000	41.669	33.325	20.840	20.840
9	.000	.000	41.669	33.325	20.840	20.840
10	.000	.000	41.669	33.325	20.840	20.840
11	.000	.000	41.669	16.832	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	12.920	.000	.000	.000
14	.000	.000	12.920	.000	.000	.000
15	.000	.000	41.669	33.325	15.069	20.840
16	.000	.000	41.669	33.325	20.840	20.840
17	.000	.000	41.669	33.325	20.840	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	.000	.000	41.669	33.325	20.840	20.840
20	.000	.000	41.669	33.325	20.840	20.840
21	.000	.000	41.669	33.325	20.840	20.840
22	.000	.000	41.669	33.325	20.840	20.840
23	.000	.000	41.669	33.325	.000	.000
24	.000	.000	40.932	.000	.000	.000
25	.000	.000	32.229	.000	.000	.000
26	.000	.000	32.229	.000	.000	.000
27	.000	.000	41.669	33.325	20.840	20.840
28	.000	.000	41.669	33.325	20.840	20.840
29	.000	.000	41.669	33.325	20.840	20.840
30	16.675	4.571	41.669	33.325	20.840	20.840
31	16.675	16.675	41.669	33.325	20.840	20.840

Table A3. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Base case—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	16.675	16.675	41.669	33.325	20.840	20.840
33	.000	.000	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	20.840	20.840
35	.000	.000	41.669	33.325	.000	.000
36	.000	.000	41.669	19.539	.000	.000
37	.000	.000	10.906	.000	.000	.000
38	.000	.000	10.906	.000	.000	.000
39	.000	.000	41.669	33.325	.000	.000
40	.000	.000	41.669	33.325	20.840	20.840
41	.000	.000	41.669	33.325	20.840	20.840
42	7.087	.000	41.669	33.325	20.840	20.840
43	16.675	16.675	41.669	33.325	20.840	20.840
44	16.675	16.675	41.669	33.325	20.840	20.840
45	.000	.000	41.669	33.325	20.840	20.840
46	.000	.000	41.669	33.325	1.203	20.840
47	.000	.000	41.669	.000	.000	.000
48	.000	.000	40.911	.000	.000	.000
49	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000
51	.000	.000	41.669	33.325	.000	.000
52	.000	.000	41.669	33.325	20.840	20.840
53	.000	.000	41.669	33.325	20.840	20.840
54	16.675	1.695	41.669	33.325	20.840	20.840
55	16.675	16.675	41.669	33.325	20.840	20.840
56	16.675	16.675	41.669	33.325	20.840	20.840
57	.000	.000	41.669	33.325	20.840	20.840
58	.000	.000	41.669	21.221	.000	.000
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	140.485	106.315	2,069.043	1,407.435	708.561	750.254

Table A4. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Cachuma Reservoir carryover sensitivity

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	255.735	564.719	70.575	0.000	0.000
2	255.735	564.719	70.575	.000	.000
3	350.217	564.719	70.575	.000	.000
4	416.687	564.719	70.575	.000	.000
5	416.687	564.719	70.575	.000	.000
6	416.687	564.719	70.575	.000	.000
7	416.687	564.719	70.575	.000	.000
8	416.687	564.719	70.575	.000	.000
9	416.687	564.719	70.575	.000	.000
10	416.687	564.719	70.575	.000	.000
11	350.217	564.719	70.575	.000	.000
12	282.722	564.719	70.575	.000	.000
13	304.637	564.719	54.637	.000	.000
14	304.637	564.719	54.637	.000	.000
15	402.620	564.719	54.637	.000	.000
16	416.687	564.719	54.637	.000	.000
17	416.687	564.719	54.637	.000	.000
18	416.687	564.719	54.637	.000	.000
19	416.687	564.719	54.637	.000	.000
20	416.687	564.719	54.637	4.862	.000
21	416.687	564.719	54.637	.000	.000
22	416.687	564.719	54.637	.000	.000
23	402.620	564.719	54.637	.000	.000
24	332.649	564.719	54.637	.000	.000
25	116.397	684.495	45.822	.000	.000
26	116.397	684.495	45.822	.000	.000
27	116.397	684.495	45.822	.000	.000
28	116.397	684.495	45.822	.000	.000
29	116.397	684.495	45.822	125.030	.000
30	116.397	684.495	45.822	125.030	57.739
31	116.397	684.495	45.822	125.030	75.447

Table A4. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Cachuma Reservoir carryover sensitivity—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	116.397	684.495	45.822	125.030	90.322
33	116.397	684.495	45.822	125.030	3.239
34	116.397	684.495	45.822	45.968	.000
35	116.397	684.495	45.822	.000	.000
36	116.397	684.495	45.822	.000	.000
37	233.277	620.495	43.890	.000	.000
38	233.277	620.495	43.890	.000	.000
39	233.277	620.495	43.890	.000	.000
40	233.277	620.495	43.890	.000	.000
41	233.277	620.495	43.890	125.030	.000
42	233.277	620.495	43.890	125.030	51.494
43	233.277	620.495	43.890	125.030	76.142
44	233.277	620.495	43.890	125.030	90.349
45	233.277	620.495	43.890	125.030	4.109
46	233.277	620.495	43.890	50.655	.000
47	233.277	620.495	43.890	.000	.000
48	233.277	620.495	43.890	.000	.000
49	.000	794.323	41.657	.000	.000
50	.000	794.323	41.657	.000	.000
51	.000	794.323	41.657	.000	.000
52	.000	794.323	41.657	.000	.000
53	.000	794.323	41.657	74.982	.000
54	.000	794.323	41.657	74.982	70.751
55	.000	794.323	41.657	74.982	91.603
56	.000	794.323	41.657	74.982	108.956
57	.000	794.323	41.657	74.982	27.388
58	.000	794.323	41.657	25.782	.000
59	.000	794.323	41.657	.000	.000
60	.000	794.323	41.657	.000	.000
Total............	13,271.494	38,744.998	3,078.967	1,752.479	747.540

Table A5. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Cachuma Reservoir carryover sensitivity

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	26.853	.000	.000	.000
5	.000	8.742	.000	83.313	.000	.000	49.988
6	.000	.000	.000	81.035	54.154	.000	49.988
7	.000	.000	.000	66.213	54.154	.000	49.988
8	.000	49.367	.000	27.812	54.154	.000	49.988
9	.000	.000	.000	71.097	20.958	.000	49.988
10	.000	.000	.000	67.363	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	50.942	.000	.000	.000
17	.000	12.096	.000	83.313	17.873	.000	49.988
18	.000	.000	.000	65.155	54.154	49.999	49.988
19	41.102	38.059	.000	.000	54.154	49.999	49.988
20	88.305	.000	.000	.000	54.154	49.999	49.988
21	.000	9.233	.000	49.895	54.154	.000	49.988
22	.000	.000	.000	78.947	.000	.000	14.014
23	.000	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	35.307	.000	.000	.000
26	.000	.000	.000	35.307	.000	.000	.000
27	.000	.000	.000	45.124	.000	.000	49.988
28	.000	2.671	.000	83.313	54.154	49.999	49.988
29	87.108	.000	.000	.000	54.154	49.999	49.988
30	87.326	.000	.000	.000	54.154	49.999	49.988
31	84.167	.000	.000	.000	54.154	49.999	49.988

Table A5. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Cachuma Reservoir carryover sensitivity—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	83.782	0.000	0.000	0.000	54.154	49.999	49.988
33	83.868	.000	.000	.000	54.154	49.999	49.988
34	83.485	.000	.000	.000	54.154	49.999	49.988
35	.000	.000	.000	68.732	.000	.000	26.380
36	.000	.000	.000	48.129	.000	.000	.000
37	.000	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000	.000
39	.000	.000	.000	30.701	.000	.000	49.988
40	.000	.000	.000	76.513	54.154	49.999	49.988
41	83.129	.000	.000	.000	54.154	49.999	49.988
42	91.645	.000	.000	.000	54.154	49.999	49.988
43	82.029	.000	.000	.000	54.154	49.999	49.988
44	82.795	.000	.000	.000	54.154	49.999	49.988
45	79.020	.000	.000	.000	54.154	49.999	49.988
46	39.688	31.207	.000	.000	54.154	49.999	49.988
47	.000	.000	.000	67.033	.000	.000	49.988
48	.000	.000	.000	.000	.000	.000	47.327
49	.000	.000	.000	.000	.000	.000	13.019
50	.000	.000	.000	.000	.000	.000	13.019
51	.000	.000	.000	.000	19.333	.000	49.988
52	.000	.000	.000	55.184	54.154	49.999	49.988
53	91.645	.000	.000	9.216	54.154	49.999	49.988
54	86.135	.000	.000	.000	54.154	49.999	49.988
55	79.289	.000	.000	.000	54.154	49.999	49.988
56	75.942	.000	.000	.000	54.154	49.999	49.988
57	73.473	.000	.000	.000	54.154	49.999	49.988
58	71.420	.000	.000	.000	54.154	49.999	49.988
59	.000	65.514	.000	.000	20.495	49.999	49.988
60	.000	75.002	.000	9.847	.000	.000	31.175
Total............	1,575.353	291.892	.000	1,316.345	1,594.960	1,249.968	1,944.499

Table A6. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Cachuma Reservoir carryover sensitivity

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	41.669	.000	.000	.000
5	.000	.000	41.669	33.325	.000	.000
6	.000	.000	41.669	33.325	.000	10.839
7	.000	.000	41.669	33.325	18.344	20.840
8	.000	.000	41.669	33.325	20.840	20.840
9	.000	.000	41.669	33.325	.000	.000
10	.000	.000	41.669	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000
16	.000	.000	41.669	33.325	.000	.000
17	.000	.000	41.669	33.325	20.840	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	.000	.000	41.669	33.325	20.840	20.840
20	.000	.000	41.669	33.325	20.840	20.840
21	.000	.000	41.669	33.325	20.840	20.840
22	.000	.000	41.669	33.325	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000
25	.000	.000	41.669	33.325	.000	.000
26	.000	.000	41.669	33.325	.000	.000
27	.000	.000	41.669	33.325	20.840	20.840
28	.000	.000	41.669	33.325	20.840	20.840
29	16.675	16.675	41.669	33.325	20.840	20.840
30	16.675	16.675	41.669	33.325	20.840	20.840
31	16.675	16.6751	41.669	33.325	20.840	20.840

Table A6. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Cachuma Reservoir carryover sensitivity—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	16.675	16.675	41.669	33.325	20.840	20.840
33	16.675	16.675	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	20.840	20.840
35	.000	.000	41.669	33.325	20.840	20.840
36	.000	.000	41.669	33.325	.000	16.157
37	.000	.000	41.669	33.325	.000	17.323
38	.000	.000	41.669	33.325	.000	17.323
39	.000	.000	41.669	33.325	20.840	20.840
40	.000	.000	41.669	33.325	20.840	20.840
41	16.675	16.675	41.669	33.325	20.840	20.840
42	16.675	16.675	41.669	33.325	20.840	20.840
43	16.675	16.675	41.669	33.325	20.840	20.840
44	16.675	16.675	41.669	33.325	20.840	20.840
45	16.675	16.675	41.669	33.325	20.840	20.840
46	.000	.000	41.669	33.325	20.840	20.840
47	.000	.000	41.669	33.325	.000	5.348
48	.000	.000	41.669	33.325	.000	.000
49	.000	.000	41.669	33.325	.000	.000
50	.000	.000	41.669	33.325	.000	.000
51	.000	.000	41.669	33.325	20.840	20.840
52	.000	.000	41.669	33.325	20.840	20.840
53	16.675	16.675	41.669	33.325	20.840	20.840
54	16.675	16.675	41.669	33.325	20.840	20.840
55	16.675	16.675	41.669	33.325	20.840	20.840
56	16.675	16.675	41.669	33.325	20.840	20.840
57	16.675	16.675	41.669	33.325	20.840	20.840
58	.000	.000	41.669	33.325	20.840	20.840
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	250.121	250.121	2,000.097	1,532.963	664.396	733.882

Table A7. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Reduced-demand sensitivity

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	380.705	439.749	70.575	0.000	0.000
2	380.705	439.749	70.575	.000	.000
3	416.687	439.749	70.575	.000	.000
4	416.687	439.749	70.575	.000	.000
5	416.687	439.749	70.575	.000	.000
6	416.687	439.749	70.575	23.922	.000
7	416.687	439.749	70.575	58.518	.000
8	416.687	439.749	70.575	69.458	.000
9	416.687	439.749	70.575	.000	.000
10	416.687	439.749	70.575	.000	.000
11	416.687	439.749	70.575	.000	.000
12	407.691	439.749	70.575	.000	.000
13	416.687	430.693	54.637	.000	.000
14	416.687	430.693	54.637	.000	.000
15	416.687	458.042	54.637	.000	.000
16	416.687	458.042	54.637	.000	.000
17	416.687	458.042	54.637	.000	.000
18	416.687	458.042	54.637	39.365	.000
19	416.687	458.042	54.637	73.888	.000
20	416.687	458.042	54.637	82.717	.000
21	416.687	458.042	54.637	3.516	.000
22	416.687	458.042	54.637	.000	.000
23	416.687	458.042	54.637	.000	.000
24	416.687	458.042	54.637	.000	.000
25	116.397	750.845	45.822	.000	.000
26	116.397	750.845	45.822	.000	.000
27	116.397	778.844	45.822	.000	.000
28	116.397	778.844	45.822	.000	.000
29	116.397	778.844	45.822	.000	.000
30	116.397	778.844	45.822	45.979	.000
31	116.397	778.844	45.822	78.511	.000

Table A7. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Reduced-demand sensitivity—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	116.397	778.844	45.822	87.496	0.000
33	116.397	778.844	45.822	8.050	.000
34	116.397	778.844	45.822	.000	.000
35	116.397	778.844	45.822	.000	.000
36	116.397	778.496	45.822	.000	.000
37	233.277	646.824	43.890	.000	.000
38	233.277	646.824	43.890	.000	.000
39	233.277	680.894	43.890	.000	.000
40	233.277	680.894	43.890	.000	.000
41	233.277	680.894	43.890	.000	.000
42	233.277	680.894	43.890	45.842	.000
43	233.277	680.894	43.890	77.527	.000
44	233.277	680.894	43.890	87.442	.000
45	233.277	680.894	43.890	7.981	.000
46	233.277	680.894	43.890	.000	.000
47	233.277	680.894	43.890	.000	.000
48	233.277	674.837	43.890	.000	.000
49	.000	849.372	41.657	.000	.000
50	.000	849.372	41.657	.000	.000
51	.000	871.221	41.657	.000	.000
52	.000	871.221	41.657	.000	.000
53	.000	871.221	41.657	.000	.000
54	.000	871.221	41.657	42.199	.000
55	.000	871.221	41.657	73.289	.000
56	.000	871.221	41.657	74.982	.000
57	.000	871.221	41.657	8.316	.000
58	.000	871.221	41.657	.000	.000
59	.000	871.221	41.657	.000	.000
60	.000	871.221	41.657	.000	.000
Total............	14,115.615	38,516.060	3,078.967	988.997	.000

Table A8. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Reduced-demand sensitivity

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	16.832	.000	.000	.000
4	.000	.000	.000	36.619	31.891	.000	49.988
5	.000	.000	.000	71.192	54.154	49.999	49.988
6	91.645	9.598	.000	.000	54.154	49.999	49.988
7	80.170	.000	.000	.000	54.154	49.999	49.988
8	82.693	.000	.000	.000	54.154	49.999	49.988
9	43.037	28.155	.000	.000	54.154	49.999	49.988
10	.000	.000	.000	58.600	50.420	.000	49.988
11	.000	.000	.000	58.500	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	26.672	.000	.000	.000
16	.000	.000	.000	.000	54.154	.000	49.988
17	.000	1.221	.000	83.313	54.154	49.999	49.988
18	91.645	8.161	.000	.000	54.154	49.999	49.988
19	78.987	.000	.000	.000	54.154	49.999	49.988
20	83.802	.000	.000	.000	54.154	49.999	49.988
21	81.018	.000	.000	.000	54.154	49.999	49.988
22	.000	51.973	.000	14.907	54.154	.000	49.988
23	.000	.000	.000	68.341	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000	.000
27	.000	.000	.000	27.169	.000	.000	.000
28	.000	.000	.000	.000	54.154	.000	49.988
29	.000	5.220	.000	83.313	54.154	49.999	49.988
30	91.645	6.210	.000	.000	54.154	49.999	49.988
31	79.148	.000	.000	.000	54.154	49.999	49.988

Table A8. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Reduced-demand sensitivity—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	84.048	0.000	0.000	0.000	54.154	49.999	49.988
33	80.482	.000	.000	.000	54.154	49.999	49.988
34	.000	66.375	.000	3.175	54.154	.000	49.988
35	.000	.000	.000	68.838	.000	.000	.000
36	.000	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000	.000
39	.000	.000	.000	.000	.000	.000	22.245
40	.000	.000	.000	.000	54.154	19.597	49.988
41	.000	3.797	.000	83.313	54.154	49.999	49.988
42	91.645	5.648	.000	.000	54.154	49.999	49.988
43	79.614	.000	.000	.000	54.154	49.999	49.988
44	83.705	.000	.000	.000	54.154	49.999	49.988
45	79.129	.000	.000	.000	54.154	49.999	49.988
46	.000	61.124	.000	.000	54.154	39.001	49.988
47	.000	.000	.000	63.914	.000	.000	.000
48	.000	.000	.000	.000	.000	.000	.000
49	.000	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	.000	.000	30.965
52	.000	.000	.000	.000	54.154	28.489	49.988
53	.000	7.279	.000	78.046	54.154	49.999	49.988
54	91.645	5.454	.000	.000	54.154	49.999	49.988
55	79.532	.000	.000	.000	54.154	49.999	49.988
56	81.348	.000	.000	.000	54.154	49.999	49.988
57	77.009	.000	.000	.000	54.154	49.999	49.988
58	.000	59.387	.000	.000	54.154	49.999	49.988
59	.000	.000	.000	72.633	.000	.000	.000
60	.000	.000	.000	5.138	.000	.000	.000
Total............	1,631.945	319.601	.000	920.517	1,869.379	1,387.054	1,802.787

Table A9. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Reduced-demand sensitivity

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	41.669	.000	.000	.000
4	.000	.000	41.669	33.325	.000	.000
5	.000	.000	41.669	33.325	20.840	20.840
6	.000	.000	41.669	33.325	20.840	20.840
7	.000	.000	41.669	33.325	20.840	20.840
8	.000	.000	41.669	33.325	20.840	20.840
9	.000	.000	41.669	33.325	20.840	20.840
10	.000	.000	41.669	33.325	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	41.669	.000	.000	.000
16	.000	.000	41.669	33.325	5.047	20.840
17	.000	.000	41.669	33.325	20.840	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	.000	.000	41.669	33.325	20.840	20.840
20	.000	.000	41.669	33.325	20.840	20.840
21	.000	.000	41.669	33.325	20.840	20.840
22	.000	.000	41.669	33.325	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000
27	.000	.000	41.669	.000	.000	.000
28	.000	.000	41.669	33.325	7.174	20.840
29	.000	.000	41.669	33.325	20.840	20.840
30	.000	.000	41.669	33.325	20.840	20.840
31	.000	.000	41.669	33.325	20.840	20.840

Table A9. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Reduced-demand sensitivity—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	0.000	0.000	41.669	33.325	20.840	20.840
33	.000	.000	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	.000	.000
35	.000	.000	.000	.000	.000	.000
36	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000
39	.000	.000	41.669	.000	.000	.000
40	.000	.000	41.669	33.325	.000	5.183
41	.000	.000	41.669	33.325	20.840	20.840
42	.000	.000	41.669	33.325	20.840	20.840
43	.000	.000	41.669	33.325	20.840	20.840
44	.000	.000	41.669	33.325	20.840	20.840
45	.000	.000	41.669	33.325	20.840	20.840
46	.000	.000	41.669	.000	.000	.000
47	.000	.000	.000	.000	.000	.000
48	.000	.000	.000	.000	.000	.000
49	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000
51	.000	.000	41.669	.000	.000	.000
52	.000	.000	41.669	33.325	.000	.000
53	.000	.000	41.669	33.325	20.840	20.840
54	.000	.000	41.669	33.325	20.840	20.840
55	.000	.000	41.669	33.325	20.840	20.840
56	.000	9.954	41.669	33.325	20.840	20.840
57	.000	.000	41.669	33.325	20.840	20.840
58	.000	.000	34.607	.000	.000	.000
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	.000	9.954	1,659.686	1,099.735	533.231	567.874

Table A10. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: 30 feet below sea level coastal head-constraint sensitivity

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	380.705	439.749	70.575	0.000	0.000
2	380.705	439.749	70.575	.000	.000
3	416.687	439.749	70.575	.000	.000
4	416.687	439.749	70.575	.000	.000
5	416.687	439.749	70.575	.000	.000
6	416.687	439.749	70.575	.000	.000
7	416.687	439.749	70.575	.000	.000
8	416.687	439.749	70.575	.000	.000
9	416.687	439.749	70.575	.000	.000
10	416.687	439.749	70.575	.000	.000
11	416.687	439.749	70.575	.000	.000
12	407.691	439.749	70.575	.000	.000
13	416.687	430.693	54.637	.000	.000
14	416.687	430.693	54.637	.000	.000
15	416.687	458.042	54.637	.000	.000
16	416.687	458.042	54.637	.000	.000
17	416.687	458.042	54.637	.000	.000
18	416.687	458.042	54.637	.000	.000
19	416.687	458.042	54.637	.000	.000
20	416.687	458.042	54.637	.000	.000
21	416.687	458.042	54.637	.000	.000
22	416.687	458.042	54.637	.000	.000
23	416.687	458.042	54.637	.000	.000
24	416.687	458.042	54.637	.000	.000
25	116.397	750.845	45.822	.000	.000
26	116.397	750.845	45.822	.000	.000
27	116.397	778.844	45.822	.000	.000
28	116.397	778.844	45.822	.000	.000
29	116.397	778.844	45.822	.000	.000
30	116.397	778.844	45.822	.000	.000
31	116.397	778.844	45.822	.000	.000

Table A10. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: 30 feet below sea level coastal head-constraint sensitivity—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	116.397	778.844	45.822	0.000	0.000
33	116.397	778.844	45.822	.000	.000
34	116.397	778.844	45.822	.000	.000
35	116.397	778.844	45.822	.000	.000
36	116.397	778.496	45.822	.000	.000
37	233.277	646.824	43.890	.000	.000
38	233.277	646.824	43.890	.000	.000
39	233.277	680.894	43.890	.000	.000
40	233.277	680.894	43.890	.000	.000
41	233.277	680.894	43.890	.000	.000
42	233.277	680.894	43.890	.000	.000
43	233.277	680.894	43.890	.000	.000
44	233.277	680.894	43.890	.000	.000
45	233.277	680.894	43.890	.000	.000
46	233.277	680.894	43.890	.000	.000
47	233.277	680.894	43.890	.000	.000
48	233.277	674.837	43.890	.000	.000
49	.000	849.372	41.657	.000	.000
50	.000	849.372	41.657	.000	.000
51	.000	871.221	41.657	.000	.000
52	.000	871.221	41.657	.000	.000
53	.000	871.221	41.657	.000	.000
54	.000	871.221	41.657	.000	.000
55	.000	871.221	41.657	.000	.000
56	.000	871.221	41.657	.000	.000
57	.000	871.221	41.657	.000	.000
58	.000	871.221	41.657	.000	.000
59	.000	871.221	41.657	.000	.000
60	.000	871.221	41.657	.000	.000
Total............	14,115.615	38,516.060	3,078.967	.000	.000

Table A11. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: 30 feet below sea level coastal head-constraint sensitivity

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	58.500	.000	.000	.000
4	.000	75.002	.000	83.313	.000	.000	35.176
5	.000	75.002	.000	83.313	54.154	49.999	49.988
6	.000	75.002	8.529	83.313	54.154	49.999	49.988
7	.000	75.002	22.053	83.313	54.154	49.999	49.988
8	.000	75.002	35.516	83.313	54.154	49.999	49.988
9	.000	75.002	.000	83.313	54.154	49.999	49.988
10	.000	75.002	.000	83.313	.000	25.698	49.988
11	.000	.000	.000	58.500	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	12.920	.000	.000	.000
14	.000	.000	.000	12.920	.000	.000	.000
15	.000	27.590	.000	83.313	.000	.000	.000
16	.000	75.002	.000	83.313	.000	42.602	49.988
17	.000	75.002	17.465	83.313	54.154	49.999	49.988
18	.000	75.002	73.490	83.313	54.154	49.999	49.988
19	31.860	75.002	55.636	83.313	54.154	49.999	49.988
20	78.629	75.002	22.874	83.313	54.154	49.999	49.988
21	.000	75.002	17.465	83.313	54.154	49.999	49.988
22	.000	75.002	.000	83.313	34.622	49.999	49.988
23	.000	27.590	.000	83.313	.000	.000	.000
24	.000	.000	.000	40.932	.000	.000	.000
25	.000	.000	.000	14.155	.000	.000	.000
26	.000	.000	.000	14.155	.000	.000	.000
27	.000	32.327	.000	83.313	.000	.000	.000
28	.000	75.002	.000	83.313	2.351	49.999	49.988
29	.000	75.002	32.706	83.313	54.154	49.999	49.988
30	32.173	75.002	58.490	83.313	54.154	49.999	49.988
31	91.645	75.002	13.568	83.313	54.154	49.999	49.988

Table A11. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: 30 feet below sea level coastal head-constraint sensitivity—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	91.645	75.002	4.426	83.313	54.154	49.999	49.988
33	.000	75.002	32.706	83.313	54.154	49.999	49.988
34	.000	75.002	.000	83.313	45.819	49.999	49.988
35	.000	32.327	.000	83.313	.000	.000	.000
36	.000	.000	.000	43.133	.000	.000	.000
37	.000	.000	.000	3.291	.000	.000	.000
38	.000	.000	.000	3.291	.000	.000	.000
39	.000	25.025	.000	83.313	.000	.000	.000
40	.000	75.002	.000	83.313	.000	49.999	49.988
41	.000	75.002	35.849	83.313	54.154	49.999	49.988
42	56.600	75.002	39.259	83.313	54.154	49.999	49.988
43	91.645	75.002	6.495	83.313	54.154	49.999	49.988
44	89.077	75.002	.000	83.313	54.154	49.999	49.988
45	.000	75.002	35.849	83.313	54.154	49.999	49.988
46	.000	75.002	.000	83.313	45.037	49.999	49.988
47	.000	25.025	.000	83.313	.000	.000	.000
48	.000	.000	.000	33.296	.000	.000	.000
49	.000	.000	.000	23.245	.000	.000	.000
50	.000	.000	.000	23.245	.000	.000	.000
51	.000	37.915	.000	83.313	.000	.000	.000
52	.000	75.002	.000	83.313	2.928	49.999	49.988
53	.000	75.002	27.790	83.313	54.154	49.999	49.988
54	41.962	75.002	41.853	83.313	54.154	49.999	49.988
55	91.645	75.002	2.918	83.313	54.154	49.999	49.988
56	81.422	75.002	.000	83.313	54.154	49.999	49.988
57	.000	75.002	27.790	83.313	54.154	49.999	49.988
58	.000	75.002	.000	83.313	44.947	49.999	49.988
59	.000	37.915	.000	83.313	.000	.000	.000
60	.000	.000	.000	51.257	.000	.000	.000
Total............	778.301	2,870.797	612.724	3,975.309	1,529.545	1,668.258	1,734.766

Table A12. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara California: 30 feet below sea level coastal head-constraint sensitivity

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	.000	.000	.000
5	.000	.000	29.551	.000	.000	.000
6	.000	.000	41.669	33.325	.000	.000
7	.000	.000	41.669	33.325	.000	.000
8	.000	.000	41.669	33.325	.000	.000
9	.000	.000	29.551	.000	.000	.000
10	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000
17	.000	.000	41.669	33.325	.000	.000
18	.000	.000	41.669	33.325	.000	.000
19	.000	.000	41.669	33.325	.000	.000
20	.000	.000	41.669	33.325	.000	.000
21	.000	.000	41.669	33.325	.000	.000
22	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000
27	.000	.000	.000	.000	.000	.000
28	.000	.000	.000	.000	.000	.000
29	.000	.000	41.669	33.325	.000	.000
30	.000	.000	41.669	33.325	.000	.000
31	.000	.000	41.669	33.325	.000	.000

Table A12. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara California: 30 feet below sea level coastal head-constraint sensitivity—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	0.000	0.000	41.669	33.325	2.791	20.840
33	.000	.000	41.669	33.325	.000	.000
34	.000	.000	.000	.000	.000	.000
35	.000	.000	.000	.000	.000	.000
36	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000
39	.000	.000	.000	.000	.000	.000
40	.000	.000	.000	.000	.000	.000
41	.000	.000	41.669	33.325	.000	.000
42	.000	.000	41.669	33.325	.000	.000
43	.000	.000	41.669	33.325	.000	12.751
44	.000	.000	41.669	33.325	15.946	20.840
45	.000	.000	41.669	33.325	.000	.000
46	.000	.000	.000	.000	.000	.000
47	.000	.000	.000	.000	.000	.000
48	.000	.000	.000	.000	.000	.000
49	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	.000	.000
52	.000	.000	.000	.000	.000	.000
53	.000	.000	41.669	33.325	.000	.000
54	.000	.000	41.669	33.325	.000	.000
55	.000	.000	41.669	33.325	3.259	.000
56	.000	.000	41.669	33.325	20.840	9.565
57	.000	.000	41.669	33.325	.000	.000
58	.000	.000	.000	.000	.000	.000
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total.............	.000	.000	1,017.482	766.482	42.836	63.997

Table A13. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Zero desalination capacity sensitivity

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	380.705	439.749	70.575	0.000	0.000
2	380.705	439.749	70.575	.000	.000
3	416.687	439.749	70.575	.000	.000
4	416.687	439.749	70.575	.000	.000
5	416.687	439.749	70.575	.000	.000
6	416.687	439.749	70.575	21.414	.000
7	416.687	439.749	70.575	59.640	.000
8	416.687	439.749	70.575	69.062	.000
9	416.687	439.749	70.575	.000	.000
10	416.687	439.749	70.575	.000	.000
11	416.687	439.749	70.575	.000	.000
12	407.691	439.749	70.575	.000	.000
13	416.687	439.749	54.637	.000	.000
14	416.687	439.749	54.637	.000	.000
15	416.687	439.749	54.637	.000	.000
16	416.687	439.749	54.637	.000	.000
17	416.687	439.749	54.637	14.139	.000
18	416.687	439.749	54.637	108.629	.000
19	416.687	439.749	54.637	124.692	.000
20	416.687	439.749	54.637	131.702	.000
21	416.687	439.749	54.637	52.954	.000
22	416.687	439.749	54.637	.000	.000
23	416.687	439.749	54.637	.000	.000
24	416.687	439.749	54.637	.000	.000
25	116.397	764.441	45.822	.000	.000
26	116.397	764.441	45.822	.000	.000
27	116.397	764.441	45.822	.000	.000
28	116.397	764.441	45.822	.000	.000
29	116.397	764.441	45.822	125.030	.000
30	116.397	764.441	45.822	125.030	.000
31	116.397	764.441	45.822	125.030	.000

Table A13. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Zero desalination capacity sensitivity—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	116.397	764.441	45.822	125.030	0.000
33	116.397	764.441	45.822	84.739	.000
34	116.397	764.441	45.822	.000	.000
35	116.397	764.441	45.822	.000	.000
36	116.397	764.441	45.822	.000	.000
37	233.277	699.197	43.890	.000	.000
38	233.277	699.197	43.890	.000	.000
39	233.277	699.197	43.890	.000	.000
40	233.277	699.197	43.890	.000	.000
41	233.277	699.197	43.890	125.030	.000
42	233.277	699.197	43.890	125.030	.000
43	233.277	699.197	43.890	125.030	.000
44	233.277	699.197	43.890	125.030	.000
45	233.277	699.197	43.890	82.049	.000
46	233.277	699.197	43.890	.000	.000
47	233.277	699.197	43.890	.000	.000
48	233.277	699.197	43.890	.000	.000
49	.000	882.335	41.657	.000	.000
50	.000	882.335	41.657	.000	.000
51	.000	885.614	41.657	.000	.000
52	.000	885.614	41.657	.000	.000
53	.000	885.614	41.657	74.982	.000
54	.000	885.614	41.657	74.982	.000
55	.000	885.614	41.657	74.982	.000
56	.000	885.614	41.657	74.982	.000
57	.000	885.614	41.657	37.082	.000
58	.000	885.614	41.657	.000	.000
59	.000	885.614	41.657	.000	.000
60	.000	885.614	41.657	.000	.000
Total............	14,115.615	38,738.439	3,078.967	2,086.270	.000

Table A14. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Zero desalination capacity sensitivity

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	26.829	.000	.000	49.988
5	.000	.000	.000	78.228	54.154	42.963	49.988
6	91.645	12.106	.000	.000	54.154	49.999	49.988
7	79.048	.000	.000	.000	54.154	49.999	49.988
8	83.089	.000	.000	.000	54.154	49.999	49.988
9	42.630	28.562	.000	.000	54.154	49.999	49.988
10	.000	.000	.000	66.850	.489	.000	49.988
11	.000	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	30.089	54.154	.000	49.988
17	44.958	75.002	.000	.000	54.154	49.999	49.988
18	81.496	.000	.000	.000	54.154	49.999	49.988
19	79.439	.000	.000	.000	54.154	49.999	49.988
20	86.435	.000	.000	.000	54.154	49.999	49.988
21	78.070	3.075	.000	.000	54.154	49.999	49.988
22	.000	68.662	.000	.000	54.154	3.447	49.988
23	.000	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000	.000
27	.000	.000	.000	.000	.000	.000	15.166
28	.000	.000	.000	56.037	54.154	.000	49.988
29	.000	.000	.000	7.162	54.154	49.999	49.988
30	55.403	.000	9.716	.000	54.154	49.999	49.988
31	79.668	.000	.000	.000	54.154	49.999	49.988

Table A14. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Zero desalination capacity sensitivity—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	91.645	2.513	0.000	0.000	54.154	49.999	49.988
33	80.802	.000	.000	.000	54.154	49.999	49.988
34	.000	15.027	.000	34.480	54.154	49.999	49.988
35	.000	.000	.000	.000	.000	.000	15.166
36	.000	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000	.000
39	.000	.000	.000	.000	.000	.000	1.986
40	.000	.000	.000	47.808	54.154	.000	49.988
41	.000	.000	.000	4.427	54.154	49.999	49.988
42	44.828	.000	19.609	.000	54.154	49.999	49.988
43	79.469	.000	.000	.000	54.154	49.999	49.988
44	91.645	2.797	.000	.000	54.154	49.999	49.988
45	80.757	.000	.000	.000	54.154	49.999	49.988
46	.000	.000	.000	47.831	54.154	45.015	49.988
47	.000	.000	.000	.000	.000	.000	1.986
48	.000	.000	.000	.000	.000	.000	.000
49	.000	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	.000	.000	.000
52	.000	.000	.000	13.891	54.154	.000	49.988
53	.000	.000	.000	37.035	54.154	49.999	49.988
54	53.940	.000	11.655	.000	54.154	49.999	49.988
55	79.602	.000	.000	.000	54.154	49.999	49.988
56	91.645	1.963	.000	.000	54.154	49.999	49.988
57	80.819	.000	.000	.000	54.154	49.999	49.988
58	.000	57.004	.000	.000	54.154	49.999	49.988
59	.000	75.002	.000	11.777	.000	.000	7.926
60	.000	.000	.000	24.734	.000	.000	.000
Total............	1,577.030	341.713	40.979	487.178	1,787.558	1,391.391	1,791.807

Table A15. Optimal Foothill-basin pumping, in acre-feet per month, Santa Barbara, California: Zero desalination capacity sensitivity

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	41.669	16.832	.000	.000
4	.000	.000	41.669	33.325	20.840	20.840
5	.000	.000	41.669	33.325	20.840	20.840
6	.000	.000	41.669	33.325	20.840	20.840
7	.000	.000	41.669	33.325	20.840	20.840
8	.000	.000	41.669	33.325	20.840	20.840
9	.000	.000	41.669	33.325	20.840	20.840
10	.000	.000	41.669	33.325	20.840	20.840
11	.000	.000	41.669	16.832	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	12.920	.000	.000	.000
14	.000	.000	12.920	.000	.000	.000
15	.000	.000	41.669	33.325	15.069	20.840
16	.000	.000	41.669	33.325	20.840	20.840
17	.000	.000	41.669	33.325	20.840	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	.000	.000	41.669	33.325	20.840	20.840
20	.000	.000	41.669	33.325	20.840	20.840
21	.000	.000	41.669	33.325	20.840	20.840
22	.000	.000	41.669	33.325	20.840	20.840
23	.000	.000	41.669	33.325	15.069	20.840
24	.000	.000	40.932	.000	.000	.000
25	.000	.000	30.355	.000	.000	.000
26	.000	.000	30.355	.000	.000	.000
27	.000	.000	41.669	33.325	20.840	20.840
28	.000	.000	41.669	33.325	20.840	20.840
29	16.675	16.675	41.669	33.325	20.840	20.840
30	16.675	16.675	41.669	33.325	20.840	20.840
31	16.675	16.675	41.669	33.325	20.840	20.840

Table A15. Optimal Foothill-basin pumping, in acre-feet per month, Santa Barbara, California: Zero desalination capacity sensitivity—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	16.675	16.675	41.669	33.325	20.840	20.840
33	.000	.000	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	20.840	20.840
35	.000	.000	41.669	33.325	20.840	20.840
36	.000	.000	41.669	17.665	.000	.000
37	.000	.000	13.614	.000	.000	.000
38	.000	.000	13.614	.000	.000	.000
39	.000	.000	41.669	33.325	20.840	20.840
40	.000	.000	41.669	33.325	20.840	20.840
41	16.675	16.675	41.669	33.325	20.840	20.840
42	16.675	16.675	41.669	33.325	20.840	20.840
43	16.675	16.675	41.669	33.325	20.840	20.840
44	16.675	16.675	41.669	33.325	20.840	20.840
45	.000	.000	41.669	33.325	20.840	20.840
46	.000	.000	41.669	33.325	20.840	20.840
47	.000	.000	41.669	33.325	20.840	20.840
48	.000	.000	41.669	1.950	.000	.000
49	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000
51	.000	.000	41.669	33.325	19.711	.000
52	.000	.000	41.669	33.325	20.840	20.840
53	5.885	.000	41.669	33.325	20.840	20.840
54	16.675	16.675	41.669	33.325	20.840	20.840
55	16.675	16.675	41.669	33.325	20.840	20.840
56	16.675	16.675	41.669	33.325	20.840	20.840
57	.000	.000	41.669	33.325	20.840	20.840
58	.000	.000	41.669	23.913	.000	.000
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	189.306	183.422	2,071.469	1,443.529	841.783	833.615

Table A16. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	380.705	439.749	70.575	0.000	0.000
2	380.705	439.749	70.575	.000	.000
3	416.687	439.749	70.575	.000	.000
4	416.687	439.749	70.575	.000	.000
5	416.687	439.749	70.575	.000	.000
6	416.687	439.749	70.575	22.968	.000
7	416.687	439.749	70.575	58.779	.000
8	416.687	439.749	70.575	58.779	.000
9	416.687	439.749	70.575	.000	.000
10	416.687	439.749	70.575	.000	.000
11	416.687	439.749	70.575	.000	.000
12	416.687	430.753	70.575	.000	.000
13	416.687	445.484	54.637	.000	.000
14	416.687	445.484	54.637	.000	.000
15	416.687	445.484	54.637	.000	.000
16	416.687	445.484	54.637	.000	.000
17	416.687	445.484	54.637	.000	.000
18	416.687	445.484	54.637	97.063	.000
19	416.687	445.484	54.637	121.894	.000
20	416.687	445.484	54.637	121.894	.000
21	416.687	445.484	54.637	48.786	.000
22	416.687	445.484	54.637	.000	.000
23	416.687	445.484	54.637	.000	.000
24	416.687	445.484	54.637	.000	.000
25	116.397	794.796	45.822	.000	.000
26	116.397	794.796	45.822	.000	.000
27	116.397	794.796	45.822	.000	.000
28	116.397	794.796	45.822	.000	.000
29	116.397	794.796	45.822	8.609	.000
30	116.397	794.796	45.822	104.941	.000
31	116.397	794.796	45.822	130.837	.000

Table A16. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	116.397	794.796	45.822	130.837	0.000
33	116.397	794.796	45.822	56.877	.000
34	116.397	794.796	45.822	.000	.000
35	116.397	794.796	45.822	.000	.000
36	116.397	794.796	45.822	.000	.000
37	233.277	708.054	43.890	.000	.000
38	233.277	708.054	43.890	.000	.000
39	233.277	708.054	43.890	.000	.000
40	233.277	708.054	43.890	.000	.000
41	233.277	708.054	43.890	31.959	.000
42	233.277	708.054	43.890	124.877	.000
43	233.277	708.054	43.890	135.385	.000
44	233.277	708.054	43.890	135.385	.000
45	233.277	708.054	43.890	78.004	.000
46	233.277	708.054	43.890	.000	.000
47	233.277	708.054	43.890	.000	.000
48	233.277	708.054	43.890	.000	.000
49	.000	840.667	41.657	.000	.000
50	.000	840.667	41.657	.000	.000
51	.000	840.667	41.657	.000	.000
52	.000	840.667	41.657	.000	.000
53	.000	840.667	41.657	52.180	.000
54	.000	840.667	41.657	132.935	.000
55	.000	840.667	41.657	138.169	.000
56	.000	840.667	41.657	138.169	.000
57	.000	840.667	41.657	90.033	.000
58	.000	840.667	41.657	.000	.000
59	.000	840.667	41.657	.000	.000
60	.000	840.667	41.657	.000	.000
Total............	14,124.610	38,736.003	3,078.967	2,019.359	.000

Table A17. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	33.165	35.345	.000	49.988
5	.000	.000	.000	71.192	54.154	49.999	49.988
6	91.645	10.552	.000	.000	54.154	49.999	49.988
7	79.909	.000	.000	.000	54.154	49.999	49.988
8	82.681	.000	.000	.000	54.154	49.999	49.988
9	42.839	28.353	.000	.000	54.154	49.999	49.988
10	.000	.000	.000	58.611	50.409	.000	49.988
11	.000	.000	.000	16.832	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	30.174
16	.000	.000	.000	.000	54.154	24.355	49.988
17	91.645	36.720	.000	.000	54.154	49.999	49.988
18	87.326	.000	.000	.000	54.154	49.999	49.988
19	76.502	.000	.000	.000	54.154	49.999	49.988
20	77.971	5.772	.000	.000	54.154	49.999	49.988
21	79.579	.000	.000	.000	54.154	49.999	49.988
22	.000	47.440	.000	18.934	54.154	.000	49.988
23	.000	.000	.000	63.500	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000	.000
27	.000	.000	.000	.000	.000	.000	26.491
28	.000	.000	.000	.000	54.154	25.682	49.988
29	91.645	34.932	.000	.000	54.154	49.999	49.988
30	88.202	.000	.000	.000	54.154	49.999	49.988
31	76.311	.000	.000	.000	54.154	49.999	49.988

Table A17. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	69.173	11.654	0.000	0.000	54.154	49.999	49.988
33	78.309	.000	.000	.000	54.154	49.999	49.988
34	.000	58.825	.000	.000	54.154	49.999	49.988
35	.000	.000	.000	59.817	.000	.000	.000
36	.000	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000	.000
39	.000	.000	.000	.000	.000	.000	34.810
40	.000	.000	.000	.000	54.154	38.951	49.988
41	91.645	30.346	.000	.000	54.154	49.999	49.988
42	89.082	.000	.000	.000	54.154	49.999	49.988
43	76.357	.000	.000	.000	54.154	49.999	49.988
44	52.527	22.702	.000	.000	54.154	49.999	49.988
45	75.945	.000	.000	.000	54.154	49.999	49.988
46	.000	59.955	.000	.000	54.154	49.999	49.988
47	.000	.000	.000	68.135	.000	.000	.000
48	.000	.000	.000	.000	.000	.000	.000
49	.000	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	14.670	.000	49.988
52	.000	.000	.000	8.840	54.154	49.999	49.988
53	65.126	45.543	.000	.000	54.154	49.999	49.988
54	85.939	.000	.000	.000	54.154	49.999	49.988
55	78.609	.000	.000	.000	54.154	49.999	49.988
56	75.368	.000	.000	.000	54.154	49.999	49.988
57	72.816	.000	.000	.000	54.154	49.999	49.988
58	.000	59.852	.000	.000	54.154	49.999	49.988
59	.000	75.002	.000	4.597	.000	10.065	49.988
60	.000	.000	.000	69.681	.000	.000	.000
Total............	1,877.148	527.648	.000	473.303	1,887.493	1,549.015	1,941.029

Table A18. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	41.669	16.832	.000	.000
4	.000	.000	41.669	33.325	.000	.000
5	.000	.000	41.669	33.325	20.840	20.840
6	.000	.000	41.669	33.325	20.840	20.840
7	.000	.000	41.669	33.325	20.840	20.840
8	10.691	.000	41.669	33.325	20.840	20.840
9	.000	.000	41.669	33.325	20.840	20.840
10	.000	.000	41.669	33.325	.000	.000
11	.000	.000	41.669	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	7.185	.000	.000	.000
14	.000	.000	7.185	.000	.000	.000
15	.000	.000	41.669	33.325	.000	.000
16	.000	.000	41.669	33.325	20.840	20.840
17	.000	.000	41.669	33.325	20.840	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	.000	.000	41.669	33.325	20.840	20.840
20	.000	6.766	41.669	33.325	20.840	20.840
21	.000	.000	41.669	33.325	20.840	20.840
22	.000	.000	41.669	33.325	20.840	20.840
23	.000	.000	41.669	.000	.000	.000
24	.000	.000	35.197	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000
27	.000	.000	41.669	33.325	.000	.000
28	.000	.000	41.669	33.325	20.840	20.840
29	.000	.000	41.669	33.325	20.840	20.840
30	.000	.000	41.669	33.325	20.840	20.840
31	.545	.000	41.669	33.325	20.840	20.840

Table A18. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	10.518	0.000	41.669	33.325	20.840	20.840
33	.000	.000	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	.000	2.007
35	.000	.000	41.669	.000	.000	.000
36	.000	.000	28.979	.000	.000	.000
37	.000	.000	4.757	.000	.000	.000
38	.000	.000	4.757	.000	.000	.000
39	.000	.000	41.669	33.325	.000	.000
40	.000	.000	41.669	33.325	20.840	20.840
41	.000	.000	41.669	33.325	20.840	20.840
42	.000	.000	41.669	33.325	20.840	20.840
43	16.675	.574	41.669	33.325	20.840	20.840
44	16.675	16.675	41.669	33.325	20.840	20.840
45	.000	.000	41.669	33.325	20.840	20.840
46	.000	.000	41.669	33.325	.000	15.716
47	.000	.000	41.669	.000	.000	.000
48	.000	.000	34.762	.000	.000	.000
49	.000	.000	41.669	.000	.000	.000
50	.000	.000	41.669	.000	.000	.000
51	.000	.000	41.669	33.325	.000	.000
52	.000	.000	41.669	33.325	20.840	20.840
53	.000	.000	41.669	33.325	20.840	20.840
54	.000	.000	41.669	33.325	20.840	20.840
55	.000	16.102	41.669	33.325	20.840	20.840
56	16.675	16.675	41.669	33.325	20.840	20.840
57	.000	.000	41.669	33.325	20.840	20.840
58	.000	.000	41.669	33.325	20.840	11.847
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	71.777	56.791	2,039.581	1,316.518	646.052	654.782

Table A19. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Current monthly Gibraltar Reservoir diversion percentages

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	380.705	439.749	70.575	0.000	0.000
2	380.705	439.749	70.575	.000	.000
3	475.187	439.749	70.575	.000	.000
4	584.998	439.749	70.575	.000	.000
5	634.998	439.749	70.575	.000	.000
6	525.000	439.749	70.575	.000	.000
7	134.998	439.749	70.575	125.030	139.100
8	109.998	439.749	70.575	125.030	217.282
9	70.001	439.749	70.575	125.030	180.492
10	575.000	439.749	70.575	.000	.000
11	470.001	439.749	70.575	.000	.000
12	407.691	439.749	70.575	.000	.000
13	440.002	429.353	54.637	.000	.000
14	420.001	449.354	54.637	.000	.000
15	496.581	470.758	54.637	.000	.000
16	584.998	470.758	54.637	.000	.000
17	634.998	470.758	54.637	.000	.000
18	525.000	470.758	54.637	.000	.000
19	134.998	470.758	54.637	134.992	163.938
20	109.998	470.758	54.637	134.992	250.000
21	70.001	470.758	54.637	134.992	198.627
22	575.000	470.758	54.637	.000	.000
23	470.001	470.758	54.637	.000	.000
24	426.610	470.758	54.637	.000	.000
25	122.935	785.187	45.822	.000	.000
26	117.351	785.187	45.822	.000	.000
27	157.860	785.187	45.822	.000	.000
28	163.451	785.187	45.822	.000	.000
29	177.421	785.187	45.822	.000	.000
30	146.686	785.187	45.822	94.112	.000
31	37.720	785.187	45.822	125.030	45.954

Table A19. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	30.735	785.187	45.822	125.030	75.527
33	19.561	785.187	45.822	125.030	.000
34	160.656	785.187	45.822	.000	.000
35	131.321	785.187	45.822	.000	.000
36	131.321	785.187	45.822	.000	.000
37	246.311	673.450	43.890	.000	.000
38	235.118	673.450	43.890	.000	.000
39	316.288	673.450	43.890	.000	.000
40	327.481	673.450	43.890	.000	.000
41	355.476	673.450	43.890	.000	.000
42	293.897	673.450	43.890	103.216	.000
43	75.574	673.450	43.890	125.030	171.275
44	61.579	673.450	43.890	125.030	210.036
45	39.187	673.450	43.890	125.030	140.940
46	321.885	673.450	43.890	.000	.000
47	263.107	673.450	43.890	.000	.000
48	263.107	673.450	43.890	.000	.000
49	.000	859.606	41.657	.000	.000
50	.000	859.606	41.657	.000	.000
51	.000	859.606	41.657	.000	.000
52	.000	859.606	41.657	.000	.000
53	.000	859.606	41.657	26.830	.000
54	.000	859.606	41.657	74.982	.000
55	.000	859.606	41.657	74.982	28.045
56	.000	859.606	41.657	74.982	34.340
57	.000	859.606	41.657	64.023	.000
58	.000	859.606	41.657	.000	.000
59	.000	859.606	41.657	.000	.000
60	.000	859.606	41.657	.000	.000
Total............	13,833.499	38,682.189	3,078.967	2,043.375	1,855.555

Table A20. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Current monthly Gibraltar Reservoir diversion percentages

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	.000	.000	.000	.000
5	.000	.000	.000	.000	.000	.000	48.702
6	.000	.000	.000	16.851	54.154	49.999	49.988
7	91.645	31.253	.000	.000	54.154	49.999	49.988
8	83.179	.000	.000	.000	54.154	49.999	49.988
9	79.006	.000	.000	.000	54.154	49.999	49.988
10	.000	.000	.000	73.139	.000	.000	.000
11	.000	.000	.000	5.186	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000	9.917
17	.000	.000	.000	.000	.000	.000	49.988
18	.000	.000	.000	50.802	54.154	49.999	49.988
19	91.645	3.888	.000	.000	54.154	49.999	49.988
20	75.476	.000	.000	.000	54.154	49.999	49.988
21	82.808	.000	.000	.000	54.154	49.999	49.988
22	.000	.000	.000	73.365	.000	.000	.000
23	.000	.000	.000	26.580	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	3.071	.000	.000	.000
26	.000	.000	.000	8.655	.000	.000	.000
27	.000	.000	.000	27.962	.000	.000	.000
28	.000	.000	.000	53.110	30.961	.000	49.988
29	.000	.458	.000	83.313	54.154	49.999	49.988
30	78.351	.000	.000	.000	54.154	49.999	49.988
31	91.645	.000	.000	.000	54.154	49.999	49.988

Table A20. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	83.546	0.000	0.000	0.000	54.154	49.999	49.988
33	83.252	.000	.000	.000	54.154	49.999	49.988
34	.000	68.192	.000	.000	54.154	7.989	49.988
35	.000	.000	.000	76.068	.000	.000	.000
36	.000	.000	.000	23.664	.000	.000	.000
37	.000	.000	.000	26.327	.000	.000	.000
38	.000	.000	.000	37.520	.000	.000	.000
39	.000	.000	.000	19.728	.000	.000	.000
40	.000	.000	.000	75.186	.000	.000	49.988
41	.000	.000	.000	66.355	54.154	49.999	49.988
42	84.728	.000	.000	.000	54.154	49.999	49.988
43	91.645	.000	.000	.000	54.154	49.999	49.988
44	81.850	.000	.000	.000	54.154	49.999	49.988
45	83.323	.000	.000	.000	54.154	49.999	49.988
46	.000	.000	.000	53.815	54.154	17.851	49.988
47	.000	.000	.000	79.298	.000	.000	.000
48	.000	.000	.000	39.536	.000	.000	.000
49	.000	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	.000	.000	45.719
52	.000	.000	.000	.000	54.154	39.899	49.988
53	87.531	.000	.000	29.548	54.154	49.999	49.988
54	91.603	.000	.000	.000	54.154	49.999	49.988
55	77.564	.000	.000	.000	54.154	49.999	49.988
56	85.275	.000	.000	.000	54.154	49.999	49.988
57	79.886	.000	.000	.000	54.154	49.999	49.988
58	.000	58.032	.000	.000	54.154	49.999	49.988
59	.000	75.002	.000	8.101	.000	.000	37.609
60	.000	.000	.000	50.742	.000	.000	.000
Total............	1,603.957	263.826	.000	1,007.922	1,493.108	1,265.707	1,641.586

Table A21. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Current monthly Gibraltar Reservoir diversion percentages

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	25.181	.000	.000	.000
5	.000	.000	41.669	33.325	.000	.000
6	.000	.000	41.669	33.325	20.840	20.840
7	16.675	16.675	41.669	33.325	20.840	20.840
8	16.675	16.675	41.669	33.325	20.840	20.840
9	16.675	16.675	41.669	33.325	20.840	20.840
10	.000	.000	2.550	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000
16	.000	.000	41.669	.000	.000	.000
17	.000	.000	41.669	33.325	9.772	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	16.675	16.675	41.669	33.325	20.840	20.840
20	16.675	16.675	41.669	33.325	20.840	20.840
21	16.675	16.675	41.669	33.325	20.840	20.840
22	.000	.000	30.238	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000
27	.000	.000	41.669	.000	.000	.000
28	.000	.000	41.669	33.325	.000	.000
29	.000	.000	41.669	33.325	20.840	20.840
30	.000	.000	41.669	33.325	20.840	20.840
31	16.675	16.675	41.669	33.325	20.840	20.840

Table A21. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	16.675	16.675	41.669	33.325	20.840	20.840
33	16.675	16.675	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	.000	.000
35	.000	.000	20.102	.000	.000	.000
36	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000
39	.000	.000	41.669	.000	.000	.000
40	.000	.000	41.669	33.325	.000	.000
41	.000	.000	41.669	33.325	20.840	20.840
42	.000	.000	41.669	33.325	20.840	20.840
43	16.675	16.675	41.669	33.325	20.840	20.840
44	16.675	16.675	41.669	33.325	20.840	20.840
45	16.675	16.675	41.669	33.325	20.840	20.840
46	.000	.000	41.669	33.325	.000	.000
47	.000	.000	35.281	.000	.000	.000
48	.000	.000	.000	.000	.000	.000
49	.000	.000	22.729	.000	.000	.000
50	.000	.000	22.729	.000	.000	.000
51	.000	.000	41.669	33.325	.000	.000
52	.000	.000	41.669	33.325	20.840	20.840
53	.000	.000	41.669	33.325	20.840	20.840
54	16.675	16.675	41.669	33.325	20.840	20.840
55	16.675	16.675	41.669	33.325	20.840	20.840
56	16.675	16.675	41.669	33.325	20.840	20.840
57	.000	.000	41.669	33.325	20.840	20.840
58	.000	.000	41.669	33.325	15.568	.000
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	250.121	250.121	1,617.214	1,066.409	525.509	521.009

Table A22. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	380.705	439.749	70.575	0.000	0.000
2	380.705	439.749	70.575	.000	.000
3	565.003	349.934	70.575	.000	.000
4	584.998	439.749	70.575	.000	.000
5	634.998	439.749	70.575	.000	.000
6	525.000	439.749	70.575	.000	.000
7	134.998	439.749	70.575	92.312	171.818
8	109.998	439.749	70.575	92.312	250.000
9	70.001	439.749	70.575	92.312	213.211
10	575.000	439.749	70.575	.000	.000
11	470.001	439.749	70.575	.000	.000
12	470.001	377.439	70.575	.000	.000
13	440.002	429.353	54.637	.000	.000
14	420.001	440.194	54.637	.000	.000
15	527.145	440.194	54.637	.000	.000
16	584.998	440.194	54.637	.000	.000
17	634.998	440.194	54.637	.000	.000
18	525.000	440.194	54.637	.000	.000
19	134.998	440.194	54.637	167.710	168.432
20	109.998	440.194	54.637	167.710	250.000
21	70.001	440.194	54.637	167.710	194.986
22	575.000	440.194	54.637	.000	.000
23	470.001	440.194	54.637	.000	.000
24	470.001	427.367	54.637	.000	.000
25	122.935	791.276	42.804	.000	.000
26	117.351	791.276	45.822	.000	.000
27	157.860	791.276	45.822	.000	.000
28	163.451	791.276	45.822	.000	.000
29	177.421	791.276	45.822	.000	.000
30	146.686	791.276	45.822	86.292	.000
31	37.720	791.276	45.822	86.292	78.604

Table A22. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	30.735	791.276	45.822	86.292	108.704
33	19.561	791.276	45.822	86.292	32.632
34	160.656	791.276	45.822	.000	.000
35	131.321	791.276	45.822	.000	.000
36	131.321	791.276	45.822	.000	.000
37	246.311	697.592	43.890	.000	.000
38	235.118	697.592	43.890	.000	.000
39	316.288	697.592	43.890	.000	.000
40	327.481	697.592	43.890	.000	.000
41	355.476	697.592	43.890	.000	.000
42	293.897	697.592	43.890	66.939	.000
43	75.574	697.592	43.890	163.769	108.394
44	61.579	697.592	43.890	163.769	148.715
45	39.187	697.592	43.890	163.769	77.278
46	321.885	697.592	43.890	.000	.000
47	263.107	697.592	43.890	.000	.000
48	263.107	697.592	43.890	.000	.000
49	.000	859.938	41.657	.000	.000
50	.000	859.938	41.657	.000	.000
51	.000	859.938	41.657	.000	.000
52	.000	859.938	41.657	.000	.000
53	.000	859.938	41.657	25.014	.000
54	.000	859.938	41.657	74.982	.000
55	.000	859.938	41.657	74.982	27.821
56	.000	859.938	41.657	74.982	33.909
57	.000	859.938	41.657	63.637	.000
58	.000	859.938	41.657	.000	.000
59	.000	859.938	41.657	.000	.000
60	.000	859.938	41.657	.000	.000
Total............	14,059.579	38,569.199	3,075.949	1,997.074	1,864.504

Table A23. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.000	.000	.000	.000	.000
5	.000	.000	.000	.000	.000	.000	48.702
6	.000	.000	.000	16.851	54.154	49.999	49.988
7	91.645	31.253	.000	.000	54.154	49.999	49.988
8	83.179	.000	.000	.000	54.154	49.999	49.988
9	79.006	.000	.000	.000	54.154	49.999	49.988
10	.000	.000	.000	72.823	.000	.000	2.865
11	.000	.000	.000	5.186	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	9.160	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000	40.481
17	.000	.000	.000	.000	19.496	.000	49.988
18	81.366	.000	.000	.000	54.154	49.999	49.988
19	91.645	24.238	.000	.000	54.154	49.999	49.988
20	73.322	.000	.000	.000	54.154	49.999	49.988
21	84.294	.000	.000	.000	54.154	49.999	49.988
22	.000	.000	.000	67.411	.000	.000	49.988
23	.000	.000	.000	57.144	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	2.566	.000	.000	.000
27	.000	.000	.000	24.940	.000	.000	.000
28	.000	.000	.000	77.983	.000	.000	49.988
29	.000	.000	.000	77.682	54.154	49.999	49.988
30	80.083	.000	.000	.000	54.154	49.999	49.988
31	91.645	.000	.000	.000	54.154	49.999	49.988

Table A23. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	83.018	0.000	0.000	0.000	54.154	49.999	49.988
33	83.269	.000	.000	.000	54.154	49.999	49.988
34	.000	70.025	.000	.000	54.154	0.067	49.988
35	.000	.000	.000	74.613	.000	.000	15.468
36	.000	.000	.000	17.575	.000	.000	.000
37	.000	.000	.000	2.184	.000	.000	.000
38	.000	.000	.000	13.377	.000	.000	.000
39	.000	.000	.000	37.254	.000	.000	.000
40	.000	.000	.000	51.043	.000	.000	49.988
41	.000	.000	.000	42.212	54.154	49.999	49.988
42	91.645	.000	.000	5.217	54.154	49.999	49.988
43	91.645	.000	.000	.000	54.154	49.999	49.988
44	80.290	.000	.000	.000	54.154	49.999	49.988
45	84.105	.000	.000	.000	54.154	49.999	49.988
46	.000	.000	.000	59.278	42.399	.000	49.988
47	.000	.000	.000	79.736	.000	.000	10.700
48	.000	.000	.000	15.394	.000	.000	.000
49	.000	.000	.000	22.397	.000	.000	.000
50	.000	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	.000	.000	49.988
52	.000	.000	.000	.000	54.154	39.567	49.988
53	91.645	.000	.000	26.919	54.154	49.999	49.988
54	91.271	.000	.000	.000	54.154	49.999	49.988
55	77.456	.000	.000	.000	54.154	49.999	49.988
56	85.374	.000	.000	.000	54.154	49.999	49.988
57	79.941	.000	.000	.000	54.154	49.999	49.988
58	.000	58.007	.000	.000	54.154	49.999	49.988
59	.000	75.002	.000	8.149	.000	.000	37.229
60	.000	.000	.000	50.410	.000	.000	.000
Total............	1,695.840	258.526	.000	917.505	1,469.888	1,239.603	1,755.059

Table A24. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara. California: State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	0.000	0.000	0.000	0.000
2	.000	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.000	.000
4	.000	.000	25.181	.000	.000	.000
5	.000	.000	41.669	33.325	.000	.000
6	.000	.000	41.669	33.325	20.840	20.840
7	16.675	16.675	41.669	33.325	20.840	20.840
8	16.675	16.675	41.669	33.325	20.840	20.840
9	16.675	16.675	41.669	33.325	20.840	20.840
10	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000
16	.000	.000	41.669	.000	.000	.000
17	.000	.000	41.669	33.325	20.840	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	16.675	16.675	41.669	33.325	20.840	20.840
20	16.675	16.675	41.669	33.325	20.840	20.840
21	16.675	16.675	41.669	33.325	20.840	20.840
22	.000	.000	16.767	.000	.000	.000
23	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000
25	.000	.000	.000	.000	.000	.000
26	.000	.000	.000	.000	.000	.000
27	.000	.000	38.602	.000	.000	.000
28	.000	.000	41.669	33.325	.000	.000
29	.000	.000	41.669	33.325	20.840	20.840
30	.000	.000	41.669	33.325	20.840	20.840
31	16.675	16.675	41.669	33.325	20.840	20.840

Table A24. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara. California: State Water Project carryover sensitivity with current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	16.675	16.675	41.669	33.325	20.840	20.840
33	16.675	16.675	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	.000	.000
35	.000	.000	.000	.000	.000	.000
36	.000	.000	.000	.000	.000	.000
37	.000	.000	.000	.000	.000	.000
38	.000	.000	.000	.000	.000	.000
39	.000	.000	.000	.000	.000	.000
40	.000	.000	41.669	33.325	.000	.000
41	.000	.000	41.669	33.325	20.840	20.840
42	.000	.000	41.669	33.325	20.840	20.840
43	16.675	16.675	41.669	33.325	20.840	20.840
44	16.675	16.675	41.669	33.325	20.840	20.840
45	16.675	16.675	41.669	33.325	20.840	20.840
46	.000	.000	41.669	33.325	.000	.000
47	.000	.000	.000	.000	.000	.000
48	.000	.000	.000	.000	.000	.000
49	.000	.000	.000	.000	.000	.000
50	.000	.000	22.397	.000	.000	.000
51	.000	.000	41.669	28.724	.000	.000
52	.000	.000	41.669	33.325	20.840	20.840
53	.000	.000	41.669	33.325	20.840	20.840
54	16.675	16.675	41.669	33.325	20.840	20.840
55	16.675	16.675	41.669	33.325	20.840	20.840
56	16.675	16.675	41.669	33.325	20.840	20.840
57	.000	.000	41.669	33.325	20.840	20.840
58	.000	.000	41.669	33.325	15.261	.000
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	250.121	250.121	1,478.014	1,061.808	536.270	521.009

Table A25. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Proposed monthly Gibraltar Reservoir diversion percentages

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	225.000	439.749	70.575	0.000	0.000
2	209.998	439.749	70.575	.000	.000
3	300.000	439.749	70.575	.000	.000
4	415.002	439.749	70.575	.000	.000
5	550.000	439.749	70.575	.000	.000
6	550.000	439.749	70.575	.000	.000
7	550.000	439.749	70.575	.000	.000
8	550.000	439.749	70.575	.000	.000
9	550.000	439.749	70.575	.000	.000
10	459.998	439.749	70.575	.000	.000
11	415.002	439.749	70.575	.000	.000
12	225.000	439.749	70.575	.000	.000
13	225.000	439.749	54.637	.000	.000
14	209.998	439.749	54.637	.000	.000
15	300.000	439.749	54.637	.000	.000
16	415.002	439.749	54.637	.000	.000
17	550.000	439.749	54.637	.000	.000
18	550.000	439.749	54.637	.000	.000
19	550.000	439.749	54.637	.000	.000
20	550.000	439.749	54.637	.000	.000
21	550.000	439.749	54.637	.000	.000
22	459.998	439.749	54.637	.000	.000
23	415.002	439.749	54.637	.000	.000
24	225.000	439.749	54.637	.000	.000
25	62.865	771.476	45.822	.000	.000
26	58.675	771.476	45.822	.000	.000
27	83.820	771.476	45.822	.000	.000
28	115.950	771.476	45.822	.000	.000
29	153.671	771.476	45.822	.000	.000
30	153.671	771.476	45.822	91.233	.000
31	153.671	771.476	45.822	116.807	.000

Table A25. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Proposed monthly Gibraltar Reservoir diversion percentages—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	153.671	771.476	45.822	125.030	0.000
33	153.671	771.476	45.822	49.252	.000
34	128.526	771.476	45.822	.000	.000
35	115.950	771.476	45.822	.000	.000
36	62.865	771.476	45.822	.000	.000
37	125.954	672.788	43.890	.000	.000
38	117.556	672.788	43.890	.000	.000
39	167.943	672.788	43.890	.000	.000
40	232.317	672.788	43.890	.000	.000
41	307.891	672.788	43.890	19.292	.000
42	307.891	672.788	43.890	91.480	.000
43	307.891	672.788	43.890	114.409	.000
44	307.891	672.788	43.890	125.030	.000
45	307.891	672.788	43.890	41.900	.000
46	257.510	672.788	43.890	.000	.000
47	232.317	672.788	43.890	.000	.000
48	125.954	672.788	43.890	.000	.000
49	.000	882.335	41.657	.000	.000
50	.000	882.335	41.657	.000	.000
51	.000	904.988	41.657	.000	.000
52	.000	904.988	41.657	.000	.000
53	.000	904.988	41.657	.000	.000
54	.000	904.988	41.657	66.087	.000
55	.000	904.988	41.657	74.982	.000
56	.000	904.988	41.657	74.982	.000
57	.000	904.988	41.657	27.091	.000
58	.000	904.988	41.657	.000	.000
59	.000	904.988	41.657	.000	.000
60	.000	904.988	41.657	.000	.000
Total............	14,196.012	38,699.691	3,078.967	1,017.575	.000

Table A26. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Proposed monthly Gibraltar Reservoir diversion percentages

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.000	0.000	62.218	0.000	0.000	49.988
2	.000	.000	.000	78.557	.000	.000	49.988
3	.000	.000	.000	83.313	.000	.000	22.764
4	.000	.000	.000	82.667	.000	.000	37.516
5	.000	.000	.000	80.436	3.276	.000	49.988
6	.000	.000	.000	68.085	54.154	15.446	49.988
7	.000	.000	.000	60.120	54.154	36.934	49.988
8	.000	69.325	.000	.000	54.154	41.191	49.988
9	.000	.000	.000	66.934	16.778	.000	49.988
10	.000	.000	.000	78.339	.000	.000	37.358
11	.000	.000	.000	18.516	.000	.000	.000
12	.000	22.806	.000	83.313	.000	.000	1.578
13	.000	.000	.000	83.313	.000	.000	46.299
14	.000	.000	.000	76.288	18.339	.000	49.988
15	.000	.000	.000	75.506	27.102	.000	49.988
16	.000	.000	.000	69.748	54.154	.000	49.988
17	.000	.000	.000	68.335	54.154	.000	49.988
18	.000	.000	.000	56.811	54.154	49.999	49.988
19	10.306	60.511	.000	.000	54.154	49.999	49.988
20	78.961	5.863	.000	.000	54.154	49.999	49.988
21	.000	.000	.000	57.030	54.154	.000	49.988
22	.000	.000	.000	65.749	54.154	.000	49.988
23	.000	.000	.000	37.594	.000	.000	.000
24	.000	3.420	.000	83.313	20.904	.000	49.988
25	.000	.000	.000	1.858	.000	.000	.000
26	.000	.000	.000	6.048	.000	.000	.000
27	.000	.000	.000	.000	.000	.000	49.988
28	.000	.000	.000	.000	54.154	49.449	49.988
29	91.645	29.588	.000	.000	54.154	49.999	49.988
30	87.956	.000	.000	.000	54.154	49.999	49.988
31	76.932	.000	.000	.000	54.154	49.999	49.988

Table A26. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Proposed monthly Gibraltar Reservoir diversion percentages—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	58.923	18.296	0.000	0.000	54.154	49.999	49.988
33	45.349	26.632	.000	.000	54.154	49.999	49.988
34	.000	67.417	.000	.000	54.154	12.924	49.988
35	.000	.000	.000	50.258	.000	.000	.000
36	.000	.000	.000	30.836	.000	.000	.000
37	.000	.000	.000	72.353	.000	.000	.000
38	.000	.000	.000	30.762	.000	.000	49.988
39	.000	.000	.000	.000	43.742	.000	49.988
40	.000	.000	.000	25.179	54.154	49.999	49.988
41	20.308	75.002	.000	.000	54.154	49.999	49.988
42	79.254	3.877	.000	.000	54.154	49.999	49.988
43	64.325	10.910	.000	.000	54.154	49.999	49.988
44	28.680	38.745	.000	.000	54.154	49.999	49.988
45	72.702	.000	.000	.000	54.154	49.999	49.988
46	.000	59.377	.000	.000	54.154	49.999	49.988
47	.000	.000	.000	65.581	.000	.000	38.781
48	.000	.000	.000	71.819	.000	.000	49.988
49	.000	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000	.000
51	.000	.000	.000	.000	.000	.000	.337
52	.000	.000	.000	.000	48.671	.000	49.988
53	0.557	75.002	.000	22.968	54.154	49.999	49.988
54	88.465	.000	.000	.000	54.154	49.999	49.988
55	68.367	7.924	.000	.000	54.154	49.999	49.988
56	74.234	.000	.000	.000	54.154	49.999	49.988
57	71.437	.000	.000	.000	54.154	49.999	49.988
58	.000	58.676	.000	.000	54.154	49.999	49.988
59	.000	27.270	.000	48.061	.000	.000	.000
60	.000	.000	.000	5.360	.000	.000	.000
Total............	1,018.399	660.644	.000	1,867.266	1,803.419	1,205.917	2,284.125

Table A27. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Proposed monthly Gibraltar Reservoir diversion percentages

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	41.669	1.831	0.000	0.000
2	.000	.000	41.669	.494	.000	.000
3	.000	.000	41.669	27.441	.000	.000
4	.000	.000	41.669	33.325	.000	.000
5	.000	.000	41.669	33.325	.000	.000
6	.000	.000	41.669	33.325	.000	.000
7	.000	.000	41.669	33.325	.000	.000
8	.000	.000	41.669	33.325	.000	.000
9	.000	.000	41.669	33.325	.000	.000
10	.000	.000	41.669	33.325	.000	.000
11	.000	.000	41.669	.000	.000	.000
12	.000	.000	41.669	33.325	.000	.000
13	.000	.000	41.669	33.325	.000	.000
14	.000	.000	41.669	33.325	.000	.000
15	.000	.000	41.669	33.325	.000	.000
16	.000	.000	41.669	33.325	.000	3.707
17	.000	.000	41.669	33.325	3.290	20.840
18	.000	.000	41.669	33.325	20.840	20.840
19	.000	.000	41.669	33.325	20.840	20.840
20	.000	.000	41.669	33.325	20.840	20.840
21	.000	.000	41.669	33.325	14.595	20.840
22	.000	.000	41.669	33.325	.000	4.729
23	.000	.000	41.669	33.325	.000	.000
24	.000	.000	41.669	33.325	.000	.000
25	.000	.000	41.669	33.325	.000	.000
26	.000	.000	41.669	33.325	.000	.000
27	.000	.000	41.669	33.325	11.560	20.840
28	.000	.000	41.669	33.325	20.840	20.840
29	.000	.000	41.669	33.325	20.840	20.840
30	.000	.000	41.669	33.325	20.840	20.840
31	.000	.000	41.669	33.325	20.840	20.840

Table A27. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Proposed monthly Gibraltar Reservoir diversion percentages—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	5.979	0.000	41.669	33.325	20.840	20.840
33	.000	.000	41.669	33.325	20.840	20.840
34	.000	.000	41.669	33.325	20.840	20.840
35	.000	.000	41.669	33.325	.000	.000
36	.000	.000	41.669	33.325	.000	.000
37	.000	.000	41.669	33.325	.000	.000
38	.000	.000	41.669	33.325	.000	.000
39	.000	.000	41.669	33.325	20.840	20.840
40	.000	.000	41.669	33.325	20.840	20.840
41	.000	.000	41.669	33.325	20.840	20.840
42	.000	.000	41.669	33.325	20.840	20.840
43	.000	.000	41.669	33.325	20.840	20.840
44	12.162	.000	41.669	33.325	20.840	20.840
45	.000	.000	41.669	33.325	20.840	20.840
46	.000	.000	41.669	33.325	6.487	20.840
47	.000	.000	41.669	.000	.000	.000
48	.000	.000	41.669	13.876	.000	.000
49	.000	.000	.000	.000	.000	.000
50	.000	.000	.000	.000	.000	.000
51	.000	.000	41.669	33.325	.000	.000
52	.000	.000	41.669	33.325	20.840	20.840
53	.000	.000	41.669	33.325	20.840	20.840
54	.000	.000	41.669	33.325	20.840	20.840
55	.611	16.675	41.669	33.325	20.840	20.840
56	16.675	16.675	41.669	33.325	20.840	20.840
57	.000	.000	41.669	33.325	20.840	20.840
58	.000	.000	41.669	2.867	.000	.000
59	.000	.000	.000	.000	.000	.000
60	.000	.000	.000	.000	.000	.000
Total............	35.427	33.349	2,333.447	1,679.449	515.260	571.126

Table A28. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	440.002	186.474	70.575	0.000	0.000
2	420.001	179.406	70.575	.000	.000
3	565.003	140.858	70.575	.000	.000
4	584.998	258.383	70.575	.000	.000
5	634.998	349.287	70.575	.000	.000
6	525.000	517.308	70.575	.000	.000
7	134.998	920.138	70.575	.000	.000
8	109.998	956.513	70.575	.000	.000
9	70.001	960.548	70.575	.000	.000
10	575.000	327.976	70.575	.000	.000
11	470.001	271.068	70.575	.000	.000
12	470.001	209.030	70.575	.000	.000
13	440.002	159.129	54.637	.000	.000
14	420.001	191.648	54.637	.000	.000
15	565.003	147.732	54.637	.000	.000
16	584.998	272.653	54.637	.000	.000
17	634.998	370.279	54.637	.000	.000
18	525.000	534.920	54.637	.000	.000
19	134.998	941.295	54.637	.000	.000
20	109.998	981.666	54.637	.000	.000
21	70.001	938.710	54.637	.000	.000
22	575.000	322.700	54.637	.000	.000
23	470.001	246.591	54.637	.000	.000
24	470.001	177.478	54.637	.000	.000
25	122.935	539.187	42.804	.000	.000
26	117.351	545.553	45.822	.000	.000
27	157.860	607.251	45.822	.000	.000
28	163.451	747.364	45.822	.000	.000
29	177.421	893.551	45.822	.000	.000
30	146.686	982.870	45.822	.000	.000
31	37.720	1,106.988	45.822	.000	.000

Table A28. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	30.735	1,129.040	45.822	0.000	0.000
33	19.561	1,053.696	45.822	.000	.000
34	160.656	763.860	45.822	.000	.000
35	131.321	605.234	45.822	.000	.000
36	131.321	533.230	45.822	.000	.000
37	246.311	424.640	43.890	.000	.000
38	235.118	436.300	43.890	.000	.000
39	316.288	460.630	43.890	.000	.000
40	327.481	599.838	43.890	.000	.000
41	355.476	737.264	43.890	.000	.000
42	293.897	859.264	43.890	.000	.000
43	75.574	1,093.016	43.890	.000	.000
44	61.579	1,122.369	43.890	.000	.000
45	39.187	1,055.120	43.890	.000	.000
46	321.885	652.829	43.890	.000	.000
47	263.107	516.957	43.890	.000	.000
48	263.107	442.258	43.890	.000	.000
49	.000	611.939	41.657	.000	.000
50	.000	612.264	41.657	.000	.000
51	.000	710.562	41.657	.000	.000
52	.000	850.871	41.657	.000	.000
53	.000	1,005.178	41.657	.000	.000
54	.000	1,061.493	41.657	.000	.000
55	.000	1,075.781	41.657	.000	.000
56	.000	1,090.064	41.657	.000	.000
57	.000	1,006.296	41.657	.000	.000
58	.000	894.567	41.657	.000	.000
59	.000	712.802	41.657	.000	.000
60	.000	643.081	41.657	.000	.000
Total............	14,196.030	38,744.996	3,075.949	.000	.000

Table A29. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
1	0.000	0.962	0.000	51.361	0.000	49.999	49.988
2	.000	63.912	.000	15.479	.000	49.999	49.988
3	.000	23.493	.000	43.928	.000	49.999	49.988
4	.000	8.586	.000	56.306	.000	49.999	49.988
5	.000	36.563	.000	35.939	.000	49.999	49.988
6	.000	25.103	.000	43.349	.000	49.999	49.988
7	.000	28.125	.000	41.022	.000	49.999	49.988
8	.000	38.352	.000	32.884	.000	49.999	49.988
9	.000	14.781	.000	61.456	.000	.000	49.988
10	.000	34.713	.000	46.219	.000	14.873	49.988
11	.000	27.650	.000	54.560	.000	.000	49.988
12	.000	.000	.000	76.752	.000	.000	49.988
13	.000	74.415	.000	.000	54.154	49.999	49.988
14	.000	61.898	.000	.000	54.154	49.999	49.988
15	.000	58.795	.000	.000	54.154	49.999	49.988
16	.000	21.216	.000	32.666	54.154	49.999	49.988
17	.000	48.076	.000	12.188	54.154	49.999	49.988
18	.000	61.646	.000	.000	54.154	49.999	49.988
19	.000	59.281	.000	.000	54.154	49.999	49.988
20	.000	57.916	.000	.000	54.154	49.999	49.988
21	.000	56.831	.000	.000	54.154	49.999	49.988
22	.000	55.851	.000	.000	54.154	49.999	49.988
23	.000	54.937	.000	.000	54.154	49.999	49.988
24	.000	54.080	.000	.000	54.154	49.999	49.988
25	.000	53.262	.000	.000	54.154	49.999	49.988
26	.000	52.481	.000	.000	54.154	49.999	49.988
27	.000	51.758	.000	.000	54.154	49.999	49.988
28	.000	51.068	.000	.000	54.154	49.999	49.988
29	.000	50.414	.000	.000	54.154	49.999	49.988
30	.000	49.786	.000	.000	54.154	49.999	49.988
31	.000	49.184	.000	.000	54.154	49.999	49.988

Table A29. Optimal Storage Unit I subbasin pumping, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Ortega well	Corporation well	Vera Cruz well	City Hall well	Alameda well	Santa Barbara High School well	Church well
32	0.000	48.605	0.000	0.000	54.154	49.999	49.988
33	.000	48.048	.000	.000	54.154	49.999	49.988
34	.000	47.509	.000	.000	54.154	49.999	49.988
35	.000	46.989	.000	.000	54.154	49.999	49.988
36	.000	46.487	.000	.000	54.154	49.999	49.988
37	.000	46.003	.000	.000	54.154	49.999	49.988
38	.000	45.535	.000	.000	54.154	49.999	49.988
39	.000	45.083	.000	.000	54.154	49.999	49.988
40	.000	44.645	.000	.000	54.154	49.999	49.988
41	.000	44.221	.000	.000	54.154	49.999	49.988
42	.000	43.811	.000	.000	54.154	49.999	49.988
43	.000	43.413	.000	.000	54.154	49.999	49.988
44	.000	43.027	.000	.000	54.154	49.999	49.988
45	.000	42.654	.000	.000	54.154	49.999	49.988
46	.000	42.289	.000	.000	54.154	49.999	49.988
47	.000	41.937	.000	.000	54.154	49.999	49.988
48	.000	41.594	.000	.000	54.154	49.999	49.988
49	.000	41.262	.000	.000	54.154	49.999	49.988
50	.000	40.937	.000	.000	54.154	49.999	49.988
51	.000	40.623	.000	.000	54.154	49.999	49.988
52	.000	40.317	.000	.000	54.154	49.999	49.988
53	.000	40.018	.000	.000	54.154	49.999	49.988
54	.000	39.728	.000	.000	54.154	49.999	49.988
55	.000	39.446	.000	.000	54.154	49.999	49.988
56	.000	39.169	.000	.000	54.154	49.999	49.988
57	.000	38.900	.000	.000	54.154	49.999	49.988
58	.000	38.639	.000	.000	54.154	49.999	49.988
59	.000	38.383	.000	.000	54.154	49.999	49.988
60	.000	38.133	.000	.000	54.154	49.999	49.988
Total............	.000	2,562.536	.000	604.110	2,599.372	2,814.800	2,999.276

Table A30. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
1	0.000	0.000	41.669	0.000	0.000	0.000
2	.000	.000	41.669	.000	.000	.000
3	.000	.000	41.669	.000	.000	.000
4	.000	.000	41.669	.000	.000	.000
5	.000	.000	41.669	.000	.000	.000
6	.000	.000	41.669	.000	.000	.000
7	.000	.000	41.669	.000	.000	.000
8	.000	.000	41.669	.000	.000	.000
9	.000	.000	41.669	.000	.000	.000
10	.000	.000	41.669	.000	.000	.000
11	.000	.000	41.669	.000	.000	.000
12	.000	.000	41.669	.000	.000	.000
13	.000	.000	41.669	.000	.000	.000
14	.000	.000	41.669	.000	.000	.000
15	.000	.000	41.669	.000	.000	.000
16	.000	.000	41.669	.000	.000	.000
17	.000	.000	41.669	.000	.000	.000
18	.000	.000	41.669	.000	.000	.000
19	.000	.000	41.669	.000	.000	.000
20	.000	.000	41.669	.000	.000	.000
21	.000	.000	41.669	.000	.000	.000
22	.000	.000	41.669	.000	.000	.000
23	.000	.000	41.669	.000	.000	.000
24	.000	.000	41.669	.000	.000	.000
25	.000	.000	41.669	.000	.000	.000
26	.000	.000	41.669	.000	.000	.000
27	.000	.000	41.669	.000	.000	.000
28	.000	.000	41.669	.000	.000	.000
29	.000	.000	41.669	.000	.000	.000
30	.000	.000	41.669	.000	.000	.000
31	.000	.000	41.669	.000	.000	.000

Table A30. Optimal Foothill basin pumping, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with current monthly Gibraltar Reservoir diversion percentages—Continued

Month	Lincolnwood #1 well	Lincolnwood #2 well	Los Robles well	Hope Avenue well	Chupparosa well	Franciscan well
32	0.000	0.000	41.669	0.000	0.000	0.000
33	.000	.000	41.669	.081	.000	.000
34	.000	.000	41.669	33.325	.000	.000
35	.000	.000	41.669	33.325	.000	.000
36	.000	.000	41.669	33.325	.000	.000
37	.000	.000	41.669	33.325	.000	.000
38	.000	.000	41.669	33.325	.000	.000
39	.000	.000	41.669	33.325	.000	.000
40	.000	.000	41.669	33.325	.000	.000
41	.000	.000	41.669	33.325	.000	.000
42	.000	.000	41.669	33.325	.000	.000
43	.000	.000	41.669	33.325	.000	.000
44	.000	.000	41.669	33.325	.000	.000
45	.000	.000	41.669	33.325	.000	.000
46	.000	.000	41.669	33.325	.000	.000
47	.000	.000	41.669	33.325	.000	.000
48	.000	.000	41.669	33.325	.000	.000
49	.000	.000	41.669	33.325	.000	.000
50	.000	.000	41.669	33.325	.000	.000
51	.000	.000	41.669	33.325	.000	.000
52	.000	.000	41.669	33.325	.000	.000
53	.000	.000	41.669	33.325	.000	.000
54	.000	.000	41.669	33.325	.000	.000
55	.000	.000	41.669	33.325	.000	.000
56	.000	.000	41.669	33.325	.000	.000
57	.000	.000	41.669	33.325	.000	.000
58	.000	.000	41.669	33.325	.000	.000
59	.000	.000	41.669	33.325	.000	.000
60	.000	.000	41.669	33.325	.000	.000
Total............	.000	.000	2,500.121	899.863	.000	.000

Table A31. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
1	225.000	401.476	70.575	0.000	0.000
2	209.998	389.409	70.575	.000	.000
3	300.000	405.860	70.575	.000	.000
4	415.002	428.378	70.575	.000	.000
5	550.000	434.284	70.575	.000	.000
6	550.000	492.308	70.575	.000	.000
7	550.000	505.135	70.575	.000	.000
8	550.000	516.511	70.575	.000	.000
9	550.000	480.550	70.575	.000	.000
10	459.998	442.978	70.575	.000	.000
11	415.002	326.067	70.575	.000	.000
12	225.000	454.031	70.575	.000	.000
13	225.000	374.132	54.637	.000	.000
14	209.998	401.651	54.637	.000	.000
15	300.000	412.735	54.637	.000	.000
16	415.002	442.648	54.637	.000	.000
17	550.000	455.277	54.637	.000	.000
18	550.000	509.920	54.637	.000	.000
19	550.000	526.292	54.637	.000	.000
20	550.000	541.663	54.637	.000	.000
21	550.000	458.711	54.637	.000	.000
22	459.998	437.703	54.637	.000	.000
23	415.002	301.590	54.637	.000	.000
24	225.000	422.479	54.637	.000	.000
25	62.865	599.257	45.822	.000	.000
26	58.675	604.229	45.822	.000	.000
27	83.820	681.292	45.822	.000	.000
28	115.950	794.864	45.822	.000	.000
29	153.671	917.301	45.822	.000	.000
30	153.671	975.885	45.822	.000	.000
31	153.671	991.037	45.822	.000	.000

Table A31. Optimal surface-water deliveries, in acre-feet per month, Santa Barbara, California: Variable monthly Cachuma Reservoir deliveries with proposed monthly Gibraltar Reservoir diversion percentages—Continued

Month	Gibraltar Reservoir	Cachuma Reservoir	Mission Tunnel	State Water Project	Desalination plant
32	153.671	1,006.105	45.822	0.000	0.000
33	153.671	919.568	45.822	.000	.000
34	128.526	795.990	45.822	.000	.000
35	115.950	620.605	45.822	.000	.000
36	62.865	601.685	45.822	.000	.000
37	125.954	544.997	43.890	.000	.000
38	117.556	553.862	43.890	.000	.000
39	167.943	608.976	43.890	.000	.000
40	232.317	695.003	43.890	.000	.000
41	307.891	784.849	43.890	.000	.000
42	307.891	845.269	43.890	.000	.000
43	307.891	860.699	43.890	.000	.000
44	307.891	876.058	43.890	.000	.000
45	307.891	786.417	43.890	.000	.000
46	257.510	717.202	43.890	.000	.000
47	232.317	547.747	43.890	.000	.000
48	125.954	579.410	43.890	.000	.000
49	.000	611.939	41.657	.000	.000
50	.000	612.264	41.657	.000	.000
51	.000	710.562	41.657	.000	.000
52	.000	850.871	41.657	.000	.000
53	.000	1,005.178	41.657	.000	.000
54	.000	1,061.493	41.657	.000	.000
55	.000	1,075.781	41.657	.000	.000
56	.000	1,090.064	41.657	.000	.000
57	.000	1,006.296	41.657	.000	.000
58	.000	894.567	41.657	.000	.000
59	.000	712.802	41.657	.000	.000
60	.000	643.081	41.657	.000	.000
Total............	14,196.012	38,744.996	3,078.967	.000	.000