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PSWP

A. B. West

United States
Department of the Interior
Stewart L. Udall, Secretary

Pacific Southwest WATER PLAN

APPENDIX
August 1963

PACIFIC SOUTHWEST WATER PLAN

APPENDICES

1. Bureau of Reclamation
2. U. S. Geological Survey
3. Bureau of Land Management
4. Bureau of Outdoor Recreation
5. Bureau of Sport Fisheries and Wildlife
6. National Park Service
7. Bureau of Indian Affairs
8. Office of Saline Water
9. Bureau of Mines
10. Lower Colorado River Land Use Office
11. Bonneville Power Administration

PACIFIC SOUTHWEST WATER PLAN

APPENDIX

Bureau of Reclamation

In the Colorado River Basin, drainage boundaries have not been recognized as a restricting barrier to water resource development and use for many years. Waters of the Colorado River drainage area either are being, or will shortly be, diverted from the Colorado Basin to be mingled with the waters of the Bonneville Basin and the Platte, Arkansas, Rio Grande, Los Angeles, Owens, Santa Ana, San Diego, Sacramento, and San Joaquin Rivers. As water needs become more critical in the West, river basin boundaries will become even less rigid in water and land resource development.

All of the surface and underground water resources of the Pacific Southwest area have been considered in development of the Pacific Southwest Water Plan. In addition, some of the surplus waters from the north coastal basins in California are considered for importation to the area. Saline water conversion plants and reuse of return flow and sewage effluent are also involved in the plan of development.

The existing and proposed developments in the Colorado River Basin and in the Central Valley and north coastal basins of California are influenced by, and influence the formulation of, any plan which proposed additional uses of the waters in these systems.

To attempt to document the wealth of information, plans, and alternative plans for water resource development that have been considered to accomplish various purposes in the Pacific Southwest would be beyond the scope of this appendix. A partial list of completed, or soon to be completed, Bureau of Reclamation reports which are pertinent to the problem is therefore provided and the several alternative plans for sea-water desalting and California supplemental diversion routes which were presented briefly in the report are discussed in further detail.

<u>Partial List of Pertinent Bureau of Reclamation Reports</u>

Buttes Dam and Reservoir, Middle Gila River Project, Arizona, January 1961
Central Arizona Project, Arizona-New Mexico, December 1947
Central Arizona Project, Supplemental Report, Arizona-New Mexico
Dixie Project, Utah, October 1961
Southern Nevada Water Supply Project, Nevada, June 1963
East Side Division, Central Valley Project, California

Colorado River Water Salvage
Palmdale Project, California
Santa Margarita River Project
San Luis Division, Central Valley Project, California
Trinity River Division, Central Valley Project, California
Calleguas Basin Reconnaissance Report, California
Arizona-Colorado River Diversions Projects, Arizona
Inventory of Water Resources, Arizona

Alternative Plans for Import from Northern California and for Desalting Plants

The following descriptive material and drawings present the alternative routes for importing surplus northern California water to the Southwest areas. More detailed information on the import plan from the Lower Eel River and the Lake Havasu Aqueduct, and the desalting alternative is also included. Seven alternative import routes show the relationship to demands and proposed facilities for the East Side Division, Central Valley Project with the conveyance of 1,200,000 acre-feet of supplemental water for southern California obtained from proposed storage reservoirs on Trinity River and South Fork Trinity River. The material also describes the features required and accomplishments obtained within the Central Valley Basin in California under each alternative plan.

The Pacific Southwest Water Plan contemplates that conveyance of the initial supply of 1,200,000 acre-feet in the Phase I program would be through an incremental enlargement of the California Aqueduct reflected in alternative plans 2 and 3.

Following the discussion of the seven alternative methods of conveying the initial 1,200,000 acre-feet, there is a description of the proposed means of conserving and conveying an additional 1,200,000 acre-feet to Lake Havasu. The storage reservoirs contemplated for this supply are on the Lower Eel River in the North Coastal section of California. The desalting alternative as a prospective source of water supply for the Pacific Southwest area also is discussed.

Alternative Route Summary--Seven alternative reconnaissance plans for conveyance of an additional annual supply of 1,200,000 acre-feet of water to southern California are presented in this section. A tabular summary comparing these plans follows.

In brief, these alternative plans all rely on conserving the additional 1,200,000 acre-feet of water in two proposed reservoirs on the Trinity River system with diversion to Sacramento River. As indicated in the discussion of the alternative plans, these proposed reservoir storage systems on Trinity River and appurtenant diversions should be authorized for construction and operation by the Bureau of Reclamation.

The additional water supply is considered to be conveyed to southern California through the following alternative routes:

(a) Enlargement of California Aqueduct along west side of San Joaquin Valley through Tehachapi pumping plants and tunnels, and thence to Perris Reservoir (Alternative Plans 2 and 3).

(b) Enlargement of East Side Division on easterly side of San Joaquin Valley; thence connecting with California Aqueduct immediately north of Tehachapi Mountains, from which location the California Aqueduct would be enlarged to its terminus at Perris Reservoir (Alternative Plan 1).

(c) Sierra Nevada tunnel diversions of east side San Joaquin Valley streams to connect with California Aqueduct south of Tehachapi Mountains, and thence through an enlarged aqueduct to Perris Reservoir. Exchange water for downstream users of east side San Joaquin Valley streams conveyed either through enlarged California Aqueduct system to south end of San Joaquin Valley, and by new canal extending northerly to intersect east side streams (Alternative Plan 4), or through an enlarged East Side Division to Kern River (Alternative Plan 6).

(d) Sierra Nevada tunnel diversions of east side San Joaquin Valley streams to the southerly side of Tehachapi Mountains, and thence to Lake Havasu on Colorado River. Exchange water for downstream users of east side San Joaquin Valley streams conveyed either through enlarged California Aqueduct system and new canal extending northerly from south end of San Joaquin Valley to intersect east side streams (Alternative Plan 5), or through an enlarged East Side Division to Kern River (Alternative Plan 7).

Alternative Plan No. 2 represents the minimum basic facilities required to convey the additional water to southern California. No recognition is given under that plan to the existing and increasing needs for additional water within Central Valley areas. To accomplish this increased diversion to southern California, it is desirable, and may well be necessary, that such additional needs en route be recognized.

Associated with the other alternative plans, therefore, are prospective Central Valley Project facilities which, under each particular alternative plan considered, would need to be authorized concurrently with the specific features analyzed for conveying additional water to southern California. These prospective Central Valley Project features relate to East Side Division and Delta Water Quality Improvement. Prospective East Side Division facilities vary among the several alternative plans in order to accomplish some measure of East Side Division service appropriately and expeditiously. Use of any alternative plan other than Plan 2, consequently, would result in related multiple-purpose benefits occurring within Central Valley Basin. Accomplishment of any alternative plan comprising the Sierra tunnel diversions could be realized only after negotiations with downstream water users.

Alternative Plans for Conservation and Conveyance of
1,200,000 Acre-Feet Additional Water Annually to Southern California

ALTERNATIVES	COSTS CAPITAL 1/ (Millions of Dollars)	COSTS ANNUAL (Millions of Dollars)	COSTS PER ACRE-FOOT 2/ (Dollars)	ASSOCIATED FEATURES AND ACCOMPLISHMENTS
Plan 1				
East Side Route	975.0 Constr.	44.1 Int. & Amor.		East Side Division and Delta
	160.9 I.D.C.	18.4 OM&R & Power		Water Quality Improvement Related
	1,135.9 Total	62.5 Total	52	Multiple-Purpose Benefits
Plan 2				
West Side Route	905.0 Constr.	41.0 Int. & Amor.		None
	149.5 I.D.C.	16.5 OM&R & Power		
	1,054.5 Total	57.5 Total	48	
Plan 3				
West Side Route with East Side Service	905.0 Constr.	41.0 Int. & Amor.		Partial East Side Division and
	149.5 I.D.C.	16.5 OM&R & Power		Delta Water Quality Improvement
	1,054.5 Total	57.5 Total	48	Related Multiple-Purpose Benefits
Plan 4				
Sierra Diversion to So. Calif. (Perris Res.)	1,810.0 Constr.	82.0 Int. & Amor.		Partial East Side Division and
(Exchange Water through California Aqueduct	298.7 I.D.C.	-2.7 OM&R & Power		Delta Water Quality Improvement
with East Side Service)	2,108.7 Total	79.3 Total	66	Related Multiple-Purpose Benefits
Plan 5				
Sierra Diversion to Havasu Lake	1,750.0 Constr.	79.2 Int. & Amor.		Partial East Side Division and
(Exchange Water through California Aqueduct	288.8 I.D.C.	-9.9 OM&R & Power		Delta Water Quality Improvement
with East Side Service)	2,038.8 Total	69.3 Total	58	Related Multiple-Purpose Benefits
Plan 6				
Sierra Diversion to Southern California	1,750.0 Constr.	79.2 Int. & Amor.		East Side Division and Delta
(Perris Res.) (Exchange Water through	288.8 I.D.C.	-3.9 OM&R & Power		Water Quality Improvement Related
East Side Division)	2,038.8 Total	75.3 Total	63	Multiple-Purpose Benefits
Plan 7				
Sierra Diversion to Havasu Lake	1,690.0 Constr.	76.5 Int. & Amor.		East Side Division and Delta
(Exchange Water through East Side Division)	278.9 I.D.C.	-11.0 OM&R & Power		Water Quality Improvement Related
	1,968.9 Total	65.5 Total	55	Multiple-Purpose Benefits

1/ Capital costs are on reconnaissance basis and include storage reservoirs and appurtenant diversions, conveyance facilities (incremental enlargement or additions), and exchange features (for Plans 4-7). Costs of associated Central Valley Project proposed facilities for East Side Division and Delta Water Quality Improvement are not included. Concurrent authorization of these C.V.P. facilities is contemplated for these alternative plans.

2/ Acre-foot costs shown represent average annual equivalent costs and are computed on basis of incremental costs of enlargement of conveyance facilities. Appropriate allocation of costs may reflect some increase in these acre-foot values.

Plan 1 (East Side Route)--This plan will conserve and convey an additional water supply of 1,200,000 acre-feet per year by storage on Trinity River and conveyance through East Side Division facilities, and thence through the California Aqueduct to southern California.

To obtain the additional yield of water, two storage reservoirs are proposed on the Trinity River. Helena Reservoir, with a gross storage capacity of 2,800,000 acre-feet, would be built on the main Trinity River downstream from Lewiston Dam. This reservoir would develop an annual new water yield of 600,000 acre-feet which would be diverted to the Sacramento River. Subsequently, Eltapom Reservoir, with a gross storage capacity of 3,100,000 acre-feet, would be constructed on the South Fork of Trinity River. This reservoir also would develop an annual yield of 600,000 acre-feet which would be diverted to Helena Reservoir, with subsequent diversion to Sacramento River. Power generating facilities would be incorporated with these proposed developments. Estimated capital costs of these reservoirs and associated facilities are $540,000,000. Annual OM&R costs would be offset by power revenues, with a net annual amount remaining of about $12,300,000.

This plan proposes to add a 2,000 c.f.s. increment to the proposed East Side Division conveyance facilities from the Sacramento River via Hood-Clay pump lift and then through the East Side Division conveyance facilities to the Kern River. From that location a new 2,000 c.f.s. canal would be constructed to connect with the California Aqueduct at Wheeler Ridge Pumping Plant No. 1.

Additional facilities required, therefore, will be the enlargement of the East Side Division conveyance facilities, and construction of the 36-mile Kern River-Wheeler Ridge canal with 2,000 c.f.s. capacity. A new pumping plant with a head of about 150 feet will be required to connect this proposed system with the California Aqueduct at Wheeler Ridge. The total capital cost, on a reconnaissance basis, is estimated to be $145,000,000 for the facilities from the Delta through the East Side System to Wheeler Ridge. Annual OM&R costs for these facilities are estimated to be $1,000,000, not including cost of pumping energy. Cost of pumping is estimated at $7,100,000.

From Wheeler Ridge the increased water supply of 1,200,000 acre-feet would be conveyed through the California Aqueduct to Perris Reservoir. The estimated capital cost for incremental conveyance facilities from Wheeler Ridge to Perris Reservoir is $290,000,000. Annual OM&R costs are estimated at $2,700,000. Net pumping costs for conveyance from Wheeler Ridge to Perris Reservoir are estimated to be $19,900,000.

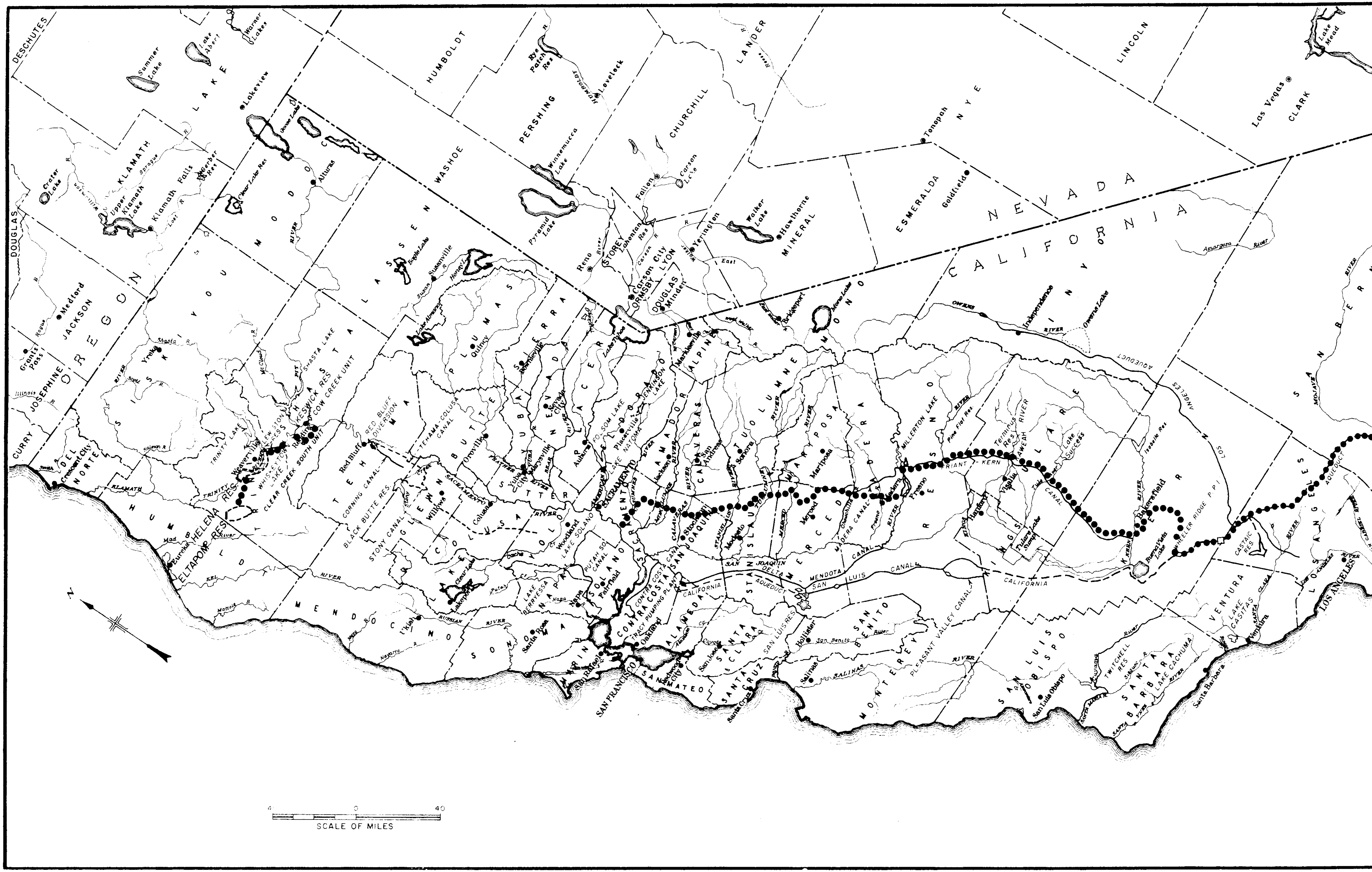
The estimated total capital cost for this prospective plan, including storage reservoir systems, incremental conveyance through the East Side Division and thence to southern California, is $975,000,000 (reconnaissance). The net annual OM&R and pumping costs are $18,400,000.

Under this proposal the 1,200,000 acre-feet of additional water would be stored and conveyed to southern California at an estimated average annual equivalent cost of $52 per acre-foot, including interest at 3 percent and amortization of the facilities in 50 years. The average annual acre-foot cost given is computed by using only the incremental costs of enlargement of conveyance facilities. Appropriate allocation of costs between the East Side Division facilities and the proposed incremental enlargement under this plan may reflect some increase in this acre-foot value.

Associated with this development would be the East Side Division which would provide 1,500,000 acre-feet of service to that area with its resulting multiple-purpose benefits. The estimated capital cost of the proposed facilities required for East Side Division is about $600,000,000, exclusive of distribution systems. The East Side Division is proposed for authorization, construction, and operation, as an integral part of the Central Valley Project. In order to accomplish the conveyance of the additional 1,200,000 acre-feet to southern California, concurrent authorization of the facilities would be required.

The reservoir storage systems proposed on the Trinity River System under this plan (Helena and Eltapom) and related diversions to Sacramento River should be authorized for construction and operation by the Bureau of Reclamation as part of the Pacific Southwest Water Plan, even though they will be integrated closely with existing and proposed features of the Federal Central Valley Project.

To other facilities--the Delta Peripheral Canal and the Kellog Unit--also should be associated with this proposed plan for authorization as part of the Central Valley Project, with financial participation by the State and other agencies as appropriate. These facilities will offset, in particular, adverse effects which may occur to water supplies in the Delta area due to further water supply development in the Central Valley Basin and increased diversions from the Delta. The total capital costs of these features are estimated at $125,000,000, with annual OM&R and pumping costs of $1,200,000.



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Redwood City
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Hollister
Salinas
San Luis Obispo
Santa Barbara
Ventura
Los Angeles
Eureka
Crescent City
Pyramid Lake
Walker Lake
Mono Lake
Lake Tahoe
Clear Lake
Tulare Lake
Buena Vista Lake
Owens Lake
Lake Mead
Shasta Lake
Keswick Res
Whiskeytown Lake
Clear Creek South Unit
Cow Creek Unit
Helena Res
Eltapom Res
Trinity Lake
Lewiston
Red Bluff Diversion
Tehama-Colusa Canal
Corning Canal
Black Butte Res.
Stony Canal
Folsom Lake
Natoma
Lake Solano
Putah So. Canal
Lake Berryessa
Contra Costa Canal
Tracy Pumping Plant
San Joaquin Delta
Delta Mendota Canal
San Luis Canal
San Luis Res
California Aqueduct
Madera Canal
Friant - Kern
Millerton Lake
Pine Flat Res.
Terminus Res
Lake Success
Isabella Res
Wheeler Ridge P.P.
Castaic Res
Lake Casitas
Twitchell Res
Lake Cachuma
Pleasant Valley Canal
Los Angeles Aqueduct
Owens River
Amargosa River
Mojave River
Sacramento River
Salinas River
Russian River
Eel River
Klamath
Trinity
Del Norte
Humboldt
Mendocino
Sonoma
Marin
Siskiyou
Modoc
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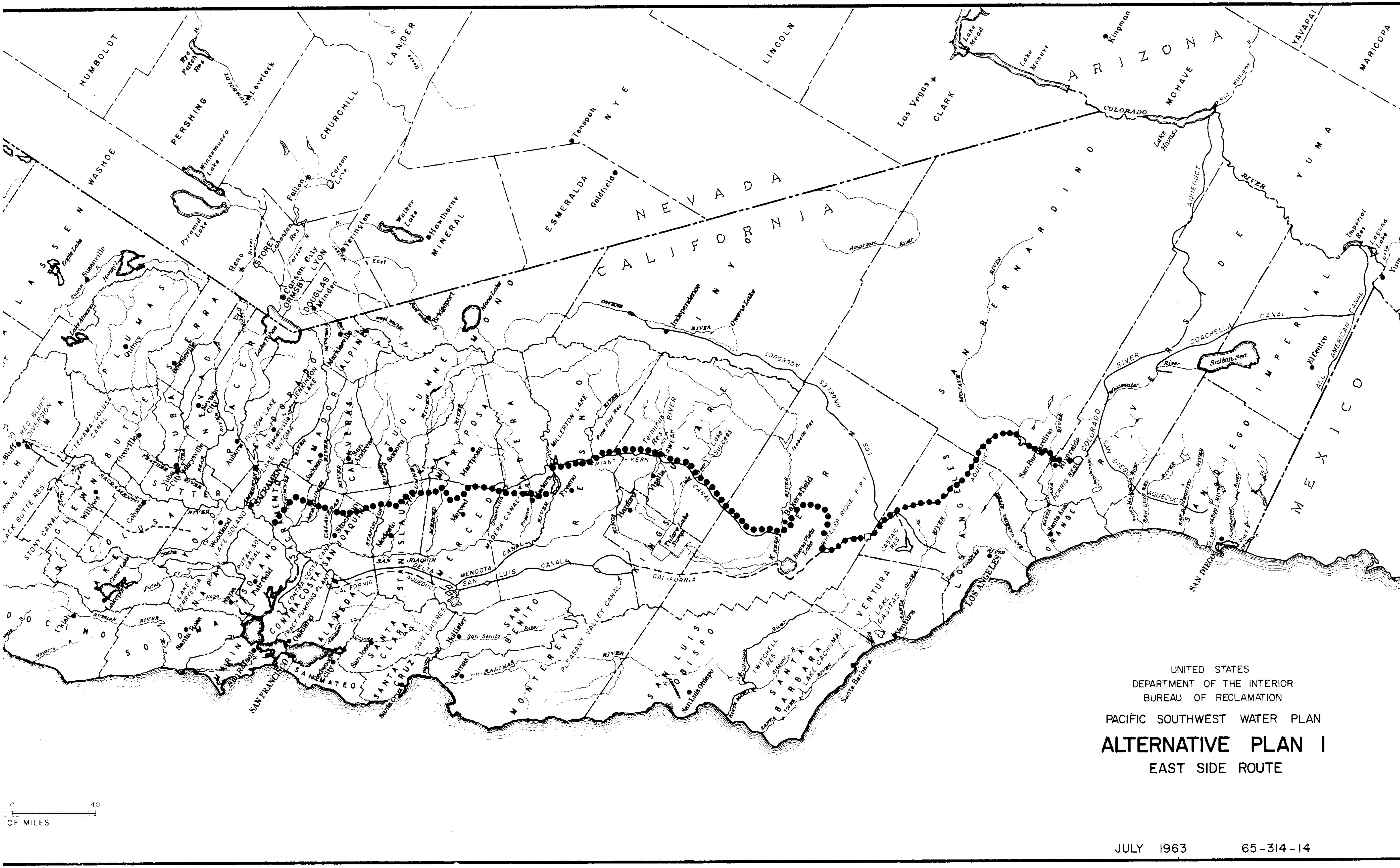
UNITED STATES
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PLACER
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ALPINE
TUOLUMNE
MONO
MARIPOSA
MADERA
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INYO
TULARE
KINGS
KERN
SAN BERNARDINO
RIVERSIDE
IMPERIAL
SAN DIEGO
ORANGE
LOS ANGELES
VENTURA
SANTA BARBARA
SAN LUIS OBISPO
MONTEREY
SAN BENITO
SANTA CLARA
SANTA CRUZ
SAN MATEO
ALAMEDA
CONTRA COSTA
SAN JOAQUIN
STANISLAUS
MERCED
SACRAMENTO
SOLANO
YOLO
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Goldfield
Minden
Las Vegas
Kingman
Yuma
Susanville
Quincy
Oroville
Marysville
Yuba City
Auburn
Placerville
Sacramento
Woodland
Fairfield
Napa
Santa Rosa
Ukiah
Lakeport
Willows
Colusa
Stockton
Modesto
Merced
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Hanford
Bakersfield
Independence
Bridgeport
San Andreas
Jackson
Sonora
Markleeville
Oakland
San Rafael
SAN FRANCISCO
Redwood City
San Jose
Santa Cruz
Hollister
Salinas
San Luis Obispo
Santa Barbara
Ventura
LOS ANGELES
San Bernardino
Riverside
Santa Ana
SAN DIEGO
El Centro
Lake Tahoe
Pyramid Lake
Winnemucca Lake
Walker Lake
Mono Lake
Owens Lake
Salton Sea
Lake Mead
Lake Mohave
Lake Havasu
Imperial Res
Laguna Lake
Clear Lake
Eagle Lake
Honey L.
Lake Almanor
Folsom Lake
Lake Natoma
Lake Berryessa
Lake Solano
Millerton Lake
Pine Flat Res.
Terminus Res
Lake Success
Isabella Res.
Buena Vista Lake
Tulare Lake Sump
Castaic Res.
Lake Casitas
Twitchell Res.
Lake Cachuma
Perris Res.
Lahontan Res.
Rye Patch Res.
Carson Lake
COLORADO
RIVER
COLORADO RIVER AQUEDUCT
ALL AMERICAN CANAL
COACHELLA CANAL
OWENS RIVER
LOS ANGELES AQUEDUCT
CALIFORNIA AQUEDUCT
SAN LUIS CANAL
DELTA MENDOTA CANAL
MADERA CANAL
FRIANT-KERN CANAL
TEHAMA-COLUSA CANAL
STONY CANAL
CORNING CANAL
RED BLUFF DIVERSION
BLACK BUTTE RES.
PUTAH SO. CANAL
CONTRA COSTA CANAL
TRACY PUMPING PLANT
SAN LUIS RES.
PLEASANT VALLEY CANAL
WHEELER RIDGE P.P.
SAN DIEGO AQUEDUCT
Amargosa River
MOJAVE RIVER
SANTA ANA RIVER
RUSSIAN RIVER
SALINAS RIVER
KERN RIVER
KAWEAH RIVER
KINGS RIVER
SAN JOAQUIN RIVER
TUOLUMNE RIVER
MERCED RIVER
SACRAMENTO RIVER
FEATHER RIVER
Bill Williams R.
Whitewater River

Plan 2 (West Side Route)--This plan proposes to conserve and convey an additional water supply of 1,200,000 acre-feet by storage on Trinity River and enlargement of the California Aqueduct. For developing the additional supply two storage reservoirs are proposed on the Trinity River. Helena Reservoir with a gross storage capacity of 2,800,000 acre-feet would be built on the main Trinity River downstream from Lewiston Dam. This reservoir would develop an annual new water yield of 600,000 acre-feet which would be diverted to the Sacramento River. Subsequently, Eltapom Reservoir, with a gross storage capacity of 3,100,000 acre-feet, would be constructed on the South Fork of Trinity River. This reservoir also would develop an annual yield of 600,000 acre-feet which would be diverted to Helena Reservoir, with subsequent diversion to Sacramento River. Power generating facilities would be incorporated with these proposed developments. Estimated capital costs of these reservoirs and associated facilities are $540,000,000. Annual OM&R costs would be offset by power revenues with a net annual amount remaining of about $12,300,000.

This increased yield of 1,200,000 acre-feet would be conveyed through the California Aqueduct. Incremental capacity would be provided in the aqueduct from San Luis Forebay to the terminal Perris Reservoir. Through the San Luis service area (Federal) a parallel canal is contemplated in view of the advanced construction status of the Federal-State system. The State of California estimates the incremental capital cost of facilities for conveying this additional water to southern California at $368,000,000. Savings of approximately $50,000,000 are estimated if the incremental capacity could be incorporated with the Federal-State system through the San Luis area. However, the advanced construction status of the San Luis system makes this improbable.

Annual OM&R costs for this increased conveyance capacity, exclusive of pumping energy, are estimated by the State at $3,326,000. Power costs for pumping the additional yield of 1,200,000 acre-feet from the Sacramento-San Joaquin Delta to Perris Reservoir would approximate $25,515,000 on a net basis after deductions for power generated along the route.

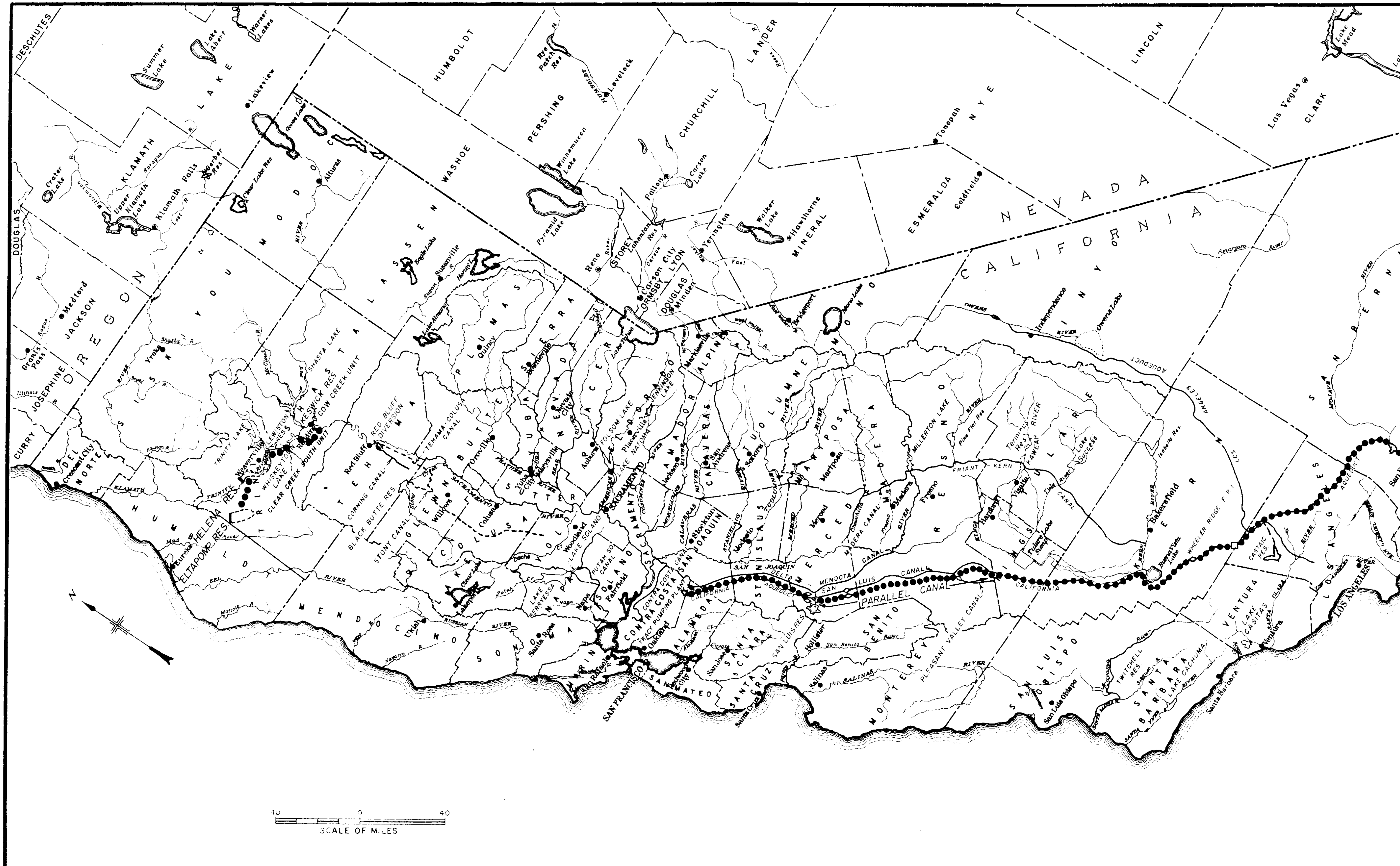
The estimated total capital cost for this prospective plan, including storage reservoir systems and incremental conveyance to southern California through the California Aqueduct, is $905,000,000. The net annual OM&R and pumping costs are $16,540,000.

Under this proposal the additional 1,200,000 acre-feet of water would be stored and conveyed to southern California at an estimated average annual equivalent cost of $48 per acre-foot, including interest at 3 percent, and amortization of the facilities in 50 years.

The average annual acre-foot cost given is computed by using incremental costs of enlargement of part of the California Aqueduct. Appropriate allocation of costs between the California Aqueduct and the proposed incremental enlargement under this plan may reflect some increase in this acre-foot value.

The reservoir storage systems and related diversions to Sacramento River proposed under this plan should be authorized for construction and operation by the Bureau of Reclamation as part of the Pacific Southwest Water Plan, even though they will be integrated closely with existing and proposed features of the Federal Central Valley Project.

The facilities proposed under this Plan are the basic minimum facilities required for conserving and conveying the additional 1,200,000 acre-feet of water to southern California. Other associated works also should be included along with this proposed plan for concurrent authorization and construction as part of the Central Valley Project. These other related facilities are summarized under Plan 3.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Summer Lake
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Upper Klamath Lake
Klamath Falls
Medford
Grants Pass
HUMBOLDT
WASHOE
PERSHING
Winnemucca
Lovelock
Rye Patch Res
CHURCHILL
Fallon
Carson Lake
LANDER
LINCOLN
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Tonopah
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CLARK
Lake Mead
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KESWICK RES
COW CREEK UNIT
SOUTH UNIT
CLEAR CREEK
WHISKEYTOWN LAKE
LEWISTON RES
TRINITY LAKE
Weaverville
Redding
DEL NORTE
Crescent City
HUMBOLDT
Eureka
HELENA RES
ELTAPOMP RES
TRINITY
TEHAMA
Red Bluff
RED BLUFF DIVERSION
TEHAMA-COLUSA CANAL
CORNING CANAL
BLACK BUTTE RES.
STONY CANAL
GLENN
Willows
COLUSA
Colusa
BUTTE
Oroville
PLUMAS
Quincy
SIERRA
YUBA
NEVADA
SUTTER
Yuba City
Marysville
PLACER
Auburn
FOLSOM LAKE
EL DORADO
Placerville
LAKE NATOMA
Lake Tahoe
ALPINE
Markleeville
SACRAMENTO
YOLO
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PUTAH SO CANAL
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SONOMA
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MARIN
San Rafael
SAN FRANCISCO
CONTRA COSTA
Oakland
TRACY PUMPING PLANT
ALAMEDA
SAN MATEO
SANTA CLARA
San Jose
SANTA CRUZ
Santa Cruz
SAN LUIS RES
Hollister
SAN BENITO
MONTEREY
Salinas
PLEASANT VALLEY CANAL
SAN JOAQUIN
Stockton
AMADOR
Jackson
CALAVERAS
San Andreas
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MILLERTON LAKE
Pine Flat Res
FRESNO
Fresno
DELTA MENDOTA CANAL
SAN LUIS CANAL
PARALLEL CANAL
CALIFORNIA AQUEDUCT
TULARE
Visalia
Terminus Res
KAWEAH RIVER
Lake Success
FRIANT-KERN CANAL
KINGS
Hanford
Tulare Lake
KERN
Bakersfield
Buena Vista Lake
Isabella Res
WHEELER RIDGE P.P.
INYO
Independence
Owens Lake
MONO
Mono Lake
Bridgeport
LOS ANGELES AQUEDUCT
SAN BERNARDINO
SAN LUIS OBISPO
San Luis Obispo
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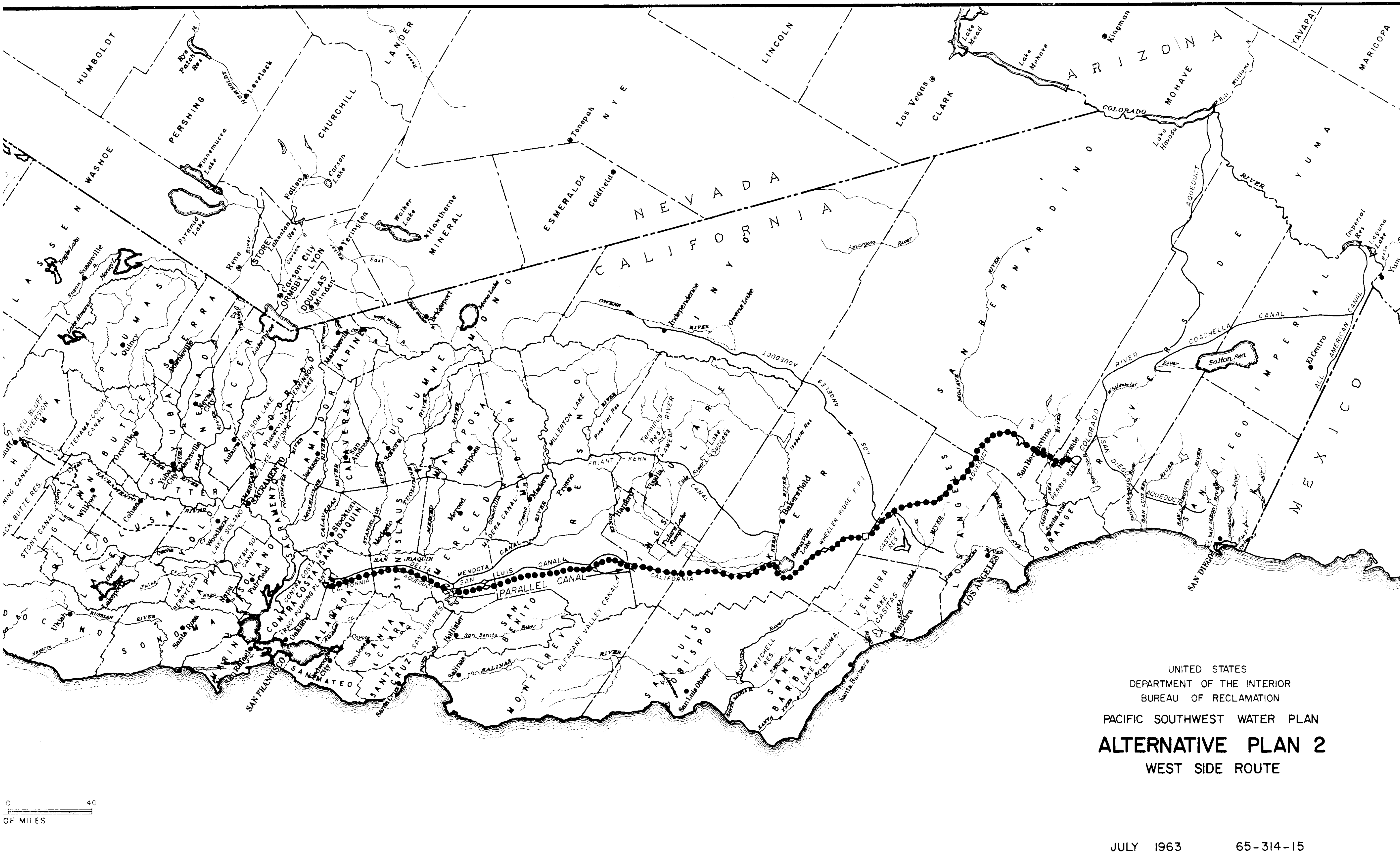


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

ALTERNATIVE PLAN 2

WEST SIDE ROUTE

JULY 1963 65-314-15

Plan 3 (West Side Route with Service to East Side)--This plan proposes to conserve and convey an additional water supply of 1,200,000 acre-feet through storage on Trinity River and enlargement of the California Aqueduct with additional service to east side San Joaquin Valley. For developing the additional supply two storage reservoirs are proposed on the Trinity River. Helena Reservoir, with a gross storage capacity of 2,800,000 acre-feet, would be built on the main Trinity River downstream from Lewiston Dam. This reservoir would develop an annual new water yield of 600,000 acre-feet which would be diverted to the Sacramento River. Subsequently, Eltapom Reservoir, with a gross storage capacity of 3,100,000 acre-feet, would be constructed on the South Fork of Trinity River. This reservoir also would develop an annual yield of 600,000 acre-feet which would be diverted to Helena Reservoir, with subsequent diversion to Sacramento River. Power generating facilities would be incorporated with these proposed developments. Estimated capital costs of these reservoirs and associated facilities are $540,000,000. Annual OM&R costs would be offset by power revenues with a net annual amount remaining of about $12,300,000.

This increased yield of 1,200,000 acre-feet would be conveyed through the California Aqueduct. Incremental capacity would be provided in the aqueduct from San Luis Forebay to the terminal Perris Reservoir. Through the San Luis service area (Federal) a parallel canal is contemplated in view of the advanced construction status of the Federal-State system. The State of California estimates the incremental capital cost of facilities for conveying this additional water to southern California at $368,000,000. Savings of approximately $50,000,000 are estimated if the incremental capacity could be incorporated with the Federal-State system through the San Luis area.

The estimated total capital cost for this prospective plan, including storage reservoir systems and incremental conveyance to southern California through the California Aqueduct, is $905,000,000. The net annual OM&R and pumping costs are $16,540,000.

Under this proposal, the additional 1,200,000 acre-feet of water would be stored and conveyed to southern California at an estimated average annual equivalent cost of $48.00 per acre-foot, including interest at 3 percent and amortization of the facilities in 50 years.

The average annual acre-foot cost given is computed by using incremental costs of enlargement of part of the California Aqueduct. Appropriate allocation of costs between the California Aqueduct and the proposed incremental enlargement under this plan may reflect some increase in this acre-foot value.

The reservoir storage systems and related diversions to Sacramento River proposed under this plan should be authorized for construction and operation by the Bureau of Reclamation as part of the Pacific Southwest Water Plan, even though they will be integrated closely with existing and proposed features of the Federal Central Valley Project.

The east side San Joaquin Valley areas are very conscious of their existing and increasing needs for additional water. They will be alert, particularly to any plan which proposes increased exportation of water from the Central Valley Basin unless that plan also includes service to the San Joaquin Valley areas. For that purpose, therefore, in addition to the aforedescribed facilities for storing and conveying water to southern California, service also would be provided under this plan to the southern portion of the East Side Division by including incremental canal capacity of 3,000 c.f.s. in the California Aqueduct from the Delta to Wheeler Ridge. From that location a 3,000 c.f.s. canal would extend to Tule River. Two off-stream storage reservoirs with a combined capacity of about 1,800,000 acre-feet and associated pumping plant facilities would be included with this proposed development. The estimated capital cost of these proposed conveyance and off-stream storage facilities for East Side Division service is estimated, on a reconnaissance basis, at $375,000,000. Costs of required distribution systems are not included. These proposed facilities, through integration with the Millerton Lake system, could supply about 1,400,000 acre-feet of additional water to the east side area. Inclusion of the increased conveyance capacity for East Side Division in the California Aqueduct, if it were increased for additional conveyance to southern California, would provide the least expensive and most rapid method of providing initial service to the southern San Joaquin Valley. It is highly important that this be done if the plan for increased conveyance through the California Aqueduct were adopted.

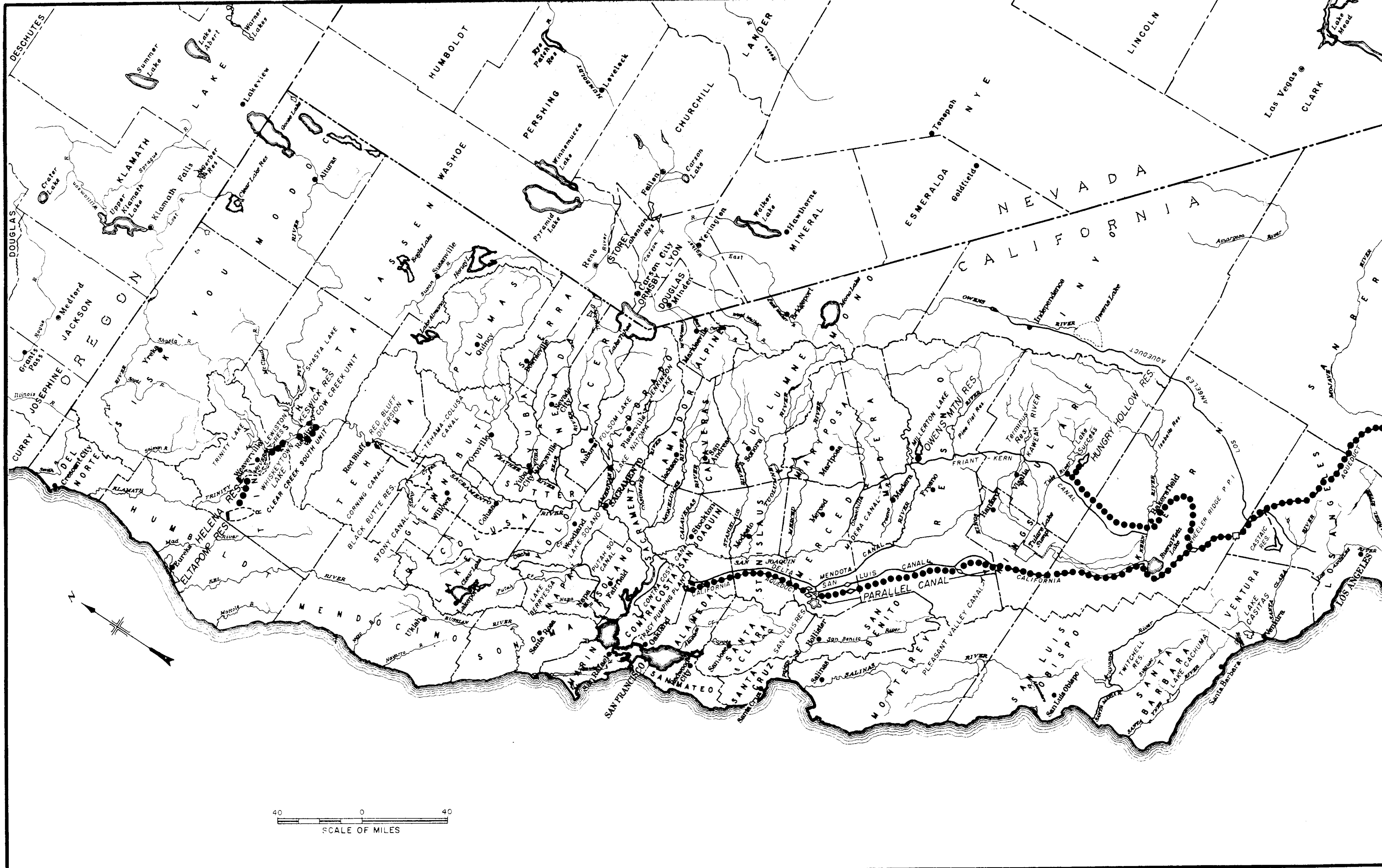
The estimated annual OM&R costs for these East Side Division facilities, exclusive of pumping energy, are $1,450,000. Pumping power costs are estimated at $9,400,000 for the east side service. Subsequently, early authorization of additional works would be required to provide increased East Side Division service through facilities on the east side of San Joaquin Valley from the Delta to connect at Tule River with the features proposed under this plan.

The transfer of additional water of a high quality through the Sacramento-San Joaquin River Delta will require modification of the present channels which were constructed as part of the extensive levee system to protect the low elevation Delta lands from flooding. To accomplish this the Bureau has proposed that a new channel around the periphery of the Delta will provide the highest possible water quality--total dissolved solids will average less than 200 parts per million. In addition, the channel will provide maximum protection to the large resident and anadromous fisheries that use the present Delta channels. The excellent quality of water will be of economic value to southern California in two ways: (1) costs of water treatment will be reduced, and (2) the low salt content of the water will permit maximum reuse.

The estimated capital cost of the Delta Peripheral Canal is $70,000,000, with an annual OM&R cost, including power, of $800,000. This facility should be authorized for Federal construction with appropriate financial participation by the State of California.

Further development of water in Central Valley Basin and increased diversions from the Delta, either for use in southern California or within the Central Valley, also expands the urgency for the Kellog Unit to offset adverse effects which may occur to water supplies relied upon by Contra Costa County. These facilities are proposed as an integral part of the Central Valley Project principally for water quality improvement, although other multiple-purpose functions would be served for the urbanized and highly industrialized Contra Costa County. This area is now being served in part by the Central Valley Project. This unit also would provide operational flexibility for the Central Valley Project through integration with operations of Tracy Pumping Plant and the Delta Peripheral Canal.

The estimated capital cost of this proposed unit is $55,000,000, with an annual OM&R cost of $285,000. In addition, an annual pumping cost of $120,000 is estimated.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TUOLUMNE
MONO
MARIPOSA
MADERA
MERCED
STANISLAUS
SAN JOAQUIN
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INYO
KERN
SAN LUIS OBISPO
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
SAN FRANCISCO
Lake Mead
Las Vegas
Tonopah
Goldfield
Hawthorne
Walker Lake
Yerington
Carson City
Minden
Reno
Fallon
Carson Lake
Lahontan Res
Pyramid Lake
Winnemucca Lake
Lovelock
Rye Patch Res
Summer Lake
Lake Abert
Warner Lakes
Lakeview
Goose Lake
Alturas
Clear Lake Res
Crater Lake
Upper Klamath Lake
Klamath Falls
Medford
Grants Pass
Yreka
Crescent City
Eureka
Weaverville
Redding
Red Bluff
Susanville
Eagle Lake
Honey L
Quincy
Oroville
Willows
Colusa
Yuba City
Marysville
Auburn
Placerville
Woodland
Sacramento
Stockton
Modesto
Merced
Madera
Fresno
Mariposa
Sonora
San Andreas
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Markleeville
Bridgeport
Mono Lake
Independence
Owens Lake
Hanford
Visalia
Tulare Lake
Bakersfield
Buena Vista Lake
Ukiah
Lakeport
Clear Lake
Santa Rosa
Napa
Fairfield
San Rafael
Oakland
Redwood City
San Jose
Santa Cruz
Hollister
Salinas
San Luis Obispo
Santa Barbara
Ventura
Lake Tahoe
TRINITY LAKE
LEWISTON LAKE
WHISKEYTOWN LAKE
CLEAR CREEK SOUTH UNIT
KESWICK RES
SHASTA LAKE
COW CREEK UNIT
RED BLUFF DIVERSION
TEHAMA-COLUSA CANAL
CORNING CANAL
BLACK BUTTE RES.
STONY CANAL
HELENA RES
ELTAPOMP RES
LAKE BERRYESSA
PUTAH SO. CANAL
LAKE SOLANO
FOLSOM LAKE
NATOMA
JENKINSON LAKE
TRACY PUMPING PLANT
CONTRA COSTA CANAL
SAN LUIS RES
SAN JOAQUIN DELTA - MENDOTA CANAL
SAN LUIS CANAL
CALIFORNIA AQUEDUCT
PARALLEL CANAL
PLEASANT VALLEY CANAL
MADERA CANAL
MILLERTON LAKE
OWENS MTN RES
FRIANT - KERN CANAL
Pine Flat Res
Terminus Res
Lake Success
HUNGRY HOLLOW RES
Isabella Res.
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TWITCHELL RES.
LAKE CACHUMA
OWENS RIVER
Amargosa River
MOJAVE RIVER
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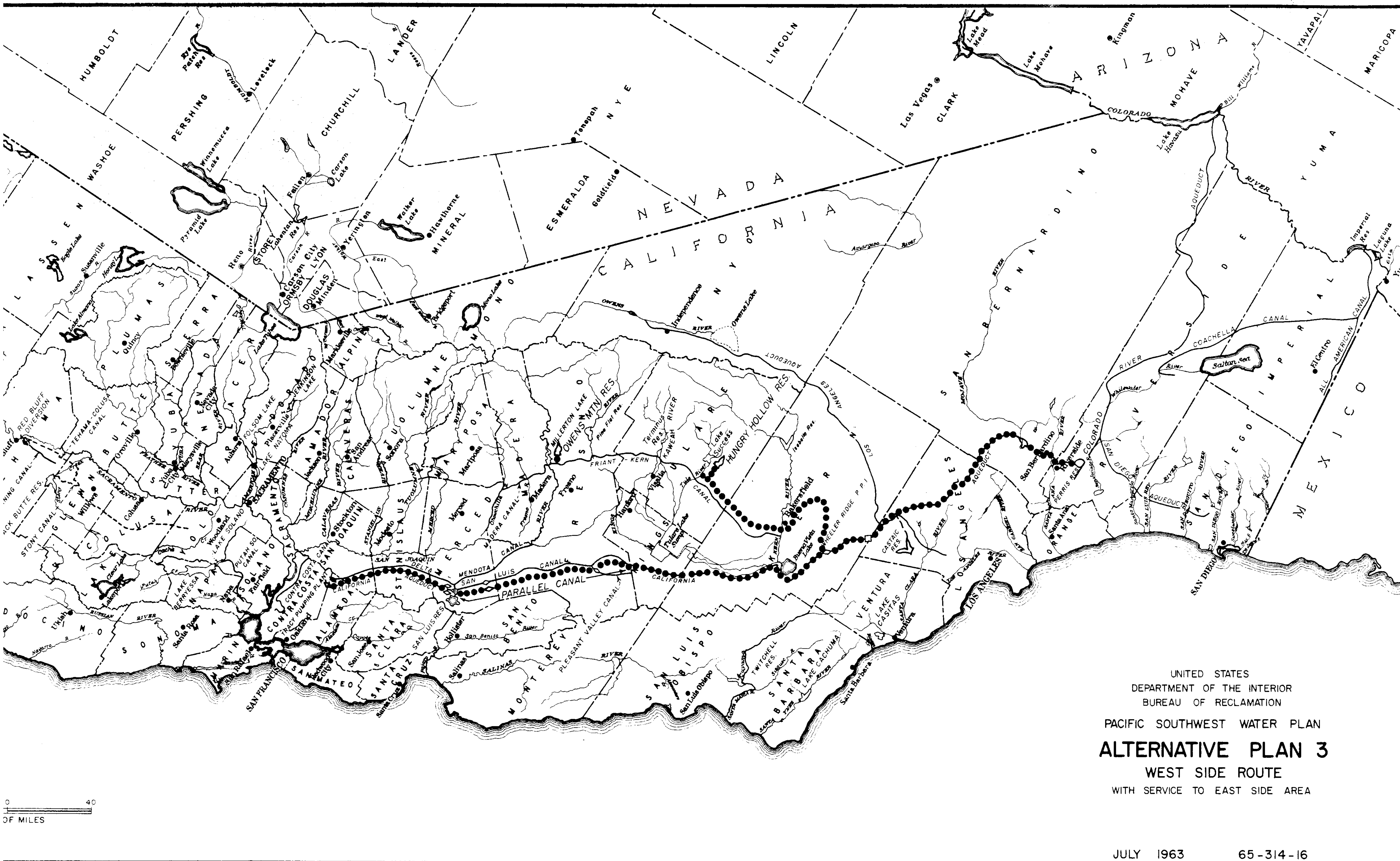


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

ALTERNATIVE PLAN 3

WEST SIDE ROUTE

WITH SERVICE TO EAST SIDE AREA

JULY 1963 65-314-16

Plan 4 (Sierra diversion to southern California--California Aqueduct exchange)--This plan proposes to divert 1,200,000 acre-feet from the major east side San Joaquin Valley streams, above about 3,000 feet elevation, by a series of tunnels of progressively larger capacity starting at the San Joaquin River above its junction with Big Creek and intersecting the Kings, Kaweah, and Tule Rivers and discharging into Isabella Reservoir. From Isabella Reservoir the water would be conveyed by tunnel to the east side of the Sierra Nevadas, and thence through Antelope Valley to join the California Aqueduct near the Cottonwood Powerplant. From that location it would be conveyed through the aqueduct to Perris Reservoir. Exchange water for the areas now being served by the east side streams from which tunnel diversions are contemplated under this plan would need to be provided.

This tunnel diversion plan would require a series of tunnels totaling 140 miles in length from San Joaquin River to Isabella Reservoir on the Kern River. Associated with these tunnels would be 11 diversion dams for diverting water from each of the streams. From Isabella Reservoir a 34-mile tunnel would convey the water southeasterly through the Sierra Nevadas to Cottonwood Creek, about 20 miles north of the town of Mojave. From this location the water would be lifted 650 feet and conveyed by a 75-mile, 2,000 c.f.s. canal to join the California Aqueduct below the Cottonwood Powerplant near Fairmont, Los Angeles County. The aqueduct would be increased 2,000 c.f.s. to convey the water to Perris Reservoir. The capital cost of the Sierra diversion tunnels and conveyance facilities to southern California (exclusive of exchange and storage facilities) is estimated on a reconnaissance basis to be $1,010,000,000, and the annual OM&R $2,100,000, not including cost of pumping energy. The net cost of pumping is estimated to be zero.

Exchange water for the areas now served below the points of diversion on the east side southern San Joaquin Valley streams would be conveyed via the west side facilities. A 3,000 c.f.s. incremental increase would be made in the California Aqueduct from the Delta to Wheeler Ridge Pumping Plant. At that location a new canal would be constructed crossing the Kern, Tule, and Kaweah Rivers and terminating at Kings River. A pumping plant with a head of about 50 feet would be required near the Kings River to lift water into the higher elevation Kings River service area canals.

The estimated capital cost (reconnaissance) for these exchange facilities is $260,000,000, including the estimated amount required to offset the adverse effect on existing powerplants below the tunnel diversions. The annual OM&R costs are estimated at $1,400,000. Pumping costs are estimated to approximate $6,100,000.

The additional water, 1,200,000 acre-feet, required for exchange purposes would be conserved in two storage reservoirs proposed on Trinity River. Helena Reservoir, with a gross storage capacity of 2,800,000 acre-feet, would be built on the main Trinity River downstream from Lewiston Dam. This reservoir would develop an annual new water yield of 600,000 acre-feet which would be diverted to the Sacramento River. Subsequently, Eltapom Reservoir, with a gross storage capacity of 3,100,000 acre-feet, would be constructed on the South Fork of Trinity River. This reservoir also would develop an annual yield of 600,000 acre-feet which would be diverted to Helena Reservoir, with subsequent diversion to Sacramento River. Power generating facilities would be incorporated with these proposed developments. Estimated capital costs of these reservoirs and associated facilities, as estimated by the State of California, are $540,000,000. Annual OM&R costs would be offset by power revenues, with a net annual amount remaining of about $12,300,000.

The estimated total capital cost for this prospective plan, including tunnel diversions and conveyance to southern California, exchange conveyance facilities, and storage reservoir systems, is $1,810,000,000. Annual OM&R and pumping costs would be offset by power revenues with a net annual amount remaining of $2,700,000.

Under this proposal, therefore, the additional 1,200,000 acre-feet of water would be stored and conveyed to southern California at an estimated annual equivalent cost of $66 per acre-foot, including interest at 3 percent and amortization of the facilities in 50 years. The average annual acre-foot cost given is computed by using incremental costs of enlargement of part of the California Aqueduct. Appropriate allocation of costs between the California Aqueduct and the proposed incremental enlargement under this plan may reflect some increase in this acre-foot value.

This plan contemplates diversion of water from several east side San Joaquin Valley streams by relatively high elevation tunnels. Since this water is now being used downstream, exchange facilities and water supplies will be required. Approval of these exchanges will require negotiations with the downstream water users. Such negotiations could be both lengthy and complex.

The reservoir storage systems and related diversions to Sacramento River proposed under this plan should be authorized for construction and operation by the Bureau of Reclamation as part of the Pacific Southwest Water Plan, even though they will be integrated closely with existing and proposed features of the Federal Central Valley Project.

The east side San Joaquin Valley areas are very conscious of their existing and increasing needs for additional water. They will be alert particularly to any plan which proposes increased exportation of water from the Central Valley Basin unless that plan also includes service to the San Joaquin Valley areas. As an integral part of this plan of development, therefore, an additional 3,000 c.f.s. increment would be added to bring an additional new supply of 1,400,000 acre-feet to the east side San Joaquin Valley. This would include conveyance through the California Aqueduct to Wheeler Ridge pumping plant, and from that location through the new canal to Tule River. In addition, off-stream reservoirs at Hungry Hollow site on Deer Creek, and Owens Mountain site on Little Dry Creek would be included for storage.

Estimated capital costs (reconnaissance) of the additional facilities proposed for east side service are $375,000,000. Annual OM&R costs are estimated at $1,450,000. Estimated costs of pumping the water for serving east side San Joaquin Valley areas are $9,400,000.

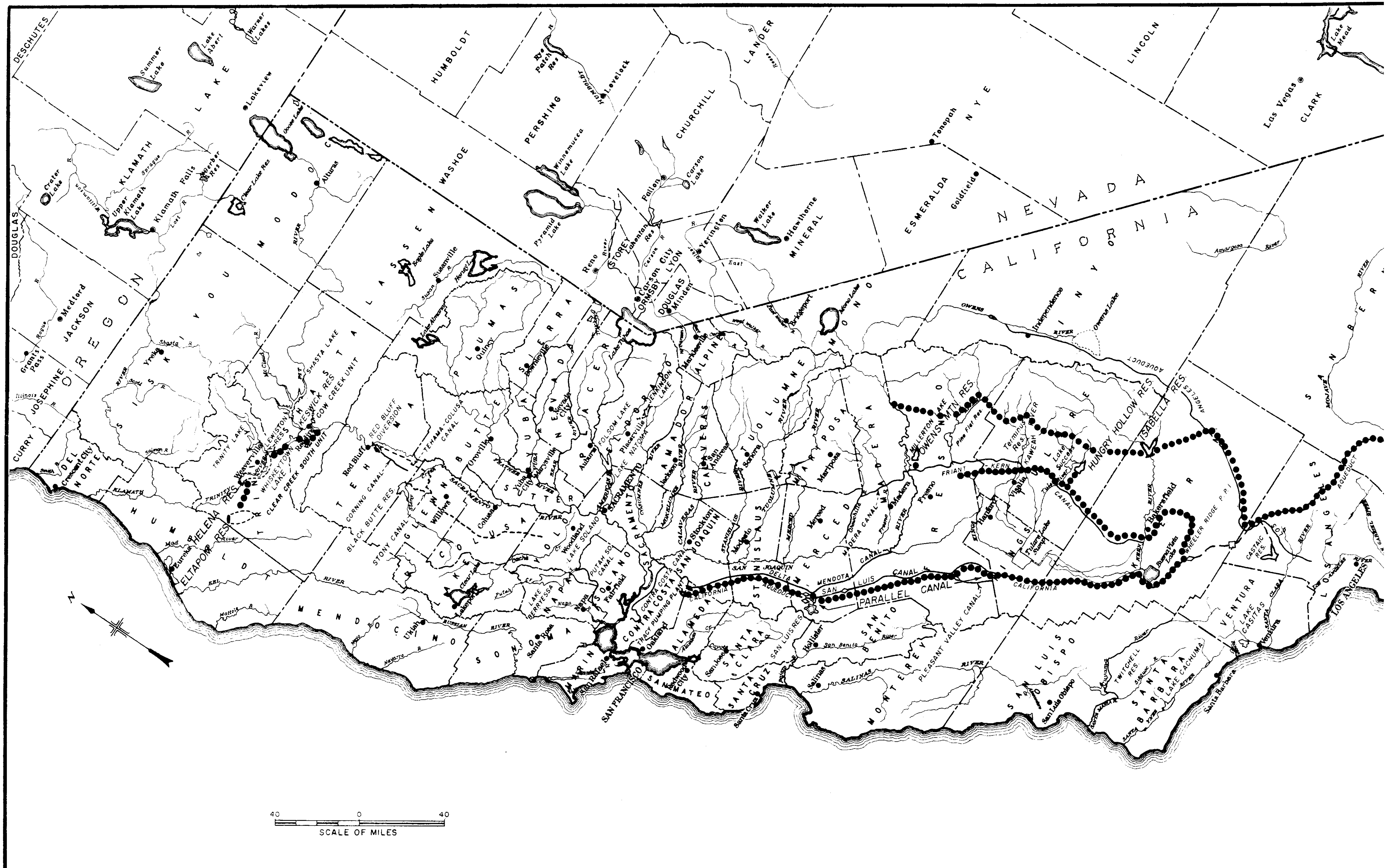
Subsequent early authorization of additional works would be required to provide increased East Side Division service through facilities on the east side of San Joaquin Valley from the Delta to connect at Tule River with the features proposed under this plan.

The transfer of additional water of a high quality through the Sacramento-San Joaquin River Delta will require modification of the present channels, which were constructed as part of the extensive levee system to protect the low elevation Delta lands from flooding. To accomplish this, the Bureau has proposed that a new channel around the periphery of the Delta will provide the highest possible water quality--total dissolved solids will average less than 200 parts per million. In addition, the channel will provide maximum protection to the large resident and anadromous fisheries that use the present Delta channels.

The estimated capital cost of the Delta Peripheral Canal is $70,000,000, with an annual OM&R cost, including power, of $800,000. This facility should be authorized for Federal construction, with appropriate financial participation by the State of California.

Further development of water in the Central Valley Basin and increased diversions from the Delta, either for use in southern California or within the Central Valley, also expands the urgency for the Kellog Unit to offset adverse effects which may occur to water supplies relied upon by Contra Costa County. These facilities are proposed as an integral part of the Central Valley Project principally for water quality improvement, although other multiple-purpose functions would be served, for the urbanized and highly industrialized Contra Costa County. This area is now being served in part by the Central Valley Project. This proposed unit also would provide operational flexibility for the Central Valley Project through integration with operations of Tracy Pumping Plant and the proposed Delta Peripheral Canal.

The estimated capital cost of this proposed unit is $55,000,000, with an annual OM&R cost of $285,000. In addition, an annual pumping cost of $120,000 is estimated.



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SACRAMENTO
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YOLO
NAPA
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SONOMA
MARIN
MENDOCINO
HUMBOLDT
Lakeview
Alturas
Klamath Falls
Medford
Grants Pass
Crescent City
Eureka
Yreka
Weaverville
Redding
Red Bluff
Susanville
Quincy
Oroville
Willows
Colusa
Yuba City
Marysville
Auburn
Placerville
Woodland
Sacramento
Stockton
San Andreas
Jackson
Sonora
Modesto
Merced
Mariposa
Madera
Fresno
Visalia
Hanford
Bakersfield
Independence
Bridgeport
Markleeville
Minden
Carson City
Reno
Fallon
Lovelock
Yerington
Hawthorne
Tonopah
Goldfield
Las Vegas
Ukiah
Lakeport
Napa
Fairfield
Santa Rosa
San Rafael
Oakland
San Jose
Hollister
Salinas
Santa Cruz
Redwood City
San Luis Obispo
Santa Barbara
Ventura
Los Angeles
Martinez
Upper Klamath Lake
Crater Lake
Summer Lake
Lake Abert
Warner Lakes
Goose Lake
Clear Lake Res
Eagle Lake
Honey L.
Lake Almanor
Pyramid Lake
Winnemucca Lake
Rye Patch Res
Carson Lake
Lahontan Res
Walker Lake
Mono Lake
Owens Lake
Lake Tahoe
Lake Mead
Clear Lake
Lake Berryessa
Tulare Lake
Buena Vista Lake
SHASTA LAKE
KESWICK RES.
LEWISTON RES.
TRINITY LAKE
WHISKEYTOWN LAKE
CLEAR CREEK SOUTH UNIT
COW CREEK UNIT
HELENA RES.
ELTAPOM RES.
RED BLUFF DIVERSION
CORNING CANAL
TEHAMA-COLUSA CANAL
BLACK BUTTE RES.
STONY CANAL
FOLSOM LAKE
LAKE NATOMA
JENKINSON LAKE
LAKE SOLANO
PUTAH SO. CANAL
CONTRA COSTA CANAL
TRACY PUMPING PLANT
DELTA-MENDOTA CANAL
SAN LUIS CANAL
PARALLEL CANAL
CALIFORNIA AQUEDUCT
SAN LUIS RES.
PLEASANT VALLEY CANAL
MADERA CANAL
FRIANT-KERN CANAL
MILLERTON LAKE
OWENS MTN. RES.
Pine Flat Res.
Terminus Res.
Lake Success
HUNGRY HOLLOW RES.
ISABELLA RES.
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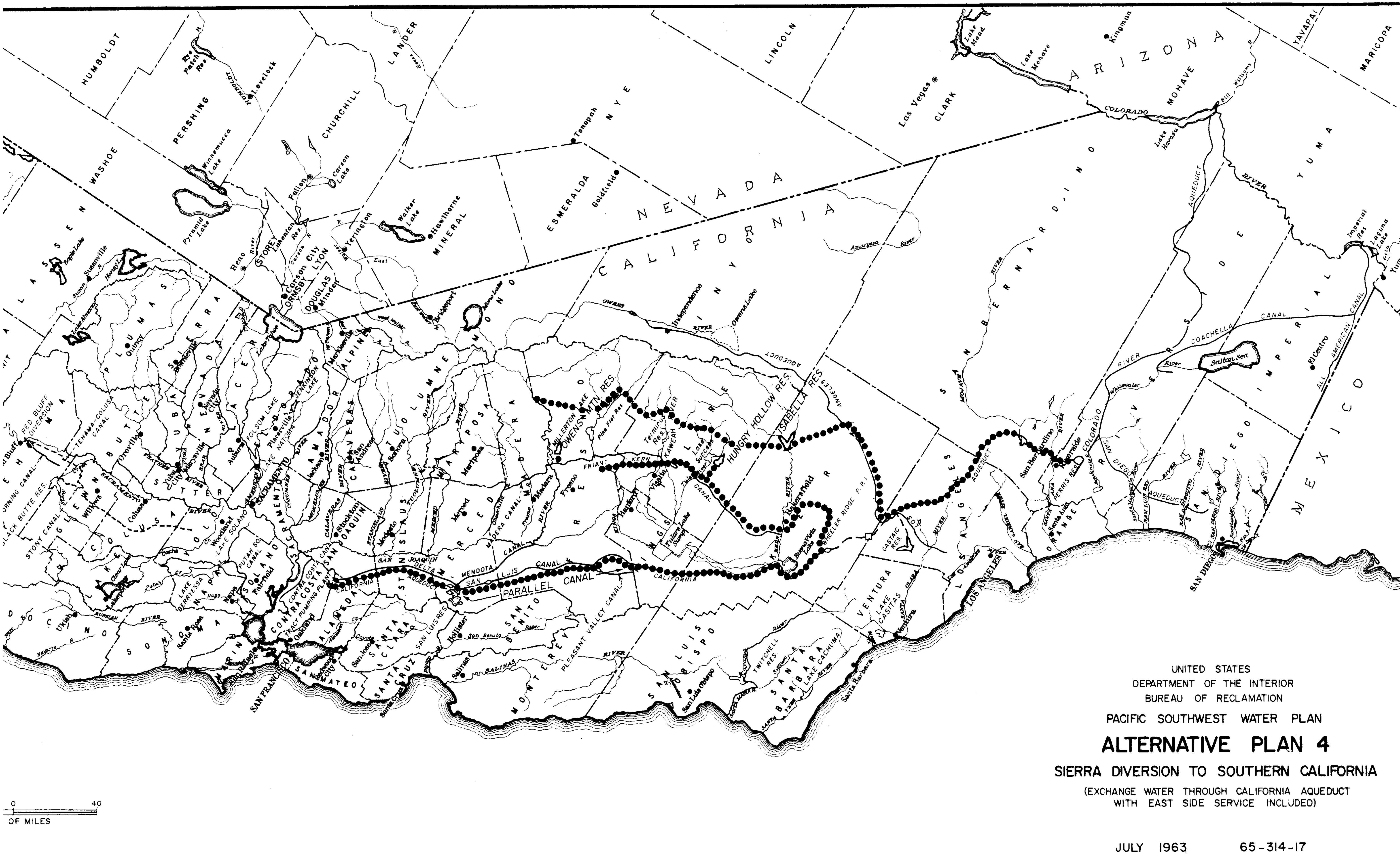
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PACIFIC SOUTHWEST WATER PLAN
ALTERNATIVE PLAN 4
SIERRA DIVERSION TO SOUTHERN CALIFORNIA
(EXCHANGE WATER THROUGH CALIFORNIA AQUEDUCT
WITH EAST SIDE SERVICE INCLUDED)
JULY 1963
65-314-17
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OWENS RIVER
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PINE FLAT RES.
TERMINUS RES.
LAKE SUCCESS
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LAKE CASITAS
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SALTON SEA
COACHELLA CANAL
ALL AMERICAN CANAL
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LAKE HAVASU
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MONO LAKE
FOLSOM LAKE
LAKE BERRYESSA
TRACY PUMPING PLANT
DELTA MENDOTA CANAL
FRIANT KERN CANAL
MADERA CANAL
PLEASANT VALLEY CANAL
WHEELER RIDGE P.P.
SAN FRANCISCO
LOS ANGELES
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Kingman
Reno
Tonopah
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Fresno
Bakersfield
Stockton
Sacramento
Oakland
San Jose
Santa Barbara
Ventura
San Bernardino
Riverside
El Centro
Yuma

Plan 5 (Sierra diversion to Lake Havasu)--This plan proposes to divert 1,200,000 acre-feet from the major east side San Joaquin Valley streams, above about 3,000 feet elevation, by a series of tunnels of progressively larger capacity starting at the San Joaquin River above its junction with Big Creek and intersecting the Kings, Kaweah, and Tule Rivers and discharging into Isabella Reservoir. From Isabella Reservoir the water would be conveyed by tunnel to the east side of the Sierra Nevadas to a point about 20 miles north of Mojave. From that location it would be conveyed east and south to Lake Havasu on the Colorado River. Exchange water for the areas now being served by the east side streams from which tunnel diversions are contemplated under this plan would need to be provided.

This tunnel diversion plan would require a series of tunnels totaling 140 miles in length from San Joaquin River to Isabella Reservoir on the Kern River. Associated with these tunnels would be 11 diversion dams for diverting water from each of the streams. From Isabella Reservoir a 34-mile tunnel would convey the water southeasterly through the Sierra Nevadas to Cottonwood Creek, about 20 miles north of the town of Mojave. From this location the water would be lifted 185 feet and conveyed 316 miles through a 2,000 c.f.s. canal to Lake Havasu on the Colorado River. The available head makes possible three power drops in this reach--Newberry Powerplant 66,000 kw., 20 miles east of Barstow; Bagdad Powerplant 140,000 kw., about 80 miles east of Barstow; and Lake Havasu Powerplant 72,000 kw., at the terminal point on the Colorado River. The capital cost of these tunnel diversions including facilities to convey the water to Colorado River (exclusive of exchange and storage facilities) is estimated to be $950,000,000, on a reconnaissance basis, and the annual OM&R $2,300,000 not including cost of pumping energy. The cost of pumping will be offset by power generated. The net power generated is estimated to return an annual revenue of $7,400,000.

Exchange water for the areas now served below the points of diversion on the east side southern San Joaquin Valley streams would be conveyed via the west side facilities. A 3,000 c.f.s. incremental increase would be made in the California Aqueduct from the Delta to Wheeler Ridge Pumping Plant. At that location a new canal would be constructed crossing the Kern, Tule, and Kaweah Rivers, and terminating at Kings River. A pumping plant with a head of about 50 feet would be required near the Kings River to lift water into the higher elevation Kings River service area canals.

The estimated capital cost for these exchange facilities is $260,000,000 (reconnaissance), including the estimated amount required to offset the adverse effect on existing powerplants below the tunnel diversions. The annual OM&R costs are estimated at $1,400,000. Pumping costs are estimated to approximate $6,100,000.

The additional water, 1,200,000 acre-feet, required for exchange purposes would be conserved in two storage reservoirs proposed on Trinity River. Helena Reservoir with a gross storage capacity of 2,800,000 acre-feet would be built on the main Trinity River downstream from Lewiston Dam. This reservoir would develop an annual new water yield of 600,000 acre-feet which would be diverted to the Sacramento River. Subsequently Eltapom Reservoir, with a gross storage capacity of 3,100,000 acre-feet, would be constructed on the South Fork of Trinity River. This reservoir also would develop an annual yield of 600,000 acre-feet which would be diverted to Helena Reservoir with subsequent diversion to Sacramento River. Power generating facilities would be incorporated with these proposed developments.

Estimated capital costs of these reservoirs and associated facilities are $540,000,000. Annual OM&R costs would be offset by power revenues with a net annual amount remaining of about $12,300,000.

The estimated total capital cost for this prospective plan, including tunnel diversions and conveyance to Lake Havasu on Colorado River, exchange conveyance facilities, and storage reservoir systems is $1,750,000,000. The annual OM&R and pumping costs are offset by power generated with an estimated annual revenue remaining of $9,900,000.

Under this proposal, therefore, the additional 1,200,000 acre-feet of water would be stored and conveyed to Lake Havasu at an estimated average annual equivalent cost of $58 per acre-foot, including interest at 3 percent and amortization of the facilities in 50 years.

The average annual acre-foot cost given is computed by using incremental costs of enlargement of part of the California Aqueduct. Appropriate allocation of costs between the California Aqueduct and the proposed incremental enlargement under this plan may reflect some increase in this acre-foot value.

This plan contemplates diversion of water from several east side San Joaquin Valley streams by relatively high elevation tunnels. Since this water is now being used downstream, exchange facilities and water supplies will be required. Approval of these exchanges will require negotiations with the downstream water users. Such negotiations could be both lengthy and complex.

The reservoir storage systems and related diversions to Sacramento River proposed under this plan should be authorized for construction and operation by the Bureau of Reclamation as a part of the Pacific Southwest Water Plan even though they will be integrated closely with existing and proposed features of the Federal Central Valley Project.

The east side San Joaquin Valley areas are very conscious of their existing and increasing needs for additional water. They will be alert, particularly to any plan which proposes increased exportation of water from the Central Valley Basin unless that plan also includes service to the San Joaquin Valley areas.

As an integral part of this plan of development, therefore, an additional 3,000 c.f.s. increment would be added to bring an additional new supply of 1,400,000 acre-feet to the east side of San Joaquin Valley. This would include conveyance through the California Aqueduct to Wheeler Ridge Pumping Plant, and from that location through the new canal to Tule River. In addition, off-stream reservoirs at Hungry Hollow site on Deer Creek, and Owens Mountain site on Little Dry Creek would be included for storage.

Estimated capital cost of the additional facilities proposed for east side service is $375,000,000 (reconnaissance). Annual OM&R costs are estimated at $1,450,000. Estimated costs of pumping the water for serving East Side San Joaquin Valley areas are $9,400,000.

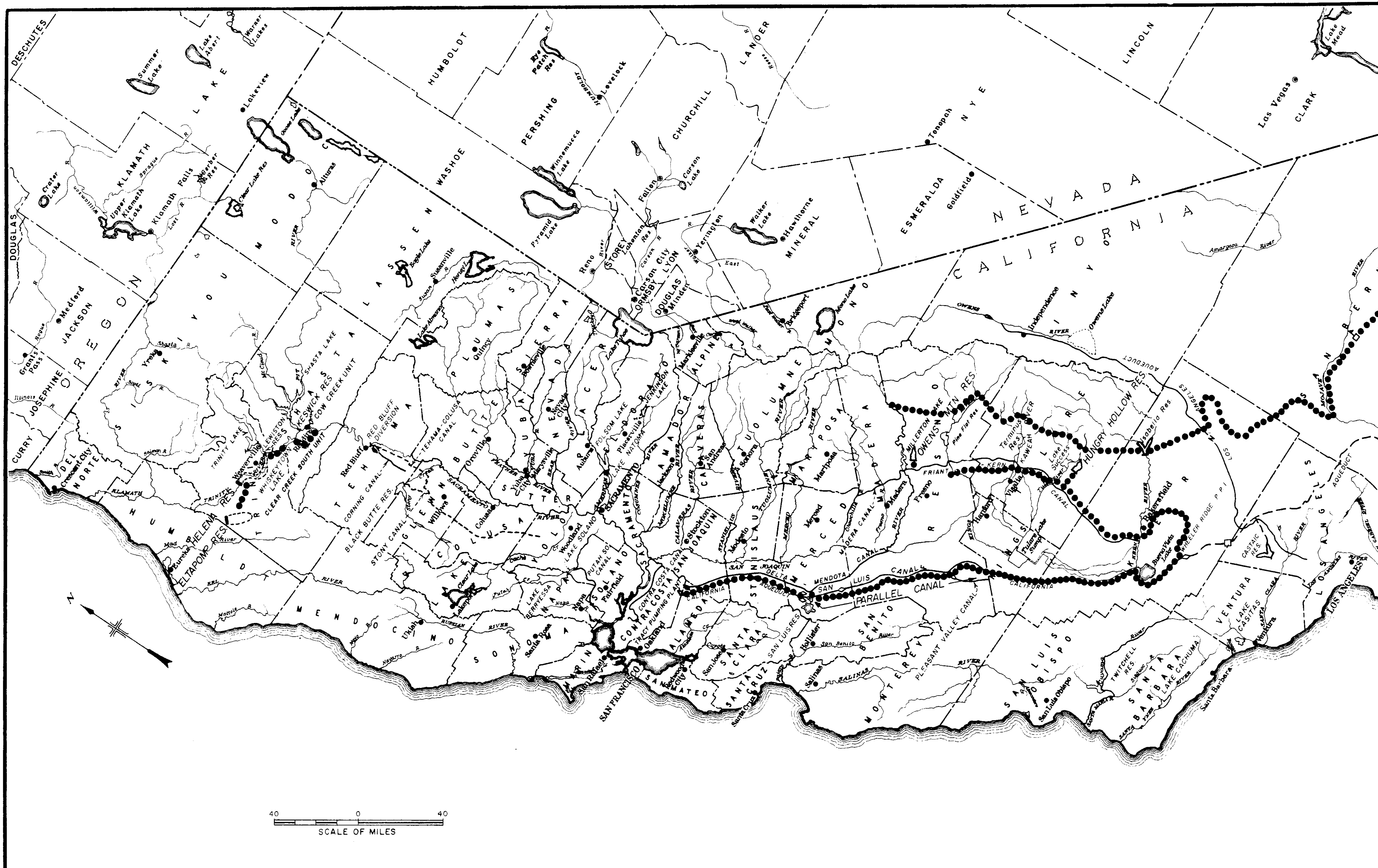
Subsequent early authorization of additional works would be required to provide increased East Side Division service through facilities on the east side of San Joaquin Valley from the Delta to connect at Tule River with the features proposed under this plan.

The transfer of additional water of a high quality through the Sacramento-San Joaquin Delta will require modification of the present channels which were constructed as part of the extensive levee system to protect the low elevation Delta lands from flooding. To accomplish this the Bureau of Reclamation has proposed that a new channel around the periphery of the Delta will provide the highest possible water quality--total dissolved solids will average less than 200 parts per million. In addition, the channel will provide maximum protection to the large resident and anadromous fisheries that use the present Delta channels.

The estimated capital cost of the Delta Peripheral Canal is $70,000,000 with an annual OM&R, including power for pumping, of $800,000. This facility should be authorized for Federal construction, with appropriate financial participation by the State of California.

Further development of water in the Central Valley Basin and increased diversions from the Delta, either for use in southern California or within the Central Valley, also expands the urgency for the Kellog Unit to offset adverse effects which may occur to water supplies relied upon by Contra Costa County. These facilities are proposed as an integral part of the Central Valley Project principally for water quality improvement, although other multiple-purpose functions would be served, for the urbanized and highly industrialized Contra Costa County. This area is now being served in part by the Central Valley Project. This proposed unit also would provide operational flexibility for the Central Valley Project through integration with operations of Tracy Pumping Plant and the proposed Delta Peripheral Canal.

The estimated capital cost of this proposed unit is $55,000,000 with an annual OM&R cost of $285,000. In addition an annual pumping cost of $120,000 is estimated.



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Upper Klamath Lake
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Summer Lake
Lake Abert
Warner Lakes
Goose Lake
Alturas
Clear Lake Res
Rye Patch Res
Lovelock
Winnemucca Lake
Pyramid Lake
Reno
Carson City
Minden
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Walker Lake
Hawthorne
Yerington
Tonopah
Goldfield
Las Vegas
Lake Mead
Bridgeport
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Independence
Owens Lake
OWENS RIVER
Amargosa River
Crescent City
Eureka
Yreka
Weaverville
Redding
Red Bluff
RED BLUFF DIVERSION
TEHAMA-COLUSA CANAL
CORNING CANAL
BLACK BUTTE RES.
STONY CANAL
Willows
Colusa
Oroville
Quincy
Susanville
Eagle Lake
Lake Almanor
SHASTA LAKE
KESWICK RES
COW CREEK UNIT
CLEAR CREEK SOUTH UNIT
WHISKEYTOWN LAKE
TRINITY LAKE
LEWISTON RES
HELENA RES
ELTAPOMP RES
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Yuba City
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TRACY PUMPING PLANT
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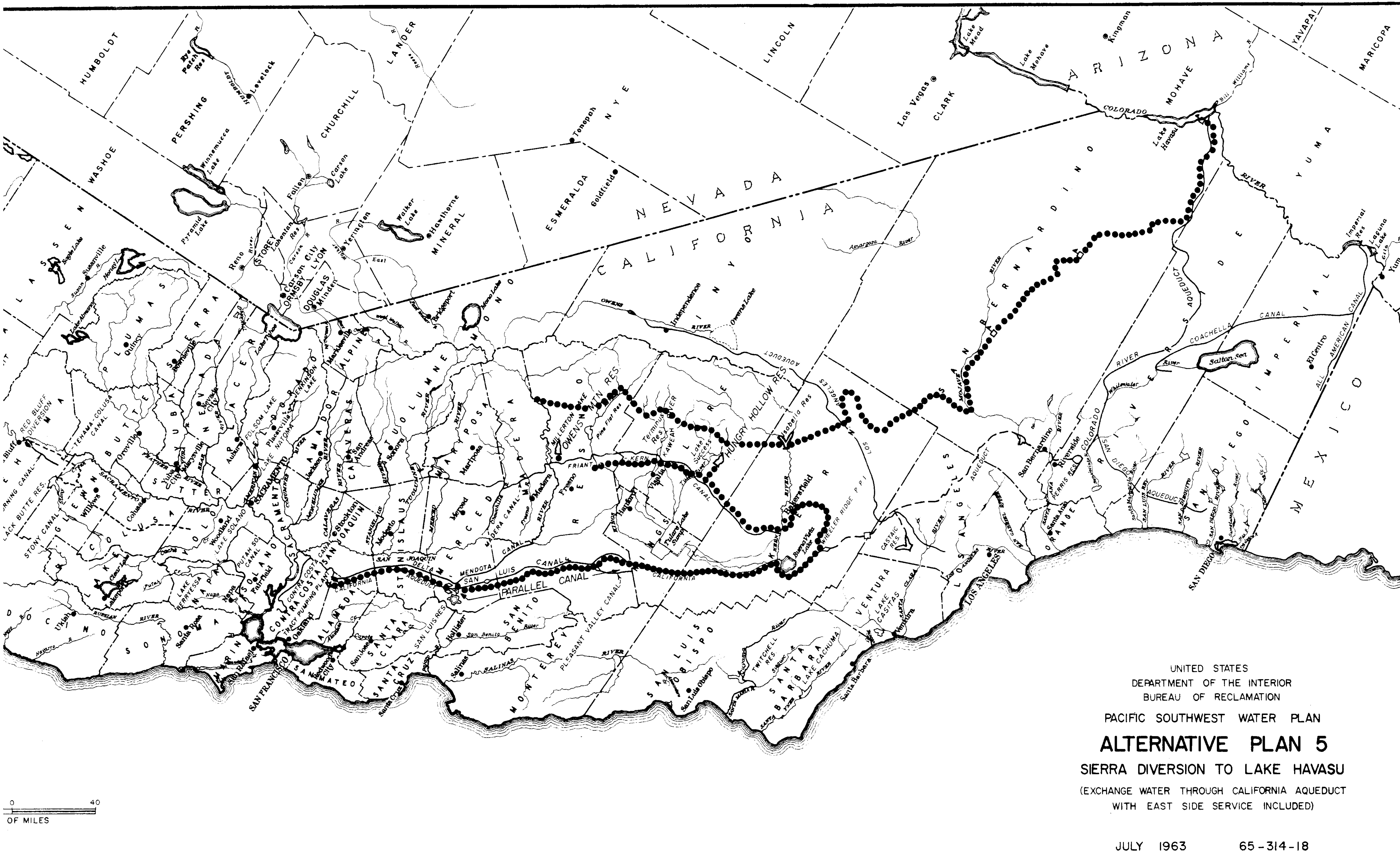


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

ALTERNATIVE PLAN 5

SIERRA DIVERSION TO LAKE HAVASU

(EXCHANGE WATER THROUGH CALIFORNIA AQUEDUCT WITH EAST SIDE SERVICE INCLUDED)

JULY 1963 65-314-18

Plan 6 (Sierra Diversion to Southern California-East Side Division Exchange)--This plan proposes to divert 1,200,000 acre-feet from the major east side San Joaquin Valley streams, above about 3,000 feet elevation, by a series of tunnels of progressively larger capacity starting at the San Joaquin River above its junction with Big Creek, and intersecting the Kings, Kaweah, and Tule Rivers, and discharging into Isabella Reservoir. From Isabella Reservoir the water would be conveyed by tunnel to the east side of the Sierra Nevadas, and thence through Antelope Valley to join the California Aqueduct near the Cottonwood Powerplant. From that location it would be conveyed through the aqueduct to Perris Reservoir. Exchange water for the areas now being served by the east side streams from which tunnel diversions are contemplated under this plan would need to be provided.

This tunnel diversion plan would require a series of tunnels totaling 140 miles in length from San Joaquin River to Isabella Reservoir on the Kern River. Associated with these tunnels would be 11 diversion dams for diverting water from each of the streams. From Isabella Reservoir a 34-mile tunnel would convey the water southeasterly through the Sierra Nevadas to Cottonwood Creek, about 20 miles north of the town of Mojave. From this location the water would be lifted 650 feet and conveyed by a 75-mile, 2,000 c.f.s. canal to join the California Aqueduct below the Cottonwood Powerplant near Fairmont, Los Angeles County. The aqueduct would be increased 2,000 c.f.s. to convey the water to Perris Reservoir. The capital cost of the Sierra diversion tunnels and conveyance facilities to southern California (exclusive of exchange and storage facilities) is estimated on a reconnaissance basis to be $1,010,000,000, and the annual OM&R $2,100,000, not including cost of pumping energy. The net cost of pumping is estimated to be zero.

Exchange water for the areas now served below the points of diversion on the east side streams would be conveyed through East Side Division (enlarged). A 3,000 c.f.s. incremental increase would be made in these facilities to the Kern River.

The estimated capital cost (reconnaissance) for this incremental enlargement for exchange purposes is $200,000,000, including the estimated amount required to offset the adverse effect on existing powerplants below the tunnel diversions. The annual OM&R costs are estimated at $750,000. Pumping costs are estimated to approximate $5,600,000 annually.

The additional water, 1,200,000 acre-feet, required for exchange purposes would be conserved in two storage reservoirs proposed on Trinity River. Helena Reservoir, with a gross storage capacity of 2,800,000 acre-feet, would be built on the main Trinity River downstream from Lewiston Dam. This reservoir would develop an annual new water yield of 600,000 acre-feet, which would be diverted to the Sacramento River. Subsequently, Eltapom Reservoir, with a gross storage capacity of 3,100,000 acre-feet, would be constructed on the South Fork of Trinity River. This reservoir also would develop an annual yield of 600,000 acre-feet which would be diverted to Helena Reservoir, with subsequent diversion to Sacramento River. Power generating facilities would be incorporated with these proposed developments. Estimated capital costs of these reservoirs and associated facilities, as estimated by the State of California, are $540,000,000. Annual OM&R costs would be offset by power revenues with a net annual amount remaining of about $12,300,000.

The estimated total capital cost for this prospective plan, including tunnel diversions and conveyance to southern California, exchange conveyance facilities, and storage reservoir systems is $1,750,000,000 (reconnaissance). The estimated annual OM&R and pumping costs would be offset by power revenues with a net amount remaining of about $3,900,000.

Under this proposal, therefore, the additional 1,200,000 acre-feet of water would be stored and conveyed to southern California at an estimated average annual equivalent cost of $63.00 per acre-foot, including interest at 3 percent and amortization of the facilities in 50 years.

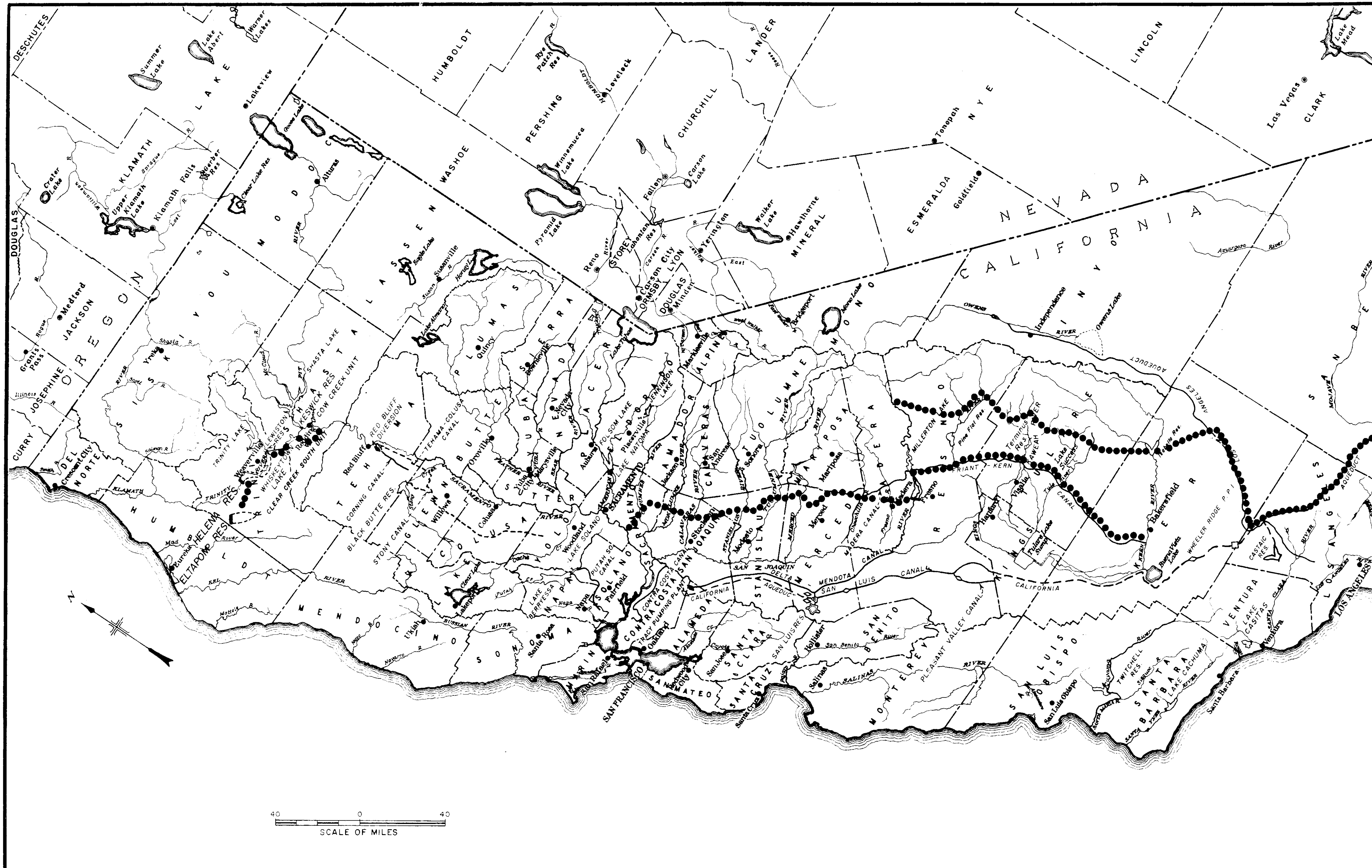
The average annual acre-foot cost given is computed by using only the incremental costs of enlargement of conveyance facilities. Appropriate allocation of costs between the East Side Division facilities and the proposed incremental enlargement under this plan may reflect some increase in this acre-foot value.

This plan contemplates diversion of water from several east side San Joaquin Valley streams by relatively high elevation tunnels. Since this water is now being used downstream, exchange facilities and water supplies will be required. Approval of these exchanges will require negotiations with the downstream water users. Such negotiations could be both lengthy and complex.

The reservoir storage systems and related diversions to Sacramento River proposed under this plan should be authorized for construction and operation by the Bureau of Reclamation as part of the Pacific Southwest Water Plan, even though they will be integrated closely with existing and proposed features of the Federal Central Valley Project.

Associated with this development would be the East Side Division, which would provide 1,500,000 acre-feet of service to that area with its resulting multiple-purpose benefits. The estimated capital cost of the proposed facilities, exclusive of distribution systems, required for East Side Division is about $600,000,000. This East Side Division is proposed for authorization, construction, and operation as an integral part of the Central Valley Project. In order to accomplish the conveyance of the additional 1,200,000 acre-feet to southern California, concurrent authorization and construction of the facilities would be required.

Two other facilities, the Delta Peripheral Canal and the Kellog Unit, also should be associated with this proposed plan for authorization as part of the Central Valley Project, with financial participation by the State and other agencies as appropriate. These facilities will offset, in particular, adverse effects which may occur to water supplies in the Delta area due to further water supply development in the Central Valley Basin and increased diversions from the Delta. The total capital costs of these features are estimated at $125,000,000, with annual OM&R costs, including pumping, of $1,200,000.



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Warner Lakes
Lakeview
Crater Lake
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Gerber Res
Medford
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COW CREEK UNIT
CLEAR CREEK SOUTH UNIT
WHISKEYTOWN LAKE
LEWISTON RES
TRINITY LAKE
Weaverville
Redding
LASSEN
Susanville
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Lake Almanor
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RED BLUFF DIVERSION
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Marysville
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Santa Rosa
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San Rafael
SAN FRANCISCO
CONTRA COSTA
CONTRA COSTA CANAL
TRACY PUMPING PLANT
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Oakland
SAN MATEO
Redwood City
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San Jose
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Santa Cruz
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TWITCHELL RES.
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ELTAPOM RES.
TRINITY
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Pine Flat Res
FRIANT - KERN
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Visalia
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Lake Success
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KERN
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Buena Vista Lake
WHEELER RIDGE P.P.
INYO
Independence
Owens Lake
OWENS RIVER
LOS ANGELES AQUEDUCT
SAN BERNARDINO
Amargosa River
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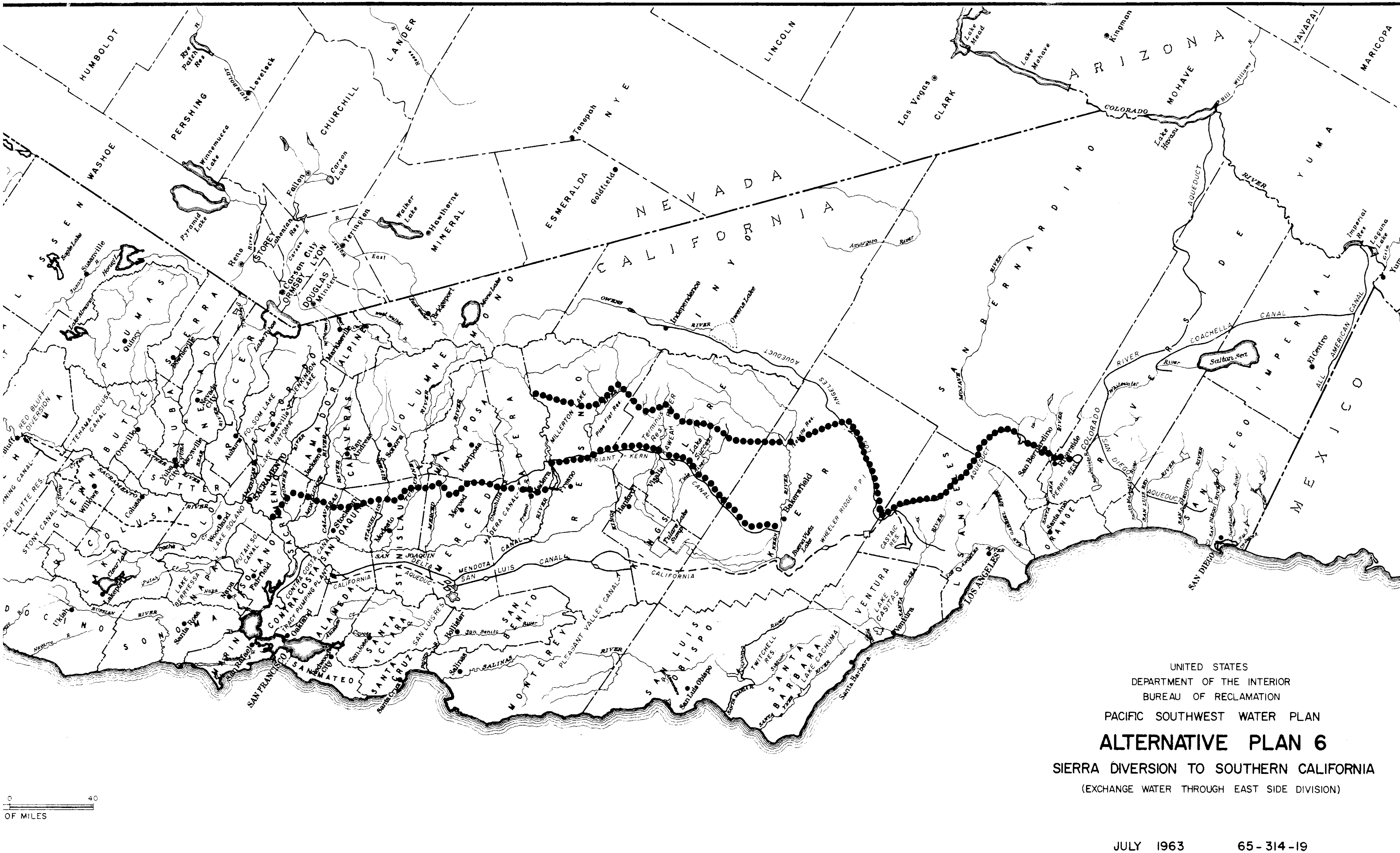
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PACIFIC SOUTHWEST WATER PLAN
ALTERNATIVE PLAN 6
SIERRA DIVERSION TO SOUTHERN CALIFORNIA
(EXCHANGE WATER THROUGH EAST SIDE DIVISION)
JULY 1963
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COLORADO RIVER AQUEDUCT
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TEHAMA-COLUSA CANAL
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Millerton Lake
Pine Flat Res
Terminus Res
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Isabella Res
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Castaic Res
Perris Res
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Lake Cachuma
Lake Casitas
Tracy Pumping Plant
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Plan 7 (Sierra diversion to Lake Havasu--East Side Division exchanges)--This plan proposes to divert 1,200,000 acre-feet from the major east side San Joaquin Valley streams, above about 3,000 feet elevation, by a series of tunnels of progressively larger capacity starting at the San Joaquin River above its junction with Big Creek and intersecting the Kings, Kaweah, and Tule Rivers and discharging into Isabella Reservoir. From Isabella Reservoir, the water would be conveyed by tunnel to the east side of the Sierra Nevadas to a point about 20 miles north of Mojave. From that location it would be conveyed east and south to Lake Havasu on the Colorado River. Exchange water for the areas now being served by the east side streams, from which tunnel diversions are contemplated under this plan, would need to be provided.

This tunnel diversion plan would require a series of tunnels totaling 140 miles in length from San Joaquin River to Isabella Reservoir on the Kern River. Associated with these tunnels would be 11 diversion dams for diverting water from each of the streams. From Isabella Reservoir a 34-mile tunnel would convey the water southeasterly through the Sierra Nevadas to Cottonwood Creek, about 20 miles north of the town of Mojave. From this location the water would be lifed 185 feet and conveyed 316 miles through a 2,000 c.f.s. canal to Lake Havasu on the Colorado River. The available head makes possible three power drops in this reach--Newberry Powerplant, 66,000 kw., 20 miles east of Barstow; Bagdad Powerplant, 140,000 kw., about 80 miles east of Barstow; and Lake Havasu Powerplant, 72,000 kw., at the terminal point on the Colorado River. The capital cost of these tunnel diversions, including facilities to convey the water to Colorado River (exclusive of exchange and storage facilities), is estimated to be $950,000,000, on a reconnaissance basis, and the annual OM&R $2,300,000, not including cost of pumping energy. The cost of pumping will be offset by power generated. The net power generated is estimated to return an annual revenue of $7,400,000.

Exchange water for the areas now served below the points of diversion on the east side streams would be conveyed through East Side Division (enlarged). A 3,000 c.f.s. incremental increase would be made in these facilities to the Kern River.

The estimated reconnaissance capital cost for this incremental enlargement for exchange purposes is $200,000,000, including the estimated amount required to offset the adverse effect on existing powerplants below the tunnel diversions. The annual OM&R and pumping costs are estimated to approximate $5,600,000 annually.

The additional water, 1,200,000 acre-feet, required for exchange purposes would be conserved in two storage reservoirs proposed on Trinity River. Helena Reservoir, with a gross storage capacity of

2,800,000 acre-feet, would be built on the main Trinity River downstream from Lewiston Dam. This reservoir would develop an annual new water yield of 600,000 acre-feet which would be diverted to the Sacramento River. Subsequently, Eltapom Reservoir, with a gross storage capacity of 3,100,000 acre-feet, would be constructed on the South Fork of Trinity River. This reservoir also would develop an annual yield of 600,000 acre-feet which would be diverted to Helena Reservoir with subsequent diversion to Sacramento River. Power generating facilities would be incorporated with these proposed developments. Estimated capital costs of these reservoirs and associated facilities, as estimated by the State of California, are $540,000,000. Annual OM&R costs would be offset by power revenues with a net annual amount remaining of about $12,300,000.

The estimated total capital cost (reconnaissance) for this prospective plan, including tunnel conveyance to Lake Havasu on Colorado River, exchange conveyance facilities, and storage reservoir systems is $1,690,000,000. The annual OM&R and pumping costs are offset by power generated, with an estimated annual revenue remaining of $11,000,000.

Under this proposal, therefore, the additional 1,200,000 acre-feet of water would be stored and conveyed to southern California at an estimated annual equivalent cost of $55 per acre-foot, including interest at 3 percent and amortization of the facilities in 50 years.

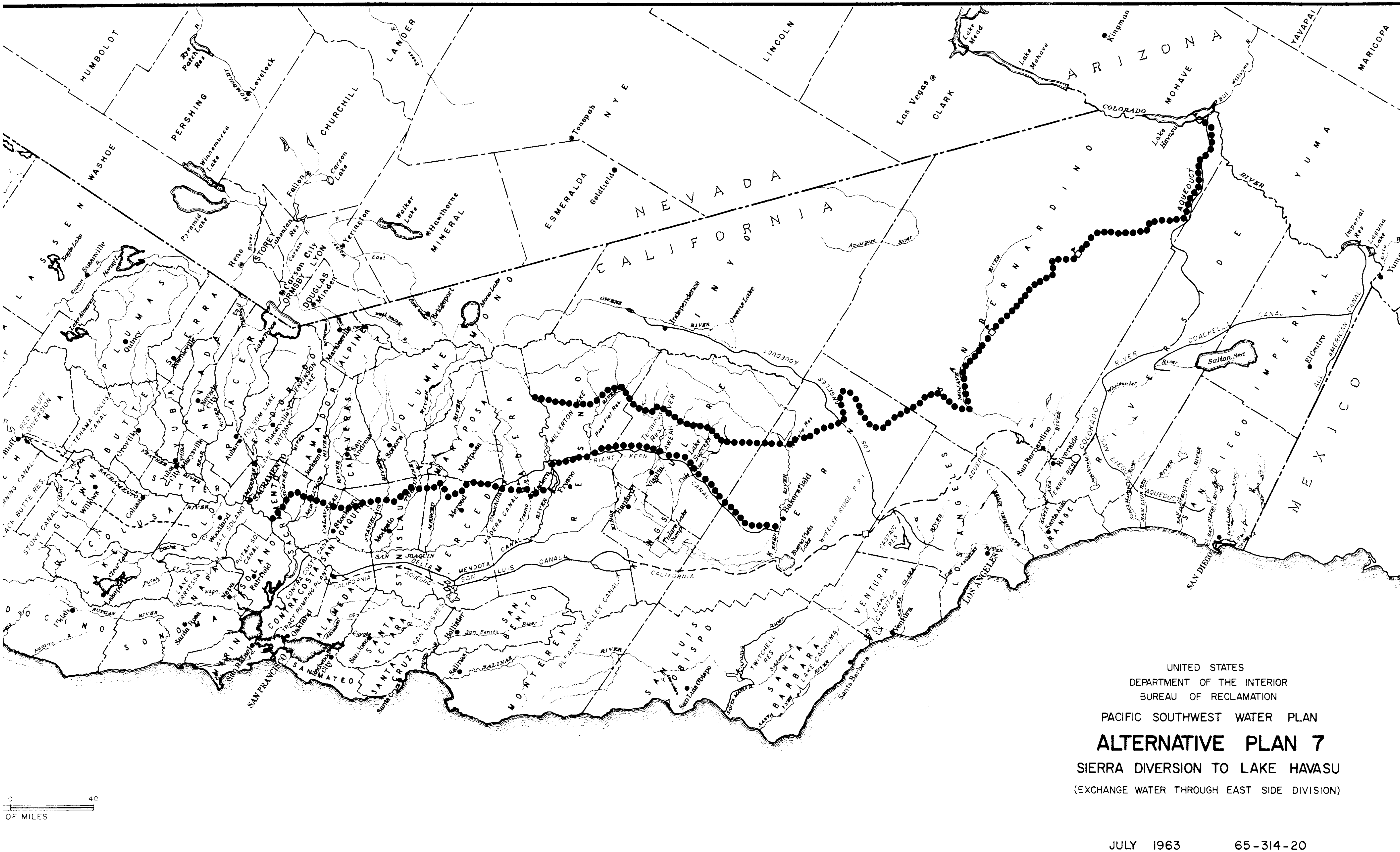
The average annual acre-foot cost given is computed by using only the incremental costs of enlargement of conveyance facilities. Appropriate allocation of costs between the East Side Division facilities and the proposed incremental enlargement under this plan may reflect some increase in this acre-foot value.

This plan contemplates diversion of water from several east side San Joaquin Valley streams by relatively high elevation tunnels. Since this water is now being used downstream, exchange facilities and water supplies will be required. Approval of these exchanges will require negotiations with the downstream water users. Such negotiations could be both lengthy and complex.

The reservoir storage systems and related diversions to Sacramento River proposed under this plan should be authorized for construction and operation by the Bureau of Reclamation as part of the Pacific Southwest Water Plan, even though they will be integrated closely with existing and proposed features of the Federal Central Valley Project.

Associated with this development would be the East Side Division, which would provide 1,500,000 acre-feet of service to that area with its resulting multiple-purpose benefits. The estimated capital cost of the proposed facilities, exclusive of distribution systems required for East Side Division, is about $600,000,000. This East Side Division is proposed for authorization, construction, and operation as an integral part of the Central Valley Project. In order to accomplish the conveyance of the additional 1,200,000 acre-feet to southern California, concurrent authorization and construction of the facilities would be required.

Two other facilities, the Delta Peripheral Canal and the Kellog Unit, also should be associated with this proposed plan for authorization as part of the Central Valley Project, with financial participation by the State and other agencies as appropriate. These facilities will offset, in particular, adverse effects which may occur to water supplies in the Delta area due to further water supply development in the Central Valley Basin and increased diversions from the Delta. The total capital costs of these features are estimated at $125,000,000, with annual OM&R costs, including pumping, of $1,200,000.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

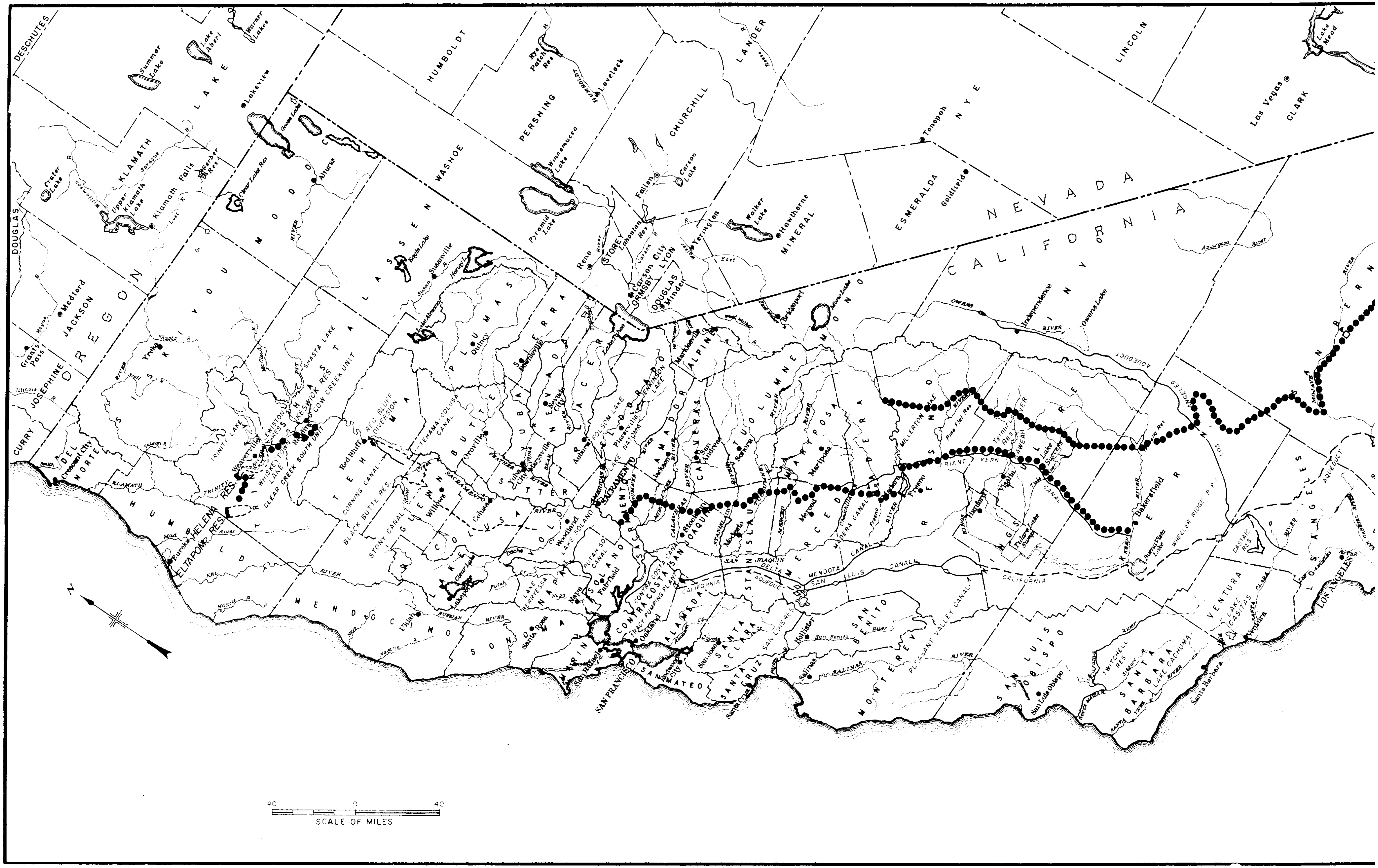
PACIFIC SOUTHWEST WATER PLAN

ALTERNATIVE PLAN 7

SIERRA DIVERSION TO LAKE HAVASU

(EXCHANGE WATER THROUGH EAST SIDE DIVISION)

JULY 1963 65-314-20



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ESMERALDA
MINERAL
STOREY
ORMSBY
LYON
MODOC
SISKIYOU
LASSEN
SHASTA
TRINITY
PLUMAS
SIERRA
TEHAMA
BUTTE
GLENN
COLUSA
SUTTER
YUBA
NEVADA
PLACER
EL DORADO
AMADOR
ALPINE
CALAVERAS
TUOLUMNE
MONO
MARIPOSA
MADERA
MERCED
STANISLAUS
SAN JOAQUIN
SACRAMENTO
YOLO
SOLANO
NAPA
LAKE
MENDOCINO
SONOMA
MARIN
CONTRA COSTA
ALAMEDA
SAN MATEO
SANTA CLARA
SANTA CRUZ
SAN BENITO
MONTEREY
FRESNO
INYO
TULARE
KINGS
KERN
SAN LUIS OBISPO
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
Lakeview
Klamath Falls
Medford
Grants Pass
Crescent City
Eureka
Yreka
Weaverville
Redding
Red Bluff
Alturas
Susanville
Quincy
Oroville
Marysville
Colusa
Willows
Auburn
Placerville
Sacramento
Woodland
Fairfield
Napa
Santa Rosa
Ukiah
Lakeport
San Rafael
San Francisco
Oakland
Redwood City
San Jose
Santa Cruz
Hollister
Salinas
San Luis Obispo
Santa Barbara
Ventura
Stockton
Modesto
Merced
Mariposa
Madera
Fresno
Hanford
Visalia
Bakersfield
Independence
Bridgeport
Markleeville
San Andreas
Jackson
Sonora
Reno
Carson City
Minden
Fallon
Lovelock
Hawthorne
Tonopah
Goldfield
Las Vegas
Lake Mead
Upper Klamath Lake
Crater Lake
Summer Lake
Lake Abert
Warner Lakes
Goose Lake
Clear Lake Res
Eagle Lake
Honey L
Lake Almanor
Lake Tahoe
Mono Lake
Owens Lake
Walker Lake
Pyramid Lake
Winnemucca Lake
Rye Patch Res
Lahontan Res
Carson Lake
Shasta Lake
Keswick Res
Whiskeytown Lake
Lewiston Res
Trinity Lake
Clear Creek South Unit
Cow Creek Unit
Clear Lake
Lake Berryessa
Folsom Lake
Lake Natoma
Jenkinson Lake
Millerton Lake
Pine Flat Res
Terminus Res
Lake Success
Isabella Res
Tulare Lake
Buena Vista Lake
San Luis Res
Twitchell Res
Lake Cachuma
Lake Casitas
Castaic Res
Helena Res
Eltapom Res
Red Bluff Diversion
Tehama-Colusa Canal
Corning Canal
Black Butte Res
Stony Canal
Putah So Canal
Contra Costa Canal
Tracy Pumping Plant
Delta Mendota Canal
San Luis Canal
California Aqueduct
Madera Canal
Friant-Kern Canal
Pleasant Valley Canal
Wheeler Ridge P.P.
Los Angeles Aqueduct
Sacramento River
San Joaquin River
Klamath River
Trinity River
Eel River
Russian River
Salinas River
Kern River
Owens River
Amargosa River
Humboldt River
40 0 40
SCALE OF MILES
N

Lower Eel River Storage and Lake Havasu Aqueduct--The selected plan, shown on Drawing No. 65-314-21, proposes to obtain the second unit of 1,200,000 acre-feet from the proposed Sequoia and Bell Springs storage reservoirs on the Lower Eel River. This system, including railroad relocation and conveyance facilities to Sacramento River, is estimated by the State of California to cost $560,000,000. It is estimated that another $40,000,000 would probably be required for additional electrical and other facilities. The yield from this system, estimated at 1,200,000 acre-feet, would be pumped and routed through the Middle Fork Eel River system to Clear Lake and Monticello Reservoir; thence to the Sacramento River. The Middle Fork Eel River Project, generally provided for by the California State Water Plan, would need to be constructed by the State or the Bureau of Reclamation prior to importation of this water. The State now has the Middle Fork Eel River Project programed for completion by 1978. Plans of the Bureau are well advanced for that unit, along with other facilities on the Eel and Russian Rivers. It is estimated that net pumping costs would be about $2,000,000 annually. Net operation, maintenance, and replacement costs of these facilities for the Lower Eel River Project, including pumping, are estimated at $3,000,000 annually.

This plan proposes to add a 2,000 c.f.s. increment to the proposed East Side Division conveyance facilities from the Sacramento River through the Hood-Clay pump lift, and thence through the East Side Division facilities to the Kern River. From that location, a new 2,000 c.f.s. canal would be constructed to connect with the California Aqueduct at Wheeler Ridge Pumping Plant No. 1.

Additional facilities required, therefore, will be the enlargement of the East Side Division conveyance facilities and construction of the 36-mile Kern River-Wheeler Ridge Canal with 2,000 c.f.s. capacity. A new pumping plant with a head of about 150 feet will be required to connect this proposed system with the California Aqueduct at Wheeler Ridge. The total capital cost, on a reconnaissance basis, is estimated to be $145,000,000 for the facilities from the Delta through the east side system to Wheeler Ridge. Annual operation, maintenance, and replacement costs for these facilities are estimated to be $1,000,000, not including cost of pumping energy. The annual cost of pumping is estimated at $7,100,000.

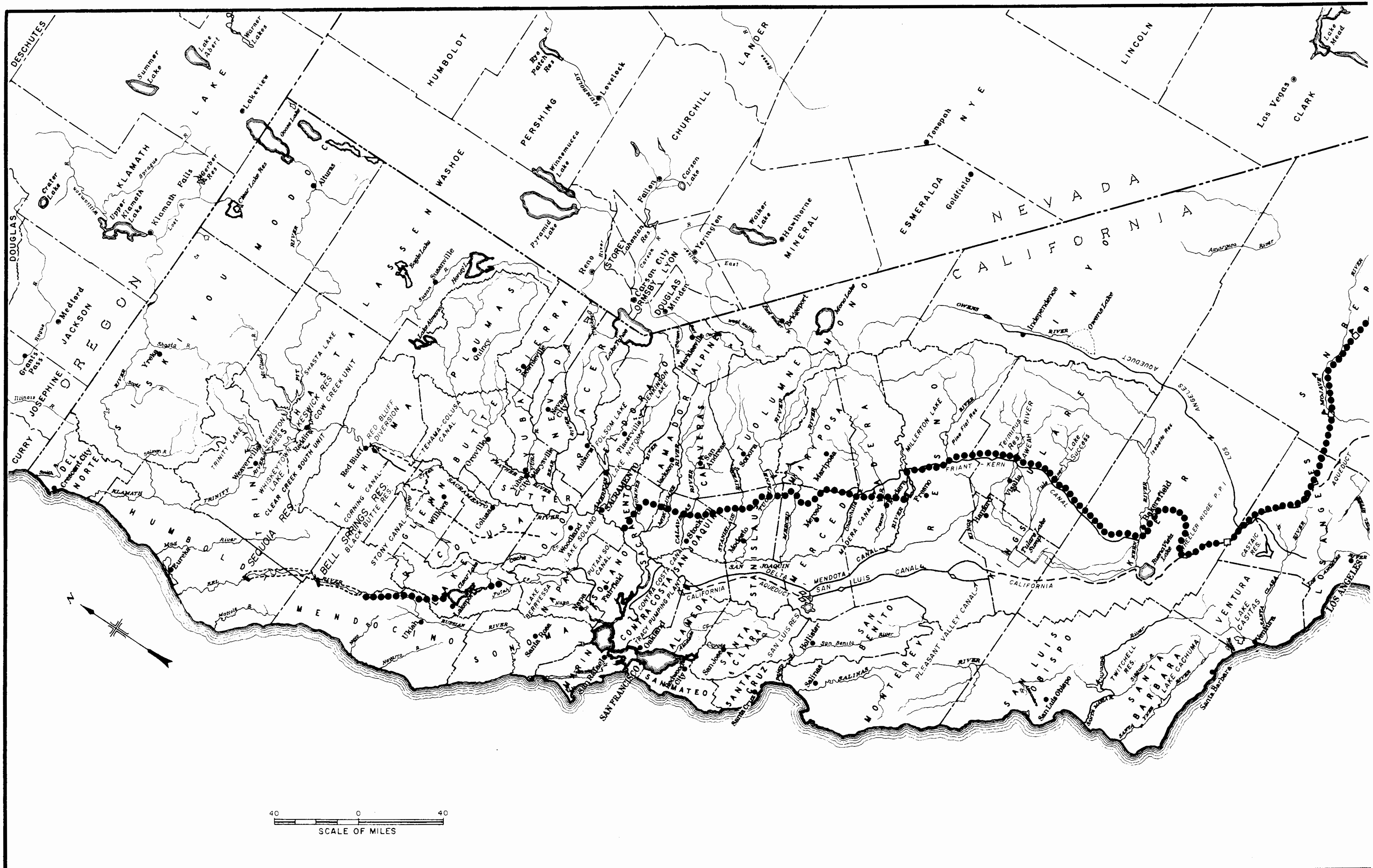
From Wheeler Ridge, the increased water supply of 1,200,000 acre-feet would be conveyed through the California Aqueduct to Pearblossom Pumping Plant. The estimated capital cost for incremental conveyance facilities from Wheeler Ridge to Pearblossom Pumping Plant is $105,000,000. Annual operation, maintenance, and replacement costs for this reach are estimated at $900,000. The net power required in this reach for pumping would be 3,740,000,000 kilowatt-hours.

From Pearblossom Pumping Plant, a new conduit, with a capacity of 2,000 c.f.s., would be constructed to Lake Havasu--a distance of about 270 miles. Four power generating plants would be installed to use the available head along this route. Two plants would have a head of about 475 feet each; one would have a head of about 975 feet, and the drop into Lake Havasu would be about 515 feet.

The capital cost of the conveyance from the California Aqueduct at Pearblossom Pumping Plant to Lake Havasu is estimated at $170,000,000, including the four powerplants. The annual operation, maintenance, and replacement cost is estimated at $2,150,000. Approximately 2,400,000,000 kilowatt-hours would be generated in the four powerplants. The net cost of pumping between Wheeler Ridge Pumping Plant and Lake Havasu is estimated at $9,850,000.

For conveying the 1,200,000 acre-feet of additional water, the capital cost from the Delta to Lake Havasu is estimated to total $420,000,000. Operation, maintenance, and replacement costs are estimated at $4,075,000, and annual costs of pumping at $16,950,000.

The estimated total capital cost for this prospective plan, including storage reservoir systems, incremental conveyance through the East Side Division, and thence through a portion of the California Aqueduct, and a new conduit to Lake Havasu is $1,020,000,000. The net annual operation, maintenance, replacement, and pumping costs are estimated to be $24,000,000. This plan would require concurrent authorization of the required incremental conveyance capacity and the East Side Division, Central Valley Project. The storage systems used in this plan, along with the other facilities, are included for analysis purposes. An alternative storage development, more desirable for meeting the requirements of other areas as well, may be developed in the future.



OREGON
NEVADA
CALIFORNIA
DESCHUTES
DOUGLAS
JOSEPHINE
JACKSON
KLAMATH
LAKE
CURRY
HUMBOLDT
PERSHING
CHURCHILL
LANDER
WASHOE
STOREY
ORMSBY
LYON
DOUGLAS
MINERAL
ESMERALDA
NYE
LINCOLN
CLARK
Las Vegas
Tonopah
Goldfield
Lovelock
Winnemucca Lake
Pyramid Lake
Reno
Carson City
Minden
Fallon
Carson Lake
Walker Lake
Hawthorne
Yerington
Lake Mead
Lakeview
Alturas
Klamath Falls
Medford
Grants Pass
Crater Lake
Summer Lake
Lake Abert
Warner Lakes
Upper Klamath Lake
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
PLACER
YUBA
SUTTER
COLUSA
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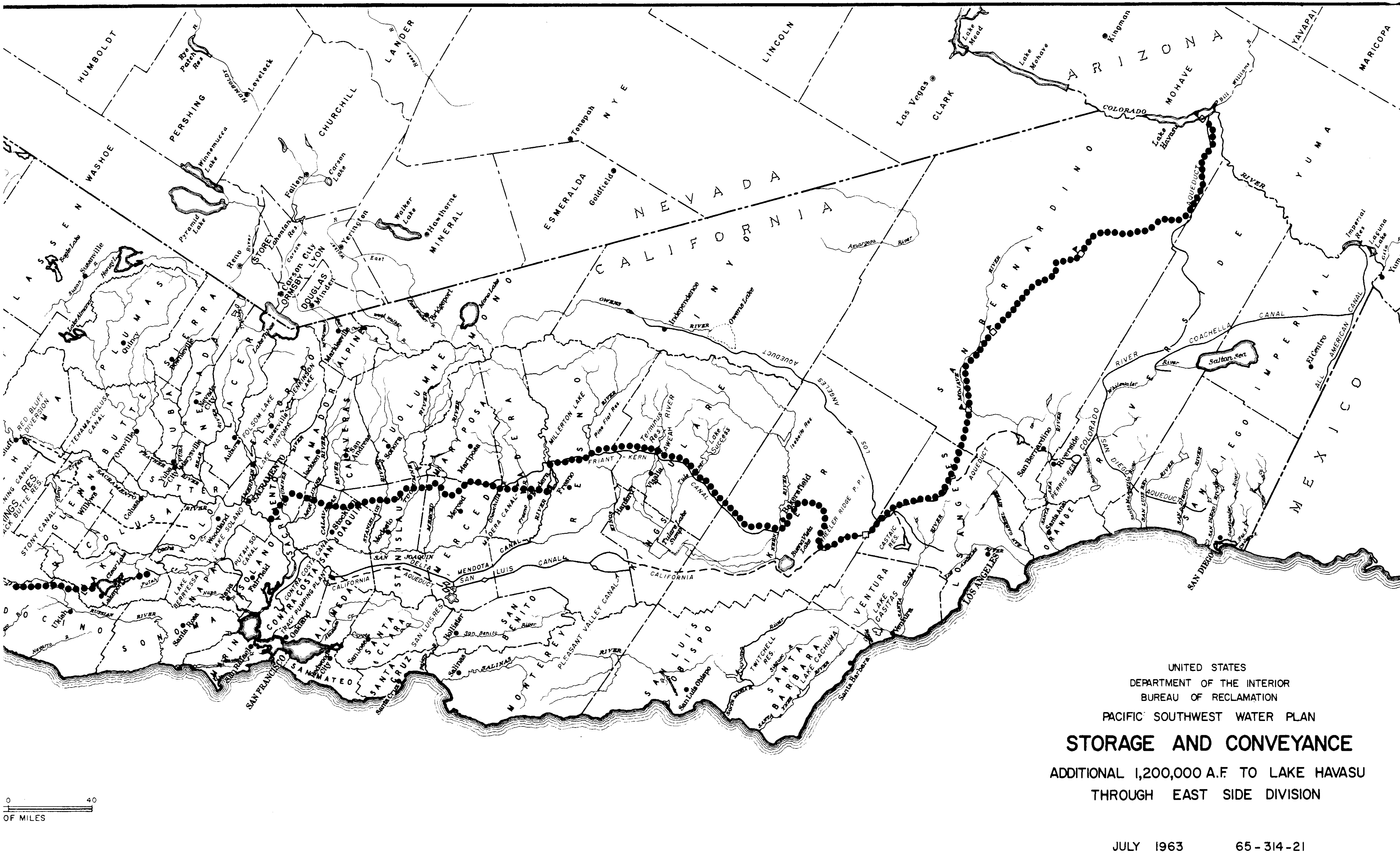
SOLANO
MARIN
SACRAMENTO
EL DORADO
AMADOR
ALPINE
CALAVERAS
SAN JOAQUIN
TUOLUMNE
MONO
MARIPOSA
MERCED
STANISLAUS
MADERA
FRESNO
INYO
TULARE
KINGS
KERN
SAN BERNARDINO
LOS ANGELES
VENTURA
SANTA BARBARA
SAN LUIS OBISPO
MONTEREY
SAN BENITO
SANTA CLARA
SANTA CRUZ
SAN MATEO
ALAMEDA
CONTRA COSTA
SAN FRANCISCO
Crescent City
Eureka
Yreka
Redding
Weaverville
Red Bluff
Susanville
Quincy
Oroville
Willows
Colusa
Yuba City
Marysville
Auburn
Placerville
Woodland
Fairfield
Napa
Santa Rosa
Ukiah
Lakeport
San Rafael
Oakland
Stockton
San Andreas
Jackson
Sonora
Mariposa
Merced
Modesto
Madera
Fresno
Visalia
Hanford
Bakersfield
Independence
Bridgeport
Markleeville
Hollister
Salinas
San Luis Obispo
Santa Barbara
Ventura
Los Angeles
SACRAMENTO
SHASTA LAKE
KESWICK RES.
TRINITY LAKE
WHISKEYTOWN LAKE
LEWISTON
CLEAR CREEK SOUTH UNIT
COW CREEK UNIT
RED BLUFF DIVERSION
CORNING CANAL
TEHAMA-COLUSA CANAL
BLACK BUTTE RES.
BELL SPRINGS RES.
SEQUOIA RES.
STONY CANAL
FOLSOM LAKE
LAKE NATOMA
JENKINSON LAKE
LAKE BERRYESSA
PUTAH SO. CANAL
LAKE SOLANO
SAN JOAQUIN DELTA
CONTRA COSTA CANAL
TRACY PUMPING PLANT
SAN LUIS RES.
DELTA MENDOTA CANAL
SAN LUIS CANAL
CALIFORNIA AQUEDUCT
MADERA CANAL
MILLERTON LAKE
FRIANT - KERN CANAL
PINE FLAT RES.
TERMINUS RES.
LAKE SUCCESS
KAWEAH RIVER
TULARE LAKE
ISABELLA RES.
WHEELER RIDGE P.P.I.
LOS ANGELES AQUEDUCT
OWENS RIVER
CASTAIC RES.
PLEASANT VALLEY CANAL
TWITCHELL RES.
LAKE CACHUMA
LAKE CASITAS
SAN LUIS OBISPO
40 0 40
SCALE OF MILES


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PACIFIC SOUTHWEST WATER PLAN
STORAGE AND CONVEYANCE
ADDITIONAL 1,200,000 A.F. TO LAKE HAVASU
THROUGH EAST SIDE DIVISION
JULY 1963
65-314-21
0
40
OF MILES
NEVADA
CALIFORNIA
ARIZONA
MEXICO
Lake Havasu
Lake Mead
Lake Mohave
COLORADO
Salton Sea
FRIANT - KERN
CALIFORNIA AQUEDUCT
SAN LUIS CANAL
ALL AMERICAN CANAL
COACHELLA CANAL
SAN FRANCISCO
SACRAMENTO
LOS ANGELES
SAN DIEGO
Las Vegas
Reno
Bakersfield
Fresno
Stockton

Desalting Alternative Plan

To supply 1,200,000 acre-feet annually for the projected municipal and industrial water demands in Central Arizona, a desalting plant complex would be created in the Yuma area drawing upon the Gulf of California for its basic sea-water supply. Cooperation with Mexico would be essential to this alternative.

The complex built by stages with ultimate annual deliveries of 1,200,000 acre-feet would cost about $900,000,000 for desalting plants and connecting ocean intake and return channels but exclusive of associated thermo-electric generating plants. Desalted water made available at Imperial Dam would be exchanged, to the users diverting through the Imperial Dam head works, for Colorado River waters at Lake Havasu. From Lake Havasu an aqueduct system parallel to the Granite Reef Aqueduct would be constructed to central Arizona. This parallel aqueduct system would cost about $353,000,000. This same capacity if built initially into the Granite Reef Aqueduct would add about $190,000,000 to the Phase I construction for an overall saving.

An alternative aqueduct from Imperial Dam to the Phoenix and Tucson metropolitan areas would cost about $400,000,000 to take the high quality water directly to the municipal and industrial use area.

The estimated annual operating costs for this alternative supply would be $78,400,000 for the desalting plants and $9,630,000 for the parallel aqueduct system. The type of desalting plants considered in this alternative are summarized below and further described in the Appendix of the Office of Saline Water.

The flash-type distillation process has been most extensively studied, with design concepts for very large plants--up to 150 million gallons per day. The current state of development limits the size of plants utilizing other processes to about 5 - 10-million-gallon-per-day size. These processes may be effectively utilized to supply high quality water to meet municipal demands of smaller cities that cannot be economically served by conveyance facilities. Results show that the flash distillation process maximizes the use of equipment items that have been previously developed in large sizes for other purposes, and can also be readily adapted to use steam from a topping turbine, resulting in a cheaper source of steam.

A combination steam-electric and water plant using the flash distillation process has been investigated using both coal and gas as a fuel source. Based on present technology a unit of 150-million-gallon-per-day fresh water capacity, constructed in combination with a 417 megawatt thermal electric generating station, is considered the most economic installation. The capital cost of the water unit is estimated to be $86,000,000. The powerplant costs which may be provided by private power companies are $53,500,000 for a gas-fired unit and $65,000,000 for a coal-fired unit. For the purpose of analysis, the unit cost of water was determined for plants located on the California coast. The gas-fired plant produced water at a plantside cost of about $105 per acre-foot, and the coal-fired plant produced water at a plantside cost of about $90 per acre-foot.

The experience gained by constructing and operating intermediate size plants should serve to decrease these unit cost values. Technological advances as a result of the basic and applied research programs of the Office of Saline Water are also predicted to further decrease these costs.

Payout Analysis

The following tabulation presents a consolidated summary of the payout analyses used in determining the financial feasibility of the plan. The tabulation indicates the subsidy assistance required for irrigation and municipal and industrial water. The accumulative development, as shown, reflects the net revenue by the year 2044 after irrigation and municipal and industrial assistance has been provided.

The tabulations reflect buildup in revenue due to increased deliveries of irrigation and municipal and industrial water. The payout extends from 1967 through 2044, a period of 78 years. This period reflects a full 50-year period after the last facility has been placed in service. Under this method of payout analysis, a facility continues to contribute revenue to the development fund after costs allocated to the facility have been repaid.

Consolidated Payout Study--Pacific Southwest Water Plan (In thousands of dollars)

POWER

Study Year	Fiscal Year	Net Operating Revenue 1/	Interest @ 3%	Plant In Service	Balance to be Repaid	Earned Surplus
1	1967					
2	1968					
3	1969			7,128	7,128	
4	1970	241	214	7,128	7,101	
5		241	213	611,103	611,048	
6		20,972	18,332	621,889	619,194	
7		29,970	18,576	628,358	614,269	
8		31,927	18,428		600,770	
9	1975		18,023		586,866	
10			17,606		572,545	
11			17,176		557,794	
12			16,734		542,601	
13			16,278		526,952	
14	1980		15,809		510,834	
15			15,325		494,232	
16			14,827		477,132	
17			14,314		459,519	
18			13,786		441,378	
19	1985		13,241		422,692	
20			12,681		403,446	
21			12,103		383,622	
22			11,509		363,204	
23		31,927	10,896		342,173	
24	1990	46,314	10,265		306,124	
25			9,184		268,994	
26			8,069		230,749	
27			6,922		191,357	
28			5,741		150,748	
29	1995		4,524		108,994	
30			3,270		65,950	
31			1,979		21,615	
32			648		0	24,051
33						46,314
34	2000					
35						
36						
37						
38		46,314				46,314
39	2005	49,172				49,172
40						
41						
42						
43						
44	2010					
45						
46						
47						
48						
49	2015					
50						
51						
52						
53						
54	2020	49,172				49,172
55		45,662				45,662
56						
57						
58						
59	2025					
60						
61						
62						
63						
64	2030					
65						
66						
67						
68						
69	2035					
70						
71						
72						
73						
74	2040					
75						
76						
77						
78	2044	45,662				45,662
TOTAL		3,139,606	326,673			2,184,575

MUNICIPAL & INDUSTRIAL WATER

Study Year	Net Operating Revenue 2/	Interest @ 3%	Plant In Service	Balance to be Repaid	Assistance Requirement	Allowable Unpaid Balance	Earned Surplus
1			43,187	43,187			
2	445	1,296	98,640	99,491			
3	-648	2,985	100,438	104,922			
4	-429	3,148	124,826	132,887			
5	234	3,987	271,041	282,855			
6	1,001	8,486	285,332	304,631			
7	1,956	9,139	309,530	336,012			
8	3,177	10,080	536,210	569,595			
9	5,400	17,088	536,210	581,283			
10	7,233	17,438	701,150	756,428			
11	21,944	22,693	825,628	881,655			
12	25,203	26,450	825,628	882,902			
13	27,295	26,487	1,579,077	1,635,543			
14	33,580	49,066	1,642,692	1,714,644			
15	35,851	51,439	2,557,859	2,645,399			
16	49,251	79,362	2,597,863	2,715,514			
17	68,274	81,465	2,597,863	2,728,705			
18	71,089	81,861	2,805,086	2,946,700			
19	70,061	88,401	2,805,086	2,965,040			
20	72,877	88,951	2,805,086	2,981,114			
21	99,125	89,433	2,820,180	2,986,516			
22	94,449	89,595	2,820,180	2,981,662			
23	94,412	89,450	2,820,180	2,976,700			
24	94,826	89,301	2,820,180	2,971,175			
25	95,213	89,135	2,863,710	3,008,627			
26	95,529	90,259	2,863,710	3,003,357			
27	95,885	90,101	2,863,710	2,997,573			
28	96,242	89,927	2,946,794	3,074,342			
29	96,538	92,230		3,070,034			
30	96,894	92,101		3,065,241			
31	97,250	91,957		3,059,948			
32	97,605	91,798		3,030,090	24,051		
33	97,962	90,903		2,976,717	46,314		
34	97,959	89,302		2,921,746			
35	97,957	87,652		2,865,127			
36	97,956	85,954		2,806,811			
37	97,953	84,204		2,746,748			
38	97,951	82,402		2,684,885	46,314		
39	97,950	80,547		2,618,310	49,172		
40	97,947	78,549		2,549,740			
41	97,945	76,492		2,479,115			
42		74,373		2,406,371			
43		72,191		2,331,445			
44		69,943		2,254,271			
45		67,628		2,174,782			
46		65,243		2,092,908			
47		62,787		2,008,578			
48		60,257		1,921,718			
49		57,652		1,832,253			
50		54,968		1,740,104			
51		52,203		1,645,190			
52		49,356		1,547,429			
53		46,423		1,446,735			
54		43,402		1,343,020	49,172		
55		40,291		1,281,540	3,826		
56		38,446		1,222,041	0		
57		36,661		1,160,757	0	2,637,264	
58		34,823		1,076,757	20,878	2,410,584	
59		32,303		965,453	45,662	2,410,584	
60		28,964		850,810		2,245,644	
61		25,524		732,727		2,121,166	
62		21,982		611,102		2,121,166	
63		18,333		485,828		1,367,717	
64		14,575		356,796	45,662	1,304,102	
65		10,704		269,555	0	388,935	
66		8,087		179,697		347,931	
67		5,391		87,143		347,931	
68		2,614		0		141,708	8,188
69						141,708	97,945
70						141,708	
71						126,614	
72						126,614	
73						126,614	
74						126,614	
75						83,084	
76						83,084	
77						83,084	
78	97,945				0	0	97,945
TOTAL	6,153,307	3,606,238			1,387,363		987,638

IRRIGATION

Study Year	Net Operating Revenue 3/	Plant In Service	Balance to be Repaid	Assistance Requirement	Allowable Unpaid Balance	Earned Surplus
1						
2						
3		30,903				
4	154	30,903	30,749			
5	154	309,092	30,595			
6	2,354	329,165	306,430			
7	6,054	363,155	320,449			
8	5,641	369,845	348,798			
9	5,563	428,345	349,925			
10	5,285	428,345	403,140			
11	5,207	456,345	397,933			
12	5,166	456,345	420,767			
13	5,168	456,345	415,599			
14	5,458	456,345	410,141			
15	5,460	476,345	404,681			
16	5,799		418,882			
17	5,801		413,081			
18	5,803		407,278			
19	5,805		401,473			
20	5,808		395,665			
21	5,810		389,855			
22	5,812		384,043			
23	5,834		378,209			
24	5,866		372,343			
25	5,788		366,555			
26	5,710		360,845			
27	5,632		355,213			
28	5,555		349,658			
29	5,477		344,181			
30	5,399		338,782			
31	5,321		333,461			
32	5,244		328,217			
33	5,166		323,051			
34	5,175		317,876			
35			312,701			
36			307,526			
37			302,351			
38			297,176			
39			292,001			
40			286,826			
41			281,651			
42			276,476			
43	5,175		271,301			
44	5,183		266,118			
45			260,935			
46			255,752			
47			250,569			
48			245,386			
49			240,203			
50			235,020			
51			229,837			
52			224,654			
53	5,183		219,471			
54	5,191		214,280		445,442	
55			167,253	41,836	167,253	
56			116,400	45,662	147,180	
57			65,547	45,662	113,190	
58			35,572	24,784	106,500	
59			30,381		48,000	
60			25,190		48,000	
61			19,999		20,000	
62			14,808		20,000	
63	5,191		9,617		20,000	
64	5,199		4,418		20,000	
65			0		0	781
66						5,199
67						
68						
69						
70						
71						
72						
73						
74						
75						
76						
77						
78	5,199					5,199
TOTAL	386,769			157,944		68,368

RECAPITULATION DEVELOPMENT FUND

Study Year	Power	M&I	Irrigation	Total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32	24,051	-24,051		
33	46,314	-46,314		
34				
35				
36				
37				
38	46,314	-46,314		
39	49,172	-49,172		
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				
51				
52				
53				
54	49,172	-49,172		
55	45,662	-3,826	-41,836	
56		0	-45,662	
57		0	-45,662	
58		-20,878	-24,784	
59		-45,662	0	
60				
61				
62				
63				
64		-45,662	0	
65		0	+781	46,443
66		0	+5,199	50,861
67		0		50,861
68		+8,188		59,049
69		+97,945		148,806
70				
71				
72				
73				
74				
75				
76				
77				
78	45,662	+97,945	+5,199	148,806
TOTAL	2,184,575	-399,725	-89,576	1,695,274

1/ Hoover power @4 mills; Bridge & Marble @6 mills; Parker-Davis @4.7 mills.

2/ M&I water rates: Central Arizona Project $45.00/a.f.; C.A.P. Increment w/Havasu Aqueduct $65.00/a.f.; Pilot Desalinization Plant $63.00/a.f.; So. Nevada $27.00/a.f. as per report; California Aqueduct Increment $40.00 a.f.; Tributary Projects $45.00 a.f.; Dixie as per report.

3/ All irrigation water sold @$10.00/a.f. except Dixie Project irrigation water which conforms with the Dixie report. There were no investment costs or revenues included for Coachella and All-American canal lining.

<u>GEOLOGICAL SURVEY</u>

<u>A PROGRAM IN THE PACIFIC SOUTHWEST</u>

CONTENTS

GEOLOGICAL SURVEY

A PROGRAM IN THE PACIFIC SOUTHWEST

INTRODUCTION

For purposes of this program statement, the Pacific Southwest comprises the lower basin of the Colorado River (below Lee Ferry, Arizona) and its water-service area to the west. Included are parts of five States -- Arizona, California, Nevada, New Mexico and Utah. Certain international complications involve parts of the adjoining Mexican States of Sonora and Baja California.

Having a very mild winter climate, the Pacific Southwest is attractive both to intensive agriculture and to light industry of diverse kinds. Its current rate of population increase is the nation's greatest. At the same time it is a water-short region in which competition for local water sources, including the Colorado River, is relatively more severe than in any other part of the mainland United States.

Man's successful use of an environment of such extremes calls for keen wits and full knowledge of both the opportunities and the limitations of that environment. Developing such knowledge is a basic responsibility of the Geological Survey -- knowledge of the availability and magnitude of the water resource, and of principles for its conservation and management; also, of the occurrence and potential productivity of mineral and fuel resources, which are actual or prospective industrial commodities, locally or nationally. Related responsibilities include production of topographic maps -- universal tools in appraising natural resources and planning their development or management; also, classification of Federal mineral lands to foster their effective conservation. These several responsibilities are inseparably and deeply interwoven in the Pacific Southwest.

THE WATER-SUPPLY SITUATION IN BRIEF

With facilities in existence and under construction, regulation of the main-stem Colorado River in the Pacific Southwest soon will be close to the optimum. To the west, in southern California, streams have small perennial flows or are intermittent; they have been developed about to the maximum. Ground-water bodies are drafted heavily in the areas of greatest population density; locally, especially in central Arizona, they are being overdrawn currently.

In the aggregate, use of water within the region now approaches the perennial capacity of local sources. With increasing population, total requirement of water will surpass that perennial local capacity. Further, domestic and industrial uses take a steadily increasing percentage of total water supply. Agricultural use, principally for irrigation, doubtless will continue to diminish as a percentage of the total; it may diminish as a volume. Thus, the pattern of water requirements within the region is not stable as to either place of use or seasonal distribution of use.

Under the recent decision of the Supreme Court of the United States, in Arizona v. California, more main-stem water of the Colorado River prospectively will be used in central Arizona and less will be used in southern California. This geographic shift in use aggravates the unstable use pattern just noted. Eventually, this prospective shift of Colorado River water to Arizona will be compensated under the California Water Plan, which will convey surplus water of the north to the water-deficient south, within the State. However, such compensation cannot be accomplished quickly.

For its economic integrity, the region must wring maximum productivity from all local water sources. A comprehensive region-wide plan to that end is essential. Alternative sources--such as desalted ocean water in the coastal area or imports from remote streams--would be substantially more costly and would not be justified wholly by the truism that the day of low-cost water is gone.

Beyond optimum regulation of the Colorado River main stem, which is imminent, all sources of water within the region, surface and underground, must be managed jointly for optimum perennial yield. The cost of developing water supplies undoubtedly will rise and will force more intensive use and re-use of water. Probably most critical, means must be devised for effective management and disposal of wastes--municipal, industrial, and agricultural--so that current and prospective depreciation of water quality can be held to the practical minimum. The need for resolving these and related matters in the Pacific Southwest is urgent. Equal urgency in other regions of the nation may well be at least a generation in the future.

Toward the end of maximum productivity of water, information at hand suffices for planning some early measures. Far more exacting, however, will be the requirements for data and information on which to base continuing project operation and over-all management of the water resource under conditions of full development, including sound administrative decision and compromise among mutually exclusive uses of water. For such decision and compromise the region is ill prepared.

The Geological Survey has done, and is doing, much toward acquiring such knowledge. Scope of this past and present accomplishment will be summarized. Necessary in regard to the lower Colorado region, however, is much more intensive and particularized investigation, much of it pioneer in character. This particularized effort will be outlined in a following list of program objectives.

HYDROLOGIC INVESTIGATIONS

Past and Current Programs

Records of streamflow in the lower Colorado River basin and service areas began with the measurement of the Colorado River at Yuma in 1902. Now, records are maintained on all principal streams and many of the minor streams, mainly in cooperation with the States of Arizona and California. In Arizona alone some 150 stations were active during 1963. These records, spanning some 4,500 station-years, form the hydrologic basis for development and operation of river-management projects.

Analyses of river-water quality are made at regular intervals at about 40 stations in the region. Thousands of analyses have been made during the past 20 years to define the chemical quality of ground waters. As wells are drilled in areas under study, additional samples are analyzed. In critical areas wells are re-sampled at intervals to define quality changes.

Ground water has been studied in numerous areas, especially those where substantial ground-water development has taken place. (See fig. 1). In Arizona, studies have been made in the Gila River and Salt River valleys near Phoenix, the Navajo and Papago Indian reservations, and the lower Santa Cruz River and Safford Valley areas. In southern California, studies are in progress in the Imperial Valley and in the Joshua Tree National Monument.

The current program of investigations is summarized by figure 2 and a following table; the active areal projects are identified in a following list.

Water-resource investigations in the Pacific Southwest by the Geological Survey, fiscal 1963

(Thousands of dollars)

Activity	Source of funds: Other Federal Agencies	Source of funds: Cooperating State Agencies 1/	Source of funds: Geological Survey	Total
Streamflow records	111	478	75	664
Chemical-quality records	15	35	9	59
Sediment records	24	2	12	38
Ground-water appraisals	190	351	8	549
Hydrologic regimen, lower Colorado River basin	0	0	336	336
Arid-zone research	0	0	412	412
Totals	340	866	852	2,058

1/ Matching funds from Geological Survey included.

Active areal projects shown on figure 2

A. Ground-water appraisal, Point Mugu area.
B. Ground-water appraisal, Indian Wells Valley.
C. Ground-water appraisal, Edwards Air Force Base.
D. Seepage rates in southern California stream channels.
E. Natural water loss in southern California.
F. Hydrologic data and geologic mapping, Mojave Valley area.
G. Ground-water appraisal, Twentynine Palms Marine Corps Base.
H. Geologic and hydrologic reconnaissance, Joshua Tree National Monument.
I. Hydrologic regimen of Lower Colorado River basin.
J. Ground-water conditions in Sarcobatus Flat, Nye County.
K. Regional hydrology of the Nevada Test Site and adjacent areas.
L. Ground-water conditions in Pahrump Valley, Clark and Nye Counties.
M. Hydrology of the Las Vegas ground-water basin.
N. Geology and ground-water resources of the Ute Mountain Indian Reservation.
O. Geology and ground-water resources, Big Sand Valley.
P. Change in water yield by removal of riparian vegetation, Cottonwood Wash.
Q. Feasibility of developing ground-water supplies, city of Flagstaff.
R. Ground-water resources and geology, Verde Valley area.
S. Ground-water study, Agua Fria River Valley.
T. Water supply for Luke Air Force Base.
U. Study of deep aquifers, Salt River Valley.
V. Potential water yield of Sycamore Creek basin.
W. Subsurface geohydrologic studies, northwestern Pinal County.
X. Availability of ground water, Papago Indian Reservation.
Y. Geology and hydrology, Tucson basin.
Z. Geology and water resources, Fort Huachuca.

AA. Geohydrology and utilization of water, Willcox basin.
BB. Electrical analog analysis, San Simon basin.
CC. Arid lands study, Safford Valley.
DD. Hydrologic effect of vegetation removal on small watershed.
EE. Geology and ground-water resources, Navajo and Hopi Indian Reservations.
FF. Ground-water resources, Apache County.
GG. Geology and ground-water resources in the Gallup area, McKinley County.
HH. Ground-water occurrences and geology of southeastern McKinley County.
II. The petrology and chemistry of the San Andres Limestone and their relation to the quality of water in the Acoma-Laguna area, Valencia County.
JJ. Geology and ground-water conditions in Grant County.

Special emphasis is placed on two of the current-program items: the hydrologic regimen of the lower Colorado River basin and the arid-zone research. These two include investigations of the intensive, particularized type needed as the basis for future water-management decisions.

Work on the regimen of the lower Colorado River basin (fig. 2, area I) began in 1960; it is scheduled to continue at least through 1965. Included are the drainage area of the main-stem river below Davis Dam and the Imperial Valley (Salton Sea); excluded are the tributary valleys of the Bill Williams and Gila rivers. Particular attention is being paid to (1) the balance among precipitation, evaporation and consumptive use, and runoff; (2) storage, movement, and chemical character of ground water, including international aspects; (3) extent and properties of the ground-water aquifers, and their relation to the river; and (4) water budget of the Salton Sea, including accurate measurements of inflow and independent measurements of evaporation. The consumptive-use studies include evapotranspirometer tanks near Yuma, Arizona, operated in cooperation with the Bureau of Reclamation. Reports on certain early phases of the work are in preparation. A general purpose of the work is to define alternative water-management steps that are possible and to appraise the potential effects of each such step.

The arid-zone research concerns (1) water consumption by phreatophytes, chiefly saltcedar, as measured in evapotranspirometer tanks at Buckeye, Arizona (in collaboration between the Geological Survey and the Bureau of Reclamation), (2) potential for water salvage by eradicating riparian vegetation in the Gila River valley above San Carlos Reservoir; (3) hydrologic effects of replacing juniper and pinyon pine with grasses in the Carrizo and Corduroy Creek basins near Showlow, Arizona; (4) soil-moisture chemistry and energy relationships in an area of riparian vegetation; (5) theory and measurement of evapotranspiration; (6) mass transfer of moisture in the atmosphere, measured by airborne equipment; and (7) thunderstorm patterns and rainfall in relation to runoff on the arid plains of southern Arizona, in part measured by radar. Digital-punch recording equipment and an unique electric-analog computer are used as appropriate.

A Long-range Program

Outlined below are principal categories of additional investigations proposed by the Geological Survey to foster and sustain full development of water resources in the Pacific Southwest. Costs, above those of the current program that has been summarized, would be about $1,000,000* in the first year and about $2,000,000 yearly from the second through the fifth year. After five years, scope and cost would be reconsidered according to experience.

Work for Early Completion

The current project on hydrologic regimen of the lower Colorado River basin and those constituting the program of arid-zone research would be completed as now scheduled. Two additional projects would utilize the hydrologic information now available, both published and in the files of field offices; these two are:

Regional water-resource appraisal.-- An up-to-date appraisal of water resources in the region would identify uncommitted stream supplies and undeveloped ground-water storage. Limited new reconnaissance data would be collected as necessary. A two-year project; total cost, about $200,000.

Statistical analysis of streamflow records.-- The ultimate regulation and management of the region's streams will be based on the observed frequency of hydrologic events of various magnitudes. To that end, appropriate region-wide statistical analyses of streamflow records are proposed to be made over an initial period of two years, and to be updated at ten-year intervals thereafter. Machine computation techniques would be used. Cost of two-year project, about $145,000.

Ground-water Sources

Potential-yield appraisals.-- For certain ground-water basins in the region, which have been developed extensively and over many years, general dimensions and characteristics have been determined. Commonly, however, information is lacking on amounts of water that could be withdrawn perennially, and on volumes in storage that might be withdrawn ("mined") within economic lifts. Reasonably dependable values of either perennial or "one-time" yields of all such sources will become increasingly necessary. It is proposed that appraisals of potential ground-water yields be accelerated several fold within five years, held at that high level over a second five-year period and then diminished progressively as proves to be appropriate. Estimated cost, first year $100,000, second to fifth year $250,000 per year.

*All estimates in 1963 dollars.

Reconnaissance appraisals.-- Reconnaissance appraisals are proposed for those ground-water basins that have not been developed or investigated, to estimate or determine extent and properties of the aquifers and chemical quality of the water, to define sources of recharge, and to estimate storage capability and yield. Some such basins doubtless contain water of good quality and appreciable quantity. Other basins are known to, or may, contain brackish water that would be unusable unless diluted. To take full advantage of new developments in the technology of desalination, the brackish-water bodies would be delineated so far as is feasible. The reconnaissance appraisals must be based on extensive knowledge of the areal geology; readily available hydrologic information would be gathered also. They are proposed to be largely completed within ten years. Estimated cost, first year $100,000, second to fifth year $250,000 per year.

Managed storage.-- In certain ground-water reservoirs, storage space can be evacuated by withdrawing water seasonally or during a succession of drought years, and then refilled from surplus streamflow either naturally or artificially. Under favorable circumstances, it should be practical to manage underground storage so that perennial water yield would be increased. Oversimplified, this is a principal method by which surface- and ground-water sources may be managed jointly. Determining potentials for such management would be an integral part of the potential-yield and reconnaissance appraisals described above.

Major opportunities for managed underground storage appear to exist beneath the valley plain along the main stem of the Colorado River. In particular, a terminal-storage facility of this kind in the vicinity of Yuma, with manageable storage capacity of 500,000 to 1,000,000 acre-feet, may prove feasible and practical. Appraisal of the physical and hydrologic features related to this potential is one objective of the Lower Colorado River investigation currently under way.

Surface-Water Sources

Gaging-station network.-- Over most of the Pacific Southwest, the network of primary gaging stations on principal streams is reasonably adequate. Ultimately, however, a moderate number of roving, secondary stations will be useful to: (1) discriminate uncommitted supplies that may prove to be developable in the Little Colorado and Bill Williams river basins and elsewhere at scattered places; and (2) determine magnitude and frequency of ephemeral discharge into numerous desert basins, discharge which is a principal source of ground-water recharge. It is proposed that, in each year of an initial five-year period, 50 secondary stations be established; also that each year thereafter, 50 such stations be relocated to new sites. Cost, first year $50,000, second to fifth year $140,000 per year.

Water-quality and Waste Management

Inventories of salt loads.-- There are proposed: (1) over an initial five-year period, a reconnaissance estimate of the natural salt loads carried by streams of the region and of the changes in load (usually increases) caused currently by irrigation, by industries, and by municipalities; (2) thereafter, by successive sub-basins or development areas, recurrent specific determinations of the man-caused changes in the salt loads of streams. This would entail about 10 primary chemical-quality stations and perhaps 50 roving stations maintained for five-year intervals at each particular site. Cost, first year $90,000, second to fifth year $250,000 per year.

Means for water-quality management.-- A most crucial goal of water management in the region should be to seek out all possible means--chemical or physical-- to counter the depreciation in water quality that results inevitably from water use. Sought here would be a means particularly adaptable to depreciated waters which, if improved but moderately in quality, could be reused without restriction. For example, means for precipitating some part of the dissolved solids, or for segregating a relatively large fraction of the waste products in a relatively small fraction of the water that then could be disposed of separately. This would involve intensive research into fundamental water chemistry, including neutron activation of contaminated waters and of base-exchange materials. Difficulties admittedly are serious but the stakes are great and a practical method would be applicable universally. From five to ten years of intensive effort is contemplated. Cost, excluding possible tests at pilot-plant scale, first year $25,000, second to fifth year possibly to as much as $150,000 per year.

Water Salvage

Some of the hottest and most arid areas in the United States lie within the Pacific Southwest. The growing season is nearly continuous and the semi-tropical climate is favorable to luxuriant growth where water is available. Evaporation and transpiration rates are extreme and, over the region as a whole, probably dissipate at least 97 percent of the sparse precipitation. Under present technology this dissipation of water cannot be diminished economically. If an economic means can be found by intensive study, however, the amount of usable water locally might be increased several fold.

Non-beneficial consumptive use.-- Salvage of water through eradication of phreatophytes and other riparian vegetation is believed to be practicable and economical in certain parts of the region. However, few reliable data are available on the amounts of water consumed by various plant species over the range of environments found in the region. In consequence, the potential for salvage of water by diminishing the consumptive use can be estimated only crudely. It is proposed, therefore, that (1) the present program of tank experiments at Buckeye and at Yuma be extended to other plant species and to environments typical of other parts of the region, that (2) suitable localities be sought for testing the eradication of vegetation by lowering the ground-water level, and that (3) the frequency of channel overflow be ascertained in relation to the extent and permanence of riparian vegetation. Cost, first year about $225,000, next four years about $275,000 yearly.

Channel losses.-- Evaporation losses from the wet channels of ephemeral streams following flood flows are known to be great. This is attested by the observed decrease in unit runoff as drainage area increases. The practicability of increasing recharge to ground water by ephemeral streams depends to a great extent upon the hydrologic regimen of the stream channels under various environmental conditions. It is proposed to measure the evaporation losses, ground-water recharge, and streamflow of typical ephemeral channels to the possible end of increasing the available water supply by manipulating the channels. Estimated cost, first year about $100,000, next four years about $175,000 yearly.

General Hydrologic Research

General research in hydrologic processes, in techniques of investigations, and in fundamental interrelationships between water and its environment are proposed to support development and management practices. Present knowledge and experience are deficient in several respects, especially as the limit of the available water supply is approached. An improved understanding of the factors governing the movement of ground water, with the complications of varying permeability and hydrostatic pressures is needed for effective management of ground-water storage. Evaporation from the land surface involves the flow of moisture through unsaturated soil, about which little is known. A better understanding of the factors influencing infiltration, also a problem in flow of water through unsaturated media, may lead to means for increasing recharge. Hydraulic characteristics of alluvial channels must be explored in considerable detail if effective measures for channel stabilization are to be developed.

Other examples would include the influence of land-use practices and of vegetation modification on the hydrologic regimen; the drought tolerance of various species of phreatophytes; the relation between depth of water table and consumptive use by vegetation; and the processes involved in natural ground-water recharge from ephemeral stream channels.

Costs are estimated to be $150,000 the first year and $300,000 a year over the next four years.

CLASSIFICATION OF FEDERAL MINERAL LANDS

In Arizona, the State which would contain the most extensive management works contemplated under the Pacific Southwest Water Plan, the Geological Survey proposes to accelerate its classification of Federal mineral lands. Classification would conserve useful mineral deposits under confirmed withdrawals and would release barren lands. Thus, areas of possible conflict between management programs for water and for minerals would be minimized.

Involved in Arizona are about 3,400,000 acres prospectively valuable for sodium and 140,000 acres for coal. These lands can be mapped and classified as to their mineral potential for about $2,500,000; a 10-year program at a uniform yearly rate of $250,000 should provide needed information in pace with orderly development of any mineral, mineral-fuel, and mineral-fertilizer resources.

Other parts of the Pacific Southwest also contain deposits of potentially useful minerals. There, however, the likelihood of conflict between management programs for water and for minerals is small. Consequently, the Federal mineral lands would be classified as an incidental product of the geologic and mineral-resource investigations to be outlined.

TOPOGRAPHIC MAPPING

General Statement

The following proposal for topographic mapping is paced to facilitate general studies involved in the Pacific Southwest Water Plan. It would supply Federal agencies and the general public with advance map materials including aerial photography and geodetic-control lists, as well as with published maps.

Mapping Completed and Currently in Progress

Of the 180,000 square miles in the Pacific Southwest as here defined, about 113,500 square miles or 63 percent is covered by topographic maps of standard accuracy. (See fig. 3). Most of these maps are published, but a few are available in advance copy only. In addition, mapping is in early stages over about 7 percent of the area.

This completed mapping covers most of the areas of the Central Arizona Aqueduct, Charleston Dam and Reservoir, and Marble Canyon Dam and Reservoir units understood to be proposed by the Bureau of Reclamation. With work in progress, it also covers parts of the Granite Reef Aqueduct, Maxwell Dam and Reservoir, and Buttes Dam and Reservoir units.

Short-range Schedule

There is proposed a short-range or six-year schedule of topographic mapping to complete work now in progress and to make certain new starts in 1965-1967. Latest of the new starts would produce advance copy by 1969 and published maps by 1970. The proposed schedule is based on the construction priorities understood to have been set by the Bureau of Reclamation, also on Survey proposals for hydrologic and geologic investigations. In total, the six-year mapping schedule would cover about 14,500 square miles in six project areas, as follows:

Project	Square Miles	Year to Start
Reserve north	740	1965
Granite Reef Aqueduct and other Central Arizona Project work	2,400	1965
Hooker Dam and Reservoir unit	1,450	1965
Bridge Canyon	1,950	1966-1967
Kaiparowits Plateau and Kanab coal field	950	1966-1967
Other mapping	7,000	1966-1967

Completion of the Bridge Canyon project under this schedule will provide topographic coverage, in either the 7½- or the 15-minute series, of all the reach of the Colorado River from the Utah-Colorado boundary to the United States-Mexico boundary. (See fig. 3).

Cost of this short-range schedule in the Pacific Southwest is estimated as about $3,000,000 to complete maps in progress, plus about $4,000,000 for the maps to be started through 1967.

Long-range Schedule

Following the six-year schedule just outlined, a long-range schedule will cover the larger unmapped blocks in the headwater parts of the Little Colorado, Gila, and Salt river basins; in the areas immediately north and south of the Bridge Canyon unit; and in the Muddy Creek and White River basins in Nevada. The long-range schedule in the Pacific Southwest would extend through 1976; its cost is estimated to be about $9,000,000 in addition to that of the short-range schedule.

This long-range schedule for the Pacific Southwest conforms to an earlier proposal by the Geological Survey for an orderly expansion of mapping capability to complete once-over topographic coverage of all the nation by 1976, in either the $7\frac{1}{2}$- or the 15-minute series. During the ensuing five years, 1977-1981, the areas previously published only in the 15-minute series would be resurveyed as necessary for covering the entire nation, except Alaska, into the $7\frac{1}{2}$-minute series.

GEOLOGIC AND MINERAL-RESOURCE INVESTIGATIONS

The economic growth of the Pacific Southwest depends on development and wise use of not only water resources but also of mineral resources. Industrial development hinges in very large measure on the amount and uses made of minerals and fuels both in and near the region.

Two programs of geologic and mineral-resource investigations in the Pacific Southwest are outlined here: (1) a short-range program that is related immediately to development and management of the water resource, and that can be accomplished within five years at an estimated total cost of $8,700,000; and (2) a long-range program that would cover all the region comprehensively within a 35-year term at an estimated total cost of about $108,000,000.

Short-range Program

Reconnaissance studies.-- Although reconnaissance geologic maps are available for all Arizona at the 1:375,000 scale, much of the information is out-dated and incomplete. Proposed for immediate remapping at scale 1:250,000 are the Williams, Prescott, Phoenix, and Ajo 2-degree sheets (see fig. 4).

In California, the Division of Mines is preparing geologic maps at the 1:250,000 scale. In the part of the State here of concern, mapping is yet pending on the Needles, San Bernardino, Los Angeles, Salton Sea, Santa Ana, and Long Beach 2-degree sheets. It is proposed that the Geological Survey accelerate these particular maps by studying the areas not well known. Cost of these reconnaissance studies is estimated at $190,000 yearly over the five-year period. They would anticipate unusual difficulties that might be encountered in constructing water-management works, and provide a necessary background for general planning of more detailed studies. Further, geologic reconnaissance constitutes the first appraisal of the crust of the earth and the characteristics and resources that will affect man's activities thereon.

General-purpose mapping.-- Geologic mapping and related studies, at scales of 1:62,500 and 1:24,000, would provide immediate background information for site planning of proposed water-development and engineering projects and for areas of urban development. The following are proposed:

1. Thirty 15-minute quadrangles that include the general alinement of the Central Arizona Aqueduct. Among these, four quadrangles at and near Phoenix, also four at and near Tucson would serve multipurpose planning related both to the aqueduct and to urban expansion, water storage, and waste disposal.

2. Thirty-one 15-minute quadrangles that include the sites of proposed dams, reservoirs, and tunnels of the Marble Canyon-Kanab, Coconino, Bridge Canyon, Alamo, Sentinel, Buttes, and McDowell projects and the Salt River above Roosevelt Reservoir, all in Arizona; the Dixie project in Utah, and the Las Vegas project in Nevada. Priority among these 31 quadrangles would be arranged with the Bureau of Reclamation. No background geologic studies of these are available.

3. In urban areas, four 15-minute quadrangles near Phoenix and four near Tucson, as noted already; also, near Los Angeles, three $7\frac{1}{2}$-minute quadrangles in addition to those currently in progress.

Estimated cost of this general-purpose mapping would increase from $335,000 in the first year to $1,105,000 in the third, fourth, and fifth years.

Appraisal of known mineral resources.-- In parallel with the general appraisal of water resources outlined on page 7, it is proposed to assemble and summarize available information on geologic environmental features and mineral resources of the Pacific Southwest. This would be accomplished in the first two years at a total cost of $190,000.

Geophysical reconnaissance.-- Gravity, aeromagnetic, and seismic surveys are proposed to afford a quick, first approximation of extent and bedrock configuration of the numerous sedimentary basins in the region. Such geophysical reconnaissance of all the region would facilitate the ground-water appraisals outlined elsewhere. It can be completed within five years at an estimated cost of $2,100,000.

Coal investigations.-- Eight main coal-bearing areas potentially can supply fuel for developing power in the Pacific Southwest. These are the Henry Mountains, Kolob, Kanab, and Kaiparowits fields in southern Utah; the Black Mesa field in northeastern Arizona; and the Gallup and Zuni fields as well as the San Juan River region in northwestern New Mexico. (See fig. 4).

Among these, the Kaiparowits field is one of the most extensive and least explored; present information is fragmentary. Mining in this field has become active recently. Here a very modest program of quadrangle geologic mapping has been started to delineate grade, extent, and thickness of coal beds as a basis for estimating reserves and classifying the land. At the present pace, however, several decades would elapse before mapping and classification are complete. It is proposed that the present pace be quickened several fold, and that mapping of the fifty $7\frac{1}{2}$-minute quadrangles in the Kaiparowits field be accomplished within the five years. Total cost is estimated at $1,175,000; from $120,000 in the first year to a maximum of $310,000 in the fourth year.

A comparable appraisal is proposed to determine the coal resources of the Black Mesa field, Arizona, and of the several fields in northwestern New Mexico. Total cost of this work is estimated to be $2,400,000.

Long-range Program

The long-range, 35-year program of geologic and mineral-resource investigations proposed by the Geological Survey would go far beyond immediate aspects of water-resource management. Its purpose would be knowledge sufficient for intelligent management and use of all resources derivable from the earth's crust within the Pacific Southwest.

It would include three phases: (1) reconnaissance, chiefly by aeromagnetic and gravity surveys, to discriminate and outline gross geologic features; (2) general-purpose geologic analysis and mapping, most commonly at scales of 1:62,500 or 1:24,000, chiefly to guide immediate search for minerals and mineral fuels, and to facilitate site selection for highways and other engineering works of diverse kinds; and (3) topical studies continually extending the frontiers of geologic knowledge to win new advantages from the earth's crust.

A substantial amount of geologic knowledge has been and is being gathered in the Pacific Southwest (see fig. 5). However, at the current rate of about 25 man-years of professional effort per day (by the Geologic Division of the Geological Survey), more than a century would elapse before all the region would be covered adequately. Current knowledge is distributed most unequally, so that some parts of the region call for much more future attention than other parts, as is shown by the following table and by figures 6 and 7.

Proposed 35-year program of geologic investigations
(In man-years of professional effort)

Sub-area outlined on figure 8	Reconn-aissance	General-purpose mapping	Topical studies	Total
California Coastal basins	19	450	250	719
Owens Valley	0	70	115	185
Mojave Desert	40	140	160	340
Colorado Desert and southern Mojave Desert	40	280	120	440
Southeastern Nevada	15	350	195	560
Colorado Plateau	0	60	50	110
Northwestern Arizona	60	190	210	460
Central Arizona and adjacent New Mexico	22	400	170	592
Southwestern Arizona	40	320	230	590
Southeastern Arizona and adjacent New Mexico	70	420	220	710
Pacific Southwest	306	2,680	1,720	4,706

Assuming a current average of $23,000 per professional man-year (technical, administrative, and logistic support included), estimated cost of this comprehensive 35-year program is about $108,000,000.

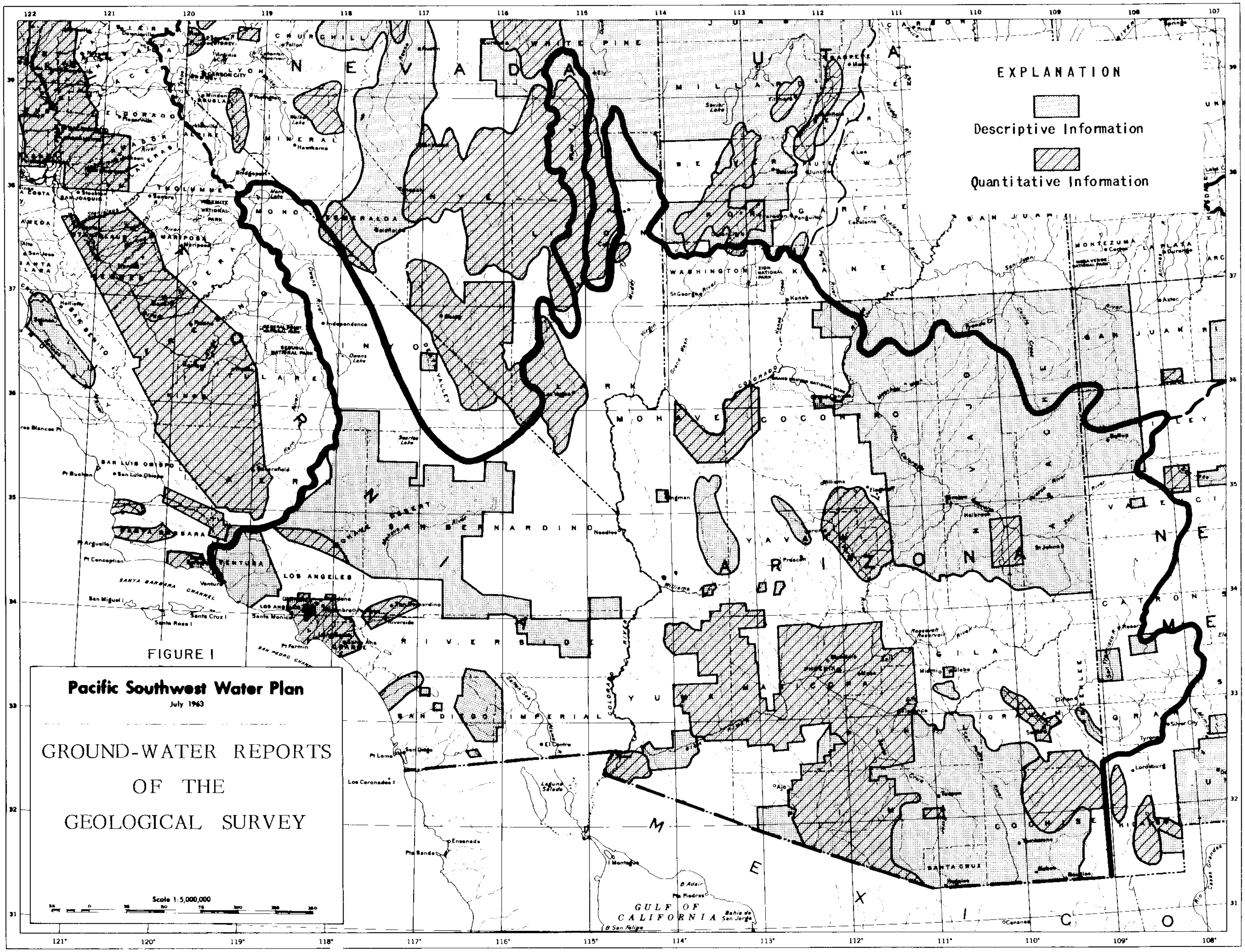
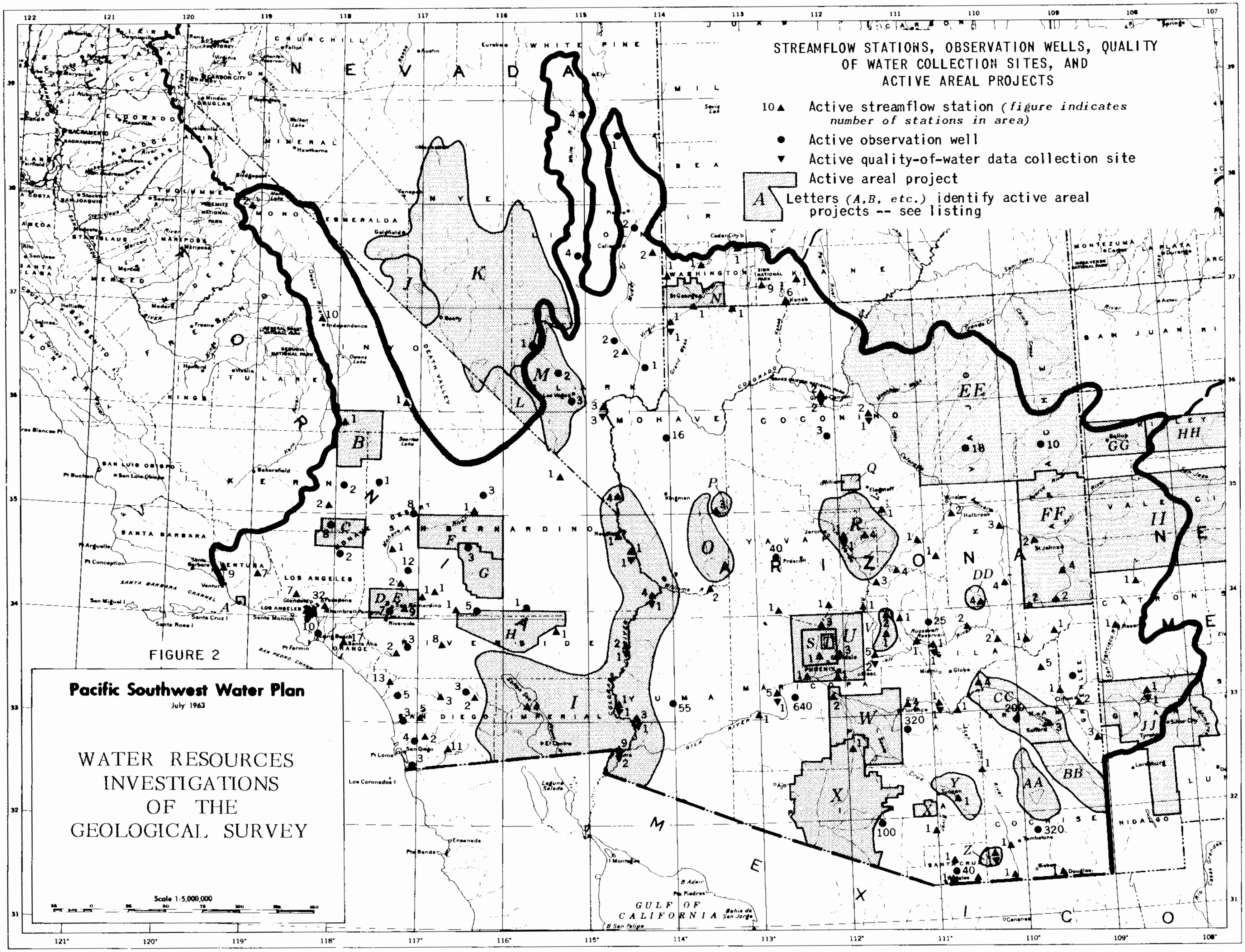


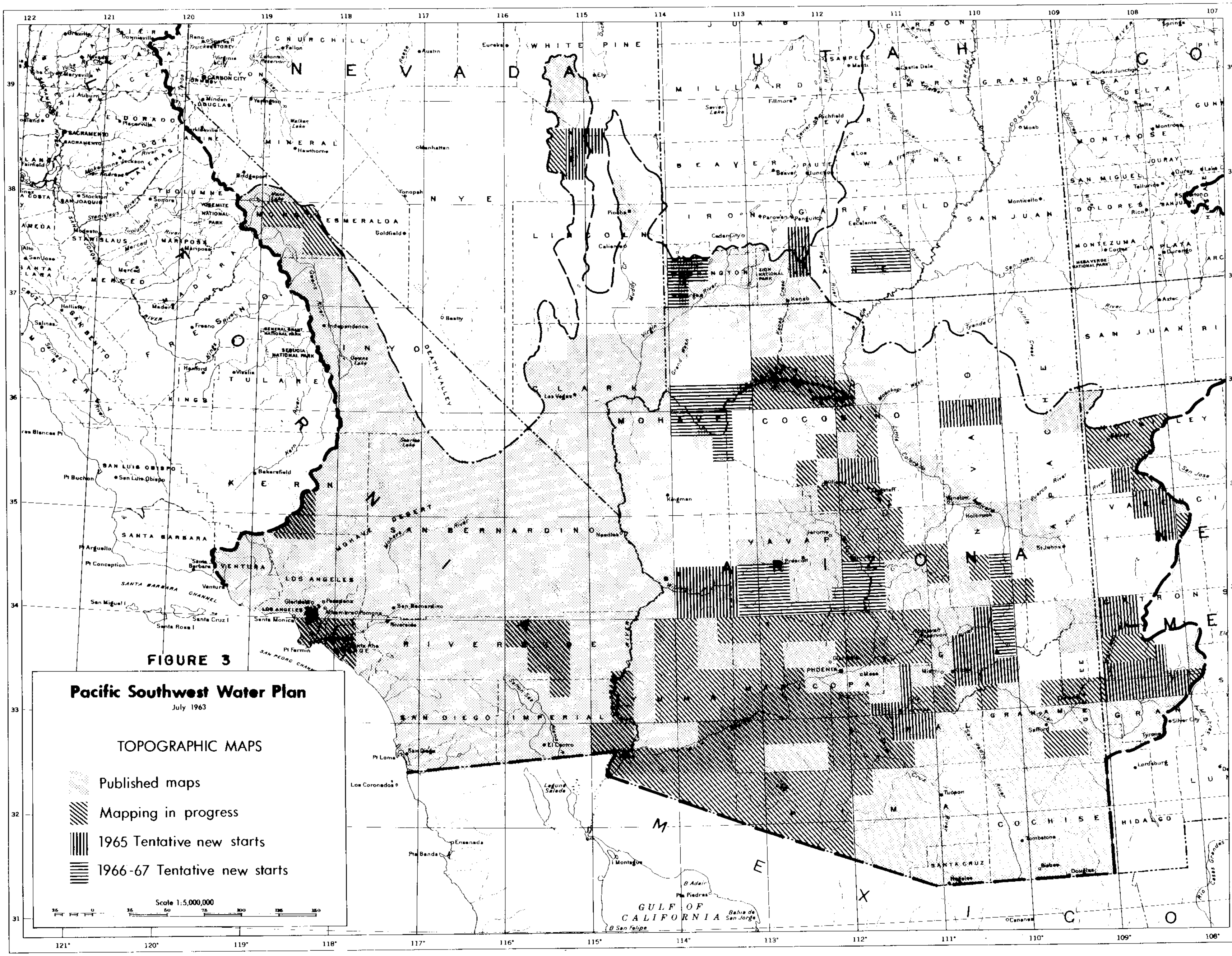
FIGURE I

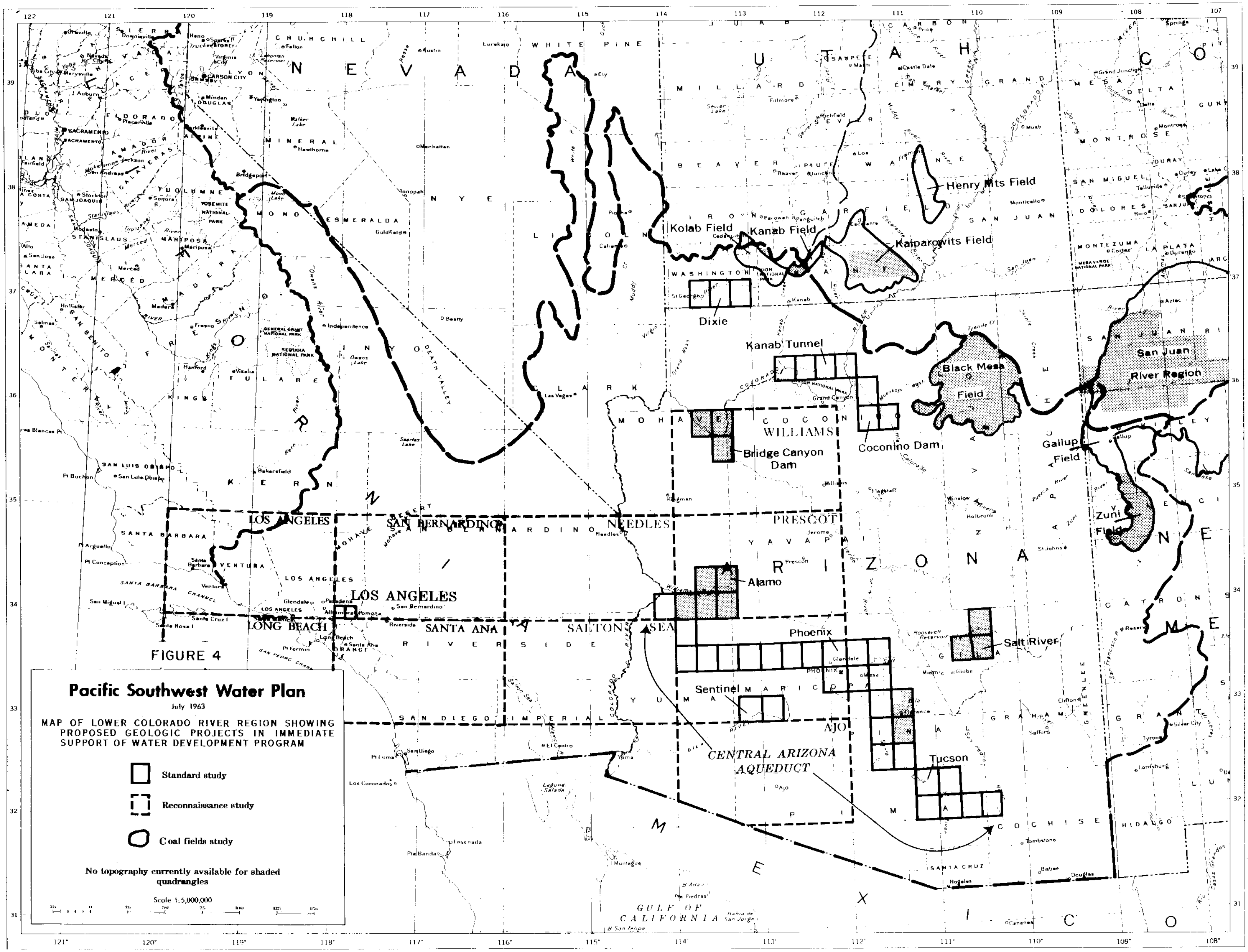
Pacific Southwest Water Plan

July 1963

GROUND-WATER REPORTS OF THE GEOLOGICAL SURVEY


STREAMFLOW STATIONS, OBSERVATION WELLS, QUALITY OF WATER COLLECTION SITES, AND ACTIVE AREAL PROJECTS
10 ▲ Active streamflow station (figure indicates number of stations in area)
● Active observation well
▼ Active quality-of-water data collection site
Active areal project
A Letters (A,B, etc.) identify active areal projects -- see listing
FIGURE 2
Pacific Southwest Water Plan
July 1963
WATER RESOURCES INVESTIGATIONS OF THE GEOLOGICAL SURVEY
Scale 1:5,000,000
NEVADA
ARIZONA
NEW MEXICO
MEXICO
GULF OF CALIFORNIA


N E V A D A
U T A H
A R I Z O N A
N E W M E X I C O
C A L I F O R N I A
M E X I C O
GULF OF CALIFORNIA
FIGURE 3
Pacific Southwest Water Plan
July 1963
TOPOGRAPHIC MAPS
Published maps
Mapping in progress
1965 Tentative new starts
1966-67 Tentative new starts
Scale 1:5,000,000



NEVADA
UTAH
ARIZONA
CALIFORNIA
MEXICO
Henry Mts Field
Kolab Field
Kanab Field
Kaiparowits Field
Dixie
Kanab Tunnel
Black Mesa Field
San Juan River Region
Coconino Dam
Gallup Field
Zuni Field
Bridge Canyon Dam
WILLIAMS
PRESCOT
NEEDLES
LOS ANGELES
SAN BERNARDINO
SANTA ANA
SALTON SEA
LONG BEACH
Alamo
Phoenix
Salt River
Sentinel
AJO
Tucson
CENTRAL ARIZONA AQUEDUCT
DEATH VALLEY
GULF OF CALIFORNIA
Pacific Southwest Water Plan
July 1963
MAP OF LOWER COLORADO RIVER REGION SHOWING PROPOSED GEOLOGIC PROJECTS IN IMMEDIATE SUPPORT OF WATER DEVELOPMENT PROGRAM
Standard study
Reconnaissance study
Coal fields study
No topography currently available for shaded quadrangles
Scale 1:5,000,000

FIGURE 4

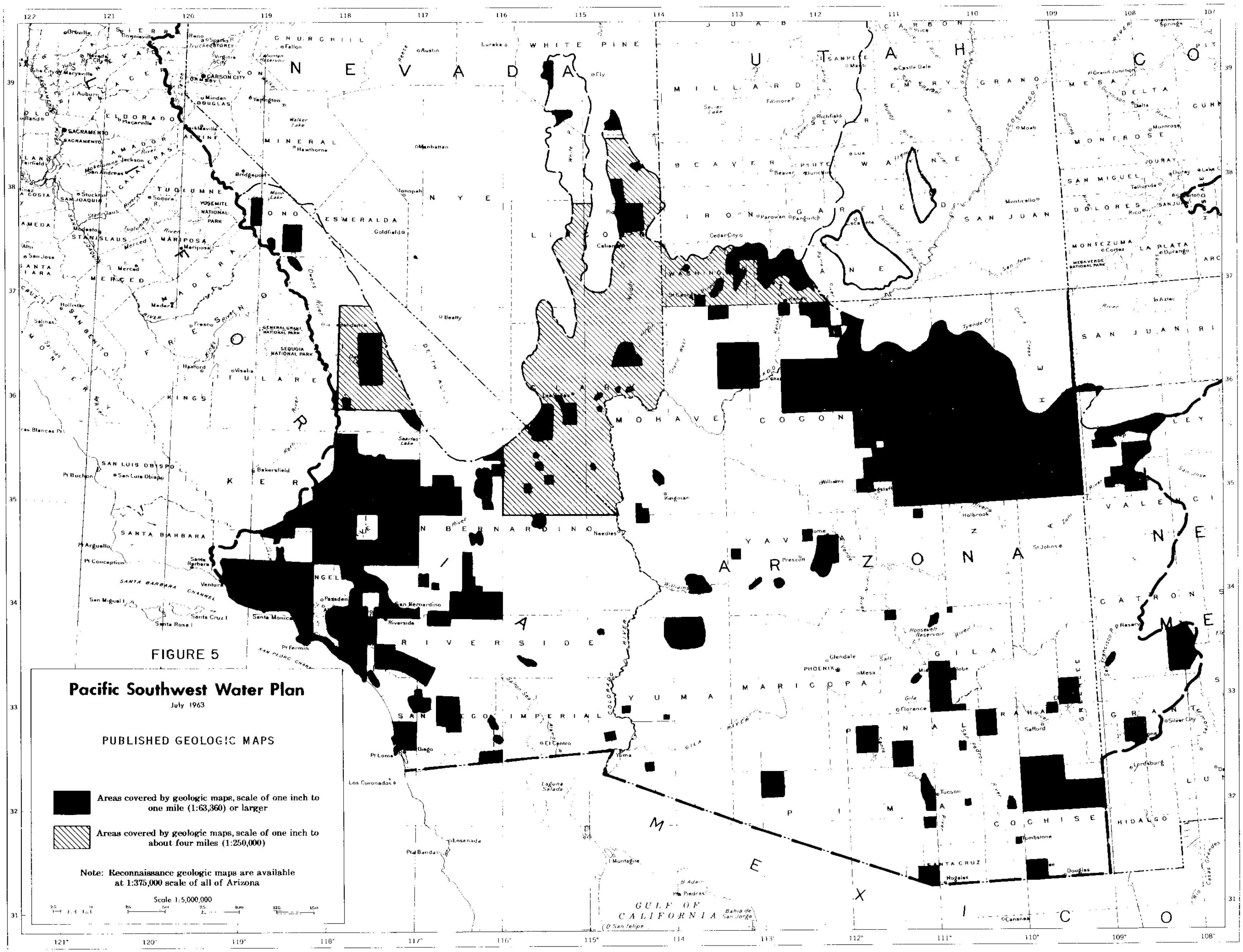


FIGURE 5
Pacific Southwest Water Plan
July 1963
PUBLISHED GEOLOGIC MAPS
Areas covered by geologic maps, scale of one inch to one mile (1:63,360) or larger
Areas covered by geologic maps, scale of one inch to about four miles (1:250,000)
Note: Reconnaissance geologic maps are available at 1:375,000 scale of all of Arizona
Scale 1:5,000,000
NEVADA
UTAH
ARIZONA
GULF OF CALIFORNIA

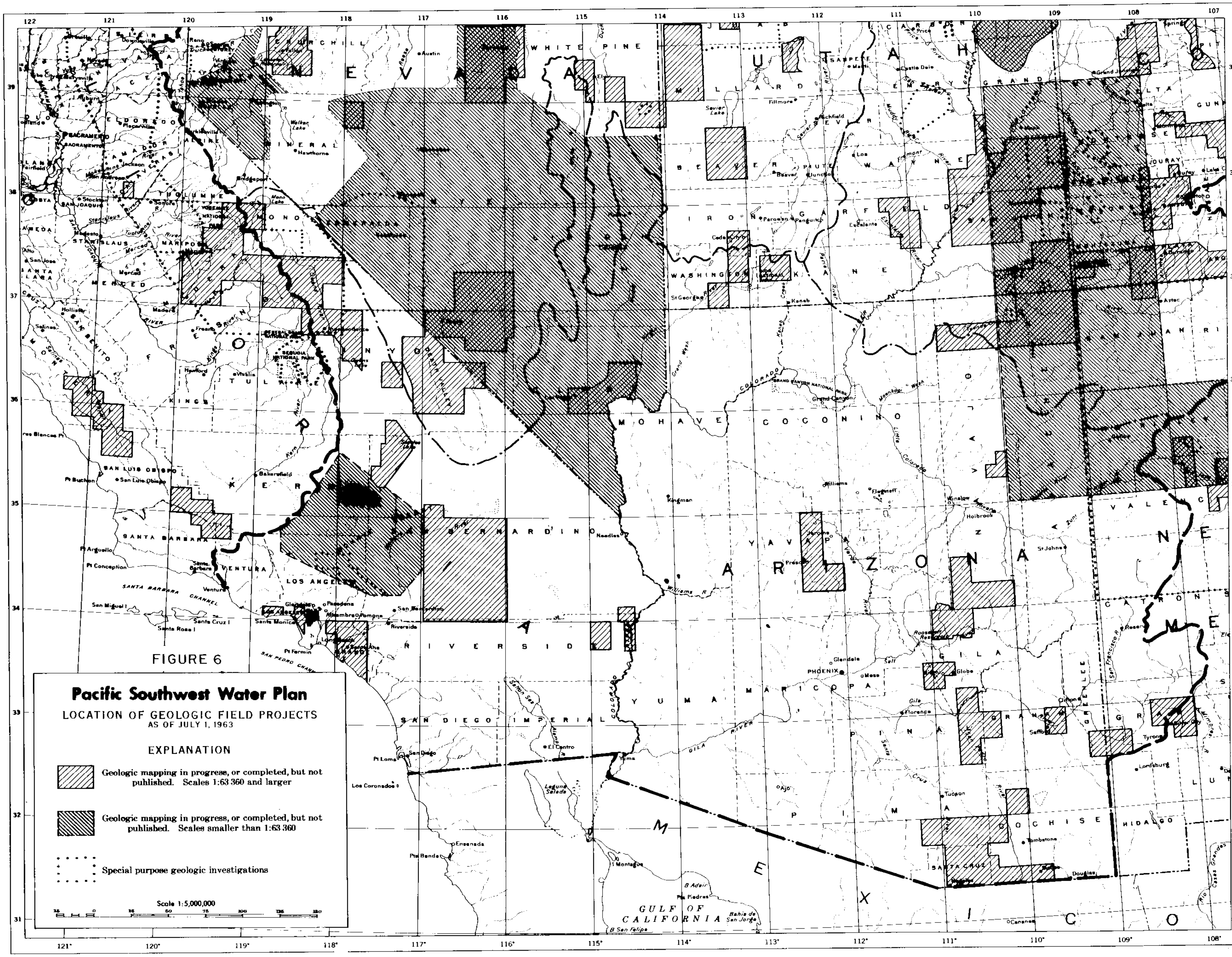


FIGURE 6

Pacific Southwest Water Plan

LOCATION OF GEOLOGIC FIELD PROJECTS
AS OF JULY 1, 1963

EXPLANATION

- Geologic mapping in progress, or completed, but not published. Scales 1:63 360 and larger
- Geologic mapping in progress, or completed, but not published. Scales smaller than 1:63 360
- Special purpose geologic investigations

Scale 1:5,000,000

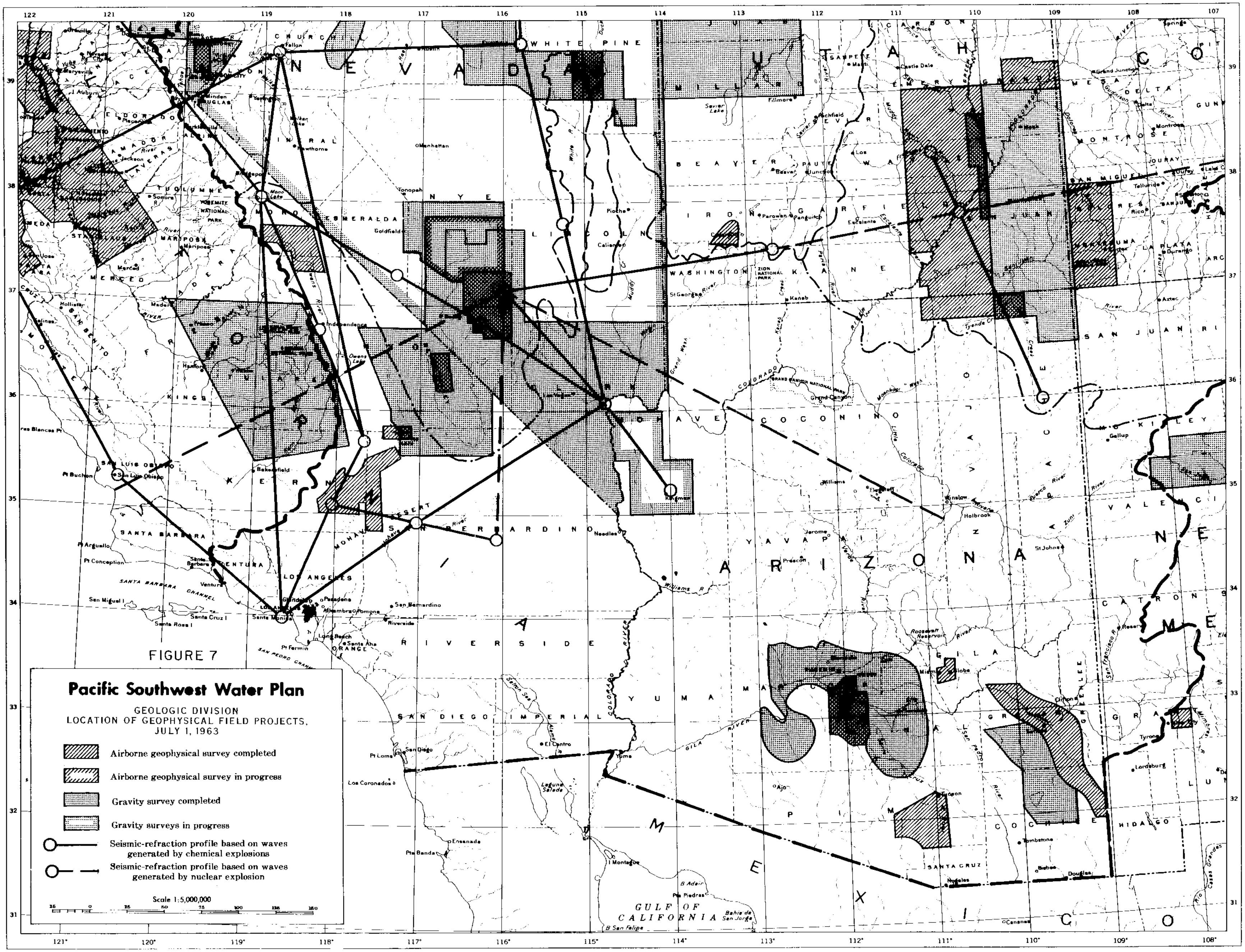


FIGURE 7

Pacific Southwest Water Plan

GEOLOGIC DIVISION
LOCATION OF GEOPHYSICAL FIELD PROJECTS,
JULY 1, 1963

- Airborne geophysical survey completed
- Airborne geophysical survey in progress
- Gravity survey completed
- Gravity surveys in progress
- Seismic-refraction profile based on waves generated by chemical explosions
- Seismic-refraction profile based on waves generated by nuclear explosion

Scale 1:5,000,000

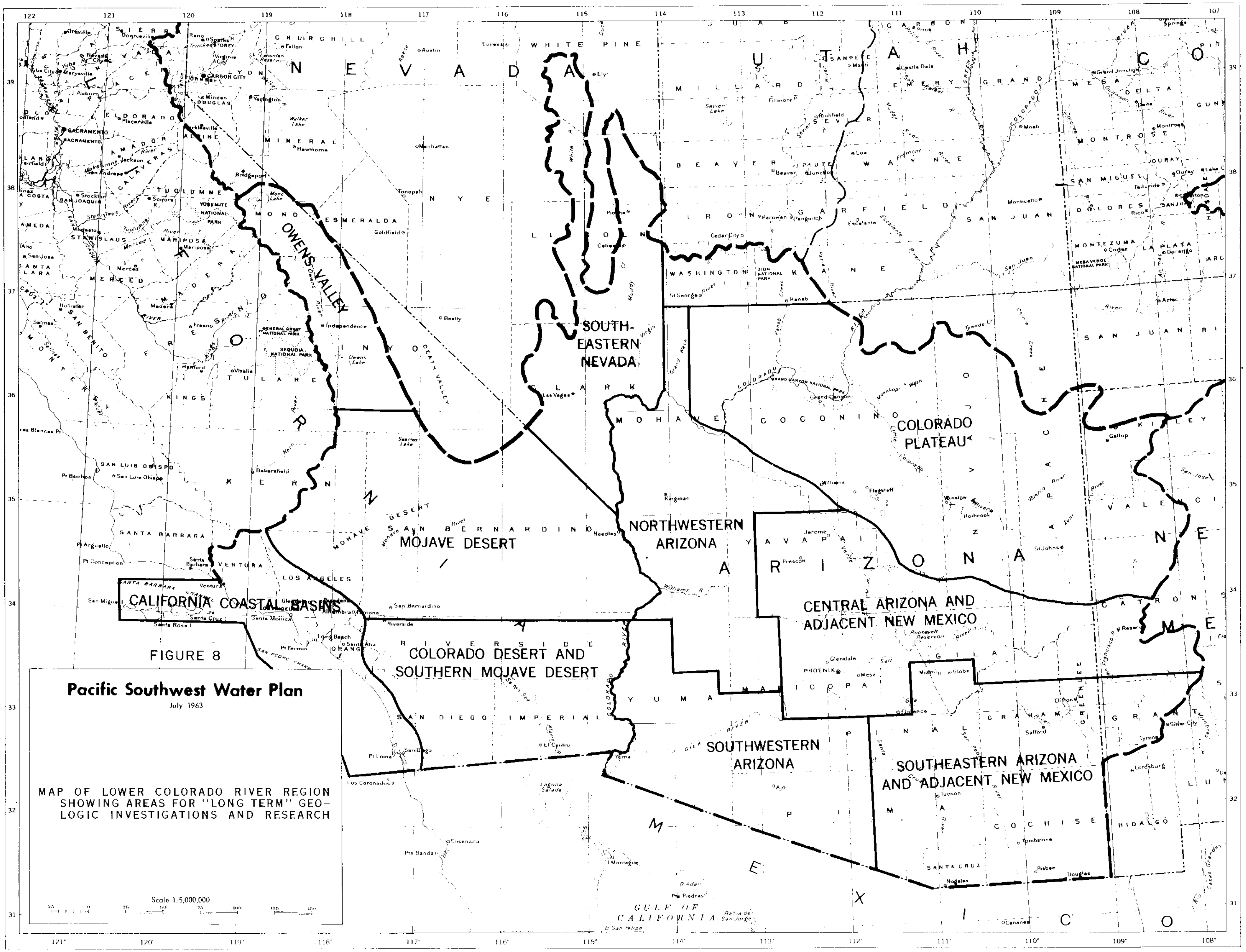


FIGURE 8
Pacific Southwest Water Plan
July 1963
MAP OF LOWER COLORADO RIVER REGION SHOWING AREAS FOR "LONG TERM" GEOLOGIC INVESTIGATIONS AND RESEARCH
Scale 1:5,000,000
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
CALIFORNIA
MEXICO
OWENS VALLEY
SOUTH-EASTERN NEVADA
COLORADO PLATEAU
NORTHWESTERN ARIZONA
MOJAVE DESERT
CALIFORNIA COASTAL BASINS
COLORADO DESERT AND SOUTHERN MOJAVE DESERT
CENTRAL ARIZONA AND ADJACENT NEW MEXICO
SOUTHWESTERN ARIZONA
SOUTHEASTERN ARIZONA AND ADJACENT NEW MEXICO
GULF OF CALIFORNIA

PUBLIC LANDS AND RELATED RESOURCES

LOWER COLORADO RIVER BASIN

BUREAU OF LAND MANAGEMENT

JULY 1963

PUBLIC LANDS AND RELATED RESOURCES--LOWER COLORADO RIVER BASIN--BUREAU OF LAND MANAGEMENT--JULY 1963

PART I--GENERAL

A. Authority

The authority for the public land management and development activities of the Bureau of Land Management are contained in a series of laws: including the Taylor Grazing Act of June 28, 1934 (48 Stat. 1269), as amended; the Soil Conservation and Domestic Act of April 27, 1935 (49 Stat. 163), as amended by Reorganization Plan Number IV (54 Stat. 1234), effective June 30, 1940; and the Halogeton Glomeratus Control Act of July 14, 1952 (66 Stat. 597). In addition, the Bureau cooperates with the Soil Conservation Service of the Department of Agriculture in carrying out the provisions of the Watershed Protection and Flood Prevention Act of August 4, 1954 (68 Stat. 666), insofar as it pertains to lands under the jurisdiction of the Bureau.

B. Scope

This report is the Bureau of Land Management's portion of the appendix of the Pacific Southwest Water and Related Land Resources Plan and covers all aspects of the Bureau's work in the area. It is based on the limited and widely dispersed data presently available both within and out side the Bureau. Preparation of the report has sharply indicated the need for more detailed and better integrated planning of the Bureau's various programs. In a large part, the limitations of the report are due to failure to provide adequate staff and financing for planning. Additional attention to and more adequate financing of planning would have made possible a more detailed and comprehensive report.

C. Lands involved

The area considered in this report is the Lower Colorado River basin, as delineated by the Colorado River Compact signed at Santa Fe, New Mexico, on November 24, 1922. Roughly, it contains those portions of the States of Arizona, California, Nevada, New Mexico, and Utah, from which water actually drains into the Colorado River below Lees Ferry and more specifically below the mouth of the Paria River, as shown on map No. 1.

The coastal plain area of California lying south of the transverse ranges and west of the peninsular ranges, which is served by Colorado River water, is not considered in this report, as the management practices on the public lands under jurisdiction of the Bureau of Land Management within the area have little effect on total water yields within the region.

D. Relationships to other agency plans

The comprehensive plan for the development of the Lower Colorado River basin is a joint effort of interested Interior agencies to plan for the orderly and proper development of the resources under the jurisdiction of the Department of the Interior.

The public domain lands are administered by the Bureau of Land Management. Under appropriate conditions, they may be classified for disposition and title transferred, or withdrawn and transferred to the jurisdiction of another Federal agency for a specific purpose, such as a wildlife refuge or a national park.

The Bureau of Land Management manages the public lands to assure that full use potentials are realized. This demands that there be continuous cooperation with local, county, State, and Federal agencies so that multiple use management will be achieved to the greatest possible extent.

The BLM and the Bureau of Indian Affairs have serious problems in common on the management of public lands in and adjacent to Indian reservations. A great deal of trespass is encountered which has resulted in terrific overgrazing of some areas. A serious overgrazing situation exists on the withdrawal created by Executive Order 5889, which withdrew land in New Mexico to aid the San Carlos Indian Irrigation project in Arizona. Since there is doubt about the land ever being used in connection with the San Carlos Indian Irrigation project, consideration should be given to placing it under multiple use management again.

The Geological Survey collects and publishes data on water uses, quantity, and quality. While there is a great deal of information available, much more is needed on groundwater and on sedimentation to facilitate proper management of the public domain lands. For instance, little information is available on sedimentation and the particular character and location of the grazing land which contributes to the tremendous load of silt carried by the Colorado River and its tributaries. It is estimated that 147 million tons of sediment are transported through the Grand Canyon each year by the Colorado River. Erosion control through proper management and construction of sedimentation barriers will become one of the most important management jobs of the BLM. Much of the information and data needed to approach the problem intelligently will have tc be furnished by the Geological Survey.

The BLM and the National Park Service work closely together to determine the recreation potentials and needs of the public domain lands. There is room for disagreement on the size of withdrawals for national recreation areas. The BLM is now staffed to properly administer lands under the multiple use concept and prefers to have withdrawals no larger than necessary.

There is need for close cooperation between the BLM and the Bureau of Reclamation in that too many small water developments in the uplands of a watershed can have adverse effects on downstream flow. The BLM, through proper management, can insure the water flow and contribute toward stemming the flow of sediment. A Solicitor's opinion prevents the BLM from computing downstream benefits in cost ratio benefits. This makes it difficult to justify some of the very important soil and moisture projects which will have valuable downstream benefits due to sedimentation control and increased flows of better quality water.

The United States Fish and Wildlife Service cooperates with the BLM in wildlife management problems on public domain lands. It is interested in proper management of the lands and water to insure the necessary environment for an abundance of healthy fish and wildlife. Large areas of public domain lands are withdrawn for wildlife refuges and game ranges. The

BLM is highly interested in seeing that withdrawals are not too large for the intended purpose, and when lands are definitely suited for multiple use management, they should remain under the jurisdiction of the BLM. A portion of the Desert Game Range in Nevada, for instance, might well be under mutliple use management.

The Bureau of Mines is interested in the management of the lands in such a manner that mineral resources can be developed consistent with other valuable land uses and management practices.

E. Summary

In view of the limited water resources within the Lower Colorado River basin, the critical shortages in many sections, and the mounting demands for water, it is imperative that all interested Federal agencies direct their efforts toward obtaining the maximum development and efficient utilization of all possible water resources. Research in all facets of this problem must be greatly accelerated and expanded in scope. It will be necessary that close cooperation exist among Federal, State, and county agencies, and private interests.

The Bureau of Land Management administers a high percentage of the land area. All planning should be based on the assumption that there will be an ever-increasing demand from competing groups, such as industrialists, stockmen, miners, and recreationists. This situation indicates the multiple use of the land must be the guiding factor in planning. Multiple use is defined as the optimum mixture of various uses (or the single use) of land based upon relative values and potentials of various resources, as well as the compatibility of their uses.

The greatest contribution of BLM toward better water management will be to manage the vegetative resources in a manner that will maximize water yields and minimize sedimentation and pollution. To this end 66 community watersheds have been delineated to facilitate planning and development. Substantial progress has been made in two watersheds involving an expenditure of $300, 000 by BLM. Planning has been undertaken, along with a small amount of development work, in 5 watersheds, which will, when the program is implemented, involve a total cost on BLM lands of about $8, 000, 000.

PART II--STUDY AREA

A. Topography and vegetation

The vast area which constitutes that portion of the Lower Colorado River watershed below Lees Ferry may be broadly categorized into three distinct physical areas--each with its own more or less individual climate, flora, and fauna.

The northern section, which includes portions of the Colorado Plateau and Basin and Range Provinces, is characterized by lofty plateaus incised by spectacular canyons with remnants of hills, buttes, and mesas. The plateaus differ from one another in temperature, rainfall, and vegetation. The average elevation of the area is 5, 000 to 7, 000 feet. Much of the area is wooded, with yellow pine or aspen at the highest elevations and piñon-juniper at the lower altitudes. Sagebrush, bunchgrasses, and desert shrubs are found in the lower, drier sections.

In the central section, high mountain ranges extend in a general northwest-southeast direction. The mountain tops generally rise 4,000 to 6,000 feet above the valley floors and several peaks exceed 11,000 feet above sea level. The vegetative cover in the central section is similar to that of the northern plateau area, but with a greater proportion of desert types as a result of the generally lower average elevation of the region.

The southern section is sometimes referred to as the desert, or plains region. It consists largely of vast stretches of desert plains broken by short mountain chains from 1,000 to 3,000 feet in elevation. The mountains are seldom forested and the plains or broad level valley support typical desert flora, or are devoid of vegetation. Portions of the area are extensively irrigated, particularly in the Gila and Salt River Valleys.

B. Geology

That portion of the study area within the Colorado Plateau Province is distinguished primarily by the horizontality of its rock formations in contrast to the folded formations in adjoining provinces. Stratigraphically, the Colorado Plateau Province is characterized by massive sandstone formations with some shale interbeds. As the formations have been subjected to extensive erosion in an arid climate, mesas, cuestas, escarpments, canyons, and dry washes are prominent features of the landscape. In some places volcanic necks, buttes, and lava flows are abundant.

The basins and low mountain ranges are distinctive for their uniformity and roughly parallel one another. Their bulk is fairly continuous and the crests are quite uniform. The slopes are fairly straight and do not tend to flatten at the base. The abrupt meeting of the valley floor and mountain side and the uniform slope of the latter are characteristic of the Basin and Range Provinces.

C. Climate

The important determinants of climate within the study area are elevation and the pattern of mountain ranges and distances from large bodies of water. In general, rainfall is light and humidity low. The percentage of possible sunshine received is high, as is the diurnal variation in temperature.

As would be expected, the southernmost areas experience the least rainfall and the highest temperatures. At Yuma, Arizona, the average annual rainfall is less than 3 inches, while as much as 30 inches per year is received in some sections of the mountains. The average annual precipitation for the State of Arizona is 12 1/2 inches. The seasonal distribution of precipitation differs. There is no marked seasonality at Yuma and other extremely arid sections. The mountain areas experience summer thundershowers and winter snows which result in summer and/or winter precipitation highs. Over most of the region there are two general periods of rainfall: December to February and July to September. As is true in most semiarid regions, extreme departures from annual "averages" of precipitation are characteristic. One year may bring many times the rain of the next and in the drier regions large areas may be practically skipped for one or more seasons. Along with this fitful character of the seasonal rainfall goes a tendency toward brief and violent showers or cloudbursts. This has a pronounced effect on runoff, infiltration, and erosion rate.

The difference between daytime and nighttime temperature is typically 30 to 40 degrees Fahrenheit. In the high plateaus or mountains, summer temperatures seldom exceed 90 degrees, while temperatures well over 100 degrees are usual in the lower and more southerly region. Winter temperatures are mild over most of the area, although temperatures well below freezing are typical in the higher elevations and northern portions of the basin. The growing season varies from 204 days at St. George, Utah, to 348 days at Yuma, Arizona.

D. Population

The Lower Colorado River basin area ranks among the Nation's fastest growing regions. The population increases, however, are largely confined to a few restricted areas within the basin, such as Maricopa and Pima Counties, Arizona, and Clark County, Nevada. More than one-half of Arizona's population, for example, resides in Maricopa County. The population of Maricopa County surged from 332,000 in 1950 to 664,000 in 1960. Pima County, with 20 percent of Arizona's population, went from 141,000 to 266,000 in 1960. In both cases the population virtually doubled in a decade. During the next decade (it has been predicted) Arizona's population will grow at three times the national rate for an expansion of 73 percent over the 1960 figure.

E. Access

An adequate network of major highways serves the principal populated valleys. These highways are primarily designed for through inter-State traffic. In addition to the principal highways, the major urban and agricultural areas are laced by adequate road nets. Traffic beyond the limits of the urban and agricultural area is light with the local roads poor and generally unpaved. The large remote areas of back country which constitute a great deal of the public domain lands have many access problems. Public land is often without roads or public access. Many miles of new roads are needed to open up these lands to meet the demands from the increasing number of people who are discovering the recreational potential of the public lands. Roads to facilitate multiple use management are also needed.

F. History of the general area

For the purposes of this report, the archaeological data concerning early man's occupancy of the area, the southwestern culture complex, the initial exploratory expeditions, and Spanish mission settlement are necessarily ignored.

Substantial non-Indian settlement in the study area was accomplished in the latter half of the nineteenth century. The discovery of gold in California and subsequently in Arizona led to the establishment of numerous mineral enterprises. Mining activities continued at an increasing tempo until the drop in silver prices in 1893. The level of mineral activity has fluctuated since that time. Currently, certain segments of the industry are in some distress, but generally the industry is healthy and an important component of the economy.

Farming and ranching activities expanded concurrently with the growth of the mineral industry. The location of farms and early settlements was usually determined by the availability of water, irrigable land, and accessibility or routes of transportation. Lands were initially irrigated by the simplest of rock or brush diversion structures, and ditches and canals. As the economy matured and higher and less accessible land was developed, more complicated and permanent irrigation structures were installed. The greater portion of the report area is devoted to the production of native forage for livestock, interspersed with areas of irrigated farms. The range areas are essentially wild lands valued chiefly for range livestock, wildlife, recreation, and as watersheds. The economy of the area has, of course, become more complex as it has expanded. Today, major industrial, commercial, business, and military establishments contribute to the diversification of the area's economy.

Ranching was one of the earliest economic activities in the basin. It expanded rapidly from 1830 to 1900. By the turn of the century virtually all of the lands adjacent or accessible to surface water supplies were appropriated. Stockmen began developing wells and fencing the ranges they sought to control. Range use of public lands during that period was uncontrolled by the Federal Government. In 1906 the Forest Service began to establish recognized grazing rights on specified areas under its jurisdiction. Lands acquired by the States upon admission to the Union were generally leased to stockmen. The enactment of the Taylor Grazing Act in 1934 finally provided the means to establish control over the public domain lands. It authorized the regulation of use and the initiation of rehabilitation measures. This latter was necessary as most of the lands had badly deteriorated from many years of misuse. Excessive stocking of the range had resulted in the diminution of the better forage plants and permitted the establishment, or spread, of less desirable plant species.

G. Present economic development

The economic growth rate of the report area is one of the highest in the country. The growth is accompanied by an increasing diversification of the economy. The principal sources of income for the area are currently derived from manufacturing, mining, tourism, crops, and livestock in that order.

Manufacturing is the economic activity which has achieved the greatest gains in recent years. The manufacturing activities include electronics, aerospace industries, clothing, chemicals, metal processing, food processing, printing and publishing, machinery, lumber, and a host of other light manufacturing enterprises.

The mining activity is based upon a wide variety of minerals, most important of which is copper. Asbestos, molybdenum, manganese, barite, lime, gypsum, and perlite are among the long list of minerals which have become substantial factors in the economy.

Forest products within the basin are derived primarily from the mountain areas. Roughly 300 million board feet of lumber are harvested annually. The chief sawmill operations are located in Flagstaff, Williams, Winslow, Fredonia, Springerville, Heber, and McNary.

Although less than 2 percent of the basin is under cultivation, the production of crops, virtually all by irrigation, is a vital segment of the region's economy. Yields per acre are among the highest in the Nation in both quantity and value. Crops produced include cotton, lettuce and other vegetable crops, melons, commercial hay and seed, dairy products, poultry, citrus fruits, and many others. Major dams, such as Roosevelt, Horse Mesa, Mormon Flat, Stewart Mountain, and Granite Reef on the Salt River, Horseshoe and Bartlett on the Verde, Coolidge on the Gila, Lyman on the Little Colorado, and Hoover, Davis, Parker, Laguna, and Imperial on the main stream of the Colorado River provided the means for the development in the last 50 years of an intensive and greatly expanded irrigation agriculture. Development of the groundwater supply has occurred throughout the basin, but the developments in the Safford Valley and in Pinal County on the Gila River are particularly dependent on pumped water. This agricultural use, coupled with increasing demands on groundwater for industrial, commercial, and urban residential uses, has resulted in a general lowering of groundwater tables. The situation is critical in many areas. The means to acquire additional water must be identified, as well as techniques to make optimum use of existing supplies if present requirements are to be met and further economic growth is to be achieved.

The vast majority of the lands in the region are devoted to the production of range livestock. The Lower Colorado River basin supports 1,963 cattle operators and 750 sheepmen, who graze about 360,000 cattle and approximately 205,000 sheep, part of the year on public domain lands.

The poor condition of the range indicates that overgrazing is still taking place. Complete adjudication of the range privileges is a must before good management practices can be instituted. Almost 800 range users' privileges have yet to be adjudicated. Many of these are small operators. For instance, 596 are in New Mexico, where the land is in a deplorable condition; 578 of the New Mexico operators are running sheep.

PART III--PRESENT PROGRAMS FOR PUBLIC LANDS

A. Types of public lands

The 28,294,000 acres of public lands administered exclusively by BLM in the basin vary from the predominate desert shrub-grassland type at the lower elevations to isolated and scattered stands of ponderosa pine at the higher elevations. A moderate belt of piñon-juniper woodland type and some chapparel occurs at medium elevations. Approximate acreages for the general vegetation types are shown on tables Nos. 1 and 2.

B. Management practices and uses of public lands

The 28 million acres of public lands in the area are used for a multiplicity of purposes:

1. Rangeland for domestic livestock and wildlife. Over 2,700 grazing permittees and lessees utilize the public lands. Many thousands of big game animals, including deer, antelope, bighorn sheep, javelina, and considerable bird life also utilize the public lands. Grazing privileges on the public lands have been established for most of the basin on the basis of permanent water distribution and water ownership or control. Nearly all surface waters are appropriated by farmers or livestock users under State laws. Federal range privileges are also granted on the basis of private land ownership, history of use, and other criteria in accordance with the provisions of the Taylor Grazing Act. The Bureau, to increase the production of forage, employs various management practices, dependent on the needs and potential of the particular terrain. Many of these are undertaken in cooperation with the livestock operators. These include (but are not limited to) fencing, reseeding, or revegetation, soil erosion control, brush eradication, noxious weed control, fire control, road construction, water development, regulation of numbers, and control of seasons of use.

2. Recreation. In cooperation with the Bureau of Sport Fisheries and Wildlife and the State game and fish departments, the Bureau manages the public lands for the optimum development and utilization of wildlife and fish consistent with other uses. This is achieved by developments and allocating public land areas necessary to propagate certain species. In addition, all of the public lands are available to the public for such recreational pursuits

as camping, picnicking, riding, hiking, sightseeing, nature study, photography, boating, hunting, and fishing. Many of the public lands are, and will remain, in their natural state because of factors such as topography, climate, and remote location. The Bureau considers public recreation values in making decisions affecting use of the public lands. It cooperates with Federal, State, and local recreation agencies in providing lands and facilities to improve the public recreation opportunities and is presently inventorying all public lands having significant values for public recreation. For example, practically all of the State, Federal, and local parks have been served out of the public lands and the Arizona State Highway Department maintains over 400 rest stops located largely on public lands. State and local recreation agencies plans include many thousands of acres of public domain for future recreational developments. In certain areas, such as Lincoln County, Nevada, where a 6-unit campground has been installed, recreation sites on public lands are being developed by the Bureau under the Accelerated Public Works Program.

3. Mining. This area has a significant mineral industry based upon the production of copper, lead, zinc, gold, and silver. In addition to these, many other metallic and nonmetallic minerals such as lime, gypsum, etc., are produced on the public lands. The Bureau administers these resources under the provisions of the general mining laws, the mineral leasing acts, and the mineral materials act. The public lands provide the greatest source of road building material in the area. Decorative and building stone

is also an important mineral resource. At present, the Bureau is conducting an inventory of the mineral resources and activities on public lands and making economic studies to facilitate identification of proper land tenure arrangements and land management practices on mineralized lands.

4. Watershed protection. The public lands are managed to achieve optimum production of forage and water and to control erosion. Land treatment measures such as brush control, seeding, and contouring are being accomplished at a rate commensurate with available manpower and funds. In addition to these practices, the Bureau rehabilitates burned-over areas; develops water facilities, including wells, springs, reservoirs, and pipelines; builds water control structures ranging from small gully plugs to large water-spreading systems using detention dams, diversions, dikes, and water-spreaders; constructs range use facilities such as fencing, cattleguards, stocktrails, and truck trails; controls or eradicates noxious or poisonous plants and reseeds the land to usable forage. The Bureau also cooperates with other conservation agencies in watershed protection activities.

5. Forest and woodland management. Timber lands in the area are primarily administered by the Forest Service. However, the public lands contain some acreage of ponderosa pine with commercial value, as well as large areas of piñon-juniper woodlands. The woodland areas produce Christmas trees, fence posts, and piñon nuts. There is currently some commercial harvesting of piñon nuts; this product is a source of livelihood

for a portion of the Indian population. The forests and woodlands of the public lands are managed on a multiple use basis, with recognition of the highest and best uses or productive capabilities. Among these are limited commercial production of forest products, recreation, wildlife habitat, grazing, and watershed protection.

6. Other beneficial purposes. As the bulk of the lands in the region are under Federal jurisdiction, the public lands have been the object of demand by governmental agencies, nonprofit organizations, and individuals, to be used for homesites, business sites, industrial sites; rights-of-way and easements for roads, microwave stations, and various utilities, public purposes, such as parks, schools, recreation facilities, churches, hospitals, and refuse disposal sites; as well as for such purposes as national defense installations, wildlife refuges, air navigation facilities, etc. Accommodating these requests for lands is a major function of the Bureau. The Bureau maintains the basic land title and survey records for the Federal Government, as well as being responsible for the survey and monumentation of the public lands so that they might be identified and described to facilitate management or title transfer.

To better fulfill its functions, the Bureau cooperates with appropriate Federal, State, and local agencies. In its management of the public lands, the Bureau also is involved in protecting the lands from fire, elimination of unauthorized use, visitor protection, and insect, disease, and pest control.

C. Significance of management practices and uses of public land

1. Present water problems and needs. Settlement in the area has been directly related to water availability. In many instances, efforts to obtain additional water for the expansion of cities and towns, or for agricultural use, have been in vain, or curtailed by prior appropriative rights. In areas having high potential for agricultural development, laws based on the doctrine of beneficial use have often inhibited other development. Agricultural developments have, in some instances, resulted in the depletion of underground water upon which urban settlements were dependent. Public lands, on which the highest and best use is for the development of residential, commercial, or industrial uses, are subject to this risk. Many areas with potential for development are limited because good quality water is unavailable.

The lack of adequate water developments for livestock and wildlife on public lands results in improper distribution of grazing animals. Additional wells, spring developments, stockponds, and reservoirs are needed in order to diminish overgrazing around existing waterholes, thereby minimizing problems with respect to erosion, runoff, and sediment damages. Additional detention dams would also provide water for livestock and wildlife, as well as alleviate erosion. These practices, together with completion of the adjudication of range privileges, would promote more efficient utilization of existing range forage and improve watershed conditions.

Cooperative ventures between the Bureau and local range users will continue and probably increase, thereby adding to the number of cooperative range and soil and moisture conservation projects. More condition and trend surveys of the public range are required to determine proper stocking rates and identify needed adjustments in the use of the range and management practices.

Complete hydrologic data such as precipitation records, groundwater recharge rates, infiltration rates, and soil moisture storing capacities are needed. Such data would facilitate the proper handling of groundwater systems, land classification, and development of range improvements, such as spring and well developments. The data would also minimize the tendency to overdesign water structures, at the same time insuring that structure specifications are adequate for the hydrologic conditions likely to be encountered.

2. Effects of public land disposition and use on the water problems and needs. The previously described public land uses and practices all, in some way, involve the need for more efficient water utilization. The vast utilization of the public lands is almost entirely dependent on local groundwater sources and as the uses intensify on the public lands, the water situation will become more and more critical. Expanding range, wildlife, recreation, and agricultural uses, as well as urban development, will deplete local water sources on the public lands. As land uses are intensified, better management of existing water sources will be required.

Certain high uses of the public lands have been curtailed because of prior appropriation of available water for a specific use, e.g., recreation use is sometimes precluded because of existing livestock or agricultural use. In many instances, the sale or transfer of public lands brings the lands into a high water-consuming use. For example, the sale or transfer of public lands may result in their development as irrigated farmland, thus further depleting the overdrawn underground water sources. Large public sale, recreation and public purpose, and townsite programs are contemplated within the basin, particularly near the Lower Colorado River. The possible sale of large tracts of land at Eldorado Valley and Fort Mohave to the State of Nevada, authorized by special legislation, and similar special acts authorizing transfer of public lands to Lincoln County and the city of Henderson, in Nevada, all contemplate intensive development with high water requirements. These developments will doubtless intensify groundwater problems.

3. Colorado River tributary projects. Bureau of Land Management projects on Colorado River tributaries consist of community watershed areas, some of which are planned in detail for management, conservation, and improvement practices (see attached map No. 2 for community watershed boundaries). There are 66 community watersheds in the basin. Improvements within two watersheds have been substantially completed.

Detailed planning has been completed and some work installed within 5 other watersheds. The community watersheds which have been partially developed, or for which detailed plans have been completed, are tabulated below by name, acreage, cost, and benefits.

a. Existing projects (substantially complete):

(1) Railroad Wash Community Watershed, Arizona.

BLM administered acreage	90,000	
Other	46,000	
Total acres	136,000	
Cost--Federal funds (approx.)		$250,000
Contributed funds (approx.)		92,000
Total cost (approximately)		$342,000

Tangible benefits include soil stabilization, increased livestock forage production, improved wildlife habitat, and control of floods and sediment for protection of downstream improvements.

(2) Upper Meadow Valley Wash Watershed, Nevada.

BLM administered acreage	169,400	
Other	5,600	
Total acres	175,000	
Cost--Public Law 566 funds		$ 80,000
BLM funds		53,000
Other		17,000
Total cost		$ 150,000

(2) Upper Meadow Valley Wash Watershed (continued).

Annual direct and indirect damages from floodwaters, sedimentation, and erosion are estimated at $10,000. After all project features are installed, reduction in damages, plus restoration of productivity will result in monetary benefits of $4,000 annually.

b. ~~Planned~~ projects (small amount of ~~work~~ completed):

(1) Fort Pierce Community Watershed, Arizona.

BLM administered acreage	799,000	
Other	174,000	
Total acres	973,000	
Cost--Federal funds (approx.)		$1,550,000
Contributed funds (approx.)		180,000
Total cost (approximately)		$1,730,000

Benefits--see statement for Railroad Wash Community Watershed above.

(2) San Simon Community Watershed, Arizona.

BLM administered acreage	496,000	
Other	917,000	
Total acres	1,413,000	
Cost--Federal funds (approx.)		$4,000,000
Contributed funds (approx.)		685,000
Total cost (approximately)		$4,685,000

(2) San Simon Community Watershed (continued).

Benefits--see statement for Railroad Wash Community Watershed above.

(3) <u>Vekol-Waterman Community Watershed, Arizona.</u>

BLM administered acreage	660,000	
Other	1,630,000	
Total acreage	2,290,000	
Cost--Federal funds (approx.)		$600,000
Contributed funds (approx.)		150,000
Total cost (approximately)		$750,000

Benefits--see statement for Railroad Wash Community Watershed above.

(4) <u>Bouse-Tyson Community Watershed, Arizona.</u>

BLM administered acreage	1,650,000	
Other	928,000	
Total acreage	2,578,000	
Cost--Federal funds (approx.)		$1,850,000
Contributed funds (approx.)		140,000
Total funds (approximately)		$1,990,000

Benefits--see statement for Railroad Wash Community Watershed above.

(5) International Border Community Watershed, California.

BLM administered acreage — 90,000 acres

Cost--Federal funds (approx.) — $202,000

Benefits--

(a) Double carrying capacity from 6,000 to 12,000 AUM's

(b) Increase groundwater yield

(c) Decrease existing soil erosion

A tabulation, table No. 3, of existing and proposed conservation and improvement practices is attached. The tabulation shows the units of significant practices involved in project development.

4. Groundwater developments. Groundwater developments on public lands include extraction developments and conservation developments. Water extraction developments are largely required by livestock and wildlife. These developments include stockponds, pipelines, and spring and well developments. The developments are constructed by BLM range users under permit or cooperatively with the Bureau. Conservation developments are designed to improve watershed conditions and promote groundwater storage capacities. The developments consist of reseeding, brush control, check dams, diversions, and spreading works.

5. Present water uses. Generally, all known waters have been appropriated and are being used. The principal uses of water on the public lands are for livestock and wildlife.

6. Research programs. The Bureau cooperates with State universities in research projects, such as ecological and range-use studies in Nevada, brush eradication in California and Arizona. Cooperation with State fish and game departments in various wildlife projects involving introduction of new species and propagation of species, such as bighorn sheep, is also taking place.

In Nevada two 2,000-acre pastures near Panaca and Crystal Springs have been segregated and actual grazing use and erosion data acquired. The project, supervised by the Soil Conservation Service, has resulted in the development of a record of use in excess of 20 years. Currently, arrangements are being negotiated whereby these areas will be returned to BLM jurisdiction and the study continued by the Bureau in cooperation with the University of Nevada.

A cooperative study to identify management alternatives for piñon-juniper woodlands is being conducted by the Bureau of Land Management and the Utah State University. Four sites for this study have been designated within the basin.

Because of the critical water shortages in many parts of the basin, several agencies are devoting considerable research to water problems. The Bureau will continue to exchange information with these agencies and rely upon them to furnish research findings. BLM will cooperate with them in providing funds and personnel where the public lands will benefit directly and where such efforts are necessary to implement a much-needed program.

PART IV--FUTURE PROGRAMS FOR PUBLIC LANDS

The Bureau of Land Management long range program (1968-1980) is based on an expected transfer of some 1.8 million acres to private ownership and other public administration. Many of these lands will be acquired by State and local governmental agencies for public purposes and by individuals for private needs. The balance will be transferred to other Federal agencies or managed by BLM to meet the requirements of resource needs. Table No. 2 reflects adjusted acreages in BLM administered lands expected to result from title transfers, withdrawals, etc.

A. Future management practices and uses of public land

The public lands will become increasingly important for many purposes and will play a greater role in the economic structure of the States. Many present uses will become subordinate to uses created or influenced by population growth, new technological developments, improved access and transportation, more leisure time, increased wages, etc.. Naturally, management programs will have to be responsive to emerging needs and the changing patterns of use and demands. Inventories, studies, and plans being made today anticipate the maximum balanced use of the public lands in the future. Construction projects, rehabilitation projects, etc., are all based on long term benefits. Greater emphasis is being placed on combinations of uses rather than single or special purpose use of the public lands. For example, recreation development is occurring on approximately 90,000 acres of public lands under lease to Maricopa County in Arizona. Other uses on these lands, however, are being administered by BLM. In the future, 100,000 acres in California will be transferred for recreation areas, sites, and parks. Most recreation will be provided for in conjunction with other land uses on specified areas with multiple use values.

Livestock grazing is expected to increase, but through better management and technological advancements, the amount of range will diminish and be more clearly defined, and almost totally confined to designated multiple use areas. Urbanization will expand and create the need for more and more public land. In the California portion of the basin alone, there will be sold or transferred into private ownership at least 100,000 acres. The expanded urbanized areas are expected to grow from existing towns such as Las Vegas; however, some locations, primarily in proximity to the Colorado River, will experience the need for new townsites. Another example of the changing management picture is in the increasing heavy demand for rights-of-way acquisition.

B. Plans in terms of use.

1. Future water problems and needs. All long range programs for the management of the public lands will encounter the problem of supplying the needed waters. Without transported water from the Colorado River, or other sources, public lands cannot be utilized to their full potential. In many areas, groundwater is currently being mined. This trend will intensify through 1980.

By the year 2010, the demands for water will probably be ten times greater than at present.

Continued improvement of range and watershed lands will add immeasurably to the efficient utilization of all water sources. However, intensification of urban, industrial, and recreation uses will eventually create water needs beyond the water yield capacities of many public lands and thereby curtail optimum utilization of those lands. The development of new water sources will be highly necessary.

2. <u>Future effects of public land use and disposition on water problems and needs.</u> The demands for public lands will continue to grow at an increasing rate. A great deal of cooperation will be necessary from the various agencies to avoid the disposition of the public lands where such action would have a detrimental effect upon water supplies and create public problems. Demand for lands will continue to be met to the maximum extent possible, but only after studies indicate that public interests will be served.

3. <u>Colorado River tributary projects (long range--1968-1980).</u> The Bureau of Land Management long range program includes project development in community watersheds containing public lands. Those watersheds containing large, solid blocks of BLM administered-land will be planned for intensive development, while those containing little public land will be planned for lesser development, or such development as is appropriate to

present or proposed land tenure arrangements. Priority of planning and development will depend on justifiable multiple purpose needs for the public lands within the various watersheds, as well as the land pattern of such public lands. Projects will be developed to provide for the needs associated with multiple use land management.

4. Groundwater developments (1968-1980). Included in the Bureau's long range plans (1968-1980) for project development will be groundwater development to provide water for such uses as recreation, livestock, wildlife, etc. These developments will consist of approximately 335 wells and 417 springs, and will be developed by the Bureau, often in cooperation with public land users. (See attached table No. 3.)

5. Planned water uses. Water use is expected to increase proportionately with population growth of the area; however, uses will be primarily for public consumption, industrial expansion, and related to supporting enterprises. On the public lands, water use will be largely confined to use by livestock, wildlife, and recreationists.

6. Research programs (1968-1980). Future demands and uses of the public lands will dictate the amount and nature of research required for maintaining the public lands at their optimum productive capacity. It is expected that the Bureau will develop research projects in outdoor recreation and continue to cooperate in certain management research projects related to such programs as range reseeding. Economic studies will be promoted

to evaluate multi-use of the public lands or specific effects of special uses on the public lands (e.g., rights-of-way, easements on values, etc.). These research projects will be planned and conducted at such time as the needs are clearly identified. Until then, the program will continue to be one of cooperation with, and reliance upon, other Federal and State agencies already involved in research programs.

7. Improvements of watershed yields (1968-1980). Long range plans for BLM administered public lands call for approximately 856,000 acres of woodland and brushland to be converted to grass. A substantial acreage of conversion of piñon-juniper to grass is involved; the goal stated here may be subject to modification as the results of the study of management alternatives for piñon-juniper become available. Although rather naturally low in water yield, these lands, when improved, will not only increase the total yield, but will also improve the quality of water as well. More intensive range management will insure that forage resources of watershed lands are properly managed.

Table No. 1

Types of lands under BLM administration in Lower Colorado River basin, 1963 (expressed in thousands of acres)

Type	Arizona	California	Nevada	New Mexico	Utah	Total
Woodland	2,145	-	1,900	700	600	5,345
Chaparral	974	254	-	-	-	1,228
Desert shrub	9,969	2,400	7,769 1/	491	2,171	22,800
Total	13,088	2,654	9,669 1/	1,191	2,771	29,373

Table No. 2

Types of lands under BLM administration in Lower Colorado River basin, as estimated for 1980 (expressed in thousands of acres)

Type	Arizona	California	Nevada	New Mexico	Utah	Total
Woodland	2,110	-	1,860	640	550	5,160
Chaparral	950	225	-	-	-	1,175
Desert shrub	9,028	2,129	7,649 1/	441	2,025	21,272
Total	12,088	2,354	9,509 1/	1,081	2,575	27,607

1/ Includes 1,079,000 acres within the Desert Game Range jointly administered by the BLM and the BSF&W

Table No. 3
Existing and proposed improvements
for public lands in Lower Colorado River basin

		ARIZONA		
			1964-1967	1968-1980
	Unit	Existing	Short range	Long range
Water management				
Springs	No.	338	6	119
Wells	"	380	44	249
Detention dams	"	61	36	181
Diversion dams	"	17	125	95
Dikes	"	400	1,015	1,200
Spreaders	"			
Reservoirs	"	1,179	130	1,185
Range seeding	acres	69,326	58,690	346,310
Brush control	"	131,101	222,790	531,210
Pitting, furrowing	"		52,700	150,000
Site improvement for reforestation	"			
Reforestation	"			
Road construction	miles	351	106	1,926

		CALIFORNIA		
Water management				
Springs	No.	15	4	12
Wells	"	2	-	4
Brush control	acres	0	1,000	1,000
Road construction	miles		12	100

Table No. 3 (continued)

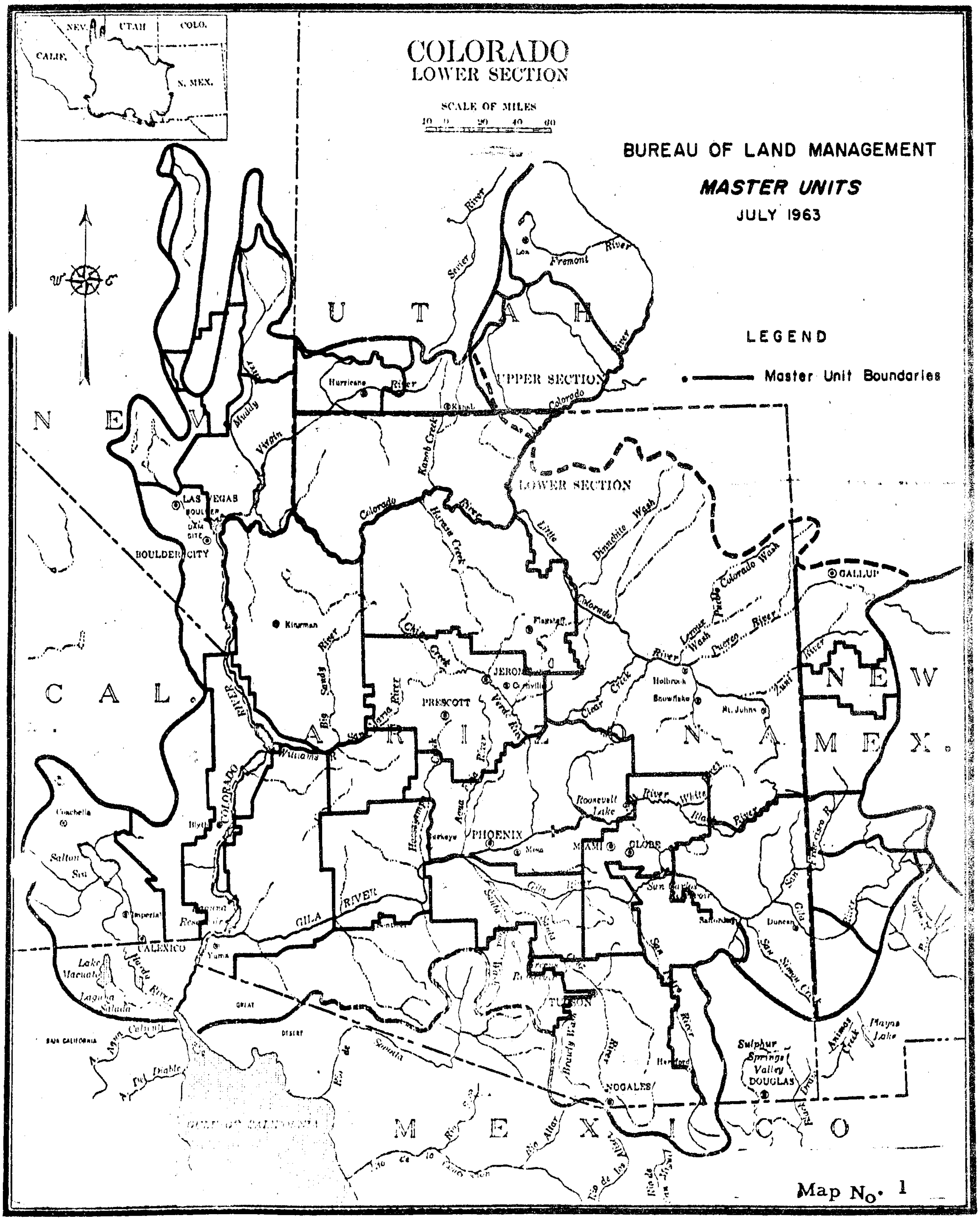
		NEVADA		
			1964-1967	1968-1980
	Unit	Existing	Short range	Long range
Water management				
Springs	No.	130	20	150
Wells	"	35	15	50
Detention dams	"	7	10	20
Diversion dams	"	12	15	30
Dikes	"		5	16
Spreaders	"	1	2	5
Reservoirs	"	46	22	45
Range seeding	acres	33,000	21,000	130,000
Brush control	"	15,000	3,000	45,000
Pitting, furrowing	"	2,000	5,000	17,000
Site improvement for reforestation	"		600	2,500
Reforestation	"		1,000	5,500
Road construction	miles	300	55	85

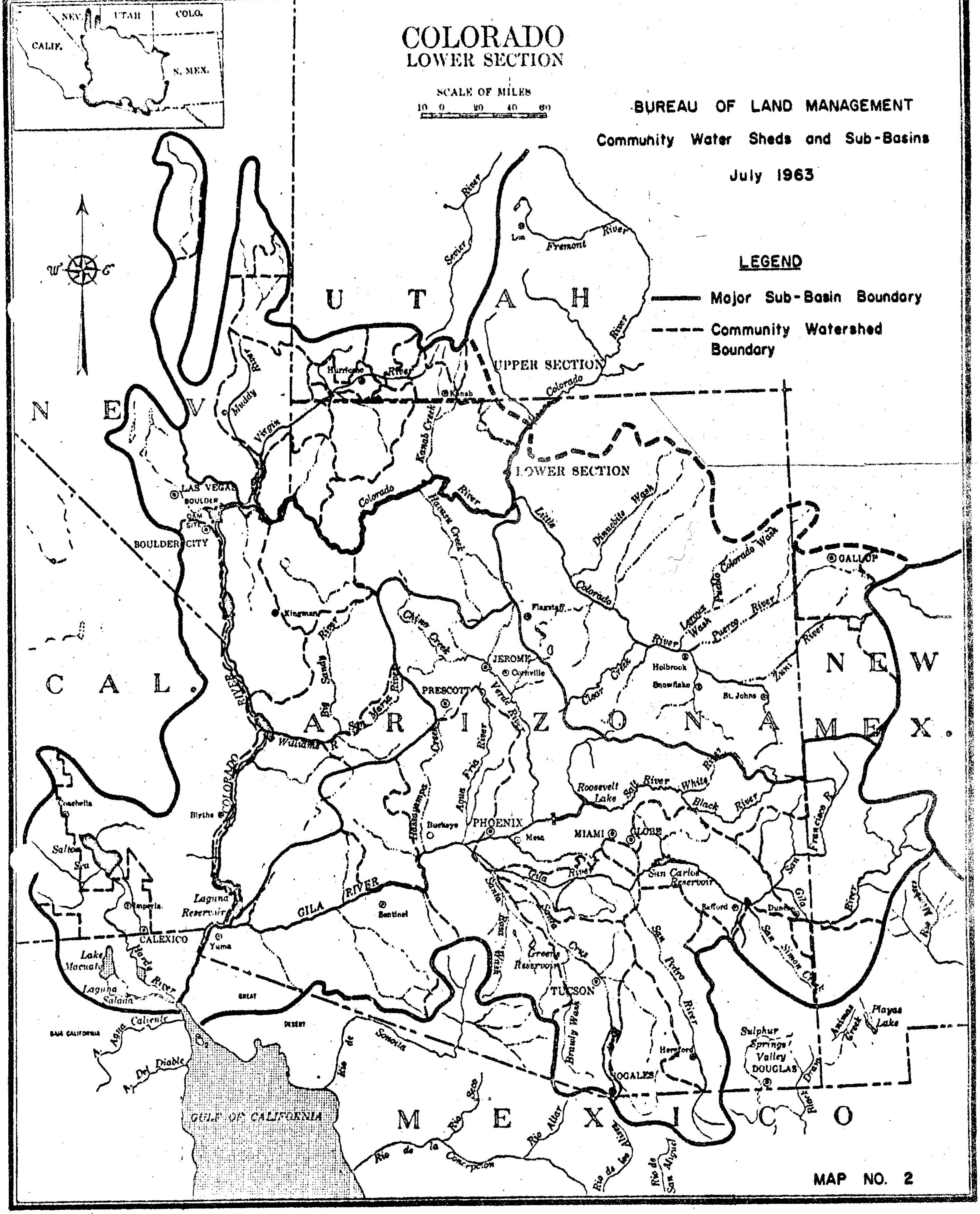
		NEW MEXICO		
Water management				
Springs	No.	12	10	10
Wells	"	5	5	5
Detention dams	"	16	15	85
Diversion dams	"		15	100
Reservoirs	"		20	80
Range seeding	acres		10,000	90,000
Brush control	"	35	15,000	165,000
Pitting, furrowing	"	5,000	5,000	7,500
Site improvement for reforestation	"			200
Reforestation	"			500

Table No. 3 (continued)

	Unit	UTAH Existing	UTAH 1964-1967 Short range	UTAH 1968-1980 Long range
Water management				
Springs	No.	47	15	126
Wells	"	14	5	27
Detention dams	"	10	5	108
Diversion dams	"	6	20	90
Dikes	"	2	-	25
Spreaders	"	0	-	3
Reservoirs	"	114	100	450
Range seeding	acres	13,225	75,000	125,000
Brush control	"	3,025	10,000	114,000
Pitting, furrowing	"	1,500	5,000	75,000
Site improvement for reforestation	"	500	1,500	20,000
Reforestation	"		2,000	20,000
Road construction	miles	0	65	29

	Unit	TOTAL Existing	TOTAL 1964-1967 Short range	TOTAL 1968-1980 Long range
Water management				
Springs	No.	542	55	417
Wells	"	436	69	335
Detention dams	"	94	66	394
Diversion dams	"	35	175	315
Dikes	"	402	1,020	1,241
Spreaders	"	1	2	8
Reservoirs	"	1,339	272	1,760
Range seeding	acres	115,551	164,690	691,310
Brush control	"	284,161	251,790	856,210
Pitting, furrowing	"	8,500	67,700	249,500
Site improvement for reforestation	"	500	2,100	22,700
Reforestation	"	0	3,000	26,000
Road construction	miles	651	238	2,140


COLORADO
LOWER SECTION
SCALE OF MILES
BUREAU OF LAND MANAGEMENT
MASTER UNITS
JULY 1963
LEGEND
Master Unit Boundaries
UTAH
UPPER SECTION
LOWER SECTION
NEV.
CAL.
ARIZONA
NEW MEX.
MEXICO
LAS VEGAS
BOULDER CITY
Kingman
Flagstaff
PRESCOTT
PHOENIX
GLOBE
TUCSON
NOGALES
DOUGLAS
Yuma
CALEXICO
GALLUP
Holbrook
Snowflake
St. Johns
Roosevelt Lake
Salton Sea
Coachella
Imperial
Blythe
Hurricane
Kanab
COLORADO RIVER
GILA RIVER
Fremont River
Sevier River
Muddy
Virgin
Little Colorado
Dinnebito Wash
Puerco River
Clear Creek
Verde River
Williams R
Big Sandy River
Hassayampa
San Pedro River
Santa Cruz
San Simon Creek
Sulphur Springs Valley
Animas Creek
Playas Lake
Laguna Salada
GREAT DESERT
GULF OF CALIFORNIA
BAJA CALIFORNIA
Rio Altar
Rio de Sonora
Map No. 1


COLORADO
LOWER SECTION
SCALE OF MILES
10 0 20 40 60
BUREAU OF LAND MANAGEMENT
Community Water Sheds and Sub-Basins
July 1963
LEGEND
Major Sub-Basin Boundary
Community Watershed Boundary
NEV.
UTAH
COLO.
CALIF.
N. MEX.
U T A H
N E V
C A L.
A R I Z O N A
N E W M E X.
M E X I C O
UPPER SECTION
LOWER SECTION
Sevier River
Fremont River
Muddy River
Virgin
Hurricane
Kanab
Kanab Creek
Colorado
Colorado River
LAS VEGAS
BOULDER DAM SITE
BOULDER CITY
Kingman
Big Sandy River
Chino Creek
Havasu Creek
Little Colorado
Dinnebito Wash
Colorado Wash
Puerco River
Zuni River
Flagstaff
JEROME
Cottonwood
PRESCOTT
Verde River
Clear Creek
Holbrook
Snowflake
St. Johns
GALLUP
San Maria River
Williams R
Hassayampa Creek
Agua Fria River
Roosevelt Lake
Salt River
White River
Black River
Blythe
Buckeye
PHOENIX
Mesa
MIAMI
GLOBE
Gila River
San Carlos Reservoir
Safford
Duncan
San Francisco R
Gila River
San Simon Creek
Sentinel
GILA RIVER
Laguna Reservoir
COLORADO RIVER
Coachella
Salton Sea
Imperial
CALEXICO
Yuma
Lake Macuata
Laguna Salada
Hardy River
GREAT DESERT
BAJA CALIFORNIA
Agua Caliente
Del Diablo
GULF OF CALIFORNIA
Santa Cruz
Greene Reservoir
TUCSON
Brawley Wash
San Pedro River
Hereford
NOGALES
Sulphur Springs Valley
DOUGLAS
Animas Creek
Playas Lake
Rio Mimbres
Rio de Sonoita
Rio Seco
Rio de la Concepcion
Rio Altar
Rio de los Alisos
Rio de San Miguel
MAP NO. 2

Preliminary Report of the
Bureau of Outdoor Recreation on the
Pacific Southwest Water Plan

The construction of major reservoirs of the proposed Lower Colorado River Project would create areas that would have a considerable potential for water-oriented and associated recreation, in addition to hunting and fishing, which are discussed separately in conjunction with fish and wildlife benefits. These reservoirs would attract two major types of recreation use: (1) daily and weekend use emanating from the Phoenix and Tucson urban complex that would bear on the major reservoirs in that locality, and (2) extended weekend and vacation use by visitors who would be primarily attracted to the large reservoirs in the upstream portion of the Lower Basin.

Significant outdoor recreation opportunities would be created by the reservoirs in the Gila drainage and the Dixie project. The other reservoirs would provide some recreation also, although they would have adverse effects on the present types of river recreation and on important intangible conservation and recreation values.

Recreation Demands in the Phoenix-Tucson Area

More than 75 percent of Arizona's population is concentrated in Maricopa, Pima, and Pinal Counties, within easy driving distance of the four proposed reservoirs in the Gila drainage. The population of these three counties is expected to increase to more than 80 percent of the State's population before the dams can be constructed and to more than 90 percent by the year 2000. Maxwell Reservoir, within 25 miles of Phoenix, would be used to full capacity, even now, if its construction included ample facilities for outdoor recreation activity. Phoenix is reputed to have the highest boat ownership per capita of any city in its size group in the United States, but present boating facilities are not adequate.

Existing water impoundments in the extremely arid Phoenix-Tucson area are already overtaxed by recreation use. Additional water-based recreation opportunities for future population expansion will necessarily be dependent upon the four proposed impoundments.

Recreation opportunities that would be provided by facilities at the Maxwell and Buttes impoundments would help to meet a growing demand for daily and weekend recreation in the Phoenix metropolitan area. To a somewhat lesser degree, facilities at Charleston Reservoir would serve a similar purpose for Tucson. The Hooker impoundment would serve both of these urban areas but, because of its more remote location, greatest use would be on weekends.

Recreation developments at these four proposed impoundments would consist of picnic and boating facilities, camping areas, nature trails, and the like. The Arizona State Parks Board has plans for administration of the recreation features of the proposed projects.

The emphasis would be on providing facilities with high carrying capacity for day use and other short-term visits. The expected visitor use has been estimated on the basis of full utilization of the recreation potentials, rather than in terms of population projections only. However, the validity of the current population projections should be restudied, in view of the wide range of projections for Arizona. These vary from a low of less than 3 million to a high of 8 million for the year 2000. The projected population for Arizona, used by the Outdoor Recreation Resources Review Commission in its study of America's recreation resources and needs, is 2,144,000 for the year 1976 and 3,859,000 for the year 2000.

Upstream Recreation Demands

A minimum amount of basic recreation facilities would be required to take care of visitors to the proposed Bridge Canyon and Marble Canyon reservoirs. Studies are needed to determine what minimum facilities are essential and what they would cost. A reasonable estimate of the monetary benefit of providing essential facilities to accommodate the visitors is that they are equal to the cost of providing them.

However, water-oriented recreation cannot be considered one of the primary purposes for constructing the Bridge Canyon and Marble Canyon dams because less costly alternatives for expanding recreation facilities in this area are available. The types of water-oriented recreation which could be supplied by the reservoirs are available at Lake Mead and Glen Canyon National Recreation Areas. These recreation areas serve the same population centers, and facilities could be added as recreation demand expands.

No additional recreation benefits can be claimed for the proposed Bridge Canyon Dam because of the unusual existing recreation values of the proposed reservoir area and the adverse effects the dam and reservoir would have on these values. The reservoir as presently planned would encroach on Grand Canyon National Park. It would further modify the natural character of the stream which created the Grand Canyon and has been continuing to wear down and deepen the canyon. The natural forces which carry silt and debris through the canyon would be lost and much of this material would be deposited in and along the sides of the river bed. Opportunities would no longer exist to enjoy the unique recreation values of exploring the area by river, through the rapids and falls, an experience that has attracted wide interest. The reservoir as presently planned would flood a portion of Havasu Creek, which is within Grand Canyon National Park and is a spring-fed stream of unusual beauty, unique in that part of the country.

Access to both the Bridge Canyon and Marble Canyon impoundments will be severely restricted by steep canyon walls and adjacent rugged topography. This will limit total visitor-use potential.

The Virgin City and Lower Gunlock reservoirs in the Dixie project should be provided with adequate recreation facilities for local use. The recreation facilities at the larger reservoir (Virgin City) should be designed for considerable State, and some national, use as well. Its location near Zion National Park makes it suitable for supplementing the scenic attractions of the park. Many of the visitors to the park would use it for picnicking, camping, swimming, fishing, and boating.

Recreation Demands in the Southern California Area

The State of California has recognized the fact that the expected large future population growth, especially in Southern California, will present an ever-increasing need for additional outdoor recreation areas and facilities.

The State Park Commission feels that the Colorado River is second only to the Sacramento River as a source of water recreation opportunities for Californians. Proposals have been made for acquiring or leasing land from the Federal Government and establishing three major parks and recreation areas along the Colorado River in Southern California. In conjunction with Southern California's present water-oriented recreation and the State's proposed Castaic, Perris, and Cedar Springs Reservoirs, these parks would help to meet the pressing needs for such recreation.

Recreation Benefits

The primary benefits that will result from the provision of recreation facilities at reservoirs included in the Pacific Southwest

Water Plan were not subjected to the usual methods of measurement employed in evaluating other project purposes. Nevertheless, the National Park Service has provided a measure of the benefits by using "A Method of Evaluating Recreation Benefits of Water Control Projects," which it adopted in August 1957 and updated in February 1963. This method provides for a monetary evaluation of the benefits to the individuals visiting the area. On a national basis, the evaluation has been determined to average 52 cents per visitor day for general public use, including picnicking, swimming, and sightseeing; an additional 55 cents per visitor day for boating and water skiing; and an additional 50 cents per visitor day for camping. The methodology assumes that all visitors will pay a general use fee. Visitors engaged in boating and water skiing or in camping are assumed to pay additional fees for these activities.

Scenic boating on the Bridge Canyon and Marble Canyon reservoirs will be of unusual quality, for reservoir boating. This would offset to some degree the encroachment of Bridge Canyon Reservoir on Grand Canyon National Park and the inundation of additional free-flowing streams.

Estimated annual recreation benefits, exclusive of hunting and fishing, have been computed by the National Park Service. The estimates of annual visits and benefits for the reservoirs in the Pacific Southwest Water Plan, other than Bridge Canyon and Marble Canyon, are shown below:

Maxwell Reservoir - Annual Benefits

Activities	Visitor Days		Value per Day		Total
General Use	175,000	x	$0.52	=	$91,000
Boating and Water Skiing	75,000	x	.55	=	41,250
Camping	50,000	x	.50	=	25,000
					$157,250

This averages $0.90 per visitor day.

Charleston Reservoir - Annual Benefits

Activities	Visitor Days		Value per Day		Total
General Use	100,000	x	$0.52	=	$52,000
Boating and Water Skiing	40,000	x	.55	=	22,000
Camping	15,000	x	.50	=	7,500
					$81,500

This averages $0.82 per visitor day.

Hooker Reservoir - Annual Benefits

Activities	Visitor Days		Value per Day		Total
General Use	30,000	x	$0.52	=	$15,600
Boating and Water Skiing	10,000	x	.55	=	5,500
Camping	15,000	x	.50	=	7,500
					$28,600

This averages $0.95 per visitor day.

Buttes Reservoir - Annual Benefits

Activities	Visitor Days		Value per Day		Total
General Use	150,000	x	$0.52	=	$78,000
Boating and Water Skiing	50,000	x	.55	=	27,500
					$105,500

This averages $0.70 per visitor day.

Virgin City Reservoir - Annual Benefits

Activities	Visitor Days		Value per Day		Total
General Use	150,000	x	$0.52	=	$78,000
Boating and Water Skiing	25,000	x	.55	=	13,750
Camping	50,000	x	.50	=	25,000
			Rounded to -		$117,000

This averages $0.78 per visitor day.

Lower Gunlock Reservoir - Annual Benefits

Activities	Visitor Days		Value per Day		Total
General Use	20,000	x	$0.52	=	$10,400
Boating and Water Skiing	15,000	x	.55	=	8,250
Camping	9,000	x	.50	=	4,500
			Rounded to -		$23,200

This averages $1.16 per visitor day.

Conclusions

1. If the reservoirs in the Gila drainage are authorized as presently planned, they will be important in helping to meet the outdoor recreation needs of present and future generations, in the Phoenix-Tucson urban complex.

2. Estimates being developed at this time on recreation benefits and on cost allocations to recreation are, of necessity, tentative. The growing importance given to recreation as a project

purposes of Federally-constructed reservoirs makes it necessary to make thorough appraisals of the extent to which reservoirs can help to meet the need for water-oriented recreation, monetary measurement of the benefits derived from meeting such needs, and the extent of justifiable Federal investment in recreation as a project purpose. These aspects of the project reservoirs, and the relationship between Federal and other responsibilities for paying the costs of recreation, require thorough review in the light of Senate Document 97 of the 87th Congress and the inter-Departmental policies being developed to implement that document.

3. The Secretary of the Interior should be authorized to take all appropriate steps to minimize damage to scenic qualities of reservoir areas.

4. An analysis is needed of the recreation potentials of the Bridge Canyon and Marble Canyon projects to determine whether they are of national or less than national significance, so that responsibility for the administration of the recreation features can be assumed at the appropriate level of government. At the other reservoirs, the recreation use is expected to consist primarily of day use and other short-term visits from the near-by vicinity. Administration of the recreation aspects of these reservoirs should be the responsibility of suitable State or local agencies.

5. Legislation should authorize the Secretary of the Interior to investigate, plan, and construct public recreation facilities at the project reservoirs.

Reservoirs in Pacific Southwest Water Plan

Annual Costs and Benefits for Recreation,
Exclusive of Hunting and Fishing

Dam and Reservoir	Annual Capital Costs	Annual O & M	Total Annual Costs	Annual Benefits
Bridge Canyon	(To be determined later)1/			
Marble Canyon	(To be determined later)1/			
Maxwell	$69,700	$36,000	$105,700	$157,300
Charleston	48,200	23,300	71,500	81,500
Hooker	15,200	6,700	21,900	28,600
Buttes	22,600	15,000	37,600	105,500
Virgin City	25,400	30,000	55,400	117,000
Lower Gunlock	13,800	9,000	22,800	23,200

1/ Benefits will be limited to the cost of providing minimum basic facilities.

Source: National Park Service.

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE

FISH AND WILDLIFE IN RELATION TO PACIFIC SOUTHWEST WATER PLAN

WASHINGTON, D. C.
AUGUST 1963

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
WASHINGTON 25, D. C.

August 21, 1963

The Secretary

of the Interior

Sir:

Transmitted herewith is the report by the Bureau of Sport Fisheries and Wildlife on Fish and Wildlife in Relation to the Pacific Southwest Water Plan. This report was prepared by that Bureau with the informal cooperation of the State fish and game departments of Arizona, California, Nevada, New Mexico, and Utah.

I wish to call your attention particularly to the amounts of water proposed in the report for use at State fish and game installations. I consider the use of water for this purpose to represent one of the more economic and desirable uses. However, it would seem appropriate for you to withhold your decision on the allocation of water to these State installations until you have received the comments and views of the Governors of Arizona, California, Nevada, New Mexico, and Utah.

I also wish to call your attention to the proposal in the report that water be supplied to these State fish and wildlife installations on a nonreimbursable basis. Since these installations would either mitigate project-occasioned losses or would provide widespread benefits to the general public, it would seem in accord with the provisions of the Fish and Wildlife Coordination Act that the costs of the water supply be considered as nonreimbursable.

I recommend that you give favorable consideration to the proposals of the Bureau of Sport Fisheries and Wildlife in this report.

Respectfully,

Clarence F. Pautzke

Clarence F. Pautzke
Commissioner

Enclosure

SYNOPSIS

The Pacific Southwest Water Plan could provide splendid and significant new opportunities for outdoor recreation based on fish and wildlife resources. The new reservoirs, together with facilities planned specifically for fish and wildlife, and the management techniques proposed, can greatly increase the fish and wildlife resources of the region and the opportunities for fishing and hunting. The proposal for the Region developed by the Bureau of Sport Fisheries and Wildlife in cooperation with the state fish and game departments, includes the construction of fish hatcheries and fishing lakes coupled with a scientific fishery management program to insure that thousands more will have a chance to fish--whether for trout or for bass or for catfish. It provides for the development of wildlife refuges and other areas together with a scientific wildlife management program to insure that people in the future will be able to enjoy through seeing, photographing, and hunting the elk, the antelope, the deer, the quail, the ducks, the geese and other game which characterize the unique climate, physiography, and ecology of the Pacific Southwest.

Hunting and fishing provided about 9.5 million days of recreation in 1960 for the present human population of 11 million. With the population of 39 million predicted for the area in 2020, opportunities for hunting and fishing to supply about 61 million days of recreation will be needed by that year. Money spent in the region by hunters and fishermen in connection with their sports amounted to nearly $50 million in 1960 and is expected to exceed $300 million by 2020 if the supply of hunting and fishing opportunities is adequate to meet the demands. A major portion of these recreational expenditures occurs in the small communities near the hunting and fishing areas and represents an important segment of their economies.

The assurance of an adequate supply of fish and wildlife resources to meet this future demand for outdoor recreation will require the dedication of water for this purpose. Since much of this demand is for water-related recreation, it is essential that future water-development programs include recreation as a major purpose along with municipal and industrial water supply, hydroelectric power, flood control, and irrigation. Of these, only water for municipal and industrial purposes ranks higher in economic value than water for fishing, hunting and other forms of outdoor recreation, according to Dr. Nathaniel Wollman of the University of New Mexico, an authority on water-resource economics in the Southwest.

The measures proposed for inclusion in the Pacific Southwest Water Plan incorporate two Federal fish hatcheries, one Federal wildlife refuge, two state fish hatcheries, eight state wildlife management areas, and 79 state fishing lakes. The annual consumptive water needs of these new facilities, when combined with the existing installations, is estimated at 246,659 acre-feet. However, of this total, 32,720 acre-feet represents existing water use at present installations and 60,339 acre-feet represents water reserved for the Imperial and Havasu Lake National Wildlife Refuges by the Supreme Court in Arizona vs. California. Thus, the net increase in consumptive use of water for fish and wildlife installations under this proposal will amount to 153,600 acre-feet annually.

The Cibola National Wildlife Refuge represents the most important single facility for fish and wildlife in the proposal. This refuge would be located along both sides of the Colorado River about 50 miles upstream from Imperial Dam. It is vital to the preservation of the Great Basin Canada goose, whose wintering habitat has been severely reduced by channelization and diversions in the lower Colorado River valley. It is also important to other waterfowl. The new Refuge would provide excellent new fishing and hunting opportunities and other outdoor recreation for thousands of people.

The Cibola Refuge would include some 16,200 acres of land and would require a diversion of about 27,000 acre-feet of water of which about 14,000 acre-feet would be for consumptive use. All of the water diversion and use would occur in Arizona. The capital costs of acquiring and developing the Refuge, totaling $2,700,000 would be funded as an integral part of the costs for implementing the over-all Pacific Southwest Water Plan.

The fish and wildlife proposal includes several smaller wildlife management areas in both Arizona and California for administration by the state fish and game agencies. These developments are designed to provide increased recreational hunting opportunities in those portions of the two states in the region where such opportunities are most needed.

The proposal includes also substantial measures to meet the needs of the public for recreational fishing opportunities. Chief among these would be the provision of the water supply for 50 fishing lakes, which would be constructed by the Arizona Game and Fish Department at a cost to it of $17.5 million. When completed, these lakes would supply 2 million man-days of recreational fishing, mostly for trout, each year. Benefits to the over-all plan from this measure alone are estimated at $6 million annually. The lakes would average 100 acres in size and would be located in the higher elevations of Arizona. Most would be within 100 miles of the Phoenix-Tucson population center. Under this proposal, water in the amount of 40,000 acre-feet a year for the lakes would be provided from the Central Arizona Project, either directly or through water exchanges, on a non-reimbursable basis in recognition of the widespread benefits and the heavy investment by the State in these facilities.

The proposal also includes 14 fishing lakes in California for construction at Federal cost to mitigate losses to existing fishing streams from channelization. It provides, as noted, for two Federal fish hatcheries, two state fish hatcheries, and a fishery management program to permit realization of optimum fishing opportunities on the project reservoirs and other waters of the Pacific Southwest. One Federal fish hatchery would produce trout for stocking in the colder reservoirs and streams, while the other would produce bass and channel catfish for stocking in the warmer waters. Access facilities and fishery management measures for each of the major reservoirs are also included in the plan.

It is to be noted that the demand for water in the quantities indicated above for state fishing lakes and the National Wildlife Refuges would be delayed for a substantial number of years, pending construction and development. The 50 Arizona State fishing lakes, for example, are likely to be constructed at the rate of only two a year--the full demand for water would not be realized for 25 years. Moreover, it is anticipated that development of the Havasu Lake and Imperial National Wildlife Refuges, for which the Supreme Court reserved 60,339 acre-feet of water for consumptive use, may require as much as 15 years.

The specific fish and wildlife costs for this proposal would total $11,126,000. This represents an annual equivalent cost of $350,000. The widespread fish and wildlife benefits which would occur on project reservoirs and elsewhere throughout the region as a result of these measures amount to $9,702,300 annually. This is a benefit-cost ratio for the fish and wildlife aspects of the plan of 27 to 1. In other words, each dollar spent for specific fish and wildlife measures would create $27 in benefits. In terms of recreation, these benefits would represent 3,735,300 man-days of increased hunting and fishing and an unmeasured but substantial increase in other forms of outdoor recreation related to fish and wildlife throughout the region each year.

Details of this fish and wildlife proposal are contained in the underlying report.

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FISH AND WILDLIFE IN RELATION TO THE PACIFIC SOUTHWEST WATER PLAN

Chapter I. The Resources

Fish and wildlife are important renewable resources of the Pacific Southwest, a large region of the United States. The area under consideration is outlined on the General Map of Fish and Wildlife Features of the Pacific Southwest Water Plan found at the end of this report. It covers most of Arizona, a substantial part of southern California, and smaller sections of southern Nevada, western New Mexico, and southwestern Utah.

The burgeoning population of the region shows great interest in fish and wildlife, especially in the species prized for their sporting attributes. By the year 2020, the present population of 11,000,000 is expected to reach 39,000,000. In 1960, about 7,000,000 days were spent by fishermen in pursuit of their favorite recreation and hunters spent about 2,500,000 days afield. It is estimated that by 2020 there will be about 45,000,000 days of fishing and 16,000,000 days of hunting.

Such estimates gauge the magnitude of participation in these outdoor activities but measure neither the demands nor the desires of the exploding population of the region. For example, the large population of southern California finds limited opportunities for fishing and hunting close at hand. The consequence is that the people of this heavily-populated area do most of their fishing and hunting outside at considerable distance. Many concentrate in Mono and Inyo Counties and along the Lower Colorado River but others fan out into northern California, contiguous states, and throughout the West. Still others cross the border into Mexico and go fishing in the Gulf of California. Many also fish the offshore waters of the Pacific Ocean.

While statistics of the kind noted do not measure the entire interest of the population at large, they do provide a significant measure of the economic importance of fishing and hunting in the Pacific Southwest. There can be no question of this importance. Such activities contribute materially to the economy of the region through the purchases of fishing tackle and sporting arms and ammunition; food, fuel, and other supplies; licenses and fees; vehicles and trailers; the hire of services and equipment; and the rentals of motels, cabins, and other hostelries.

Understandably, the interest in fish and wildlife goes beyond that shown by fishermen and hunters. From all walks of life, people of the Pacific Southwest find interest in such highly satisfactory activities as observing and studying fish and wildlife and especially birds. They belong to clubs dedicated to exchanging information on identification and various other aspects of avian life histories including the occurrence, migration, and numerical abundance of birds, to mention but a few facets of bird study. Others in turn derive great satisfaction in wildlife photography, taking nature hikes, reading about wildlife, and attending lectures and movies. Many other similar activites could be described. And in one way or another, the exercise of this interest contributes to the well-being of a large segment of the growing population of the Pacific Southwest and to its economic bloodstream.

It will be difficult to meet the future demands of fishermen and hunters and of that large segment of the population that has other sympathetic interests toward fish and wildlife. Present demands are not being met, and there is little likelihood that those of the future can be met. And yet, because of the importance of fish and wildlife to the economy of the region, efforts should be renewed to capitalize on all available opportunities to provide more and adequate fish and wildlife habitat and, concomitantly, more space in which to fish and hunt and study. For these purposes, land is important and water even more so in the arid Pacific Southwest.

Distribution

The Pacific Southwest is a region of great contrasts in physiography, climate, and vegetation. There are vast deserts; mountains that are barren, some that are sparsely forested, and still others that are forested; fertile agricultural valleys; open foothills and those covered with chaparral; deep gorges of the Colorado River; and cold deep-water lakes, many of which are man-made. It is a region where precipitation for the most part is extremely low and yet contains sections where rain and snow are fairly heavy. With such extremes, there is a variety of plant life and habitats and of fish and wildlife species.

Several species of trout occur in the Pacific Southwest. In the high-country streams of the cool forests, rainbow, cutthroat, brook, and brown trout are commonly caught. And in the cold impounded waters of the Lower Colorado River and the cool reaches of the river below the dams, rainbow trout reach good size and provide very attractive fishing.

For the most part, however, introduced warmwater fishes predominate in the waters of the Pacific Southwest. Lake Mead, back of Hoover Dam, is justly famed for its excellent largemouth bass which are found as well in many of the other impoundments and rivers of the area. Smallmouth bass, also highly regarded, are more restricted in range and are limited to such locations as the Verde River in Arizona and the lower reaches of the Colorado River.

Less glamorous than the basses perhaps, bluegills, crappies, and sunfishes abound in the warmwater lakes and streams. They provide much sport to thousands of young and adult fishermen alike. Channel and other catfish too can be caught in many of the streams and yellow bass are taken locally in a few waters.

The heavy use of the shorelands and water of an outstanding fishing reservoir used mainly by Southern Californians suggests tremendous demands for future years. **Fishing not only will** be limited by the supply of available water but by the pressure of competitive recreationists.

Nearly all of the important fisheries of the Lower Colorado River and its reservoirs and those of the Salton Sea in California have resulted from man's efforts. Reservoirs and water regulation have created the present favorable environments and fishes have been introduced and managed to provide the present productive fisheries. In addition to the common warmwater fishes, notable introductions include rainbow trout in suitably cold waters of the Colorado River below Hoover Dam, threadfin shad as forage for game fish in the Lower Colorado River system, and orangemouth corvina and sargo in the Salton Sea. Striped bass have been introduced in the Lower Colorado River and have produced catches of good-sized fish although proof of a sustaining population is lacking.

Some forms of wildlife of the Pacific Southwest are migratory, others are not. Most are indigenous to the region. The resident game consists of upland game and big game. The wild turkey, classed as big game in some states, is a highly regarded species. For the most part, it inhabits forested country and furnishes select hunting for several thousand sportsmen.

Unspectacular and often taken for granted, the cottontail rabbit probably is the most important small-game animal of all. It is found throughout the region. Gambel's, scaled, Mearns, mountain, and valley quails provide much sport throughout portions of the area and squirrels are hunted in some localities. Pheasants also are hunted on a limited basis in some restricted areas, notably where planted in the Imperial Valley of California. Some foreign game bird introductions, such as chukar partridge, show promise of adaptation in restricted areas.

Mule deer, javelina, elk, white-tailed deer, desert bighorn, antelope, black bear, mountain lion, and even buffalo on a very limited basis, provide hunting. Deer are the most popular animals and are present in most parts of the Pacific Southwest. Javelina, the little wild pigs of the desert, provide a unique attraction all of their own. Within the region, they are for the most part confined to the southern third of Arizona. Coues deer, also called fantails or Sonoran whitetails, inhabit most of the southern mountains of Arizona and are found as well in the northern part of the state along the Mogollon Rim.

Exterminated at one time, elk have been successfully reintroduced in the timbered areas of northern Arizona and western New Mexico. Desert bighorns are staging a comeback in Arizona and hunting of these prized animals is allowed on a limited basis. Small, well-sustained populations of bighorns also occur in southern California where they provide celebrated targets for stalking with telescope and camera. Hunting bighorns is prohibited in California.

Dove hunting is very popular throughout much of the Pacific Southwest. Mourning doves and white-winged doves are important species. Focal points for dove-hunting include the Gila River below Phoenix, Arizona, along the Colorado River between Needles, California, and Yuma, Arizona, and in the

Imperial Valley in California. Southern California provides some band-tailed pigeon shooting as well.

The Pacific Southwest contains wintering areas for ducks, geese, and other water-loving birds especially along the Lower Colorado River and in the vicinity of the Salton Sea where the marshes, lakes, reservoirs, and other water areas provide good habitat. Much reduced in comparison with historical times, available waterfowl habitat in recent years has taken on significance because of its present limited extent. Hunting ducks and geese remains in high favor in the Pacific Southwest.

Fur animals of the region do not have the economic importance they have in other sections of the United States but are of interest to a large segment of the human population and add variety to the wildlife of the region. Muskrats, beavers, raccoons, opossums, bobcats, coyotes, and ring-tailed cats are part of the larger and more commonly recognized fauna of the Pacific Southwest, and coati-mundi are found in the extreme southern part of Arizona and possibly the southwestern part of the region in New Mexico. Minks are not uncommon in some localities while badgers and skunks are common in most of the region. The ubiquitous gray foxes and the desert-dwelling kit foxes also occur in the Pacific Southwest.

Programs for Development

Recognizing the great interest in fish and wildlife resources, the Bureau of Sport Fisheries and Wildlife and the several State fish and game departments have expended much effort and money to meet the increasing demands for fishing and hunting in the Pacific Southwest.

Broadly viewed, the programs of these agencies fall into several categories: regulation, habitat management and improvement, introduction and stocking, and research. The chief concern here is that adequate land and water be allocated and maintained to meet the human wants related to fish and wildlife. Because of its scarcity, water is of critical importance to fish and wildlife of the Pacific Southwest, yet the increasing attrition of the habitat of such natural resources for the so-called higher uses of man must be reckoned with here as elsewhere.

Toward the end that land and water may produce more fish and wildlife, the Bureau of Sport Fisheries and Wildlife and its state counterparts have shown great interest in the habitat, the physical plant on which fish and wildlife are so dependent. Lands have been purchased and leased and agreements entered into with the objective of producing more of these resources and, relatedly, space in which the public may fish and hunt and otherwise enjoy fish and wildlife.

Some of the facilities and installations developed and managed are single-purpose in nature, expressly designed for bettering particular fish and wildlife environments. Many more are related to other purposes wherein fish and wildlife habitats are important but essentially by-products of projects built for such other purposes. In the first category are fishing lakes developed with state fish and game funds primarily for fishing. In the second are Federal wildlife refuges which were made possible by reservoirs impounded for the primary purposes of providing municipal and irrigation water, generating hydroelectric power, regulating river regimens, and controlling floods. Additional examples could be given.

Augmenting the efforts at developing and improving habitat for fish and wildlife are such facilities as Federal and state fish hatcheries and state game farms. The output of such installations serves the propagative needs for stocking and replenishing developed areas for fish and wildlife.

To date, these complementary Federal-state programs have not kept pace in supplying the wants of the public they serve. Additional water and lands are needed, as indicated in succeeding pages.

The location of these existing installations is shown on the map at the end of this report.

Chapter II. Water - Present Uses and Future Needs

The scarcity of water in much of the arid Pacific Southwest presents grave problems for the agencies concerned with fish and wildlife conservation. Programs to better fish and wildlife environments are severely hampered by lack of water.

Because of its scarcity in much of the arid Pacific Southwest, water for fish and wildlife takes on special significance. Its importance and relationships to such resources are sharp and distinct and it is axiomatic to think of these resources in terms of the location of water, its availability, and its quality.

Fortunately, many multiple-purpose projects designed and operated for such purposes as domestic water, irrigation, hydropower generation, flood control, and other uses provide much suitable habitat and hence many fish and wildlife benefits. Many of these benefits, however, could be materially increased by taking proper measures in the interest of wise fish and wildlife use.

Some of these measures include the establishment of basic conservation (minimum) pools of adequate size, releasing flows at appropriate times, and the opening to fishing of reservoirs presently closed. The restoration of badly depleted streams offers other possibilities, and provisions for access should be incorporated into project plans wherever possible.

The maintenance of fish conservation pools in numerous reservoirs primarily used for other purposes can largely be accomplished by coordinated operation during most years. Storage and withdrawals can be managed to maximize the fishery use of the reservoirs. Extreme drawdowns in critically dry years will still occur in some reservoirs, but even they can be synchronized to some extent with rough-fish control measures.

The required allocations of storage for fish conservation under coordinated operation of a large group of reservoirs are small. The water requirements for evaporation from such storage also are small. On the other hand, in the case of uncoordinated operations of individual reservoirs operated by various individual agencies, the maintenance of minimum fish conservation pools may require substantial quantities with specific allocations in the reservoirs.

While the larger multiple-purpose projects of the Pacific Southwest offer good possibilities for creating fish and wildlife benefits, the smaller single-purpose facilities and installations as a rule do not. In the broad spectrum of current water use in the arid Pacific Southwest, such fish and wildlife facilities and installations are supported by a slender thread indeed. Altogether too often the water they use is not commensurate with their importance.

Today the Bureau of Sport Fisheries and the state fish and game departments have going programs and plans covering the acquisition, development, and management of areas as fishing lakes, wildlife refuges and management areas, and facilities like fish hatcheries. In the Pacific Southwest, the present and future areas with which they are concerned are taking on more and more significance as foci of faunal life and of recreational interest. They will become increasingly important as the human population of the Pacific Southwest continues to expand.

Except for the raising of agricultural crops to feed wildlife on refuges and management areas and evapo-transpiration on ponds, lakes, and marshes, consumptive use of water by the installations designed around bettering the environment for fish and wildlife generally is minor. On fish and wildlife areas, the use of water is often but little in excess of natural evapo-transpiration losses. In fact, it is not unlikely that, in many cases, development has decreased such losses through manipulation of plant cover and elimination of water-wasting plants having low value to wildlife. Fish hatcheries need firm supplies of water of the right quantity, quality, and temperature, but the amounts so needed while important are relatively negligible in quantity and in the main, non-consumptive. As for the aggregate amount of water currently used on all installations, the total is low and does not reflect the role and importance of fish and wildlife resources to the economy of the Pacific Southwest.

An analysis of the present water uses and future water needs for fish and wildlife facilities and installations in the Pacific Southwest is presented below.

Lower Colorado River

The Willow Beach National Fish Hatchery is located in Arizona 14 miles below Hoover Dam on the eastern shore of Lake Mohave. It has a production of about 250,000 pounds of rainbow trout per year, the output being used for the most part in stocking the cooler waters of the Lower Colorado River. Its water requirement of 35 second-feet of water, a non-consumptive use, is met adequately by pumping from the river.

A national fish hatchery with an annual production of 250,000 pounds of trout should be established along the Lower Colorado River. Its output would meet the need for stocking waters affected by water-resource development proposals planned for central and southern Arizona and the Lower Colorado River itself. A non-consumptive use of 25 second-feet of water of good quality with a temperature range of 50-65° would be required.

Another new national fish hatchery, for warmwater species, is needed to produce 100,000 pounds of channel catfish and 5,000 pounds of bass for stocking in areas bordering the Colorado River, mainly in Arizona. An annual diversion of 2,000 acre-feet with a consumptive use of 1,000 acre-feet annually would be needed for this facility.

The Havasu Lake National Wildlife Refuge is a 44,430-acre area along the Colorado River extending 55 miles from Parker Dam to the upper end of Topock Swamp. This important installation was established in 1941 on Havasu Lake, the Reclamation reservoir back of Parker Dam, as a wintering refuge for waterfowl and other migratory birds traveling the Pacific flyway. It is of special value to the Great Basin Canada goose. Compatible public uses are fishing and hunting, picnicking, swimming, boating, and water-skiing. Hunting is permitted at specified locations on the refuge. Currently this refuge makes little or no consumptive use of Colorado River water. There is an agreement signed by the Secretary of the Interior permitting a 35-second-foot diversion only. Water is needed on the Havasu Lake Refuge for ponding and the raising of agricultural food crops to feed waterfowl. For these purposes there is an annual need of 41,839 acre-feet of Colorado River diversion or 37,339 acre-feet for consumptive use, whichever is less. These amounts were recognized in the Supreme Court Decision of June 3, 1963, Arizona vs. California, et al.

The Imperial National Wildlife Refuge is a 43,382-acre unit also along the Colorado River. It extends from below Imperial Dam upstream approximately 36 miles. It serves the same purposes as the Havasu Lake Refuge and permits similar compatible uses. Like the Havasu Lake Refuge, it was established in 1941 on a Reclamation impoundment, in this instance on the Imperial reservoir. There is no current consumptive use of water on this refuge. Needed is an annual diversion of 28,000 acre-feet of Colorado River mainstream flow or 23,000 acre-feet for consumptive use, whichever is less. These amounts also were recognized in the Supreme Court Decision noted above.

The Salton Sea National Wildlife Refuge, a 36,507-acre area, is located at the southern tip of the Salton Sea in California's Imperial Valley. It was established in 1930 primarily as a wintering area for an important segment of the birds of the Pacific Flyway. Over the years, the inflow of agricultural spillwater has raised the sea level, gradually inundating all of the original refuge area. At present, 4,097 acres are leased from the Imperial Irrigation District. Portions of the refuge have been opened some years to waterfowl hunting. The Salton Sea Refuge consumptively uses 3,000 acre-feet of water annually under operations that have been restricted by encroachment of the Sea onto areas managed previously. The water is purchased from the irrigation district. For more intensive waterfowl development and management, the refuge will require a consumptive use of 6,000 acre-feet a year to produce the required waterfowl foods.

A new unit in the national system of wildlife refuges, a 16,120-acre wintering refuge for waterfowl and migrating birds to be known as the Cibola National Wildlife Refuge, is proposed along the Colorado River just above the Imperial National Wildlife Refuge. Optimum operation of the proposed unit will require an estimated 27,000 acre-feet of water per annum diverted from the Colorado River and requiring a consumptive use of 14,000 acre-feet a year for the growing of waterfowl food crops.

At the present time, the Arizona Game and Fish Department has three waterfowl management areas along the Colorado River. Totaling 4,141 acres, they are called the Mittry Lake, Cibola Valley, and Topock Waterfowl and Management Areas. The Cibola area has a crop-raising consumptive use of about 4,000 acre-feet a year, the other two areas, none. To develop and properly manage these areas, there is a need for a diversion of 17,000 acre-feet annually, of which about 8,000 acre-feet would be used consumptively to raise agricultural waterfowl food crops, flooding marshes, and maintaining water levels, especially in Mittry Lake.

The California Fish and Game Department has its 11,893-acre Imperial Waterfowl Management Area which is adjacent to the Salton Sea. The current consumptive use is about 9,000 acre-feet annually. To develop and manage the area fully, a consumptive use of 20,000 acre-feet annually is needed.

The California Fish and Game Department would like to develop six areas, primarily for waterfowl, totalling 18,200 acres along the Lower Colorado River. Water would be needed for ponding purposes and raising waterfowl foods. The total annual need for these purposes amounts to 33,000 acre-feet of which an estimated 13,000 acre-feet would be used consumptively.

In addition, the California Department feels that about 14 small fishing lakes totalling 3,500 surface acres should be developed along the Lower Colorado River, in compensation for past and future channelization work. The requirement for water, 35,000 acre-feet of consumptive use, would be needed to maintain lake levels.

The Nevada Fish and Game Commission operates the 9,805-acre Overton Wildlife Management Area. It is located on Federal lands on the Overton Arm of Lake Mead. It utilizes return irrigation and other waste flows for ponding and the production of agricultural food crops for waterfowl. Full development of this area by the Commission for waterfowl and upland game would require a water supply of 6,000 acre-feet to be used consumptively.

The Nevada Fish and Game Commission also is interested in a proposed 4,600-acre wildlife management area for waterfowl and upland game along the Colorado River immediately upstream from the Fort Mohave Indian Reservation. Its development would require a diversion of 15,000 acre-feet annually and an estimated 8,000 acre-feet of consumptive water use.

Lower Colorado River Tributaries

The Williams Creek National Fish Hatchery is located 13 miles from the town of McNary, Arizona on the Fort Apache Indian Reservation. The hatchery produces 100,000 pounds of trout annually and the production goes into various public waters in Arizona and New Mexico and to waters on a number of Indian reservations. By long-term agreement with the Bureau of Indian Affairs, concurred in by the White Mountain Apache Tribe who hold the water rights, the hatchery receives an average of 4 second-feet from springs. The use is non-consumptive and the water supply is adequate.

The Alchesay National Fish Hatchery is located about 5 miles from Whiteriver, Arizona, also on the Fort Apache Indian Reservation. It, too, produces trout, with an average production of 150,000 pounds per year. This hatchery operates under a water agreement similar to the one for the Williams Creek Hatchery. Alchesay uses a flow averaging about 12 second-feet. The supply is adequate and non-consumptive. The fish are distributed as are those produced at the Williams Creek Hatchery.

The Arizona Game and Fish Department maintains three trout hatcheries, the Sterling Springs, Page Springs, and Tonto installations, all located in the north-central part of the State. These units produce a total of 235,000 pounds of trout per year. Throughout much of the year, the Sterling Springs Fish Hatchery uses a constant flow of 1 second-foot; the Tonto Fish Hatchery, 2 second-feet; and the Page Springs Hatchery, 20 second-feet. Water supplies for these hatcheries are non-consumptive and adequate.

On the tributary waters of the Lower Colorado River, Arizona has developed 15 fishing lakes totalling 1,734 surface acres. On these lakes, some of which were planned in conjunction with larger multiple-purpose reservoirs, there is a consumptive use, due to evapo-transpiration, of 8,700 acre-feet a year. These fishing lakes have reasonably adequate supplies of water.

The Arizona Game and Fish Department plans on developing 50 additional lakes with a total surface acreage of 5,000. For these lakes an initial diversion of 60,000 acre-feet would be needed. Thereafter, 40,000 acre-feet a year would be used consumptively.

Arizona also operates seven wildlife management areas, chiefly for waterfowl, totalling 2,140 acres, having an annual consumptive use of 5,400 acre-feet. A need exists for an annual consumptive use of 11,000 acre-feet, largely for growing agricultural food crops, ponding, and stabilizing water levels.

The New Mexico Game and Fish Department operates the Glenwood Fish Hatchery near Glenwood, New Mexico. A redistribution center for trout, it uses a non-consumptive flow up to 2 second-feet to maintain its annual output of 15,000 pounds. Needed is an appropriate flow of 10 second-feet.

The New Mexico Department also has developed two fishing lakes, one of 22 acres and another of 70 acres. Consumptive use is around 500 acre-feet a year. Water supplies appear to be adequate.

New Mexico sees the need for five additional fishing lakes with a total surface acreage of 500 acres. The estimated water need is a total diversion of 6,000 acre-feet with a consumptive use of 4,000 acre-feet annually.

The Red Rock Public Hunting Ground, a 2,269-acre area, lies in Hidalgo County, New Mexico. Recently acquired by the New Mexico Game and Fish Department, it provides public hunting for chukar partridge and scaled quail. It is expected that the installation will be used in the near future as a holding area for exotic big-game species with which New Mexico hopes to experiment. A pasture of 40 acres will be developed using a water right for 120 acre-feet per year. The supply is adequate for this unit.

The New Mexico Department also would like to develop a 300-acre waterfowl management area at the upper end of Hooker Reservoir. This unit would require an annual consumptive use of 1,000 acre-feet.

Southern California

California's Fillmore and Mojave Fish Hatcheries near Los Angeles derive 7 and 14 second-feet of flow, respectively, from wells. The water is returned to drains from which it is diverted for other uses. The State's Chino Fisheries Base, a combination fish distribution and management research station, uses up to 1 second-foot from wells, with little consumption. The Fillmore and Mojave trout-rearing installations each will require a doubling of capacity and water use, raising their water demands to 14 and 28 second-feet, respectively. The operations will continue to be mainly non-consumptive. The Fillmore and Mojave units produce a total of 265,000 pounds of trout a year.

The California Department anticipates it may need new hatcheries in connection with the California aqueduct system reservoirs. A trout hatchery would require 25 second-feet of water of high quality but essentially would have no consumptive use. A warmwater fish hatchery also may be needed. It would require about 6,000 acre-feet of water annually most of which would be consumed.

The California Fish and Game Department has developed nine small fishing lakes totalling 333 acres, on which it has provided fishing access and public facilities. The annual consumption is about 2,000 acre-feet a year. Water supplies for these lakes appear to be adequate.

It is anticipated that the California Department will create 10 additional small fishing lakes totalling 500 surface acres in southern California outside the Colorado River drainage. These lakes will require an annual consumption of about 2,000 acre-feet.

Summary

A summary of present water uses and future water needs for Federal and State fish and wildlife installations appears in Table 1. This summary does not include all of the Federal and state fish and wildlife installations in the service area of the Pacific Southwest Water Plan. The units listed are limited to those related to water resource development.

The overall estimate of consumptive water use in the amount of about 246,659 acre-feet is an estimate of the total amount of water needed by the various fish and wildlife installations listed. The 212 second-feet is a non-consumptive requirement.

Of the total indicated consumptive use requirement of 246,659 acre-feet in the table, 32,720 acre-feet specified as present use represents valid existing uses. In addition, the Supreme Court Decision of June 3, 1963, Arizona v. California, et al, vests 60,339 acre-feet for consumptive use for the Havasu Lake and Imperial National Wildlife Refuges. The 32,720 acre-feet added to the 60,339 acre-feet specified in the Supreme Court Decision totals 93,059 acre-feet already in valid and existing rights for fish and wildlife installations. This figure subtracted from the 246,659 acre-feet shown in the table leaves 153,600 acre-feet as a net new requirement of water for consumptive use for needed fish and wildlife installations in connection with the Pacific Southwest Water Plan.

Much of the anticipated consumptive use is represented by waters from fishing lakes and other installations which through seepage and percolation return to the ground water supply of the Pacific Southwest. Additionally, a substantial amount of the consumptive use is represented by evapo-transpiration losses which will occur on managed marshes, pools, and croplands to be developed on Federal wildlife refuges and state wildlife management areas, but which will represent no net increase in the evapo-transpiration which exists in the absence of such developments at the planned sites. In some instances, the evapo-transpiration at these developed sites will be less than that which occurs under natural conditions.

Table 1. Water - Present Uses and Future Needs
of Fish and Wildlife Installations
Pacific Southwest Water Plan

Installations	Present Annual Water Uses				Future Annual Water Needs[1]			
	No. Units	Acreage	Acre-ft. (Consump. Use)	Sec.-ft. (Non-consump. Use)	No. Units	Acreage[2]	Acre-ft. (Consump. Use)	Sec.-ft. (Non-consump. Use)
Lower Colorado River								
Federal fish hatcheries	1	--	--	35	3	--	1,000	60
Federal refuges	3	124,319	3,000	35	4	140,519	80,339	35
State fishing lakes	--	--	--	--	14	3,500	35,000	--
State wildlife mgt. areas	5	25,839	13,000	--	12	48,639	55,000	--
Lower Colorado R. Tribs.								
Federal fish hatcheries	2	--	--	16	2	--	--	16
State fish hatcheries	4	--	--	25	4	--	--	33
State fishing lakes	17	1,826	9,200	--	72	7,326	53,200	--
State wildlife mgt. areas	8	4,409	5,520	--	9	4,709	12,120	--
Southern California								
State fish hatcheries	3	--	--	22	5	--	6,000	68
State fishing lakes	9	333	2,000	--	19	833	4,000	--
Totals	52	156,726	32,720	133	144	205,526	246,659	212

1/ Present annual water uses included.

2/ If water is available, some units may increase in acreage, as in the case of state wildlife management areas.

Table 1a. Water - Present Uses and Future Needs
of Fish and Wildlife Installations
Pacific Southwest Water Plan
(By States)

Installations	Present Annual Water Uses: No. Units	Present Annual Water Uses: Acreage	Present Annual Water Uses: Acre-ft. (Consump. Use)	Present Annual Water Uses: Sec.-ft. (Non-consump. Use)	Future Annual Water Needs[1]: No. Units	Future Annual Water Needs[1]: Acreage[2]	Future Annual Water Needs[1]: Acre-ft. (Consump. Use)	Future Annual Water Needs[1]: Sec.-ft. (Non-consump. Use)
Lower Colorado River								
Arizona								
Federal	3[a]	55,337	--	70	6[b]	68,337	75,339	95
State	3	4,141	4,000	--	3	4,141	8,000	--
California								
Federal	3[a]	68,982	3,000	--	4[b]	72,182	6,000	--
State	1	11,893	9,000	--	21	33,593	68,000	--
Nevada								
State	1	9,805	--	--	2	14,405	14,000	--
Lower Colorado R. Tribs.								
Arizona								
Federal	2	--	--	16	2	--	--	16
State	25	3,874	14,100	23	75	8,874	59,700	23
New Mexico								
State	4	2,361	620	2	10	3,161	5,620	10
Southern California								
State	12	333	2,000	22	24	833	10,000	68
Totals	52[c]	156,726	32,720	133	144[c]	205,526	246,659	212

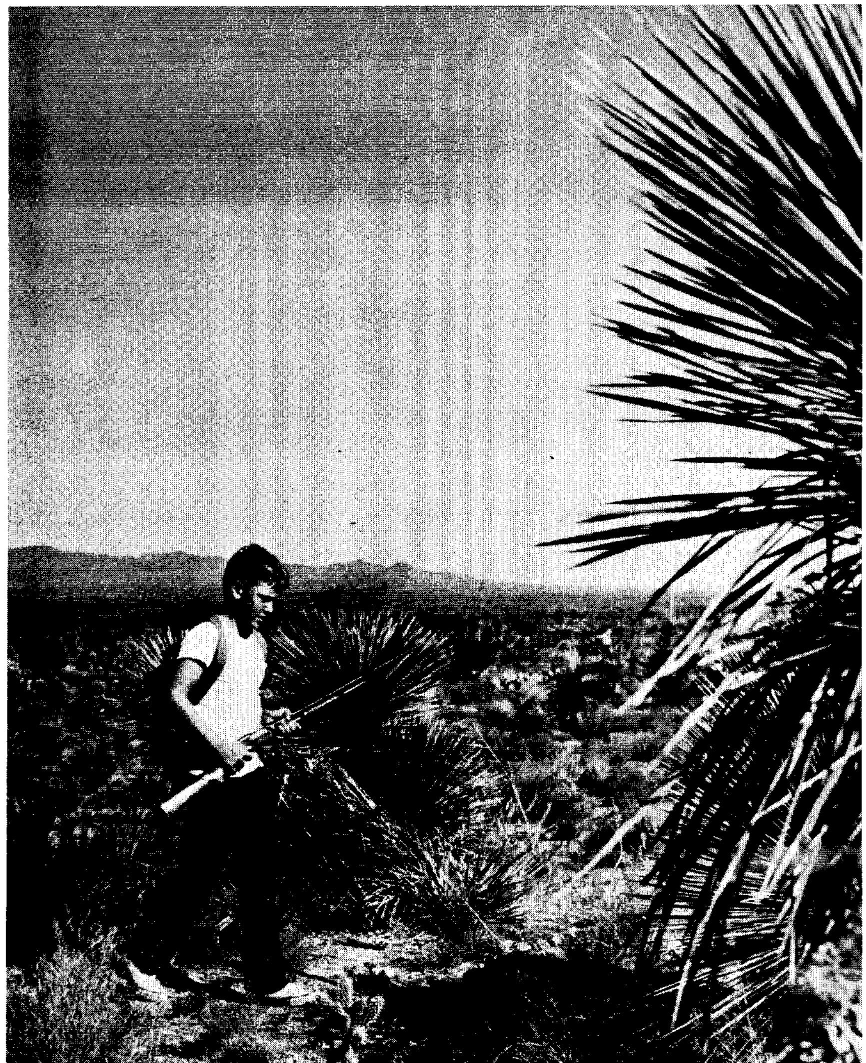
[1] Present annual water uses included.

[2] If water is available, some units may increase in acreage, as in the case of state wildlife management areas.

[a] Parts of two units are in both California and Arizona.

[b] Parts of a proposed unit are in both California and Arizona.

[c] Units both in Arizona and California counted once only.



Planning for the resources of the Pacific Southwest should consider, among other things, the needs of this boy and boys of future generations.

Chapter III. Plan of Development

Immediate Action Program

The immediate action program of the Pacific Southwest Water Plan would: (1) create nine reservoirs which because of their locations, intended operations, and generally high minimum pools will support substantial fisheries without important loss of stream fisheries or wildlife, (2) distribute waters into areas permitting improvements of fishing in existing reservoirs and providing opportunities for establishing new fishing lakes and wildlife areas, and (3) present problems of potential damage to essential habitats of fish and wildlife through water reclamation and salvage.

A brief analysis of the effects of the major project units follows:

Central Arizona Project

Maxwell Reservoir

The reaches of the Verde and Salt Rivers to be inundated by this proposed reservoir are intensively used for family-type fishing in conjunction with picnicking and camping. Largemouth bass, channel catfish, sunfishes, and several species of nongame fish such as suckers and carp comprise the catch. The proposed reservoir should provide good fishing for largemouth bass, white crappies, sunfishes, and catfishes. Located at the edge of the Phoenix metropolitan area, the impoundment should receive heavy fishing. Relatively minor losses of hunting will occur. Some Gambel's quail, mourning dove, and white-winged dove hunting will be lost. No significant waterfowl hunting is expected to occur on the reservoir.

Buttes Reservoir

Fishing today in the reach of the Gila River to be inundated is insignificant. The water is muddy and productive for the most part of nongame species. The reservoir should receive extensive use by fishermen from the Florence-Coolidge area as well as Tucson. Gambel's quail, mourning doves, and white-winged doves are hunted to some extent in the reservoir area and this hunting will be lost. Some waterfowl will undoubtedly use the reservoir but no hunting of consequence is expected.

Hooker Reservoir

Some channel catfish and other fishing takes place in the Gila River within the reservoir site. But its loss will be more than compensated by the largemouth bass, channel catfish, and other warmwater fishing on the proposed reservoir. Fishing waters are scarce in this section of Arizona and fishermen should make good use of the reservoir. Some scaled quail, cottontail, and mourning dove hunting takes place within the reservoir site. It will be lost by inundation. No extensive waterfowl hunting is expected.

Charleston Reservoir

The San Pedro River is muddy and often dry in this reach. There is virtually no fishing. On the other hand, the reservoir should provide good fishing for largemouth bass, white crappies, and channel catfish. Located in the southeastern corner of Arizona where there is little good fishing, the reservoir should be fished intensively. Some hunting of javelina, deer, Gambel's quail, mourning doves, white-winged doves, and cottontails will be lost. No hunting of significance is attached to the reservoir.

Bridge Canyon

This reach of the Colorado River has extremely limited access and very little fishing takes place today. With impoundment, the reservoir and tailwater will be stocked with rainbow trout and fishing should be good. There is virtually no hunting in this stretch of the Colorado River and little or none is expected with the reservoir.

Dixie Project

A few trout are present in the Santa Clara River within the project area. Fishing is minor although commercial fishing for bait minnows is important, having a market value of $10,000 annually. Two reservoirs are proposed, the Lower Gunlock and the Virgin City. Collectively, they should provide some good fishing but the bait fishery will suffer with about one-half being lost. At the present time, pheasants, Gambel's quail, and waterfowl offer attractive hunting. With more irrigation, game-bird habitat will increase and hunting should improve.

Southern Nevada Water Supply

The offstream River Mountains Reservoir should support a put-and-take trout fishery where no fishing exists at the present time. Hunting is virtually non-existent in the affected area and no significant change is expected with the project.

To realize the benefits listed in Table 2, certain means and measures should be taken during the immediate action phase of the Pacific Southwest Water Plan. Fish hatcheries should be built to stock impounded waters, coarse fishes should be controlled through careful and selective methods, and access and public-use facilities should be provided. In addition, fishery management investigations of reservoir waters and those on Indian lands will be necessary to chart the course for managing the fisheries of these new waters. Wildlife management areas should be developed and maintained and other comparable measures taken. A new Federal refuge should be built along the Lower Colorado River to compensate for the wintering habitat lost along the river and investigations should be instituted so that phreatophytes may be controlled without damage to wildlife habitat.

Benefits

The annual fish and wildlife benefits associated with this Plan are indicated in Table 2. They are contingent on the inclusion of the particular fish and wildlife measures listed in Table 3, Specific Fish and Wildlife Costs, Immediate Action Program.

Table 2. Annual Fish and Wildlife Benefits

Project	Fishing & Hunting (Man-days)	Annual Benefits
Central Arizona		
Maxwell Reservoir	670,000	$1,000,000
Buttes Reservoir	30,000	75,000
Hooker Reservoir	100,000	200,000
Charleston Reservoir	180,000	360,000
Bridge Canyon Reservoir	500,000	1,500,000
Arizona Fishing Lakes	2,000,000	6,000,000
Marble Canyon	120,000	360,000
Dixie	68,300	68,300
Southern Nevada Water Supply		
River Mountains Reservoir	40,000	40,000
California and Arizona		
Wildlife management areas	27,000[1]	99,000
Totals	3,735,300	$9,702,300

[1] Covers hunting use; other figures in column cover fishing use.

Specific Fish and Wildlife Costs

The specific costs of fish and wildlife measures are indicated in Table 3 and explained in the text following the table. They were developed cooperatively by the Bureau of Sport Fisheries and Wildlife and the fish and game departments of the States of Arizona, California, New Mexico, Nevada, and Utah.

Table 3. Specific Fish and Wildlife Costs, Immediate Action Program

Project and Measure	Amount
Central Arizona Project	
Central Arizona fishing lakes	($17,500,000)[1]
Maxwell Reservoir	
Access and facilities	$ 450,000
Fishery management investigations	100,000
Rough-fish eradication	10,000
Buttes Reservoir	
Access and facilities	100,000
Fishery management investigations	32,000
Hooker Reservoir	
Access and facilities	300,000
Fishery management investigations	100,000
Charleston Reservoir	
Access and facilities	350,000
Fishery management investigations	100,000
Rough-fish eradication	5,000
Bridge Canyon	
Access and facilities	1,638,000
Fishery management investigations	100,000
Marble Canyon	
Access and facilities	1,400,000
Fishery management investigations	100,000
Dixie	
Rough-fish eradication	11,000
Game-bird watering devices	5,000
Southern Nevada Water Supply	
Fish screen	10,000
Other fish and wildlife measures	
National fish hatchery, warmwater	800,000
National fish hatchery, trout	1,200,000
Cibola National Wildlife Refuge	2,700,000
Arizona State Wildlife Management Areas	325,000
California State Wildlife Management Areas	640,000
Rough-fish eradication, general	50,000
Fishery management studies, Indian reservations	500,000
Phreatophyte investigations	100,000
Total	$11,126,000
Annual Equivalent	$ 352,000 [2]

[1] This cost is a non-add item. It will be borne by the Arizona Game and Fish Department out of funds available to it if the Central Arizona Project will make available the needed 40,000 acre-feet of water on a non-reimbursable basis.

[2] Computed at 3 percent, 100 years.

Arizona Fishing Lakes

The initial, immediate action phase of fish and wildlife development for the Pacific Southwest Water Plan includes 50 fishing lakes to be constructed by the Arizona Game and Fish Department in connection with the Central Arizona Project. These 50 lakes, to be selected from a list of 89 which has been prepared by the Arizona Department, would provide 2,000,000 man-days of fishing, mostly for trout. Based on the interim schedule for evaluating benefits adopted by the Inter-Agency Committee on Water Resources, these 50 fishing reservoirs would produce annual benefits of $6,000,000.

These reservoirs would be built by the Arizona Game and Fish Department with funds available to it. The cost for the dams and reservoirs would be about $350,000 each for a total of $17,500,000. In addition, $50,000 to $75,000 would be required at each one for roads, access facilities, parking areas, and the like. These costs likewise would be borne by the Arizona Department.

The lakes would average 100 acres in size. They would be located in the higher elevations of central Arizona mostly in the yellow-pine forests of that area. None would be far from good roads. All would be within 200 miles of the Phoenix-Tucson population center and most would be within 100 miles. They would be managed and stocked with trout by the Arizona Game and Fish Department.

Water to fill and maintain these fishing lakes would be supplied by the Central Arizona Project. It is proposed to allocate 60,000 acre-feet the first year for filling and then 40,000 acre-feet annually from project water sources for this purpose on a non-reimbursable basis. That is, the cost of water would be borne by the Federal Government and the water would be delivered without charge to the Arizona Game and Fish Department. This is in recognition of the wide-spread outdoor recreation benefits of the lakes and also in recognition of the heavy investment by the State in these facilities.

Most of the lake sites are beyond reach of the new water-conveyance system planned for the Central Arizona Project. In circumstances where the intended use of water for the fishing lakes might be in conflict with established water rights, exchanges of water would be effectuated to provide, in effect, for Central Arizona Project water to supply these lakes. Detailed engineering surveys, currently underway, will make possible selection of the sites for the 50 fishing lakes.

Access and Facilities

The access and facilities associated with the particular reservoirs indicated in Table 3 are needed to realize the fishing benefits associated with such impoundments. Maxwell Reservoir, for example, will receive intensive fishing use. Developing at least 10 access points with car-parking, boat-launching, and sanitary facilities will be needed. These facilities would be in addition to those developed at other sites for recreation in general. Costs of construction of the 10 units is estimated at an average of $4,500 per unit, including road construction of 2 miles per unit.

Buttes Reservoir will need road construction and some fishermen-use facilities similar to those for Maxwell Reservoir. Hooker Reservoir lies largely within a canyon. It, too, will require road construction together with car-parking and boat-launching items. Charleston Reservoir will need similar improvements to capitalize on the fishery benefits.

Marble Canyon Reservoir and its tailwater, lying within the inner gorge of the Colorado River, will be virtually unuseable by fishermen unless access roads are developed together with appropriate boat-launching facilities including modification of the power-plant elevator to the tailwater below the dam.

Bridge Canyon Reservoir and tailwater, also in the main gorge of the Colorado River, will be relatively inaccessible unless a good road is built and maintained into the reservoir and an elevator provided to reach the tailwater. Docking and launching of boats as well as car-parking also will be needed at this reservoir.

Fishery Management Investigations

The impact of impounding waters in the reservoirs of the Pacific Southwest Water Plan will create problems in fishery management. There is a need for Federal-state cooperation in developing information needed for managing the extensive new waters to be developed with Federal financing. Without studies to develop such information, the state fish and game departments concerned will not be able to manage the new waters properly. Such studies should be conducted over the first five years for each impoundment. They will assist materially in bringing about the expected benefits.

Rough-fish Eradication

Virtually all of the new waters will need stocking with fish. But before the fish planting is done, the rough fishes frequenting particular streams or sections thereof should be removed so that the newly stocked fish may be given an opportunity to get a fresh start in new waters without having to compete for food or be preyed upon. Some areas are identifiable at this time but others are not.

Particular care will be utilized in undertaking this program to prevent damaging side effects. Full compliance with the Department's careful policies and standards will be scrupulously required.

Game-bird Watering Devices

Largely intended for quail and other upland birds, these devices catch precipitation and store it for use by such birds. Very successful in arid areas, even though storage capacities of individual units is usually limited to less than 1,000 gallons, these quail guzzlers, as they are often called, are designed to make water available by runways as the water evaporates. Evaporation itself is reduced since the devices are sheltered.

Fish Screen

This fish screen would be located on the inlet-outlet of River Mountains Reservoir of the Southern Nevada Water Supply Project. It would prevent the escape of planted fish from the reservoir during drawdowns.

National Fish Hatchery, Warmwater

To stock suitable project waters with warmwater species of fish, a suitable hatchery at an appropriate site yet to be determined would be necessary to realize the expected fishing benefits. The unit would annually produce 100,000 pounds of channel catfish and 5,000 pounds of bass for stocking in areas bordering the Colorado River, mainly in Arizona.

The excellent bass fishery of Lake Mead has been noted here. People from all over the Southwest and from many other parts of the Nation have been attracted to try their angling luck and skill there. Lake Mead provides about 400,000 man-days of fishing a year. The purpose of the new warmwater hatchery would be to help create similarly attractive conditions in new reservoirs and other waters of the Pacific Southwest Water Plan. The establishment of balanced populations of desirable species of fish in large bodies of water which are created by the construction of reservoirs, requires the initial stocking of tremendous numbers of fish during early stages of reservoir filling. In warm water lakes subsequent management to maintain a suitable level of populations of those species most sought by sportsmen may require additional stockings.

The cost of such a hatchery is estimated at $800,000, to be financed with funds appropriated for the implementation of the Pacific Southwest Water Plan. The location and other physical details of the new warmwater hatchery would be determined during the planning stage following authorization and preceding the construction phase of the Pacific Southwest Water Plan.

National Fish Hatchery, Trout

To stock the colder reservoirs and streams with trout, a suitable hatchery at a site yet to be determined would be required to realize the fishing benefits indicated. Its production of 250,000 pounds of trout a year would meet the need for stocking waters affected by water-resource developments planned for central and southern Arizona and the Lower Colorado River itself.

Fish hatcheries are important elements in the maintenance of productive trout fisheries in units of habitat where fishing pressure exceeds the natural productivity or where otherwise productive areas lack the spawning conditions essential to fullfillment of the complete life cycle of the fish. Man-made lakes, such as some of the reservoirs to be constructed in the Pacific Southwest Water Plan will develop waters of a temperature suitable for the growth of trout. Releases from the lower depths of reservoirs will create flows of cool water in the streams below dams which may be ideal for growth of cold water species. However, these waters may lack the conditions necessary for natural reproduction by these stream spawning species.

In such instances high quality trout fisheries may be attainable through the stocking of young fish from a hatchery or where exceptionally heavy fishing pressure is to be encountered, fish of catchable size.

Exceptionally fine trout fisheries now exist in the Colorado River below Lake Mead and below Lake Mohave. The cold waters released from Lake Mead flow as a density current below the surface in upper reaches of Lake Mohave but rise to the surface about midway in the reservoir, making possible a fine trout fishery in the lower reaches of this lake. These fisheries are heavily utilized where accessible but could not be nearly so productive without hatcheries as a source of young fish.

The new cold water fish hatchery is designed to help maximize opportunities for good trout fishing in the areas of suitable waters created by the Pacific Southwest Water Plan. The recommended cold water hatchery would also be funded as an integral part of the Pacific Southwest Water Plan with appropriations made for the implementation of that Plan. Its estimated cost is $1,200,000. Here, too, the precise location and other physical characteristics would be determined following authorization of the Plan and prior to construction.

Cibola National Wildlife Refuge

The most important single facility in the Pacific Southwest Water Plan for fish and wildlife is the proposed Cibola National Wildlife Refuge along the lower Colorado River. The site is located along both sides of the mainstem about 50 miles up the river from Imperial Dam.

The Lower Colorado River Valley historically has been a most important wintering ground for waterfowl. Ducks and geese produced in eleven western States and three provinces of Canada contribute to the waterfowl populations wintering there. Such species as the canvasback and redhead, the pintail, the green-winged teal, the gadwall, and others were formerly abundant. A large portion of the Great Basin Canada goose population, which breeds in the vast interior basin area of Western United States, winters there. During recent years, there has been a drastic reduction in the waterfowl populations of this area.

The reduction goes with the loss of such wintering habitat as overflow lakes, lagoons, and marshlands, due to lower flows in the river resulting from more complete development of the water resources in the United States and the requirement for full deliveries under the Water Treaty with Mexico of 1944.

The Bureau of Sport Fisheries and Wildlife has long been cognizant of the value of the Palo Verde-Cibola Valley portion of the Lower Colorado River for waterfowl and has considered it as having outstanding potential for establishment of a national wildlife refuge for the preservation and development of waterfowl resources. It is now proposed to establish a refuge there in connection with the implementation of the Pacific Southwest Water Plan.

Establishment of the refuge is vital to the maintenance and conservation of the Great Basin Canada goose, whose very existence is threatened by the continued loss of its essential wintering grounds. The refuge is needed to mitigate the losses to waterfowl and their habitat which have resulted from water development and water conservation projects along the river. Most immediately, the water program with the principal effect is the channelization project for the Lower Colorado, past and contemplated.

The Cibola Refuge would include some 16,200 acres of land. It would require a diversion of about 27,000 acre-feet of water of which about 14,000 would be for consumptive use. All of the water diversion and use would occur in Arizona. Under the doctrine embraced by the Supreme Court in _Arizona vs. California_, the necessary water rights could be established by a Secretarial decision to establish the Cibola Refuge and to withdraw the public land within its proposed boundaries. This water right would bear the date of such decision.

The consumptive use of water would be primarily for waterfowl food production through agricultural practices on some 3,500 acres of the land devoted to alfalfa, small grains, hay, and sorghums. The remaining water is needed to replace evapo-transpiration losses from some 1,200 acres of managed marsh and rest ponds to be provided for waterfowl on the refuge.

Under the proposed plan for the Cibola Refuge, a new permanent body of water would be created in the old river channel, and the level of water in one existing lake locally referred to as Cibola Lake would be controlled. There would be a controlled outflow structure for fish management purposes and fresh water inlets to prevent stagnation in the two bodies of water; adjustment of levee location and a control dike near the upper end of Cibola Lake to form a new lake in a present slough; a fresh water inlet for Three Fingers Lake; and boat ramps on the river and lakeside levees at Cibola and Three Fingers Lakes.

It is estimated that the new refuge would provide an expected 8,800,000 waterfowl-days[1] of use in this strategic wintering area. Peak waterfowl population on the area will be as many as 150,000 ducks and geese. This waterfowl use will make a vital contribution to the maintenance of waterfowl populations in far-flung sections of the Pacific and Central Flyways, to the benefit of thousands of waterfowl hunters in many parts of the West.

The ownership status of the 16,200 acres proposed for the Cibola Refuge is as follows:

Ownership	Acres
Federal	9,800
Private	3,750
State and County	900
Undetermined	1,750
Total	16,200

Under the plan, the Federal public land would be withdrawn for refuge purposes. The remainder would be acquired with funds appropriated to the Department of the Interior to implement the Pacific Southwest Water Plan.

It is estimated that the land acquisition cost would be $1,400,000. The cost of developing the basic refuge facilities would be an additional $1,300,000, also to be financed from funds appropriated to implement the Pacific Southwest Water Plan. This would be a total of $2,700,000 for initial capital investment from this source. Annual operation and maintenance costs of $110,000 would be borne by the Bureau of Sport Fisheries and Wildlife out of appropriations made to it for that purpose.

The Cibola Refuge is not only indispensable in maintaining an adequate residual stock of the Great Basin Canada goose, but also will provide a substantial amount of waterfowl hunting along the lower Colorado River for the benefit of residents of the Pacific Southwest. Additional dividends from the establishment of the refuge, as suggested above, will be the provision of substantial fishing and general outdoor recreation opportunities for the public. Facilities on the refuge are to be planned and developed with that secondary objective in mind.

1/ A waterfowl-day is a unit commonly used in expressing the value or capacity of a waterfowl area. It is equivalent to occupancy of an area by one bird for one day. This measure is well adapted to expressing the value of an area for waterfowl because of the migratory habits of these birds.

Arizona State Wildlife Management Areas

The Arizona Game and Fish Department hopes to develop three areas along the Lower Colorado River, namely Mittry Lake, 1,536 acres; Cibola Valley, 2,285 acres; and Topock Swamp, 320 acres, for waterfowl and upland game. A total of $325,000 is needed as follows: Mittry Lake, $200,000 for development only; Cibola Valley, $50,000 for land acquisition and $50,000 for development; Topock Swamp, $25,000 for development only. The water requirements of these areas, outlined in Chapter II, Water - Present Uses and Future Needs, should be provided under the immediate action program.

The Mittry Lake and Topock Swamp areas are in Federal ownership, currently in Reclamation withdrawals. The lands can be made available to the Arizona Game and Fish Department by agreement, lease, or similar device. The acquisition on the Cibola Valley unit would entail the purchase of 575 acres, which is a portion of the 1,425 acres the Arizona Department is currently leasing from non-Federal owners. The development costs would cover ponding, raising food crops, and other measures for making the areas attractive to wintering waterfowl. Other wildlife, including upland game, would benefit from these measures. Development of these lands would help restore waterfowl habitat lost through channelization, impoundment, phreatophyte control, and the ever-encroaching conflicting human uses.

These proposals also would contribute to the water salvage objectives of the Pacific Southwest Water Plan through substitution of plants with low water consumption and high wildlife value for those currently consuming much water but having little value for wildlife. Further, they would provide very generous hunting benefits.

California State Wildlife Management Areas

The California Department of Fish and Game plans to obtain administration of six areas for waterfowl and upland-game management along the Lower Colorado River, namely Quien Sabe Point, 7,500 acres; California Swamp, 3,500 acres; Mission Wash, 1,000 acres; Mohave Lateral Area, 600 acres; Yuma Island, 4,500 acres; and Araz Area, 1,100 acres, for a total of 18,200 acres. Virtually all of the land is in Federal ownership except for a very small acreage in state ownership. These lands would be made available to the California Department by agreement, lease, or similar device. The development costs of $640,000 would cover ponding, raising food for waterfowl, and other measures for making the areas attractive to wintering waterfowl. The water requirements set forth in Chapter II, Water - Present Uses and Future Needs, should be provided under the immediate action program.

As in the case of the three Arizona wildlife management areas noted above, it is expected that these proposals also would mitigate losses and contribute in some measure to the water salvage objectives of the Pacific Southwest Water Plan through the substitution of desirable wildlife plants with low water consumption and high wildlife value for those of low value and high water consumption. These areas likewise would provide hunting benefits.

Fishery Investigations on Indian Reservations

The Bureau of Sport Fisheries and Wildlife has agreements with various Indian tribes to provide them with technical assistance in the development and management of fishing waters on tribal lands, to the end that the economic well-being of the tribes will be improved. Because elements of the Pacific Southwest Water Plan will affect the Navajo Indian Reservation (Marble Canyon Project), the Hualapai and Supai Reservation (Bridge Canyon Reservoir), the Fort McDowell and Salt River Indian Reservations (Maxwell Dam), investigations and surveys will be needed to assist the tribes in managing the fishery resources of interest to them. The studies will last five years. These studies also will assist in realizing fishing benefits on related Indian irrigation projects.

Phreatophyte Investigations

The planned control of phreatophytes must be carried out in a manner that will maintain critical areas of wildlife habitat to the fullest possible extent. Non-critical but important habitat should be preserved through on-site development of replacement habitat and continued management to that end. Unavoidable habitat losses should be mitigated through development of habitat on other sites.

Water-wasting plants generally have low value for wildlife except on special sites where they provide nesting or other critical cover. On non-critical sites, phreatophytes can be eliminated and beneficially replaced with grasses, forbs, and shrubs selected for low water demand and high value for habitat and food needs of wildlife. Control programs must therefore embrace the objective of maintaining and improving habitat for wildlife as well as saving water. And wherever consistent with the highest and best land use, areas programmed for phreatophyte control might well be assigned to wildlife agencies under agreements designed to insure realization of these objectives in addition to salvaging water.

The phreatophyte investigations indicated are thus justified to assist in the selection of control sites and methods that will not impair wildlife values. The studies would be conducted by the Bureau of Sport Fisheries and Wildlife.

Water Supplies for Fish and Wildlife Installations

As indicated in Chapter II, Water - Present Uses and Future Needs, the scarcity of water in much of the arid Pacific Southwest presents grave problems to the agencies concerned with fish and wildlife conservation. Future water needs are listed in Table I of Chapter II. To meet in some measure the needs of fish and wildlife and hence of the people of the Pacific Southwest, water should be provided by the immediate action program wherever possible as indicated in the chapter.

Millions of dollars have been spent to date by the Federal and state fish and game agencies in the interest of fish and wildlife conservation. To assist in maintaining the attractiveness of the Southwest as a section in which to live, such agencies are prepared to spend millions more. The greatest need, of course, is water. Compared with the other needs of the Pacific Southwest Water Plan as a whole, the aggregate amount needed a year for fish and wildlife is low indeed.

Additional Considerations

The Salton Sea provides annual fishing and hunting and water sports attracting myriad day-use recreationists from the 200-mile distant Los Angeles area. This 220,000-acre body is fed by waste and return irrigation flows. Its salinity which approximates sea water in total strength was 34 parts per thousand (p.p.t.) in 1955, and is increasing about 0.4 p.p.t. per year. The orange-mouth corvina and sargo, the important sport fish, and the food-chain life important to the fish and waterfowl, are endangered by the increases. This condition apparently will be aggravated by any water-saving measures instituted on the tributary streams and drains in the Imperial and Coachella Valleys. Careful study must be given this problem to determine if feasible means can be found to halt or at least delay increase of the salinity. If possible, both the salinity and the water level should be stabilized to maintain the distinctive fish and waterfowl values. No means are apparent for accomplishment of this desirable objective but some means may be found relative to water salvage or to design of desalting plants which may be located on or near the Sea.

Features of the California Aqueduct System, which will be enlarged and integrated with the Pacific Southwest Water Plan, will have great impact on fish and wildlife not only in the served areas of Southern California but also in areas at the source and along the conveyance route in northern California and at critical points in the Central Valley of California. Extremely important waterfowl values attach to wintering areas along the San Joaquin Valley aqueduct routing. The several reservoirs in Southern California and along the San Joaquin Valley routing of the aqueduct will provide over 3,000,000 days of outstanding warmwater fishing annually when completed, and an estimated 6,000,000 days in 1990 at sites having exceptionally favorable relation in availability and need to the great population centers of the State of California.

Salmon, striped bass, and other fish of the source streams and the natural waters of the Sacramento River system to be used for conveyance have current value of $10,000,000 annually and an estimated value in 1990 of $40,000,000 for sport and commercial fishing without the import project. It can confidently be expected that every effort will be made by the concerned state and Federal conservation agencies to maintain these fisheries. Both the fish enhancement and the mitigation needs of this import project are being carefully planned for by state agencies with the cooperation of Federal agencies. However, so that related and complementary fishery programs of the California Department can continue to be effectively coordinated with this import project, specific authority should be provided in the Federal legislation enabling integration of the project with the Pacific Southwest Water Plan.

Intermediate and Long-Range Program

In formulating the intermediate and long-range program of the Pacific Southwest Water Plan, the fish and wildlife of the water source areas must be protected and benefited. Open canals should be provided with facilities to permit public fishing at selected locations adapted to such use. Along the conveyance routes and on the service areas all opportunities for improving both fish and wildlife habitat and fishing and hunting should be fully implemented.

Exchanges of water should be arranged so as to effect improvements outside planned direct-service areas. Water salvage and drainage units and water reclamation units of the Plan should be coordinated with fish and wildlife programs to preserve, restore, and create essential habitats and provide fully for anticipated fishing and hunting demands. An appropriate share of waters developed with the Plan must be devoted to the critical needs of wildlife. Pollution abatement, water quality control, and salvage of sewage effluents must be planned with due regard for the requirements of fish and wildlife.

All phases of the Pacific Southwest Water Plan will have great impact on the national waterfowl program. Thus, with the intermediate and the long-range program of the Plan, as with the features for immediate construction, key waterfowl areas must be retained or provided so that the resource can be built up commensurate with the ever-increasing human wants.

Individual features and units of the intermediate and long-range program will be considered fully in detailed future reports. A few specific comments on this program will serve to highlight the more apparent areas of concern.

Arizona

It is likely that the establishment of another national wildlife refuge in southwestern Arizona will be needed, to alleviate agricultural crop depredations by wintering waterfowl. It is also likely that a new state-operated fish hatchery in southern Arizona may be necessary. Long-range planning might well include additional fishing lakes as well.

California

Extremely important wildlife habitat exists in Owens Valley, and the California Fish and Game Department has several trout hatchery and rearing installations in the Mono-Inyo area and on the Kern River which are concerned almost entirely with meeting the needs of southern California residents. Future development of water resources in this valley must maintain the wildlife habitat and provide adequate water supplies for the production of trout both in the fish hatcheries and rearing ponds and in the natural watercources. Restoration of groundwater levels would solve most fish and wildlife problems of the valley. A national wildlife refuge of 10,000 acres is needed in Owens Valley. It would have an annual diversion requirement of 60,000 acre-feet and a consumptive use of perhaps 40,000 acre-feet, some of which would be available as return flow for reuse. The Owens Valley unit of the Plan should include this water among the demands to be suppled in the valley. Maintenance and improvement of natural streams also must be included in plans, and would not require consumptive use of water if restricted to sections between reservoirs or between reservoirs and delivery points.

The ten small fishing lakes in southern California totalling 500 surface acres and requiring 2,000 acre-feet will be planned and developed during the intermediate or long-range phase of the Pacific Southwest Water Plan. A further consideration in the formulation of water-resource development plans must be the maintenance of coastal wetlands fed by drainages tributary to the sea. Wetlands of this type have all but disappeared. Diversions have reduced the feeder streams to trickles while harbor and shore construction has extinguished the wetlands by drainage and filling. It may yet prove possible to restore a few key wetlands, mainly for shore birds and waterfowl. The water demands will be small, for the areas susceptible of restoration are small; but the need should be recognized both in plans for diversion of coastal streams and in selecting sites for desalting plants. Black brant, a species singularly dependent on coastal marshes, is especially noteworthy among the birds to be preserved by such restoration. Water needs of key wetlands should be provided through releases to natural channels or by other means. Site selection for desalting plants should avoid destruction of key wetlands, and where feasible, small wetlands should be acquired and developed as a part of the site landscaping for these plants.

Nevada

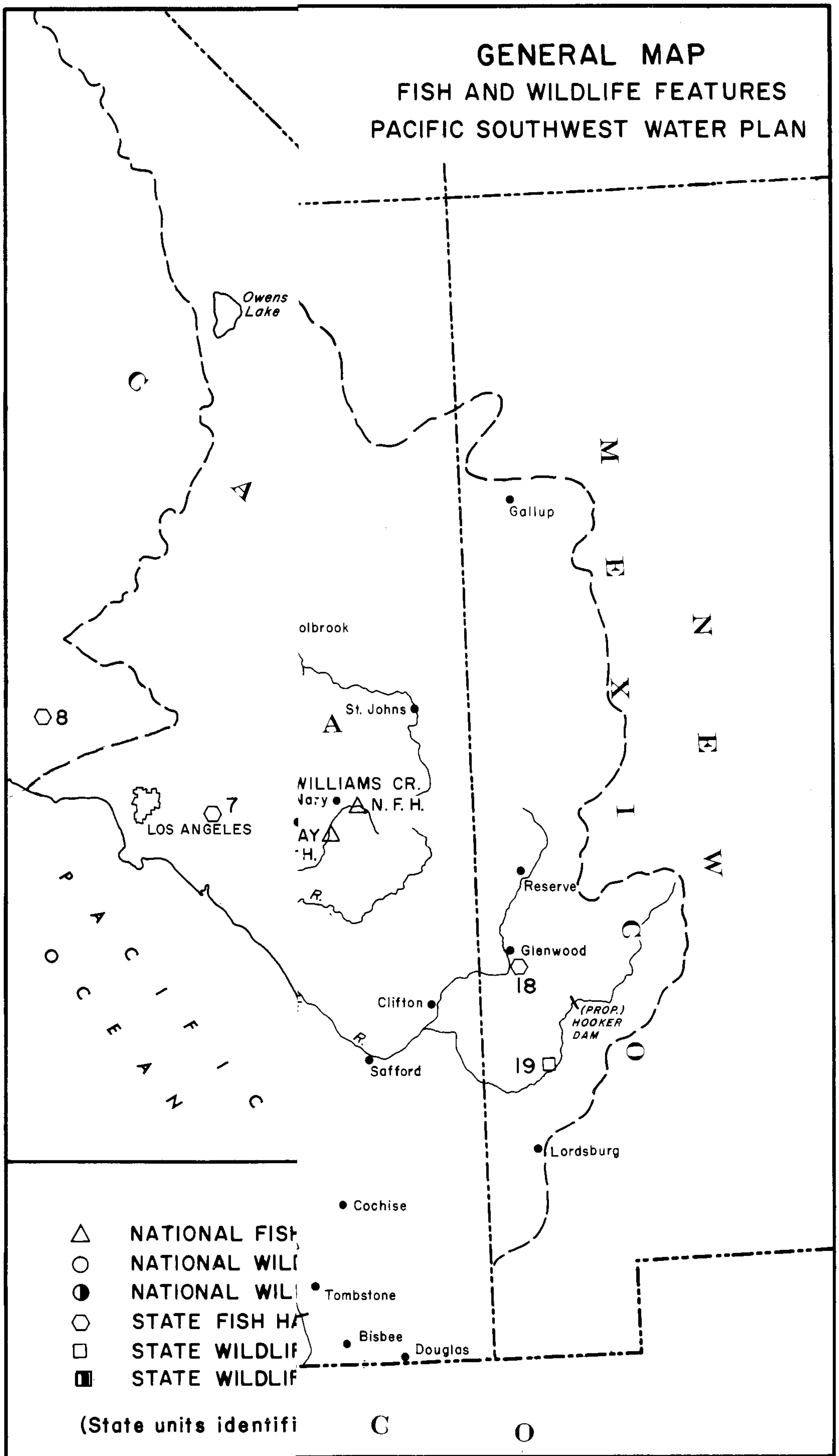
Fulfilling the established role of the Overton Waterfowl Management Area, operated by the Nevada Fish and Game Commission, will require 4,000 acre-feet of good quality water as a supplement to its present supply of waste and return irrigation water. This water can be supplied by the Moapa Valley Pumping Project of the Bureau of Reclamation. The development and intensified management dependent on the 4,000 acre-feet of new water would triple the effectiveness of the management area in supporting the waterfowl of the Pacific Flyway. This increase is sufficient to justify the water costs but monetary benefits also would accrue from the increased local hunting.

In addition, in Nevada along the Colorado River immediately upstream from the Fort Mohave Indian Reservation are lands in a block of 3,300 acres and a strip about 1/2-mile wide extending 4 miles further upstream, which total about 4,600 acres that are suited to development for waterfowl and upland game. These lands contain abandoned sloughs and old river meanders occupied by good populations of quail, doves, rabbits, and some waterfowl, which support moderately heavy hunting.

The priority of the above-described development in southern Nevada and the agency that would establish and administer it are matters for determination after further study. The water quantities required for intensive crop production on 1,000 acres to provide food for waterfowl and to maintain related ponds for waterfowl would total 15,000 acre-feet annually.

UNITED STATES
DEPARTMENT OF THE INTERI

FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE



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Effects on Grand Canyon National Park and Monument

of proposed Lower Colorado River Project

I. INTRODUCTION

The components of Lower Colorado River developments considered herein are the proposed Bridge Canyon and Marble Canyon Dams and Reservoirs. Each component is treated separately, since each will cause changes of a different nature. The proposed Bridge Canyon Reservoir would change the character of a particularly scenic length of wild river to something far less desirable from the National Park standpoint.

The basic purpose of national parks and monuments, as stated in the Act of August 25, 1916, is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

In the Act to establish Grand Canyon National Park, approved February 26, 1919, there is, however, the following provision:

> That whenever consistent with the primary purposes of said park, the Secretary of the Interior is authorized to permit the utilization of areas therein which may be necessary for the development and maintenance of a Government reclamation project.

To determine whether water control projects would be consistent with that purpose, it is necessary to ascertain and weigh the effects.

II. BRIDGE CANYON DAM AND RESERVOIR

This proposed damsite is located some 2.5 miles upstream from the head of Lake Mead and 237.5 miles downstream from Lees Ferry at an elevation of approximately 1200 feet. When filled, if constructed to an elevation of 1783 feet, as previously recommended by this Service, the reservoir will back water through the eastern portion of Lake Mead National Recreation Area and through Grand Canyon National Monument.

If the dam is constructed to a height of 1876 feet, it would back water 13 miles into Grand Canyon National Park.

A. Bridge Canyon Dam Constructed to Elevation 1783 Feet

Although we realize that Grand Canyon National Monument was established with the recognition that at some future date a dam might be constructed at Bridge Canyon, it is important that we consider carefully the effects such a dam will create.

If the dam height is limited to 1783 feet above sea level, the elevation of the Colorado River at the western boundary of Grand Canyon National Park, the reservoir would extend upstream a distance of 80 miles. The greatest distance, 53 miles, would be within Lake Mead National Recreation Area, with the remaining 27 miles either bordering or totally within the National Monument.

1. Values to be Lost

The construction of a reservoir in this reach of the Canyon would inevitably result in the loss of park values of national significance and the creation of other values.

The river, with its ever changing currents, pools, and rapids, would be blotted out by the slack water of the reservoir.

a. Streambank Ecology

The existing, natural streambank ecology would be drastically changed throughout the extent of the reservoir. The existing plant and animal habitats would be drowned out, and colonization by exotic species would be expected. In the uppermost regions of the reservoir, silt deposition and debris accumulation would be inevitable.

b. Aquatic Fauna

The change from river to reservoir would change the aquatic fauna. The limited natural range of native fish, such as the bonytail (Gila Robusta), Humpback Chub (Gila Cypha), Colorado Squawfish (Ptychcheilus Lucius), and Humpback Sucker (Xyrauchen Texanus), would be further changed and reduced. Non-native species would become established in the new environment.

c. Geological Features

The Grand Canyon of the Colorado affords the finest study area available for students of geology. The effects of the dam on geologic features in this vicinity are discussed in detail by Dr. Edwin D. McKee, now of the United States Geological Survey, in a report he submitted to the Directed of the National Park Service by memorandum dated October 21, 1942. The following is quoted from Dr. McKee's report:

> The greatest losses, in so far as geologic features are concerned, from the backing up of water behind the Bridge Canyon Dam will be in the area of volcanic activity at and

westward from Toroweap Valley. In this section several features illustrating the early stages of canyon cutting and of local vulcanism will be concealed. Also covered will be remnants of lavas that flowed down the river channel and sediments, in two places, formed in ancient lakes or reservoirs behind natural lava dams.

A detailed account of these remnants of lava flows and other features of local vulcanism appears in a paper by McKee and Schank titled "The Lower Canyon Lavas and Related Features of Toroweap in Grand Canyon," published in the Journal of Geomorphology, Volume 5, Number 4, pages 243-273 (1942).

d. Recreation

The most obvious change in recreational use of the canyon brought about by the Bridge Canyon Project would be the limitation of the traditional and exhilarating experience of wild river boating, for which the Grand Canyon is famous. This unique form of recreation was beginning to show a marked increase prior to the closure of the Glen Canyon Dam. Since 1955, more than 1300 persons enjoyed boat trips through Grand Canyon; nearly 400 of these made the trip last year.

Undoubtedly, the running of the Grand Canyon would grow in popularity in the years ahead as the quality of such an experience and its safety with proper preparation, equipment, and guidance became more widely known. The proposed low Bridge Canyon Dam would reduce the amount of possible river running through the Grand Canyon by more than 80 miles, a reduction of 36.8 percent.

2. Values to be Gained

A fair evaluation of the effects of the proposed Bridge Canyon Reservoir cannot be made without giving consideration to artifically created values which will result. With the completion of the dam and a highway from U. S. 66 to the damsite, the Bridge Canyon Reservoir would become a new recreation attraction of the region. This wild and presently relatively inaccessible area would be opened to large numbers of people who will want to take boat trips on a fjord-like reservoir set in the incomparable scenery of the Grand Canyon.

The kind of activity common to recreation areas such as power boating, water skiing, fishing, swimming, and camping would be enjoyed by an estimated 500,000 people a year, of which it is estimated that 150,000 would take scenic boat trips.

Species of sport fish, as in Lake Mead, would probably be introduced into the reservoir--largemouth black bass, bluegill, crappie, sunfish, and others. An additional, possible recreation benefit may be the flushing of a portion of the silt from the Grand Canyon section of Lake Mead below Bridge Canyon Dam, sufficient perhaps to permit boating in this spectacular setting again.

B. <u>Bridge Canyon Dam Constructed to Elevation 1876 Feet</u>

If a high Bridge Canyon Dam is constructed at an elevation of 1876 feet above sea level, the resulting reservoir would extend into Grand Canyon National Park, a distance of 13 miles to within one-tenth of a mile of the mouth of Kanab Creek. At the lower end of the Park, the water surface at maximum operating elevation of 1866 feet would be raised about 83 feet above natural conditions of flow.

<u>Values to be Lost</u>

The values lost upon construction of the high dam would be essentially the same as described for the lower dam but, in addition, the reservoir would extend 13 miles into Grand Canyon National Park.

This section of the inner canyon is characterized by extreme narrowness and high, sheer walls of sedimentary rock. Near the mouth of Havasu Creek, the inner gorge is at its narrowest along the entire length. The views into the canyon are spectacular and awe-inspiring.

The late Norman Neville, well-known organizer of the boat trips through the Grand Canyon, stated of this section of the inner gorge:

> In all of my notes, on four separate trips, I have noted again and again that the section of river canyon from Kanab Creek to Havasu Canyon is outstanding and among the most beautiful of all the Grand Canyon.

The high dam would result in silt deposition and debris accumulation in this section of the National Park and would further restrict inner gorge native plant and animal habitat and natural river boating in Grand Canyon.

The late Frederick Law Olmstad, noted landscape architect, made a study of the effects of the proposed high Bridge Canyon Dam upon the Park. In his report, Mr. Olmstad said in part:

> This section of the Grand Canyon as a whole is notable for the distinctive character of its scenery . . . It was completely included from rim to rim in the portion of Grand Canyon originally set apart in 1908 as a national monument for preservation of the noneconomic values of its unique and inspiring scenery . . .
>
> If that is to remain the policy of the Government concerning this entire unit of the Grand Canyon . . . then the limitations of Bridge Canyon Reservoir to an elevation that will not encroach on that protected area should be continued . . .
>
> Choice . . . depends . . . upon broad considerations of public purpose; in the last analysis upon how much the people of the United States care about preserving the natural conditions and scenery in the portion of the Grand Canyon selected for such preservation in 1908, and whether they are able and willing to pay the economic price of such preservation.

This Service has recommended that the height of the proposed Bridge Canyon Dam be limited to 1783 feet (the normal river elevation at the west boundary of the Park) thus preventing encroachment on the Park.

III. MARBLE CANYON DAM

The proposed Marble Canyon Dam to be located some 12.5 miles upstream from Nankoweap Canyon at the northeast corner of Grand Canyon National Park would have no appreciable effect on the Park, provided that all water released for power generation and other purposes is allowed to continue to flow through the Park. It is our understanding that the proposed Kanab Creek Tunnel is not a part of the overall program and therefore we have not commented on its possible effect on the Park.

PACIFIC SOUTHWEST WATER PLAN

Appendix Section

Bureau of Indian Affairs

Introduction

This Appendix is the participation of the Bureau of Indian Affairs in the preparation of the report on the Pacific Southwest Water Plan. In presenting the material the Washington draft of the outline of the report for the Pacific Southwest Water Plan has been followed. Chapters and subheadings used are the same as in the outline. Statements have been prepared under the headings indicated for Bureau of Indian Affair's participation in the outline of the report. In a few cases statements have been presented although not indicated for Bureau of Indian Affairs participation in the outline.

PACIFIC SOUTHWEST WATER PLAN

(Bureau of Indian Affairs' Statement)

THE PACIFIC SOUTHWEST

Natural Resources

Land

There are five Indian Reservations along the main stream of the Lower Colorado River, eighteen reservations on tributaries, six in the inland basin of California, and several in the southern California coastal area. In succession down the river, the mainstream reservations are: Fort Mohave in Arizona, California, and Nevada; Chemehuevi in California; Colorado River in Arizona and California; Yuma in California; and Cocopah in Arizona. The reservations on tributaries and in California are listed later in this report, with estimates of water requirements.

The principal resources of most of the reservations are their irrigable lands and appurtenant water rights. The irrigable acres and water rights for the mainstream reservations, as provided under the Supreme Court decision in Arizona vs. California, are shown in the following tabulation:

	Irrigable Area (Acres)			
	Arizona	California	Nevada	TOTAL
Fort Mohave	14,916	2,119	1,939	18,974
Chemeheuvi	0	1,900	0	1,900
Colorado River	99,375	8,213	0	107,588
Yuma	1/	7,743	0	7,743
Cocopah	431	0	0	431
Totals	114,722	19,975	1,939	136,636

1/ Indian Homesteads included with non-Indian lands of Yuma Project (USBR).

Diversion Right
(Acre Feet)

	Arizona	California	Nevada	TOTAL
Fort Mohave	96,416	13,698	12,534	122,648 1/
Chemeheuvi	0	11,340	0	11,340
Colorado River	662,402	54,746	0	717,148 1/
Yuma	2/	51,616	0	51,616
Cocopah	2,744	0	0	2,744
Totals	761,562	131,400	12,534	905,496

1/ The Supreme Court did not determine boundaries in cases of controversy. Figures shown are those recommended by the Special Master.

2/ Indian Homesteads included with non-Indian lands of Yuma Project (USBR).

The average precipitation for the reservations along the Colorado River is so low that almost no grazing is afforded outside the irrigated areas and river bottom lands. Grazing is a very important resource of the tributary reservations.

Lands and waters suitable for recreational purposes also are important resources of many reservations.

Minerals

Several reservations have mineral deposits which have been or eventually may be developed into profitable mines. Among these are iron and asbestos on the Fort Apache Reservation; copper, manganese, asbestos, gypsum, and terrazzo stone on the San Carlos Reservation; and copper on the Papago Reservation.

Fish and Wildlife

In addition to the Colorado River, which flows entirely within the Colorado River Reservation for 56 miles of its length, the irrigation canals, drains, and sloughs in the Colorado River Irrigation Project furnish abundant habitat for fish and wildlife. The cultivated fields and adjacent natural vegetation furnish excellent food and living conditions for quail, doves, other small game, and a considerable number of deer. Geese and ducks also find the water and food supply furnished by cultivated lands attractive. Including a commercial fish farm, there are approximately 558 acres of ponds and sloughs on the Colorado River Reservation. On the Fort Apache Reservation there are 310 miles of trout streams, and 542 acres of trout lakes.

<u>Economic Growth</u>

Economic growth on some of the Indian Reservations has been rapid in recent years, and continues slow on other reservations. The abundance of water following the construction of Headgate Rock Dam on the Colorado River has permitted expansion of the Colorado River Indian Irrigation Project from 6,500 acres to approximately 35,000 acres net. Proceeding with this development has been the construction of two packing sheds for cantaloupes and other vegetables, a second cotton gin, a large feed lot, and an expanding trucking business from the Project to the West Coast.

There is great demand for lands along the Colorado River for recreational purposes and for homesites for winter visitors. The Colorado River Tribes have leased a considerable part of reservation water front for these purposes and have plans for land developments back of the river front as well as along much of the remaining river front. Included in the proposed developments are recreational enterprises such as motels, marinas, and resort type establishments. Development of recreational potentials is very important to other reservations also, such as at Fort Mohave, Fort

McDowell, Salt River, and San Carlos. At Salt River, San Xavier, and Gila River Reservations development of lands for urban and industrial purposes is becoming an immediate possibility.

On the Fort Apache Indian Reservation the recreational enterprise has been expanding with a rapid growth because of the rapid increase in population in Arizona. The White Mountain Apache Tribe has built a series of lakes for trout fishing, service stations, motels, boat landing facilities, and camp grounds, to take care of this recreation demand, and employs many of its members in maintaining and operating their projects.

Economic growth on the Gila River Reservation has been retarded due to an insufficient water supply for their San Carlos Irrigation Project. However, the value of crops produced on the San Carlos Irrigation Project has reached approximately eleven million dollars, of which approximately two and a half million dollars is on the Gila River Reservation.

Recreational, Cultural, and Scientific Development. The Colorado River attracts great numbers of people because of recreational values. During holidays and week-ends recreational use of the river is exceptionally heavy. Most of the use is by people from Los Angeles and other southern California areas. One of the favorite places is a stretch of river on the Colorado River Reservation upstream from Headgate Rock Dam, where the constant water level maintained by the dam furnishes excellent boating and other water sport activities. The shores outside the reservation are occupied almost solidly with recreational enterprises and river front home developments. Also motels and river front homes occupy a large part of the shore line on the three miles of river within the reservation above Headgate Rock Dam. Downstream from Headgate Rock

Dam are 53 miles of river on which very little development has taken place, although the potential is great and there have been many inquiries regarding commercial developments along this stretch of the river. Adequate ground has been reserved along the river front for recreational development instead of agricultural development. The constant water level above Palo Verde Diversion Dam is particularly attractive for water sport activities. Channelization of the Colorado River , such as has been done below Davis Dam, will add greatly to the recreational value of the river, if recreational possibilities are considered in design of the channelization works.

THE WATER PROBLEM

Historical Background

Irrigation has been practiced by the Indian Tribes since before the coming of Europeans to the American continent. Prehistoric canals are in evidence at several of the Reservations especially on the Gila and Salt River Reservations, and remains of ancient villages are found on almost every reservation. The Pima Indians furnished grains and other food stuffs to the first white settlers coming to the area and to those traveling to California. The Apache Indians were raising corn, beans, and other food stuffs when first encountered by the whites. The Mohave, Chemeheuvi, Yuma, and Cocopah Indians of the Colorado River valleys practiced a method of irrigation which was dependent on overflow of the lands by spring floods of the Colorado River.

The Colorado River Indian Reservation was established by Act of Congress, approved by the President March 4, 1865, for settlement of Indians of the Colorado River and its tributaries. In 1866 a survey for an irrigation

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The Colorado River Indian Reservation was established by Act of Congress, approved by the President March 4, 1865, for settlement of Indians of the Colorado River and its tributaries. In 1866 a survey for an irrigation canal was made, and an appropriation of $50,000 was made by Act of March 2, 1867, for beginning construction on the canal. This was the first appropriation by the United States Congress for irrigation purposes.

A second appropriation of $50,000 was made on July 27, 1868. Water was first turned in the canal on July 4, 1870. Due to greatly fluctuating levels of the Colorado River, the canal could be used only during flood periods and the crops suffered for water during low stages. In 1872 an appropriation was made by Congress for extension of the canal upstream, including four tunnels, aggregating 4,158 feet in length, to Headgate Rock. The extension was completed June 23, 1874. Due to difficulty in maintaining the tunnels this work was not successful. Diversion at high stages of the river were continued when possible.

In 1899 a steam engine and a 15" centrifugal pump were installed and operated until 1912. In 1912 a steam pumping plant containing two 20" centrifugal pumps with a capacity of 25 c.f.s. each, was constructed. In 1918 a 36" centrifugal pump with a capacity of 75 c.f.s. was added. Diesel engine power replaced the steam power in 1929. Construction of Headgate Rock Dam across the Colorado River was authorized by Congress August 30, 1935. Construction of the dam was completed in 1941. The 3-mile section of canal connecting Headgate Rock Dam with the old irrigation system was completed in June 1942.

The maximum area irrigated prior to construction of the dam was approximately 6,500 acres. Approximately 35,000 acres, net, are presently irrigated.

Estimate of Present Situation.

With the definite establishment of rights to use water, the Indian lands along the Colorado River mainstream can be developed with assurance of continued operation and economic success. The lands are productive and the market is good because of the proximity to the large population centers of southern California.

On tributary streams the limited water supplies at lower elevations have restricted development except where groundwater is being pumped. The groundwater is being mined and the economic limit for pumping will be reached within the foreseeable future. It is essential that a new water supply be secured for reservations such as the Ak Chin, Gila River, Papago, and San Xavier. Approximately 46,500 acres on these reservations are entirely dependent on pumped groundwater and approximately 100,000 acres on the San Carlos Irrigation Project are partially dependent on pumping from groundwater.

The Reservations on tributaries higher on watersheds of the Gila and Salt Rivers have adequate total sources of water but full use is not made of the water supplies because of physical conditions of the irrigation systems, or lack of storage capacity. The Bureau of Indian Affairs and Tribal Councils on these reservations plan to proceed energetically on programs for use of the waters on these reservations.

Effects of Recent Supreme Court Decisions

The Supreme Court Decision has established definitely the amount of water to which the Indian lands along the mainstream of the Colorado River are entitled. Although the tributary stream reservations were not included in the decision, the basic doctrine by which water rights are claimed for Indian reservations was reaffirmed. With this decision, plans can be made with confidence and development of the lands can proceed.

Effects of Arizona-California Boundary Settlement

Settlement of the Arizona-California boundary location will not have a great effect on Indian lands, since the areas of Indian Reservation lands involved in adjustment of the boundary location are small.

Effects of Public Land Use and Disposition

Very little of the public land in the lower Colorado River basin is used by Indians, as their activities generally are confined to their reservations or in cities and towns. The disposition of public lands, therefore, will have little effect on Indian affairs.

Future Water Needs

The principal future water needs on Indian Reservations along the mainstream will be for full development of 136,636 acres of irrigated lands for which the Supreme Court has allocated water. Accompanying this expansion will be a moderate expansion of municipal, industrial, and recreational needs.

The future needs of the reservations on tributaries will include municipal and industrial uses required as the urban areas of Phoenix and Tucson expand on nearby reservations and as industrial developments are made on the other reservations. Additional agricultural use of water will primarily be for augmenting existing supplies, or replacement of water now being pumped from groundwater. Use of water for recreational purposes is important economically but the quantities of water involved are relatively small.

PRESENT WATER SUPPLIES AND USES

Lower Colorado River Main Stream Water

Water Use Projects (See accompanying tabulation entitled "Present (Water Supplies and Uses on Indian Reservations."

Present uses of water of the mainstream of the Lower Colorado River on Indian Reservations are at the Colorado River, Yuma, and Cocopah

PRESENT WATER SUPPLIES AND USES ON INDIAN RESERVATIONS

RESERVATION	IRRIGATION Source	IRRIGATION Acres	IRRIGATION Diversion Capacity A.F.	IRRIGATION Diversion Actual A.F.	MUNICIPAL & INDUSTRIAL Source	MUNICIPAL & INDUSTRIAL Diversion Capacity A.F.	MUNICIPAL & INDUSTRIAL Diversion Actual A.F.	RECREATION, FISH & WILDLIFE Source	RECREATION, FISH & WILDLIFE Diversion Actual A.F.	LIVESTOCK Source	LIVESTOCK Diversion Actual A.F.	TOTAL Diversion Actual A.F.
MAINSTREAM												
Arizona												
Cocopah	Colo. River	300	2,744	1,890	Wells	20	10	-	-	Colo.River	Minor	1,900
Colorado River	" "	35,061	614,000	450,000	"	2,000	1,300	Ponds	5,200*	" "	"	456,500
Fort Mohave	" "	0	0	0	-	0	0	Colo.Riv.	*	" "	"	
Subtotal		35,361	616,744	451,890		2,020	1,310		5,200			458,400
California												
Chemehuevi	Colo. River	0	0	0	Colo.Riv.	Minor	Minor	Colo.Riv.	*	Colo.River	*	Minor
Colorado River	" "	0	0	0	Wells	150	100	" "	*	" "	Minor	100
Fort Mohave	" "	0	0	0	-	0	0	" "	*	" "	"	
Yuma	" "	7,743	51,616	51,616	City & Wells	150	100	" "	*	" "	"	51,716
Subtotal		7,743	51,616	51,616		300	200					51,816
Nevada												
Fort Mohave	Colo River	0	0	0	-	0	0	Colo.Riv.	*	Colo.River	Minor	
TOTAL - Mainstream		43,104	668,360	503,506		2,320	1,510		5,200		Minor	510,216
TRIBUTARIES												
Arizona												
Ak Chin	Wells	11,186	40,000	23,000	Wells	30	20	-	-	Wells	30	23,050
Camp Verde	Verde River	216	1,020	1,020	Wells	30	20	Verde Riv.	*	Verde Riv.	*	1,040
Fort Apache	Streams	2,885	14,420	5,500	Streams	2,000	1,220	Lakes	1,000	Ponds	1,910*	9,630
Fort McDowell	Verde River	1,300	6,870	1,800	Wells	50	30	Verde Riv.	*	Verde Riv.	30	1,860
Gila Bend	Wells	621	2,950	2,000	Wells	20	10	-	-	Wells	10	2,020
Gila River***	Wells	19,254	100,340	63,000	Wells	1,000	750	Wells	100	Wells	50	63,900
Havasupai	Havasu Cr.	175	1,110	800	Wells	40	20	Havasu Cr.	*	Havasu Cr.	*	820
Hopi	Misc.Washes	731	3,140	360	Wells	300	210	Misc.Washes	200	Ponds & Wells	840	1,610
Hualapai	Springs & Cr.	83	410	150	Peach Springs	100	50	Colo.River	-	Ponds & Wells	1,100	1,300
Kaibab	Springs & Wash	84	270	60	Springs	40	20	Springs	150	Ponds & Spr.	260	490
Navajo	Lit.Col.R.& Trib.	5,635	24,140	7,100	Wells & Spr.	6,000	5,160	Lakes	3,900	Wells & Ponds	14,200	30,360
Papago	Wells & Washes	4,700	13,600	6,000	Wells	150	100	-	-	Wells & Ponds	1,880	7,980
Salt River	Salt Riv.& Wells	12,625	57,480	46,000	Phx.& Mesa Sys.	100	50	Salt River	*	Wells & Salt R.	10*	46,060
San Carlos Res.	Gila & San C.Riv.	2,326	14,000	3,780	Wells	1,500	1,000	Lakes	720	Ponds	3,440*	8,940
San Car.Irr.Pr**	Gila R. & Wells	102,090	612,540	274,000	(Incl.in Irrigation Use)			(Incl.in Irrig.Use)		-	-	274,000
San Xavier	Wells	1,600	7,040	4,200	Wells	70	20	-	-	-	Minor	4,220
Yavapai(Prescott)	-	-	-	-	City of Prescott			-	-	-		
Subtotal		165,511	899,330	438,770		11,430	8,680		6,070		23,760	477,280
New Mexico												
Navajo	Lit.Col.Ri.&Trib.	592	2,220	750	Wells & Spr.	110	110	Lakes	500	Wells & Ponds	290	1,650
Zuni	" " " "	7,752	24,600	7,500	" "	3,900	380	"	150	" "	930	8,960
Subtotal		8,344	26,820	8,250		4,010	490		650		1,220	10,610
Nevada												
Moapa	Muddy River	571	3,540	3,000	Muddy Riv.	10	10	Muddy Riv.	*	Muddy Riv.	10	3,020
TOTAL - Tributaries	All States	174,426	929,690	450,020		15,450	9,180		6,720		24,990	490,910

* Consumptive use on stream not included.

** Including San Carlos Irrigation and Drainage District, Florence, Casa Grande Project, and San Carlos Project Indian Unit lands.

*** Excluding San Carlos Project.

PRESENT WATER SUPPLIES AND USES ON INDIAN RESERVATIONS

RESERVATION	IRRIGATION Source	IRRIGATION Acres	IRRIGATION Diversion Capacity A.F.	IRRIGATION Diversion Actual A.F.	MUNICIPAL & INDUSTRIAL Source	MUNICIPAL & INDUSTRIAL Diversion Capacity A.F.	MUNICIPAL & INDUSTRIAL Diversion Actual A.F.	RECREATION, FISH & WILDLIFE Source	RECREATION, FISH & WILDLIFE Diversion Actual	LIVESTOCK Source	LIVESTOCK Diversion Actual A.F.	TOTAL Diversion Actual
INLAND BASIN												
California												
Agua Caliente-Palm Springs	-	-	-	-	San Andres & Tahquitz Cr.	-	624	-	-	-	-	624
Augustine	Colo.River	543	2,942	0	-	-	-	-	-	-	-	0
Cabazon	Colo.River	1,521	8,320	450	Wells	10	5	-	-	-	-	455
Mission Creek	Mission Creek	110	550	40	Mission Cr.	-	-	-	-	-	-	40
Morongo	Potrero Cr.& Well	220	880	880	Tunnel & Well	80	60	-	-	-	-	940
Torres-Martinez	Colo.River	209	36,383	1,254	Wells	20	13	-	-	-	-	1,267
Subtotal		2,603	49,075	2,624		110	702					3,326
COASTAL												
Southern California												
Barona	Well	60	40	40	Well	30	20	-	-	-	-	60
La Jolla	Ypecha Cr.	184	600	90	Ypecha Cr.	10	10	-	-	-	-	100
Pala	San Luis Rey River & Wells	620	2,480	800	Well	150	100	-	-	-	-	900
Pauma - Yuima	Pauma & Ysedro Cr.	21	63	45	Well	40	24	-	-	-	-	69
Pechanga	-	-	-	-	Spring	16	16	-	-	-	-	16
Rincon	San Luis Rey River & Wells	558	2,790	90	Well	100	15	-	-	-	-	105
San Manuel	Bear Valley Wat.Co.	9	45	45	Well	50	25	-	-	-	-	70
Soboba	East.Mun.Wat.Co.	185	925	925	Eastern Municipal Water Co.	150	100	-	-	-	-	1,025
Viejas	Well	5	20	20	Well	30	15	-	-	-	-	35
Subtotal		1,642	6,963	2,055		576	325					2,380
TOTAL - ALL RESERVATIONS		221,775	1,654,088	958,205		18,456	11,717		11,920		24,990	1,006,832

Reservations. The Colorado River Irrigation Project diverts approximately 450,000 acre-feet of water annually for irrigation of approximately 40,000 acres (35,000 acres net) of Indian lands, and returns to the river through drainage canals approximately 270,000 acre-feet.

Indian lands of the Fort Yuma and Cocopah Indian Reservations are served through the irrigation system of the Yuma Project of the Bureau of Reclamation. On the Fort Yuma Reservation are 7,743 acres of irrigable lands, and on the Cocopah Reservation there are 431 acres of irrigable lands. Also on the Yuma Project are 480 acres of homestead allotments belonging to Yuma Indians and served by the Yuma Project. The quantities of water used for the Yuma homestead lands are included in the accounting of the Bureau of Reclamation for the Yuma Project.

Colorado River Land Use Activity

Fish and Wildlife

On the Colorado River Reservation are six sloughs having approximately 150 acres of water surfaces now providing fisheries which receive considerable use. In addition there is a commercial fish farm containing 408 acres, which derives its water supply by pumping directly from the Colorado River. The total surface area of these fisheries is 558 acres, which is in addition to the fishery provided by the Colorado River itself.

Municipal and Industrial.

Present uses of water for municipal and industrial purposes on the Colorado River are approximately 1,400 acre-feet per year. This is exclusive of the city of Parker, and the population adjacent to the reservation. It includes the use of water at Government administered buildings and grounds. Use of water for municipal and industrial purposes at the other mainstream reservations is minor, the greatest being 100 acre-feet at Fort Yuma.

Lower Colorado River Tributary Areas

Water Use

Irrigation

Present use of water for irrigation is made on 18 reservations on tributaries of the lower Colorado River. These reservations and their uses of water are shown in the accompanying tabulation entitled: "Present Water Supply and Uses on Indian Reservations".

Southern California

Water Use

Southern California Indian areas may be divided into two groups, those in the inland basin and those in the coastal region. In the inland basin are six reservations. In the coastal area are nine reservations. Their use of water is shown in the tabulation entitled "Present Water Supplies and Uses on Indian Reservations".

FUTURE WATER DEMANDS AND SUPPLIES

Water Demands

The future demand for water on Indian Reservations along the mainstream will be principally for agricultural purposes. The principal future water needs on Indian Reservations along the mainstream will be for full development of 136,636 acres of irrigated lands. Accompanying this expansion will be a moderate expansion of municipal, industrial, and recreational needs.

On the reservations on tributaries, the future needs will include municipal and industrial uses as the urban areas of Phoenix and Tucson expand to reservation areas. Agricultural use of water principally will be for augmenting existing supplies, or replacement of water now being pumped from wells. Use of water for recreational purposes is important economically but the quantities of water involved are relatively small.

The tabulations entitled "Future Water Demands and Supplies on Indian Reservations - Phase I, Immediate Action Program, Phase II, Long Range Program", show the need at each reservation.

Possibilities for Augmentation of Future Supplies from Present Sources

Conservation of Available Water

Principal possibilities of conservation of water on Indian Reservations are from the elimination of phreatophytes along the mainstream reservations and on the San Carlos Reservoir area on the San Carlos Reservation; the capture of flood flows on the Papago Reservation now wasted before reaching irrigation projects; and by lining of canals and ditches on all reservations. Improved farm practices can be applied on reservations, as elsewhere. Very probably the effects of urbanization will be noted on the Salt River Reservation in the near future. The irrigated area on this reservation is only a part of the area available for urbanization and while there may be a net savings of water on the irrigation tracts, a substantial amount of additional water will be required in the process of urbanization.

Improvement of Watershed Yields.

The Bureau of Indian Affairs has shown that grazing values may be increased by proper long range watershed treatment, and that accompanying the treatment there probably will be an increase in water yield. The increase in grazing values has definitely been demonstrated, but increase in water yields is more difficult to determine. Investigations by the U. S. Forest Service and Soil Conservation Service at several experimental stations have indicated that water yields will be increased when undesirable brush and timber is replaced by grass.

FUTURE WATER DEMANDS AND SUPPLIES ON INDIAN RESERVATIONS

PHASE I, IMMEDIATE ACTION PROGRAM

(Uses Prior to 1990 - Excluding Present Uses)

RESERVATION	IRRIGATION (Additional)			MUNICIPAL & INDUSTRIAL		RECREATION, FISH & WILDLIFE		LIVESTOCK		TOTAL
	Source	Acres	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Acre-Feet
MAINSTREAM										
Arizona										
Cocopah	Colo.River	131	826	Wells	18	-	-	Colo.River	Minor	844
Colorado River	" "	64,314	212,400	Colo.R.& Wells	10,800	Colo.R.& Wells	-	" "	-	223,200
Fort Mohave	" "	14,916	95,462	" " "	954	" " " "	-	" "	-	96,416
Subtotal		79,361	308,688		11,772					320,460
California										
Chemehuevi	Colo.River	1,900	11,227	Colo.River	113	-	-	Colo.River	-	11,340
Colorado River	" "	8,213	54,204	" "	542	Colo.River	-	Colo.River	-	54,746
Fort Mohave	" "	2,119	13,562	" "	136	" "	-	" "	-	13,698
Yuma	" "		(Drainage)	City & Wells	230	" "	-	" "	-	230
Subtotal		12,232	78,993		1,021					80,014
Nevada										
Fort Mohave	Colo.River	1,939	12,410	Colo.River	124	Colo.River	-	Colo.River	-	12,534
TOTAL - Mainstream		93,532	400,091		12,917					413,008
TRIBUTARIES										
Arizona										
Ak Chin	Wells & Co.R.	-	17,000	Wells	20	-	-	Wells	-	17,020
Camp Verde	Verde Riv.	-	-	Wells	30	-	-	Verde Riv.	-	30
Fort Apache	White Riv.	3,200	19,490	Streams	1,650	Lakes	2,030	Ponds	190	23,360
Fort McDowell	Verde River	-	4,440	Wells	30	Verde River	-	Verde Riv.	-	4,470
Gila Bend	Wells	-	1,600	Wells	30	-	-	Wells	-	1,630
Gila River *	Wells & Colo.R.	-	37,340	Wells	2,750	-	-	Wells	-	40,090
Havasupai	Havasu Cr.	29	310	Havasu Cr.	30	Havasu Cr.	-	Havasu Cr.	-	340
Hopi	Misc.Washes	-	2,780	Wells	280	Lakes	1,800	Ponds	200	5,060
Hualapai	Misc.	-	230	Peach Springs & Colo.Riv.	450	Colo.River	-	Wells & Ponds	1,620	2,300
Kaibab	Springs & Washes	-	280	Springs	-	Springs	-	Ponds & Spr.	-	280
Navajo	Little Colo.& Trib.	-	-	Wells & Springs	-	Lakes	20,000	Wells & Ponds	-	20,000
Papago	Wells & Colo.R.	12,000	64,680	Wells	380	Ponds	680	Wells & Ponds	2,580	68,320
Salt River	Salt R. & Wells	Urbanization		Phx.& Mesa Sys. & Wells	8,350	Salt River	-	Wells & Salt R	-	8,350
San Carlos Reserv.	Gila & San C.Ri.	3,400	25,220	Wells	10,520	Lakes	3,300	Ponds	2,760	41,800
San Car.Irr.Proj.	Colo.R. & Wells	-	338,540**	-	-	-	-	-	-	338,540
San Xavier	Wells	2,225	9,460	Wells	6,940	-	-	Wells & Ponds	-	16,400
Yavapai (Prescott)	-	-	-	Prescott Sys.	-	-	-	-	-	
Subtotal		20,854	521,370		31,460		27,810		7,350	587,990
New Mexico										
Navajo	Lit.Co.Ri.& Tri.	-	-	-	-	Lakes	5,000	Wells & Ponds	-	5,000
Zuni	" " " "	-	-	-	-	-	-	-	-	-
Subtotal		-	-	-	-		5,000		-	5,000
Nevada										
Moapa	Muddy River	20	660	Muddy River	10	-	-	-	-	670
TOTAL - Tributaries	All States	20,874	522,030		31,470		32,810		7,350	593,660

* Excluding San Carlos Project. ** Based on decreed diversion right of 6 acre-feet per acre.

FUTURE WATER DEMANDS AND SUPPLIES ON INDIAN RESERVATIONS

PHASE I, IMMEDIATE ACTION PROGRAM

(Uses Prior to 1990 - Excluding Present Uses)

RESERVATION	IRRIGATION (Additional)			MUNICIPAL & INDUSTRIAL		RECREATION, FISH & WILDLIFE		LIVESTOCK		TOTAL
	Source	Acres	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Acre-Feet
INLAND BASIN										
California										
Agua Caliente-Palm Springs	-	-	-	Not Determined	41,776	-	-	-	-	41,776
Augustine	Colorado River	-	2,942	Colorado River	30	-	-	-	-	2,972
Cabezon	Colorado River	-	7,788	Colorado River	77	-	-	-	-	7,865
Mission Creek	-	-	-	-	-	-	-	-	-	-
Morongo	-	-	-	Not Determined	1,500	-	-	-	-	1,500
Torres-Martinez	Colorado River	-	35,130	Colorado River	350	-	-	-	-	35,480
Subtotal			45,860		43,733					89,593
COASTAL										
Southern California										
Barona	Not Determined	700	3,000	Not Determined	810	-	-	-	-	3,810
La Jolla	" "	116	810	" "	300	-	-	-	-	1,110
Pala	" "	-	1,680	" "	200	-	-	-	-	1,880
Pauma - Yuima	-	-	-	" "	76	-	-	-	-	76
Pechanga	-	-	-	-	-	-	-	-	-	-
Rincon	Not Determined	-	2,700	Not Determined	1,000	-	-	-	-	3,700
San Manuel	-	-	-	-	-	-	-	-	-	-
Soboba	Not Determined	1,856	9,280	Not Determined	8,940	-	-	-	-	18,220
Viejas	" "	500	2,000	" "	800	-	-	-	-	2,800
Subtotal		3,172	19,470		12,126					31,596
TOTAL - ALL RESERVATIONS		117,578	987,451		100,246		32,810		7,350	1,127,857

FUTURE WATER DEMANDS AND SUPPLIES ON INDIAN RESERVATIONS

PHASE II, LONG RANGE PROGRAM
(Additional Uses After 1990)

RESERVATION	IRRIGATION (Additional)			MUNICIPAL & INDUSTRIAL		RECREATION, FISH & WILDLIFE		LIVESTOCK		TOTAL
	Source	Acres	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Acre-Feet
MAINSTREAM										
Arizona										
Cocopah	-	-	-	-	-	-	-	-	-	-
Colorado River	-	-	-	-	-	-	-	-	-	-
Fort Mohave	-	-	-	-	-	-	-	Colo.River	Minor	-
California										
Chemehuevi	-	-	-	-	-	-	-	-	-	-
Colorado River	-	-	-	-	-	-	-	-	-	-
Fort Mohave	-	-	-	-	-	-	-	-	-	-
Yuma	-	-	-	City & Wells	330	-	-	-	-	330
Subtotal					330					330
Nevada										
Fort Mohave	-	-	-	-	-	-	-	-	-	-
TOTAL-MAINSTREAM					330					330
TRIBUTARIES										
Arizona										
Ak Chin	Wells & Col.Ri.	1,812	8,810	Wells	40	-	-	-	-	8,850
Camp Verde	-	-	-	Wells	50	-	-	-	-	50
Fort Apache	White River	1,129	5,650	Streams	14,000	-	-	Ponds	380	20,030
Fort McDowell	-	-	-	Wells	2,120	-	-	Verde River	-	2,120
Gila Bend	-	-	-	Wells	40	-	-	-	-	40
Gila River *	-	-	-	Wells & Col.R.	73,800	-	-	-	-	73,800
Havasupai	-	-	-	Havasu Cr.	100	-	-	-	-	100
Hopi	-	-	-	Wells	1,530	-	-	Ponds	520	2,050
Hualapai	-	-	-	Peach Sp.& Co.R.	100	Colo.River	**	Wells & Ponds	-	100
Kaibab	-	-	-	Springs	10	Springs & Lakes	450	Ponds & Springs	200	660
Navajo	Lit.Col.R.& Trib.	1,609	9,830	Str.,Spr.& Wells	83,280	Lakes	25,000	-	-	118,110
Papago	-	-	-	Wells	250	-	-	-	-	250
Salt River	-	Urbanization		Wells & Colo.Riv.	10,000 ***	Salt River	-	-	-	10,000
San Carlos Res.	-	-	-	Wells	10,500	Lakes	18,000	-	-	28,500
San Car.Irr.Proj.	-	-	-	-	-	-	-	-	-	-
San Xavier	-	-	-	Wells & Col.Riv.	6,000	-	-	-	-	6,000
Yavapai (Prescott)	-	-	-	Prescott Sys.	20	-	-	-	-	20
Subtotal		4,550	24,290		201,840		43,450		1,100	270,680
New Mexico										
Navajo	Lit.Col.R.& Tr.	654	3,959	Str.,Spr.& Wells	373	-	-	-	-	4,332
Zuni	" " " "	818	2,680	Wells	802	Lakes	833	-	-	4,315
Subtotal		1,475	6,639		1,175		833			8,647
Nevada										
Moapa	-	-	-	Muddy River	20	-	-	-	-	20
TOTAL - Tributaries	All States	6,022	30,929		203,035		44,283		1,100	279,347

*Excluding San Carlos Project.
**Consumptive Use on Streams Not Included.
***Municipal and Industrial, minus Irrigation.

FUTURE WATER DEMANDS AND SUPPLIES ON INDIAN RESERVATIONS

PHASE II, LONG RANGE PROGRAM
(Additional Uses After 1990)

RESERVATION	IRRIGATION (Additional)			MUNICIPAL & INDUSTRIAL		RECREATION, FISH & WILDLIFE		LIVESTOCK		TOTAL
	Source	Acres	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Source	Acre-Feet	Acre-Feet
INLAND BASIN										
California										
Agua Caliente - Palm Springs	-	-	-	-	-	-	-	-	-	-
Augustine	-	-	-	-	-	-	-	-	-	-
Cabezon	-	-	-	-	-	-	-	-	-	-
Mission Creek	Not Determined	-	510	-	-	-	-	-	-	510
Morongo	" "	1,780	7,120	-	1,440	-	-	-	-	8,560
Torres-Martinez	-	-	-	-	-	-	-	-	-	-
Subtotal		1,780	7,630		1,440					9,070
COASTAL										
Southern California										
Barona	-	-	-	-	-	-	-	-	-	-
La Jolla	-	-	-	-	-	-	-	-	-	-
Pala	-	-	-	-	-	-	-	-	-	-
Pauma-Yuima	Not Determined	185	555	-	-	-	-	-	-	555
Pechanga	" "	1,640	4,920	-	-	-	-	-	-	4,920
Rincon	" "	162	810	-	-	-	-	-	-	810
San Manuel	-	-	-	-	-	-	-	-	-	-
Soboba	-	-	-	-	-	-	-	-	-	-
Viejas	-	-	-	-	-	-	-	-	-	-
Subtotal		1,987	6,285		-					6,285
TOTAL - ALL RESERVATIONS		9,789	44,844		204,805		44,283		1,100	295,032

THE PLAN OF DEVELOPMENT

Phase I - Immediate Action Programs.

Authorization of Construction.

Construction or completion of Lower Basin Indian Projects.

Planned for immediate authorization by Congress are the proposed Vaiva Vo Irrigation Project, a feature of the Santa Rosa Wash Multiple Purpose Project on the Papago Reservation, which has been planned by the Corps of Engineers and the Bureau of Indian Affairs; and the White River Irrigation Project on the Fort Apache Indian Reservation. Also planned is the completion of the Colorado River Project irrigation system, and rehabilitation and betterment of the San Carlos Reservation Irrigation systems. Improvement of drainage of Indian lands on the Yuma Project of the Bureau of Reclamation should be accomplished in the immediate future. A program of canal lining and other betterment works on all reservations will be undertaken as rapidly as funds can be secured. Urbanization of reservation areas near Phoenix and Tucson, development of recreational facilities, motels, resorts, etc., will require additional uses of water.

Watershed programs.

A Bureau of Indian Affairs' Range-Soil Survey crew is working on the Fort Apache Indian Reservation preparing a resources inventory on 1,664,872 acres of range land. This will provide a complete inventory which the Bureau will use to initiate management plans on the watersheds of the Fort Apache Indian Reservation. In addition, the removal of undesirable vegetation will go forward on all watersheds, at the rate of 35,000 acres per year. In support of the watershed programs it will be necessary to continue conservation practices which annually approximate the construction of 10 miles of dikes, 237 diversion dams in protecting approximately 129 miles of gully banks and stream beds. Approximately 12,000 acres will be seeded to improved grasses each year.

Recreation, cultural, and scientific programs.

Recreational projects using water are planned at the proposed Santa Rosa Wash Multiple Purpose Project on the Papago Reservation. This project has been planned by the Corps of Engineers and the Bureau of Indian Affairs, and the feasibility report is nearing completion. Expansion of recreational activities is proposed on the Fort Apache, San Carlos, Colorado River, Hopi, and Navajo Reservations. The water requirements for these recreational projects are shown on the table entitled "Future Water Demands and Supplies on Indian Reservations".

Authorization of Priority of Planning.

Arizona Projects.

Headgate Rock Power Plant.

When the Colorado River between Headgate Rock Dam and Palo Verde Dam is channelized an additional head can be made available to improve the economic feasibility of a power plant at Headgate Rock Dam. Preliminary estimates of costs and revenues indicate that a feasibility type study should be made. Power produced at this plant may be delivered into the adjacent transmission line belonging to the Bureau of Reclamation, and distributed as a part of the Lower Colorado River power generation.

Phase II - Long-Range Programs

Project Investigations

Water Supply.

Rehabilitation and Betterment of Existing Irrigation Projects.

All of the Indian irrigation projects are in need of rehabilitation and betterment of some type. These projects have been in existence for many years. Many structures have almost served their useful life; lining of canals and laterals is necessary; many well casings are old; and on some reservations proper protection against flood damage has not been provided.

The Bureau of Indian Affairs is preparing rehabilitation and betterment reports on the reservation irrigation systems as rapidly as available manpower can do it. As much of the rehabilitation and betterment work as possible will be done under the Immediate Action (Phase I) program. Any works not completed will be done under the Long Range (Phase II) program.

Ground-water projects.

Ground-water projects on Indian reservations in Central Arizona are facing the most serious prospect of depletion of ground-water reserves. This is especially true at the Ak Chin, Gila River, Papago, and San Xavier Reservations. The only opportunity for continuing these projects into the long-range future will be for importation of water from the Colorado River. There are approximately 46,500 acres of such lands, which require approximately 230,000 acre-feet of water.

Agency Programs.

Project investigations should be carried out for the Fort Mohave, and Chemehuevi Reservations on the mainstream of the Colorado River. Plans for these projects have not been completed, although their locations adjacent to the mainstream provide adequate water supply. Uses of water for municipal and industrial purposes on almost all of the reservations is known only in a general way. The exact determinations of future requirements should be investigated more thoroughly. It is known for certain that urban expansion on the Salt River Reservation is eminent, and prospects for industrial enterprises, motels and resorts, have been proposed and are being negotiated at the present time at a number of the reservations.

Specific Investigations.

Watershed Management and Improvement.

The 146,000 acre Corduroy Watershed on the Fort Apache Indian Reservation in Arizona was planned for initiation of treatment in 1955. Gaging stations were established and will remain until definite conclusions are reached regarding the effect of treatment on watershed discharge. Treatment was completed in 1959 including the following:

1. Juniper, pinon, manzanita removal - 34,646 acres.
2. Logging (pine) 201,852,000 Board Feet.
3. Prescribed burning (pine) - 17,880 acres.
4. Logging Oak - 250 cords.
5. Slash burning - 2,900 acres.
6. Grass seeding - 9,361 acres.
7. Roads and trails - 80 miles
8. Fence construction and repair - 30 miles.

Total cost - $271,128.

Data collected by U.S.G.S. following treatment has not been published. Studies are in progress on two controlled areas on the Fort Apache Indian Reservation by the U.S.G.S. One study is on the Cibicue Ridge watersheds which are composed of two small watersheds each with gaging stations and complete weather recording stations including canopy interception gages and measurement of soil moisture penetration. When collection of basic data is completed one watershed will be cleared and seeded to grass. No conclusive data has been released on this study.

The second small watershed study is also on the Fort Apache near Cedar Creek and is called the Apache Ponds. Two small, uniform watersheds were selected side by side and interception ponds built on each. Timber and brush were removed from one watershed in 1958. The cleared area was seeded to grass and is gaged each year. When the study has been completed there is little doubt that the cleared area will show a marked increase in runoff.

The 186,000 acre Cibicue watershed, also on the Fort Apache Reservation, is in the final year of treatment and will be under study for at least three years thereafter to determine effect of treatment on water yield. In the adjacent Carrizzo Creek watershed no treatment has been initiated and surface gauging is carefully recorded each year for comparison.

Water Salvage.

Phreatophyte control.

Tests were initiated this year by the U.S.G.S. on the Gila River bottoms west of Bylas, Arizona, above Coolidge Lake to determine consumptive use of water by phreatophytes, principally salt cedar, and on the San Carlos River where the study is conducted on mesquite and cottonwood. At the completion of the first three years of testing the areas will be cleared to provide the environment for determining results. Concurrently the University of Arizona and Bureau of Reclamation are cooperating with the Bureau of Indian Affairs and the San Carlos Tribe in working out the most successful method of phreatophyte eradication and grass species for replacement of the worthless vegetation.

Channel losses.

Channel losses as distinguished from use of water by phreatophytes growing adjacent to the channel, is not important on Indian Reservations, except at the Colorado River Reservation. There the width of the Colorado River is greater than necessary in some locations causing evaporation losses which might be reduced by channelization.

Recreation, Cultural and Scientific Programs.

In a program of channelization on the Colorado River Reservation, consideration should be given to placing the excavated material in such a manner as to provide beaches for recreational purposes. The Colorado River is an important recreational feature for Southern California and Arizona, and the addition of useable beaches would be of great advantage.

On the Fort Apache Reservation are important opportunities for additional recreational facilities, especially lakes for fishing, and potable water supplies at camp grounds and for the communities in the area. Without question communities on the reservation as well as off the reservation are going to expand greatly in the future and will need water. It is proposed that reservoir sites on the reservation be investigated with the viewpoint of utilization of the water for multiple purpose uses. Improvement of irrigation supplies for Indian lands along East Fork of White River, projects taking water from North Fork of White River, and from other streams on the reservation, would be of importance. These uses could be combined with recreational and fish and wildlife uses in multiple purpose projects.

APPENDIX 8

THE USE AND VALUE OF DESALTING PLANTS

Saline Water Conversion Plants are part of the Pacific Southwest project area at the present time, and will be a source of supply in the future. Attention is directed within the report to two plants now in operation and to the potential value of desalting plants in the development of water resources for the area. This Appendix provides more detailed information discussed in the following paragraphs:

CHAPTER III--PRESENT WATER SUPPLIES AND USES

Lower Colorado River Tributary Areas

Water Use
- Desalting, Buckeye, Arizona

Southern California

Water Use
- Desalting, San Diego, California
  - Principles of Operation
  - Recent Developments
  - Future Developments

CHPATER IV--FUTURE WATER DEMANDS AND SUPPLIES

Sources of Supply

- Desalting
- Cost of Energy
- Large Size Plant Cost Studies
- Prototype Plant
- Description of Water Conversion Plant
- Description of Power Generating Plant

OFFICE OF SALINE WATER

Charles F. MacGowan
Director

UNITED STATES DEPARTMENT OF INTERIOR

CHAPTER III--PRESENT WATER SUPPLIES AND USES

Lower Colorado River Tributary Areas

Water Use - Desalting

Buckeye, Arizona

The City of Buckeye, Arizona installed a 650,000 gallon per day desalting plant in 1962 to provide municipal water. The plant consists of three stacks of two stages each of 275 membrane pairs which we intended to reduce the feed water of 2060 ppm. The salt passing through the water mains which was formerly 14,000 pounds per day is reduced to 2720 pounds per day. The plant is monitored by three water level controls, five pH controls, three conductivity controls, two pressure controls, and one electric current control. The waste stream of 160,000 gallon per day contains 8300 ppm total dissolved solids, and joins the City effluent from the City's sewage treatment plant before being fed to the Arlington Canal River.

The cost of the water produced is about $0.33 per 1,000 gallons, with 11 mill per Kwh power, when operating at full load. The City water rates, however, have increased from $0.47 per 1000 gallons to $1.28 per 1000 gallons, becuase the plant operates on partial load most of the time. The $0.81 increase also includes other expenses incurred to assure a more adequate water supply for the City. The cost of the plant was $305,000.

The results obtained illustrate the costs that can be obtained by the use of an electrodialysis process plant with water low in those constituents that cause polarization of the membrane. The high water temperature 85°F also contributes to low cost water. The plant has been in operation since January 1962 and will be useful for evaluation of this process for special water containing chiefly salt.

Southern California

Water Use - Desalting

San Diego, California

The City of San Diego, State of California, and the United States Government have made agreements which resulted in the construction and operation of a modest size demonstration plant to develop the engineering, economic, and operating potential of the flash distillation process for desalting sea water. The cost of the construction contract was shared equally by the Office of Saline Water of the Department of the Interior and the Department of Water Resources of the State of California. The prime responsibility remained with the Office of Saline Water. The California Department of Water Resources performed valuable services by checking drawings and making field inspections. The City of San Diego provided the grading for the site, an improved road to the site, and installed a pumping plant and pipe line to convey the product water to a city reservoir.

The plant is the first large multi-stage flash in the United States and is among the largest in the world. It makes the most efficient use of fuel energy of any plant, and embodies a new concept of long tube evaporators which would be utilized in large size production plants.

The primary purpose of the plant is to demonstrate the technical and economic aspects of the distillation process for desalting sea water. In line with this purpose, the plant will continue to produce fresh water, as it has since March 1962, to establish engineering, reliability, and cost data for evaluation of the process.

A secondary and highly important purpose is to find ways of improving the process and to eliminate any technical difficulties that may develop. In line with this purpose there are design features that will extend the range of operating temperature which will provide a more efficient use of the fuel energy.

Operating under design conditions, the plant has consistently produced a million gallons of water per day having 10 to 15 parts per million (ppm) by weight of dissolved solids. It has 36 flash chambers or stages, and provides for recirculation of brine to supply the heat required for vaporizing the water, thereby economizing on the fuel energy required. The stages are contained in ten horizontal vessels, which were factory built and transported to the site as assembled units. They are connected together to form one continuous circuit of 36 stages, in series. Auxiliary equipment includes the boiler, pumps, piping, brine heater, instruments, and an operations building. The entire plant occupies a working space of approximately 1.5 acres.

Principles of Operation

The operation of the plant is pictured in the flow sheet of Figure 2. Sea water is brought into the plant at about four times the production rate and pumped through the condensers of the lowest temperature stages to accomplish the condensing of steam at low temperature. About 45% of the intake water is returned to the sea, while the rest is introduced to the degasifier where the oxygen, nitrogen, and some carbon dioxide are removed to the vacuum jet eductor. The sea water then combines with the brine stream which is continuously recirculating through the condenser tubes passing through each chamber or stage (zigzag line) of the 34th to 1st or highest temperature stage. Throughout this part of the circuit, the brine passes to the brine heater where the brine is heated 8 to 10°F before being released to the flash chambers. Heat for the brine heater is supplied by steam from the boiler. For better economy, the steam is first used to drive turbines throughout the plant.

From the brine heater, the brine passes to evaporation side of the first stage where a small portion flashes into vapor, and then in succession through the remaining stages back to the 36th stage. Each successive stage is maintained at a lower pressure than the preceeding one which results in approximately 0.3% of the brine flashing in each stage. This steam condenses into product water, giving up its heat of vaporization to the brine flowing inside the tubes. By this arrangement, about 90% of the heat required for boiling is recirculated and only 10% needs to be "new" heat added from the boiler. The plant actually produces at an economy ration of 10.5, that is, produces 10.5 pounds of water for each 1000 Btu of "new" heat added.

Brine is withdrawn continuously by the blowdown pump in an amount equal to the product steam in order to control the quantity of dissolved salts in the recycle steam.

The product water flows from stage to stage and is cooled by partial flushing and recondensing on the brine tubes above. The product water is withdrawn from the 36th stage by the product pump and delivered to the San Diego water supply system.

Recent Developments

The control of scale forming constituents in the brine was originally achieved by adding four ppm of additive compound, Hagevap, to the feed water. This was effective for temperatures up to 200°F. More recently, acid additive has been used to control the alkaline scale forming constituents. This method known as the "pH control method" releases all the carbon dioxide in the incoming water, which is then 95% or more removed in the degasifier.

Use of this method of scale control has permitted operation at temperatures up to 250°F without scale formation. This method reduces the quantity of fixed gases in the condensing zone so that greater output can be obtained for the same heat transfer surface. The plant output has actually been increased 40 per cent--to 1,400,000 gallons per day. Another advantage has been the elimination of caustic addition to adjust the pH of the product water or of the circulating stream.

For an optimized design the higher temperature operation will result in higher economy ratio. For the large plants the 250°F operation will optimize at 13.4 economy ratio, which makes a material reduction in steam requirements.

The cost of the "pH control method" of scale prevention is about the same as that for the chemical additive Hagevap.

Future Developments

Process improvements are currently under development that indicate the flash distillation can be adapted for use with brackish waters where high concentrations can be obtained for the blowdown waste. Pilot plant results have shown that the flash process can operate successfully with a calcium sulfate slurry of one percent which will prevent scale formation at temperatures up to 300°F. Economic studies show that operating temperatures as high as 350°F can be justified and success with the calcium sulfate slurry appears likely.

Success with high-temperature, high concentration operation can be assured by operating the multi-stage flash process in part as multi-effect. The use of three or four groups of stages or effects operating each at given concentrations will provide conditions to assure that the calcium sulfate will remain in suspension. Under these conditions, the blowdown may be brought to 16 to 18% total salts without deleterious effect upon the process. The high concentration would occur in the low temperature effect where the boiling point elevation, due to salt concentration, is minimized.

When working with sea water, the concentration factor would be about five and the volume of blowdown reduced to one quarter of that from the present operation of the San Diego plant. With brackish waters of about 3000 ppm total dissolved solids, the blowdown would be only one-twentieth of the product stream, thus minimizing the waste disposal problem.

The multi-effect, multi-stage flash process operating at temperatures up to 350°F would lend themselves to large energy savings. With fuel at $0.30 per million Btu, these plants would optimize at an economy ratio of 20 to 22 to one thus reducing the energy required to half of that required in the presently designed plants. It is expected that the advanced concept of multi-effect, multi-stage, high temperature, high concentration factor flash process will be developed on a million gallon per day scale at the San Diego plant by suitable modification to the equipment.

There are other variations of the distillation process under study such as the thin film evaporators, the use of drop wise condensation promotors, the vapor reheat technique, plate type heat exchangers, and plastic heat transfer films which may add incremental advantages to the distillation process. Additional improvements are anticipated from the research and development studies which are being conducted on an expanded and accelerated basis by the Office of Saline Water.

CHAPTER IV--FUTURE WATER DEMANDS AND SUPPLIES

New Sources of Supply

Summary

New sources of supply for future water demand for the Pacific Southwest Area must include consideration of desalting presently unuseable saline waters that are readily and abundantly available in the area. Because of energy considerations, two specific situations were considered for this study. The first of these is for three plants located in the Los Angeles area, each of which will produce 135,000 acre feet of high quality water per year (150,000,000 gpd). For this area, fuel cost for gas was based upon experience of 36 cents per million Btu. The cost of water from water plants of this size, combined with a 417 megawatt electric power generating station, would be about $105 per acre foot (32 cents per 1000 gal). The investment cost for this plant is estimated at $86,000,000 and for the power plant at $53,500,000, making a total of $139,500,000 for both.

In the San Diego area and other locations in the Pacific Southwest, coal offers a low cost source of energy. Using Four Corners Area coal, a base price of 23 cents per million Btu has been computed. The cost of water from a 150,000,000 gpd water plant combined with a 417 megawatt electric power generating station would be $90 per acre foot (28 cents per 1000 gal.). The investment cost for this plant is placed at $86,000,000 and for the power plant at $65,000,000, making a total of $151,000,000 for both.

Desalting

The desalting of water on a large scale is an entirely new approach as a source of supply. With good foresight, the Congress, in 1952, directed the Department of the Interior to sponsor a program of research and development in this field. The program has been conducted by the Office of Saline Water, and two processes have been developed to a degree that large size practical plants can be built based on design concepts that have been successfully demonstrated in small scale operating plants.

The first of these is the electrodialysis process, which is being utilized in two production plants - one at Buckeye, Arizona (city financed) and the other at Webster, South Dakota. Both are using incremental components of as large a size as can be manufactured. The former is designed to produce about 650,000 gpd at $0.33 per 1000 gallons from a water having chiefly salt (NaCl) as an impurity. The latter is producing about 250,000 gpd at about $0.95 per 1000 gallons on a water requiring extensive pretreatment of the brackish feed water.

There are few water supplies in which the saline content is chiefly salt, hence the opportunity of realizing costs from large electrodialysis plants of less than $0.50 per 1000 gallons ($160 per acre foot) is not very promising. The cost of water by this process from very large plants has been estimated at from $0.30 to $0.60 per 1000 gallons when handling brackish waters of 2000 to 3000 ppm total dissolved solids content. While this process may show promise after more development, it is not now recommended for very large plants.

The second of these is the distillation process, exemplified by the three demonstration plants located at San Diego, California; Freeport, Texas; and Roswell, New Mexico; using, respectively, the multistage flash evaporator, the multi-effect falling film evaporator, and the forced-circulation vapor-compression evaporator. The results obtained from these plants (all at a million gallons per day capacity) have been good, and the multistage flash process is presently only slightly superior to the other two.

The flash type distillation process has been most extensively studied, including design concepts for very large plants - up to 150 million gallons per day. The other two processes tend to optomize in plants of 5-10 million gallon per day size. Results show that the flash distillation process maximizes the use of equipment items that have been previously developed in large size for other purposes. In addition to this, the flash process can be readily adapted to use steam from a tapping turbine and thus in this combination is provided with a cheaper source of steam.

It is in combination with electric generation stations that two sizes of plants - 50,000,000 and 150,000,000 gallons per day - have been studied and the cost of water developed. Energy cost studies have been made by the Office of Oil and Gas, Office of Coal Research, and the Bureau of Mines.

Cost of Energy

Energy costs constitute about half of the total cost of producing water from the very large plants. The investment cost accounts for another third of the costs, while the operating and maintenance costs make up about one-sixth of the costs. When producing water from the combination of an electric power generating station and a sea water conversion plant, there are a number of ways the resulting costs can be distributed.

For this particular study, the basic guide has been that the electric power produced should cost the same as that from an unassociated plant having the same net electric output as the combined plant. The procedure adopted was to charge all energy costs to the power plant and derive the difference in electric generating costs for two hypothetical plants - one combined with a water plant and the other unassociated. Thus increased operating, investment and fuel costs are reflected in the difference in electric power costs from the two plants. The electric costs have been developed in Tables II and III for the unassociated and combined plants of 150,000,000 capacity, respectively. When using gas, the difference in electric cost is 2 mills per Kwh which, when credited with 40 MWH power, results in a fuel charge of $0.22 per million Btu, 60% of the cost of gas originally. When burning coal, the difference is 1.5 mills per KWH, with a net fuel charge of $0.16 per million Btu, which is 70% of the cost of coal originally.

Energy for the plants could be either of nuclear origin or any one of the three fossil fuels. A recent study by the Bechtel Corporation has indicated that the cost of energy from the former may be competitive with conventional fuel and will depend upon the progress being made in reducing costs from large plants. For this reason, it was decided to use fossil fuel costs and leave the choice of fuels for a later decision when nuclear fuel costs are more clearly defined.

Because of restrictions imposed by the City of Los Angeles to avoid smog formation, the use of natural gas for electric generation is required eight months of the year. Gas supplied to the Los Angeles area has increased in cost from 25 to 36 cents per million Btu in the six-years prior to 1961. Residual fuel oil cost has fluctuated considerably during this period and, more recently, has stabilized at about the same cost. For these reasons, a basic gas fuel cost of $0.36 per million Btu was adopted with standby provision for conversion to oil for the Los Angeles area.

For other sites in the Pacific Southwest, coal is a cheaper source of energy when supplied from the Four Corners Area (New Mexico, Arizona, Utah and Colorado) by pipeline. This coal at 10,500 Btu per pound heating value is available for about $2.80 per ton at the mine. The cost of transporting the coal, based upon past experience, should be less than 4 mills per ton-mile. The cost per million Btu of coal delivered to four sites has been calculated to be: Phoenix, arizona - 18.2 cents; Yuma, Arizona - 21 cents; San Diego, California - 23.4 cents, and Mecca, California - 21.9 cents; or an average cost of 21.1 cents per million Btu. The use of pipeline coal requires somewhat more energy than train-delivered coal, therefore the adjusted cost of coal used in this study was 23 cents per million Btu. (see Ref. 14).

Each 150,000,000 gallon per day plant requires coal at a rate of 2,860,000 ton per year of Four Corners Coal. The economical transportation of coal is based upon the delivery of 8 to 10 X 10^6 tons per year. This would mean that three water plants should be located in the same area so that the demand for coal would justify this means of transport.

Large Size Plant Cost Studies

Under contract with the Office of Saline Water, the Bechtel Corporation developed the distillation plant economics for 16 case studies that encompassed a range of design criteria. These were: inlet water temperatures of 65 and 85°F.; brine maximum temperature of 250 and 300°F.; and steam costs of 5, 15, 25, and 35 cents per million Btu, all for the 150,000,000 gallon per day capacity plant. In addition, a single cost study for 50,000,000 gallon per day plant was undertaken using 250°F. maximum temperature and 20 cent per million Btu for fuel.

Not all the above criteria were considered in this study; however, the results of the study showed the following:

1. The effect of combining power generation with water production is to reduce the cost of water about 20 percent.

2. The effect of increasing the scale of operation in combination plants from 50 to 150 million gallons per day is to reduce the cost of water about 25 percent.

3. The effect of reducing inlet water temperature from 85 to 65°F. is to reduce the cost of the water by about 3 percent with brine temperature at 250°F.

The sea water conversion plant selected for this study would be one combined with a thermal electric power plant. The 150,000,000 gallon per day water plant would be coupled with a 417 Mwh generator station (net for sale). The gross generating capacity would be about 500 Mwh, of which 40 Mwh would be used in the water plant. The 40 Mwh is not included in the 417 Mwh net capacity.

The investment cost of the water plant was determined to be $86,000,000, and the cost of the product was found to be 28 cents per 1000 gallons, or about $90.00 per acre-foot, as shown in Table I. Of this total cost, 10 cents results from capital costs, and 13 cents is the energy cost. These unit costs were derived for the coal-fired electric power plant which produces power for 7 mills per Kwh. An unassociated power plant would produce power at 5.5 mills per Kwh. The difference between these two net energy costs was used as the basis for the energy cost for the water plant. The derivation of the electric power cost is given in Tables II and III for the two power plants. The costs for the power are based upon private utility financing and upon Federal Power Commission data published in Technical Memorandum No. 1 and Supplement No. 1 of January 1962. The power plant for the combined plant is higher because of the larger boiler required to produce the extra steam. The unit costs as developed in Table III for the combined plant are based upon producing 457 mwh, but the final unit cost is based upon selling 417 Mwh.

These same tables show the cost of water from a 150,000,000 gallon per day water plant combined with a gas-fired thermal power plant. The cost of water from such a plant is 32 cents per 1000 gallon, or $105.00 per acre foot. The energy cost of 36 cents per million Btu for gas is considerably higher than the 23 cents per million Btu for coal; however, investment and operating costs are lower and bring the cost of water to nearly the same value.

NOTE: Capital and operating costs given above were obtained from a report by Burns and Roe, Engineers and Constructors of N.Y.C. entitled "Engineering Evaluation of Costs of Dual Purpose Conversion and Power Plants; (OSW contract No. 14-01-0001-336).

The capital required for the combined plant is $86,000,000 for the water plant, plus $65,000,000 for the coal-fired power plant, making a total of $151,000,000. The gas-fired power plant cost is placed at $53,500,000, making a total of $139,500,000 for the combined plant. A seaside acreage of about 160 acres with 1500 foot frontage on the sea would be suitable for the plant site.

Prototype Plants

Construction of very large size plants should be preceded by the construction of a prototype plants of lesser capacity but embodying the design concepts necessary for the large-size plant. As a part of this program, it is proposed to build a 50,000,000 gallon per day water plant combined with a 139 Mwh thermal electric power plant. The investment cost of such a combination would be $30,300,000 for the water plant and $28,000,000 for the coal-fired power plant, for a total of $58,300,000. The net cost of energy from such a combination would be 6 mills per Kwh (Table IV) and the cost of water 34 cents per 1000 gallon or $110 per acre foot (Table I).

A gas-fired power plant would cost $23,000,000, and the total cost for the combined plant would be $53,300,000. The net cost of energy from such a combination would be 7 mills per Kwh (Table IV) and the cost of the water 36 cents per 1000 gallon or $120 per acre foot (Table I). A seaside acreage of about 85 acres with 1200 foot frontage on the sea would be suitable for the plant site.

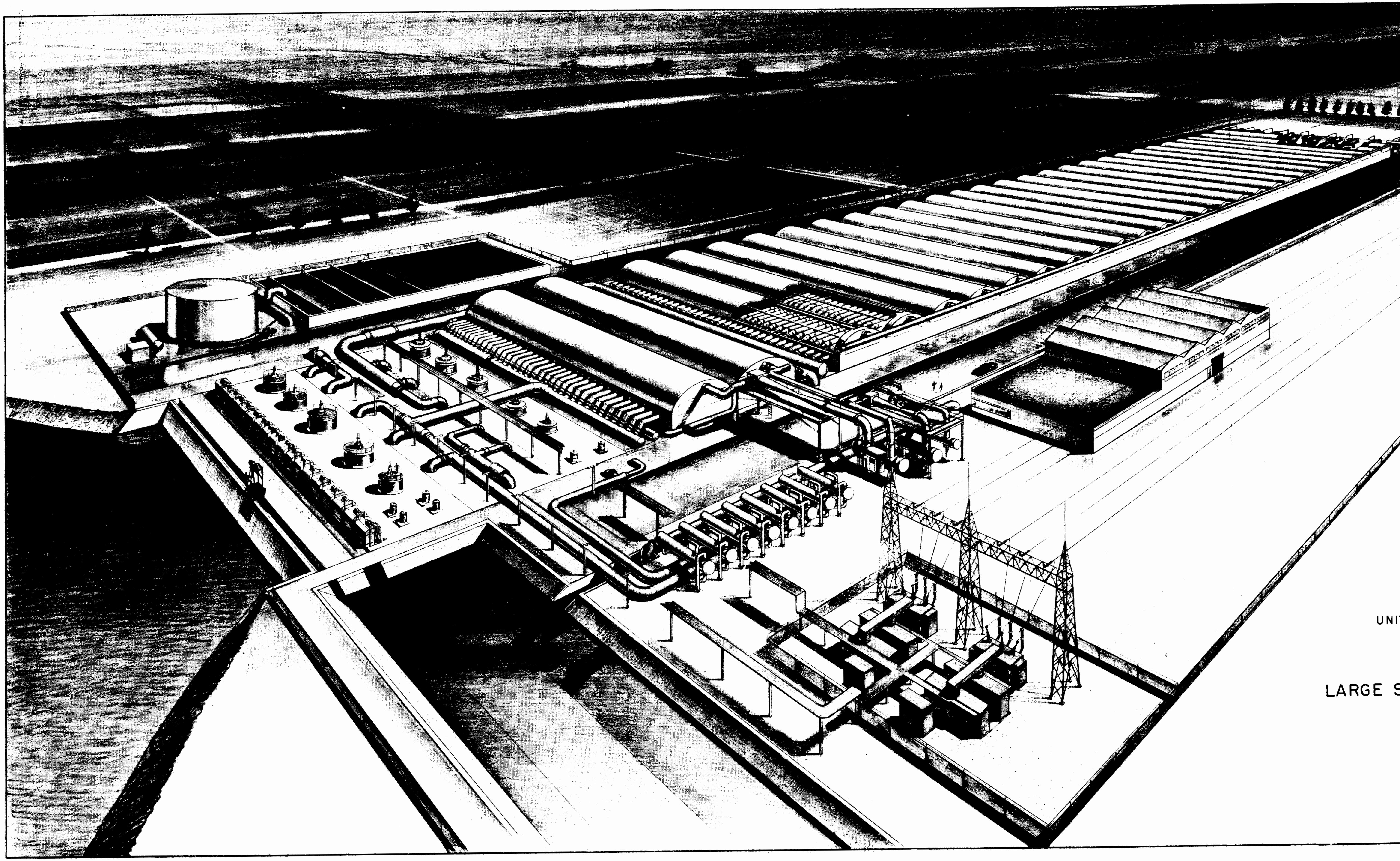
A pictorial presentation of a 150,000,000 gpd plant is shown in Figure 1. The perspective depicts in the left foreground the intake system with the stop log and associated trash rake, the line of 18 rotating screens, and the sluiceway for the discharge of trash into the disposal canal, followed by the concrete forebay and the intake, cooling water, and screen wash pumps. Next in line are the recycle, blowdown, and product pumps in front of the two heat rejection evaporator sections. The first of these incorporates an internal degasifier and the ejector system for removal of fixed gases. Following this are the 26 stages of evaporators and, last in line, the brine heaters.

The power generating plant is to the right, with two boiler units and two steam-driven generators. The exhaust steam from the steam turbines is used in the brine heaters to heat the circulating brine. In the center of the picture is the operations building, control room, and shops. Product coolers are shown next to the power substation. In the left background is the chlorine and sulfuric acid storage tanks and a carbon dioxide equalizing tank.

Description of Water Conversion Plant

Flow Description

The presumed site of this mutlistage flash vaporization plant is adjacent to a sea water channel so that intake water can flow directly into a forebay where trash is removed and the water is screened and chlorinated before entering the pumps. Net makeup water is acidified for scale prevention and then allowed to degasify in an atmospheric open



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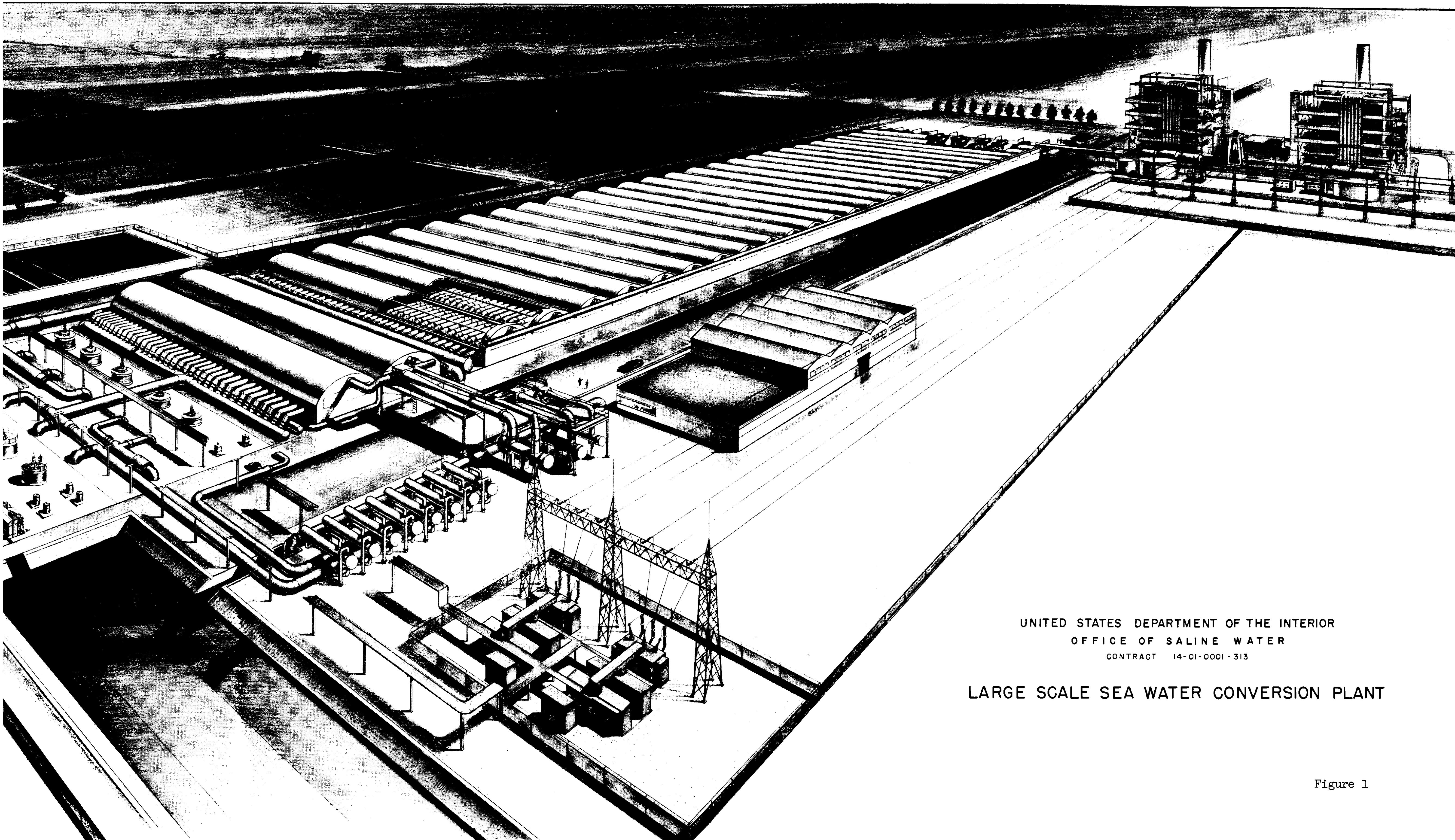

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OFFICE OF SALINE WATER
CONTRACT 14-01-0001-313

LARGE SCALE SEA WATER CONVERSION PLANT

Figure 1

tank before flowing through the condenser coils in the heat rejection stages. It is then deaerated and mixed with the recycle brine in the last heat rejection stage.

In order to save on pumping costs because of difference in pressure losses, sea water for heat rejection only is pumped through other condensers in the heat rejection stages and is finally discharged into an open channel to return it to the sea two miles away. Rejected brine from the flashing brine stream in the last stage and other cooling water streams are also discharged into this channel.

Recycled brine is pumped from the vacuum sump in the final stage and returned through the condensers in the heat recovery stages counterflow to the flashing brine.

After finally being heated to 250°F. in shell- and tube-type heat exchangers by means of 30 psig exhaust steam from the boiler plant, the hot recycle brine flows into the first stage of the evaporator to begin the series of flashings.

Accumulations of noncondensible gases are drawn from every sub-atmospheric stage through the steam jet ejector system. Pressure stages are vented to atmosphere.

Distilled water product is collected in an open stream within the evaporator. It also is arranged to flash from stage to stage as a means of recovering its sensible heat. It is finally pumped through sea water coolers for delivery to plot boundary at 90°F maximum and 25 psig.

Condensate from the brine heaters and steam jet ejectors is returned as boiler feed water.

Intake System

For the approximately three quarters of a million gallons per minute of sea water taken into the plant, a forebay entrance 300 feet wide is used. Gratings across the entrance collect trash and debris. Mechanical raking facilities collect the trash where it is lifted out and dumped into a sluiceway for discharging to the outlet canal. Travelling screens then collect finer material from the water flow. Water is pumped to backwash the screens into a collection trough which discharges into the sluiceway.

Chemical Treatment

A system of spargers is used to inject chlorine directly into the concrete forebay at frequent intervals to prevent biological growths. It is estimated that about 750 lbs. per day of chlorine is required for one hour's dosage per day.

Scale formation in the heated brine system is prevented by decomposing the carbonates with sulfuric acid. To minimize acid consumption, only the net makeup water is treated. Acid is injected into the pump discharge stream, and resulting pH is controlled so that alkalization is not required. 330 barrels of acid are used per day.

The acidified stream discharges over baffles for agitation into an open basin where the major part of CO_2 is released to atmosphere. The water flows by pressure differential into the deaerator.

Evaporator

The evaporator train will consist of 28 stages to obtain a high gain ratio of 13.4 pounds of product water per pound of steam used.

The concept of the proposed concrete evaporator structure design includes use of prestressed and pretensioned sections to permit use of thinner walls capable of withstanding the differential pressures to the atmosphere and between stages. Additionally, the use of stressed concrete will minimize cracking and leakage. Flexible seals embedded in the concrete at section joints provide for thermal expansion while preventing in-leakage of air.

Each stage has been established with a length of 40 ft. in the direction of flow. In order to provide adequate brine surface for release of vapors, the stages are 260 ft. wide. Brine flows across the floor at about 5 ft. per second and about 1-1/4 ft. deep. Distillate collected from troughs under each condenser bundle flows in a separate central channel along the floor. It increases in width through the stages.

The flowing streams take their pressure drops through "under flow" weirs in the barrier walls with orifices properly sized for each stage.

The last of the recycling stages has extra length to contain large piping manifolds. At this point, the heat rejection water leaves the condenser streams and recycle brine enters.

The concrete floor and portions of walls exposed to flowing water are lined with bonded neoprene materials as suited for the various temperature levels. Suppliers of the materials give assurance of good service life for the exposure conditions encountered.

The arched roofs of each stage are arranged in sections for removal in case condenser bundles are replaced. Rails in each valley carry a gentry crane which spans the arch and carries its load to either side of the evaporator. Access at each side permits a track crane to pick up the load from the gantry. The gantry can also be transferred from stage to stage.

Condensers

Condenser sections are provided as open tube bundles with fixed tube sheet and bolted channel at each end. The channels are essentially tapered transition pieces flanged to serve as connecting nozzles. The bundles are carried in structural steel members and are supported from the evaporator floor.

The tubes are 1 inch in diameter, 18 B. W. G., and of aluminum brass material. Each stage contains about 318,000 sq. ft.

With condensers connected end to end in parallel streams through the stages, the only internal piping is the short sections through each wall and the one area where the incoming recycle and outgoing heat reject waters are manifolded to the condenser rows.

Brine Heaters

Tubular surface for the brine heaters is divided into 9 units. This permits collection of brine from four condenser streams to each unit, and yet results in units of reasonable size.

Design comparable to standard steam surface condensers is used. Tubing is the same as in the condensers except for length, which is selected to give a proper balance between velocity and surface. The bundles are arranged for single pass flow. A sump in the bottom of each shell collects condensate for pumping and carries level controls.

Pumps and Drives

Principal pumping units for the water conversion plant are summarized on the attached Exhibit.

The large water pumps are all of the vertical, low speed type as used in hydroelectric and large pumped water storage installations. They are drivel directly with vertical synchronous motors. Multiple units permit reduced rate operation of the plant in care of unscheduled shutdown of a pump.

Two pumps of 127,000 gpm each are provided for supplying feed water to the plant. Two pumps of 216,000 gpm capacity each are provided for supplying heat reject water, and one pump of 120,000 gpm capacity takes care of miscellaneous cooling needs. A total of 806,000 gpm of water are required, of which 336,000 gpm are used for cooling purposes.

The pumps taking water from the vacuum sump adjacent to the deaerator stage are designed with a submerged impeller to provide NPSH for the second impeller. This arrangement is recommended by a manufacturer of these large pumps.

The other pumps listed are of conventional type for the respective services. Each brine heater carries its own condensate pump. If a pump, heater, or condenser section fails, only one of nine streams would then be shut down.

A substation is furnished to provide power and control equipment for the water pumps. Power for the substation is taken from the generator station switchyard at the primary voltage. Two three-winding transformers rated 30/40 MVA, OA/FA, 138,000 volts wye, 13,800 volts delta, 4,160 volts delta with ± 10% LTC on the primary furnish power to the motors. The recycle pump drivers are wound for 12,000 volts and controlled by air circuit breakers in a double ended switchgear rated 15KV, 250 MVA and fed from the 13.8 KV windings of the two transformers. The motors from 1500 to 4000 horsepower will be wound for 4000 volts and will be controlled by air circuit breakers in a double-ended switchgear rated 5KV, 250 MVA and fed from the 4.16 KV windings of the two transformers.

One circuit breaker in each half of the 5KV bus furnishes power to a 1000/1125 KVA OA/FA 4160 - 480 volt transformer to provide power to two 480 volt switchgear units. All motors 100 to 250 horsepower are controlled by air circuit breakers in this switchgear. One or more 440 volt motor control centers is installed as required to provide power and control for miscellaneous small motors, lighting, etc. in the water plant.

All 4000 volt and 12,000 volt drivers are synchronous motors. All 440 volt motors are NEMA design B induction motors. Enclosures for the synchronous motors are NEMA 2 weatherproof; enclosures for induction motors are dripproof. All switchgear are outdoor with protected aisles.

Description of Power Generation Plant

The power plant is a conventional gas-fired steam-electric unit except for the deletion of a surface condenser. Two identical units, each with a net generator output of 227 megawatts are provided. After allowing for losses in transformers, etc., station net output is estimated at 208.5 megawatts each.

The heat rate for the unit was taken as 14,000 Btu per KWH.

Four feed-water tanks,with a combined capacity of 14 million pounds of water, provide two hours of surge capacity at maximum load.

The following description covers one of the twin units. Total quantities should therefore be doubled to estimate tht total output of the combined plants.

The turbine is a two-stage unit with intermediate reheat of steam, and fluid-drive-coupled boiler feed water pump. An auxiliary, electrically-driven, feed water pump is provided for startup. Extraction steam is taken from five points on the two-stage turbine to provide feed water preheat.

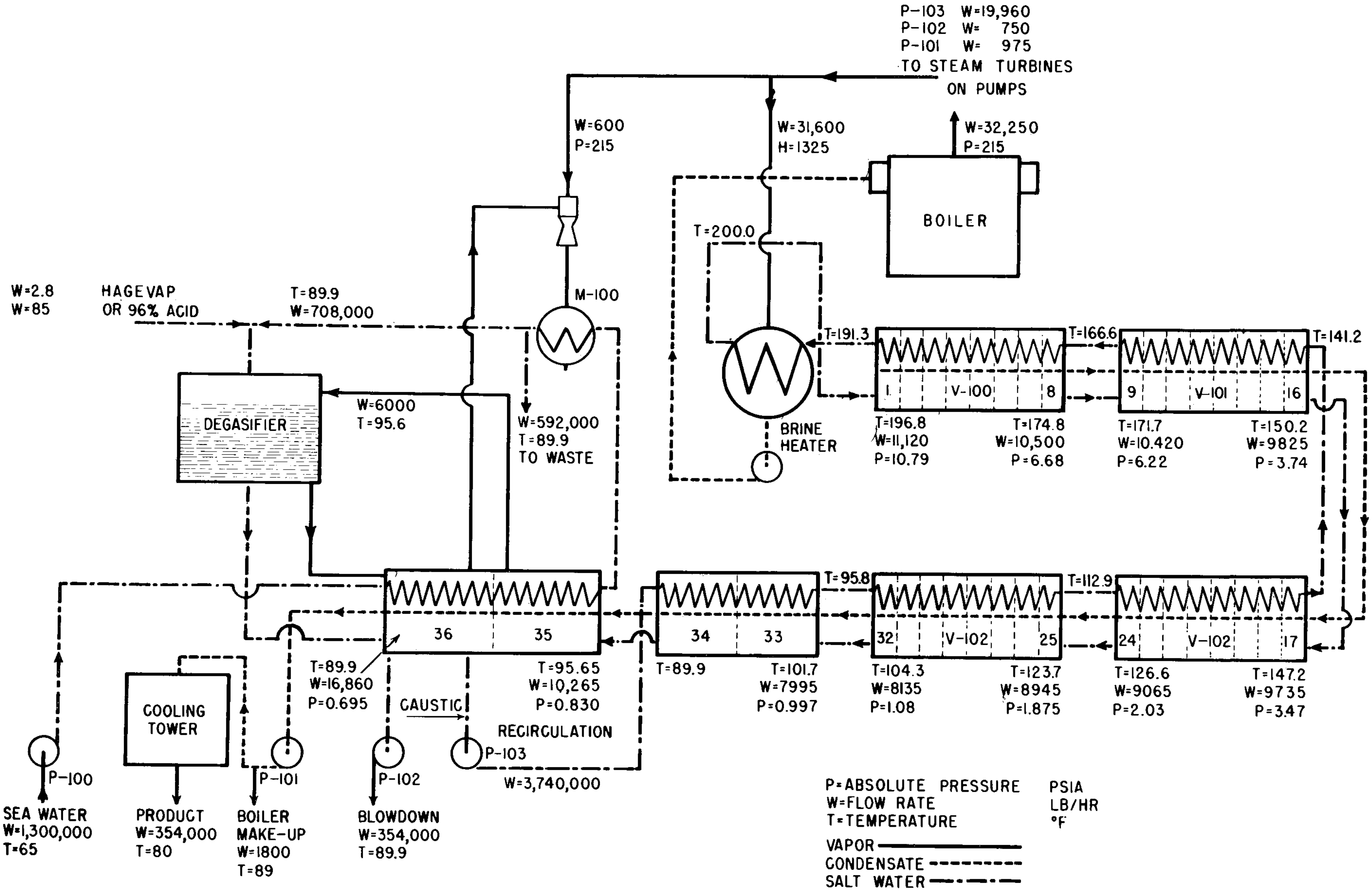
A conventional power plant supplies energy where primary steam is generated in the boiler from feed water preheated to 528F. The steam condition is 1050°F. at 2400 psig. It is expanded to 560 psia in the high pressure turbine, and returned to the boiler where it is reheated to 760°F., 530 psia. The reheated steam is then expanded in the second stage from where it flows to the brine heaters at 44 psia, saturated. The brine heaters and the condensate return pumps are described in more detail in the section on the water plant.

The two-stage turbines develop a gross output of 247 megawatts each. The boiler feed pump absorbs 9.3 megawatts, and the remaining auxiliaries an additional 7.2 megawatts. Generator losses are estimated at 3.5 megawatts, leaving a gross output of 227 megawatts (electrical).

Total station output is therefore 457 megawatts. After deducting 40 megawatts requirements in the water plant, the saleable power is 417 megawatts at full load. The net annual heat rate of 14,000 Btu/Kwh is required for the generating plant.

Steam to operate the ejectors at the water plant is extracted at 185 psia from the reheat turbine. Condensate from the ejectors at 90°F is first heated by extracted steam to 213°F., combined with brine heater condensate and deaerated. Makeup water from the feed water tanks is first demineralized and then deaerated. Normally, make-up from the water tanks is not required, since the ejector condensate should suffice to make up all losses.

Deaerated condensate is pumped up to 2815 psia and returned to the boiler via steam-heated feed water heaters.



U.S. DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
WASHINGTON, D.C.

R.H.J.

FIGURE 2. FLOW SHEET FOR FLASH DISTILLATION PLANT FOR 200°F OPERATION 36 STAGE

TABLE I (A)

COST OF WATER FROM
MULTI STAGE FLASH DISTILLATION PLANT
(7000 Hours'Operation per Year)

		150 Million Gallon per Day $/million gallon average output	$/acre-ft average output
		$86 x 10^6	
A. Investment Cost per 10^6 gallon		1,960.00	640.00
B. Annual Capacity Cost			
1. Fixed Charges			
a. Interest	3.0 %	58.80	19.15
b. Amortization	1.654	32.30	10.52
c. Interim Replacements	0.35	6.88	2.24
d. Insurance (in lieu of)	0.25	4.90	1.60
Total Fixed Charges	5.254%	102.88	33.51
2. Fixed Operating Costs			
a. Operation & Maintenance		9.06	2.96
b. Gen & Adm Exp. -25% of 2a		2.26	0.74
Total Fixed Operating Costs		11.32	3.70
Total Annual Costs B(1)+ B(2)		114.20	37.21
C. Variable Operating Costs			
1. Energy - Coal		130.00	42.40
- Gas		170.00	55.45
2. Operation & Maintenance		4.89	1.59
3. Chemicals (3,988/150)		25.90	8.45
Total Variable Operating Costs-Coal		160.79	52.44
-Gas		200.79	65.49
Total Costs (Coal)		274.99	89.65
D. Total Cost per Net 1000 gal (Coal)		0.275	
Total Cost per Acre-ft 326 x .275			89.60
Total Costs (Gas)		314.99	102.70
E. Total Cost per Net 1000 gal (Gas)		0.315	
Total Cost per Acre-ft 326 x .315			102.70

NOTES:

(1) Water Plants only federal financing
(2) Coal cost at 22.9 cents per million Btu
(3) Gas cost at 36 cents per million Btu
(4) Energy charge based on difference in cost between combined and unassociated power plants, i.e. (6.98-5.43= 1.55 mills for coal) and (8.41-6.37= 2.04 mills for gas). See Tables II and III.
(5) 326,000 gallon= one acre-ft

TABLE I (B)

COST OF WATER FROM
MULTI STAGE FLASH DISTILLATION PLANT
(7000 Hours' Operation per Year)

		50 Million Gallon per Day	
		$/million gallon average output	$/acre-ft average output
			$\$30.3 \times 10^6$
A. Investment Cost per 10^6 gallon		2,075,00	676.00
B. Annual Capacity Cost			
1. Fixed Charges			
a. Interest	3.0 %	62.20	20.25
b. Amortization	1.654	34.30	11.18
c. Interim Replacements	0.35	7.15	2.33
d. Insurance (in lieu of)	0.25	5.19	1.69
Total Fixed Charges	5.254%	108.84	35.45
2. Fixed Operating Costs			
a. Operation & Maintenance		18.90	6.15
b. Gen & Adm Exp - 25% of 2a		4.73	1.54
Total Fixed Operating Costs		23.63	7.69
Total Annual Costs B(1) + B(2)		132.47	43.19
C. Variable Operating Costs			
1. Energy - Coal		170.20	55.50
- Gas		194.50	63.40
2. Operation & Maintenance		10.20	3.32
3. Chemicals (3,988/150)		26.62	8.68
Total Variable Operating Costs-Coal		207.02	67.40
-Gas		231.32	75.30
Total Costs (Coal)		339.49	110.59
D. Total Cost per Net 1000 gal (Coal)		0.339	
Total Cost per acre-ft	326 x .275		110.60
Total Costs (Gas)		363.79	118.49
E. Total Cost per Net 1000 gal (Gas)		0.364	
Total Cost per acre-ft	326 x .315		118.50

NOTES:
(1) Water Plants only federal financing
(2) Coal cost at 22.9 cents per million Btu
(3) Gas cost at 36 cents per million Btu
(4) Energy charge based on difference in cost between combined and unassociated power plants, i.e. (6.98 -5.43 = 1.55 mills for coal) and (8.41 -6.37 = 2.04 mills for gas). See Tables II and III.
(5) 326,000 gallon = one acre-ft

TABLE II

ELECTRIC POWER GENERATING COSTS, 150 mgpd
UNASSOCIATED PLANTS
(7000 Hours Operation per Year)

			COAL (1)	GAS (2)
	Gross Output Megawatt Hours		463	453
	Net Capacity Megawatt Hours		417	417
	Investment Cost		$60 x 10^6	$49.5 x 10^6
			$/NET KW	$/NET KW
A.	Investment Cost			
	Plant (Excluding Substation)		$144.00	$118.70
B.	Annual Capacity Cost			
	1. Fixed Charges			
	a. Cost of Money	6.25%	9.00	7.42
	b. Depreciation (6.25% - 35 yrs)	0.71	1.02	0.84
	c. Interim Replacements	0.35	0.50	0.42
	d. Insurance	0.25	0.36	0.30
	e. Taxes	5.72	8.24	6.80
	Total Fixed Charges	13.28%	$19.12	$15.78
	2. Annual Cost on Fuel Stock Investment			
	13.1 million Btu	(Coal)	0.19	
	14 million Btu	(Gas)		0.32
	3. Fixed Operating Costs			
	a. Fuel - 6.73 x 10^6	(Coal)	1.54	
	5.75 x 10^6	(Gas)		2.07
	b. Operation & Maintenance (65%)			
		(Coal)	1.87	
		(Gas)		1.49
	c. Gen. & Adm. Expense(25%-3b)		0.47	0.37
	Total Fixed Operating Costs		3.88	3.93
	Total Annual Costs per KWH		$23.19	$20.03
			Mills/KWH	Mills/KWH
	Total Fixed Costs in Mills/Net Kw		3.31	2.86
C.	Energy Cost - Variable Operating Costs			
	1. Energy Fuel (9,600 - 960) Btu/KWH		1.98	
	(10,250 - 820) Btu/KWH			3.39
	2. Operation & Maintenance		0.14	0.12
	Total Variable Operating Cost		2.12	3.51
D.	Total Cost per Mills per KWH		5.43	6.37

Capital Costs Based Upon Private Utilities Costs
(1) Coal at 22.9 cents per million Btu
(2) Gas at 36 cents per million Btu

TABLE III

ELECTRIC POWER GENERATING COSTS
COMBINED WITH WATER CONVERSION PLANTS, 150 mgpd
(7000 Hours' Operation per Year)

			COAL (2)	GAS (3)
	Gross Output MWH		503	493
	Net Capacity from Power MWH (1)		417	417
	Investment Cost		$\$65 \times 10^6$	$\$53 \times 10^6$
			$/Net Kw	$/Net Kw
A.	Investment Cost			
	Plant (Excluding Substation)		$155.00	$128.00
B.	Annual Capacity Cost			
	1. Fixed Charges			
	a. Cost of Money	6.25%	9.75	8.00
	b. Depreciation (6.25% 35 yrs)	0.71	1.10	0.91
	c. Replacements	0.35	0.55	0.45
	d. Insurance	0.25	0.39	0.39
	e. Taxes	5.72	8.90	7.33
	Total Fixed Charges		$20.69	$17.08
	1A Annual Cost on Fuel Stock Investment		0.46	0.72
	2. Fixed Operating Costs			
	a. Fuel 9,800,000 Btu		2.24	2.82
	b. Operation & Maintenance 65%		2.08	1.64
	c. Admin & General Expense (25%-3b)		0.52	0.41
	Total Fixed Operating Costs		$ 4.84	$ 4.87
	Total Annual Costs per KWH		$25.99	$22.67
			Mills/KWH	Mills/KWH
	Total Fixed Costs in Mills/Net Kw		3.72	3.25
C.	Energy Cost-Variable Operating Cost			
	1. Energy Fuel (14,000 - 1400) Btu/KWH @ 0.228 per million Btu		3.01	4.96
	2. Operation & Maintenance 35%		0.25	0.20
	Total Variable Operating Cost		3.26	5.16
D.	Total Cost per Net Kilowatt-hour, Mills		6.98	8.41
E.	Difference in Cost Combined - Unassociated (Mills/KWH)		1.56	2.03

(1) 40 MWH generated in addition used in Water Plant.
(2) Coal at 22.9 cents per million Btu.
(3) Gas at 36 cents per million Btu.
(4) Variable operating costs are based upon 457 MWH.

TABLE IV

ELECTRIC POWER GENERATING COSTS, 50 mgpd
UNASSOCIATED PLANT
(7000 Hours' Operation per Year)

			COAL (2)	GAS (3)
	Gross Output MWH		153	153
	Net Capacity from Power MWH		139	139
	Investment Cost		20.5×10^6	17×10^6
			$/Net Kw	$/Net Kw
A.	Investment Cost		$147.50	$126.50
B.	Annual Capacity Cost			
	1. Fixed Charges			
	a. Cost of Money	6.25%	9.21	7.91
	b. Depreciation	0.71	1.05	0.90
	c. Interim Replacement	0.35	0.52	0.44
	d. Insurance	0.25	0.37	0.32
	e. Taxes	5.72	8.44	7.25
	Total Fixed Charges		$19.59	$16.82
	2. Annual Cost on Fuel Stock Investment			
	14 million Btu @ 36¢ X 6.25%			0.32
	13.1 Million Btu @ 22.9 x 6.25%		0.19	
	3. Fixed Operating Costs			
	a. Fuel - 5.75×10^6 Btu @ 36¢/10^6			2.07
	6.73×10^6 Btu @ 22.9¢/10^6		1.54	
	b. Operation & Maintenance		3.06	2.51
	c. G & A - 25% of 2b		0.79	0.63
	Total Fixed Operating Costs		5.39	5.21
	Total Annual Costs B(1)+B(2)+B(3)		$25.17	$22.35
			Mills/Kwh	Mills/Kwh
	Total Fixed Costs in Mills/Net Kw		3.59	3.19
C.	Energy Cost-Variable Operating Costs			
	1. Energy Fuel (10,250 - 820) Btu/Kwh			3.39
	(9,600 - 960) Btu/Kwh		1.98	
	2. Operation & Maintenance		0.24	0.19
	Total Variable Costs		2.22	3.58
D.	Total Cost per Net Kilowatt-Hour, Mills		5.81	6.77

(1) Capitol Costs based upon private utility
(2) Coal at 22.9 cents per million Btu
(3) Gas at 36 cents per million Btu

TABLE V

ELECTRIC POWER GENERATING COSTS, 50 mgpd
COMBINED WITH WATER CONVERSION PLANTS

			COAL (2)	GAS (3)
	Gross Output		170	167
	Net Capacity		139	139
	Investment Cost (1)		$28 x 10^6	$23 x 10^6
			$/Net Kw	$/Net Kw
A.	Investment Cost (1)			
	Plant (Excluding Substation)		$183.00	$150.00
B.	Annual Capacity Cost			
	1. Fixed Charges			
	a. Cost of Money	6.25%	11.43	9.40
	b. Depreciation	0.71	1.30	1.07
	c. Interim Replacement	0.35	0.64	0.53
	d. Insurance	0.25	0.46	0.38
	e. Taxes	5.72	10.48	8.60
	Total Fixed Charges		$24.31	$19.98
	2. Annual Cost on Fuel Stock Investment 29.5 x 10^6 Btu		0.46	0.73
	3 Fixed Operating Costs			
	a. Fuel - 14,000 x 7000 x 10% x 22.9¢/10^6		2.46	
	14,000 x 7000 x 8% x 36¢ /10^6			3.10
	b. Operation & Maintenance 65%		3.22	2.64
	c. Admin. & General Expense 25% of 2b		0.81	0.66
	Total Fixed Operating Costs		6.49	6.40
	Total Annual Costs B(1)+B(2)+B(3)		$31.26	$27.11
			Mills/Kwh	Mills/Kwh
	Total Fixed Costs in Mills/Net Kw		4.46	3.88
C.	Energy Cost - Variable Operating Costs			
	1. Fuel (14,000 - 1400) Btu/Kwh		3.16	5.00
	2. Operation & Maintenance 35%		0.25	0.22
	Total Variable Costs		3 41	5.22
D.	Total Cost per Net Kilowatt-Hour, Mills		7.87	9.10
E.	Difference in Cost - Combined - Unassociated			
	(Mills/Kwh) (7.12 - 5.81) coal		2.06	
	(8.39 - 6.77) gas			2.33

(1) Power Plant Privately Financed
(2) Coal cost at 22.9 cents per million Btu
(3) Gas cost at 36 cents per million Btu

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CONTENTS

ILLUSTRATIONS

TABLES

SUMMARY

The Lower Colorado River Basin includes southeastern California, southern Nevada, southwestern New Mexico, southwestern Utah, and almost all of Arizona (see Geological Survey Appendix for map). As southern California is generally treated as a single market area, data from the following southern California counties were included in this brief study: Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, and Ventura.

Historically a mining area, the value of mineral production in 1962 was about $1.5 billion (fig. 2). Petroleum and copper are the major mineral products of the basin (tables 1 through 4).

Reserves of fossil fuels are more than adequate to meet foreseeable future power needs which appear to be increasing exponentially (fig. 5), as basin population increases linearly (fig. 1). In the Arizona area, coal will become the dominant source of energy; in southern California, nuclear generation will be the major source of energy (table 6).

Water consumption by the basin's mineral industry will increase from 130,000 acre-feet in 1960 to over 320,000 acre-feet by 2000 (fig. 3). Most of the water consumed will be for the processing of copper ore, crude petroleum, and nonmetallic minerals such as sand and gravel (table 4).

Employment in the Lower Colorado River Basin mineral industry, about 44,000 in 1960, will nearly double by 2000 (fig. 4).

The mineral industry of the Lower Basin States will benefit directly from the Lower Colorado River Project. Large quantities of electrical energy, over and above the hydroelectric power available, would be required to obtain and transport waters from various sources to the consumer. This will create a very substantial demand for coal and perhaps other fuels from Utah, New Mexico, and such additional sources as may be economic. Construction of project features--dams, hydroelectric plants, aqueducts--will require cement, sand and gravel, and other products of the mineral industries.

The Bureau of Mines specifically recommends that plans for the Lower Colorado River Project include, insofar as possible, provisions of adequate supplies of water of suitable quality for existing and potential mineral development. Achieving this objective is essential to the defensive strength and economic growth of the Nation.

INTRODUCTION

The Bureau of Mines has been asked by a special Departmental task force, appointed by Secretary of the Interior Stewart L. Udall, to make a preliminary analysis of the impact on mineral industries of a five-State regional plan that is being formulated to meet water requirements of the fast-growing Lower Colorado River Basin.

The need for a plan of water development arose from the Supreme Court decision on June 3 in the case of Arizona v. California, which decided basic issues of long standing and presented "to the people of the Pacific Southwest...their greatest conservation challenge...to meet the water needs of that region which is at once the driest and fastest growing in the United States."

In broad outline, the objectives of the plan being prepared for consideration by the affected States are to alleviate present water deficiencies and to meet future water demands without detriment to any area. Additional water for the immediate future, defined as the 17-year period to 1980, will be obtained from conservation of existing supplies through reclamation and other techniques , desalinization of saline waters, import from areas of surplus, or a combination of all three.

Personnel of newly formed Areas V and VI of the Bureau of Mines at Denver and San Francisco collaborated in the analysis of mineral industry statistics under the guidance of a Bureau representative on the Departmental task force in Washington, D. C. Mineral resource and industry considerations involving Arizona, New Mexico, and Utah were assigned to Area V at Denver; those involving California and Nevada were handled by Area VI at San Francisco, including coordination of the report.

Major subjects that the report discusses include the past mineral production in the Lower Colorado River Basin, current and long-range water requirements of the mineral industry, sources of energy for future power requirements, and applicable Bureau of Mines research efforts. Mineral examinations that the Bureau of Mines has made on proposed reservoir sites in the area are listed, together with those reservoir sites and aqueduct routes that should be examined in the future.

LOCATION AND PHYSICAL FEATURES

The Lower Colorado River Basin, comprising a major portion of the Pacific Southwest, is an area of geographic, topographic, geologic, and climatic extremes.

Although usually regarded as arid desert land, which much of it is, the area also contains high plateaus and mountainous regions that are heavily forested. Altitudes range from below sea level in the Imperial Valley and Salton Sea of California to 12,670 feet atop Humphrey's Peak, north of Flagstaff, Arizona.

Annual precipitation in Arizona, the central State in the Lower Colorado River Basin and the only one drained entirely by the Colorado and its tributaries, ranges from 4 inches in the desert southwest to as much as 30 inches in some mountainous areas. High temperature and low relative humidity are responsible in this area for the highest evaporation rates in the nation, rivaled only by the Rio Grande Basin in Texas.

Sharp contrasts are evident on all sides--lush irrigated croplands; parched and barren alkali flats; wide expanses of level or gently rolling desert blanketed with mesquite, sage, yucca, and cactus; awesome gorges dominated by the Grand Canyon of the Colorado; and verdant highlands that culminate in rugged peaks on which snowcaps are not uncommon.

The area includes parts of two regions of the Intermontane Highlands (ref. 10), the Colorado Plateau, which lies largely in Utah, Colorado, New Mexico, and Arizona, and the Basin and Range Region (Great Basin), which is chiefly in Nevada and Utah, but extends into southern California and Arizona where it merges into the Mexican Plateau. The Colorado Plateau consists actually of many plateaus separated by steep escarpments and deep canyons carved into sedimentary rock. In recent years, the Colorado Plateau has become notable for its production of uranium, petroleum, and natural gas. The Basin and Range region, which includes Death Valley and the Mohave desert, is characterized by numerous north-south mountain ridges; thick blankets of unconsolidated sediments usually occupy the depressions between ridges. A richly mineralized belt extends through central and southeastern Arizona, where most of the copper mines are situated.

MINERAL INDUSTRY

The following topics under the major heading "Mineral Industry" will present trends in value, water consumption, and number of employees of the mineral industry of the Lower Colorado River Basin. Past performance records of the industry have been studied for the ten-year period 1953 through 1962. The performance data for this period have been extrapolated to obtain an estimate of anticipated performance of the mineral industry of the basin for the year 1980 (see figures 1-5 and tables 1-7). The graphs (figures 1-5), although based upon the accurate data found in tables 1-7, are smoothed in an effort to predict long-range trends of the industry. Data referred to in the following discussion are from the figures and so do not always coincide with corresponding data in the tables.

Oil and gas and copper currently account for almost three-fourths of the total value of mineral commodities produced in the basin. In 1953 the total value of all mineral commodities was $1.17 billion. In the following ten years to 1962 mineral production increased 28 percent to $1.51 billion per year. The value will be $1.8 billion per year by 1980, based upon extrapolation of past production. Also in 1953 the mineral industry consumed 100,000 acre-feet of fresh water. Over the ten-year study period water consumption increased 40 percent. It is expected to reach 230,000 acre-feet by 1980. The number of persons employed by the mineral industry increased from 41,000 to 46,000 between 1955, the first year for which employment records were available, and 1962. The number of employees is expected to increase to 57,000 by 1980.

Nonferrous Metals

Production of nonferrous metals, over 90 percent of which are copper and associated metals from Arizona, accounts for about one-third of the total annual mineral value and water consumption in the basin. A continuing drop in the grade of copper ore mined will greatly increase the tonnage of ore processed and the quantity of water used in flotation of the ores.

The annual production value of nonferrous metals grew from $289 million to $480 million between 1953 and 1962. The value is expected to reach $600 million by 1980. Water consumption grew from 35,000 acre-feet per year to 41,000 per year during the same study period and is expected to be 50,000 acre-feet per year by 1980. Employment grew from 13,000 to 15,000 and is expected to be 18,000 by 1980.

Ferrous Metals

Ferrous metals, principally iron from California and molybdenum from Arizona, account for less than 2 percent of the total value and water consumption of the basin's mineral industry. Between 1953 and 1962 ferrous metals production grew in value from $16 million per year to $35 million; water consumption grew from 1,200 acre-feet per year to 2,100; and employment grew from 2,000 persons to 3,000. Partly due to anticipated increased iron ore exports to Japan, it is estimated that by 1980, value of annual production will be $50 million; water consumption, 4,000 acre-feet; and employment, 5,000 persons.

Nonmetallic Minerals

Nonmetallic minerals account for 20 percent of the total mineral production value and for 35 percent of the total water consumption by the Lower Colorado River Basin's mineral industry. Sand and gravel, stone, and cement make up about 65 percent of the nonmetallic minerals production. In the metropolitan areas of the basin, the anticipated population increase will result in a greater demand for water by nonmetallics, especially the sand and gravel industry.

From an annual production value of $140 million in 1953, nonmetallics rose 118 percent to $305 million by 1962. Annual production by 1980 is estimated to be $400 million. Annual water consumption was 30,000 acre-feet in 1953; 49,000 in 1962; and is estimated to reach 75,000 by 1980. The industry employed 8,000 persons in 1953; 10,000 in 1962; and may employ 15,000 by 1980.

Fuels

Fuels, consisting mostly of petroleum and natural gas products from California, account for over 40 percent of the total value of the basin's annual mineral production and for over 30 percent of the water consumption. Water is used in the petroleum industry primarily for cooling in refinery operations.

The value of fuels production was $723 million in 1953, $1 billion in 1957, and back to $700 million in 1962. However, in terms of a constant 1960-value dollar, fuels production in the basin declined about 17 percent between 1953 and 1962, as reflected in the curve on figure 2. During the same period water consumption by the industry increased steadily from 34,000 acre-feet per year to 48,000. Employment remained fairly constant at about 18,000 throughout the period.

The seeming paradox between the decline in production value as opposed to the rise in water consumption is explained by the fact that California's reserves are being depleted, thereby reducing production, while crude oil imports have increased, thereby increasing refinery operations and associated water consumption.

By 1980 the fuels industry of the basin is expected to have an annual production value of $750 million, annual water consumption of 100,000 acre-feet, and employment of 19,000 persons.

Reserves of fossil fuels in the basin and surrounding areas are more than adequate to meet foreseeable future demands.

Future Possibilities

Despite a current downward trend (in terms of 1960 dollars) the value of mineral production of the Lower Colorado River Basin will increase (fig. 2), as the Lower Colorado River Basin population increases. The downward trend is caused by a declining production of the southern California oil fields (an increasing percentage of California-refined crude oil is from foreign sources). This trend will be reversed as the immense reserves of southern California offshore oil come into production in the near future. The estimates depicted in figure 2 are very approximate and are merely offered to indicate the trend.

Many mineral resources, not now major factors in the Lower Colorado River Basin mineral industry, are found in large, but low-grade deposits in the basin area. Changing technology or price increases could encourage the utilization of these resources in the future. Thus it is possible that the predicted mineral production value (fig. 2), water consumption (fig. 3), and employment estimates (fig. 4), especially for the year 2000, are on the conservative side. The major commodities are discussed briefly below:

Anorthosite, used (from Wyoming) as an experimental source of aluminum during World War II, occurs in large exposures in the Los Angeles area. A combination of unavailability of foreign bauxite, increased aluminum consumption, and technologic breakthroughs, may effect the utilization of this resource.

Extensive seafloor phosphorite deposits, discovered off the coast of southern California, may soon become technologically feasible to mine for the California market.

Kern and San Bernardino Counties contain the largest gold mines in southern California. The Randsburg district, once exceptionally productive, could become an important gold producing area under favorable economic circumstances.

The Atolia district in San Bernardino County has been one of the two major sources of tungsten in California. Research, now being conducted on a worldwide basis for new applications and markets for tungsten, may boost the demand for this high-temperature metal.

Future continued development of heavy industry in the Lower Colorado River Basin may bring about utilization of the potentially great low-grade iron ore deposits throughout Arizona.

WATER CONSUMPTION BY THE MINERAL INDUSTRY

Water consumption by the mineral industry in the Lower Colorado River Basin will increase from approximately 130,000 acre-feet in 1960 to over 320,000 acre-feet by 2000 (fig. 3). Most of the water consumed will be for the processing of copper ore, crude petroleum, and nonmetallic minerals such as sand and gravel (table 4).

Consumption data represent a minimum as they include only that quantity of water lost by evaporation or by incorporation in a product (ref. 9). Recirculation of water notwithstanding, a given mining operation usually takes in considerably more new water (fresh water used for the first time in an operation) than it consumes. Most of the difference is lost by discharge into a stream or ground water or may be stored in a reservoir. While discharge into surface water may be available for immediate reuse, discharge into ground water may not be available for reuse until it has percolated to an area where it can be utilized. This can take many years. For this reason the mineral industry requires some quantity of water that is less than their total intake of new water but more than the total actual consumption. This relationship is not clearly defined.

Based upon the fact that the Arizona mineral industry as a whole takes in twice as much new water as it consumes (ref. 9), a total basin water intake estimate, ranging from 260,000 acre-feet in 1960 to 650,000 acre-feet in 2000, is shown on figure 3. This estimate assumes that the same relationship between new water intake and consumption exists in southern California and southern Nevada, a fact that has not yet been determined.

In southern California the major demand has been about equally divided between the petroleum and the nonmetallics industries (table 7). The main use for water in the petroleum industry is for cooling in refinery operations. This use will not increase as rapidly as refinery capacity because of emphasis on recirculation of fresh water and increased use of saline water wherever possible.

In Arizona most of the water required by the mineral industry is used in copper operations. A continuing drop in the grade of copper ores mined will greatly increase the tonnage of ore processed and the quantity of water used in flotation of the ores.

Water consumption by the mineral industry in southern Nevada is relatively minor (about 2,000 to 3,000 acre-feet in 1962). Nonmetallic minerals processing requires most of that. Those portions of New Mexico and Utah within the Lower Colorado River Basin have no significant mineral production.

In the metropolitan areas of the basin, the population increase will result in greater demand for water by the nonmetallic minerals industry, especially the sand and gravel industry.

POWER REQUIREMENTS AND SOURCES

Although the Lower Colorado River Basin's population will increase linearly (fig. 1), its power requirements will increase exponentially (fig. 5) as energy use per capita continues to grow. Electrical requirements will increase from about 44.3 billion kwh in 1960 to 171.5 billion kwh by 1980 (fig. 5 and table 5) and may exceed 700 billion kwh by 2000 (fig. 5).

Hydroelectric capacity will continue to grow but its relative importance will be dwarfed by the increase in thermal generation capacity. Most thermal generation units in the Arizona area will utilize coal or gas. Coal will become the dominant source of energy by 2000. In the southern California area the situation is different. Despite large local reserves of oil and gas and the possibility of Western coal being transported to the load centers by means of coal slurry pipelines or integral trains, nuclear generation will become the major source of energy by 1985. Table 6 shows the predicted relationship of energy sources in the State of California. Because of air pollution regulations, nuclear generation will be encouraged to develop even more rapidly in southern California.

Reserves of fossil fuels are more than adequate to meet foreseeable future power needs.

Estimated proved reserves of natural gas in California, as of 1961, were 9.1 trillion cubic feet (ref. 1). Interconnected fields in the Mountain States and Texas contained an estimated 143 trillion cubic feet in 1960 (ref. 3). Tied-in pipelines make at least a portion of the total quantity available to the Lower Colorado River Basin area. Assuming 1,075 Btu per cubic foot of natural gas and 34 percent (ref. 13) efficiency (future thermal plants will be even more efficient, thereby decreasing fuel demands), only 6.5 trillion cubic feet of gas would be required to generate the 700 billion kwh energy requirement predicted for 2000. Of course, not all of the power requirement will be met by utilizing natural gas energy.

Proved reserves of crude petroleum in California, as of 1961, were 3.9 billion barrels (ref. 1). At 6 million Btu per barrel and 34.5 percent efficiency (ref. 13) the 700 billion kwh year 2000 requirement is equivalent to about 1.1 billion barrels of oil. Although other Western States' oil reserves could be tapped, oil is not expected to play a vigorous role in the expanding thermal generation field (table 6).

While California has only 47 million tons of coal and lignite (ref. 8), Colorado, New Mexico, and Utah have a combined bituminous coal reserve of 85 billion tons (ref. 3). Assuming 25 million Btu per short ton of bituminous coal and 35 percent efficiency (ref. 13), only about 270 million tons of bituminous coal would be consumed in generating the 700 billion kwh year 2000 requirement.

FUEL FOR SALINE WATER CONVERSION

The Office of Saline Water has been successful with its one-million-gallon-per-day multistage flash distillation demonstration plant at San Diego, California. It now plans to construct a 300-million-gallon-per-day plant, utilizing the same conversion process, to be on stream by 1975. The facility will be located in California, either near Los Angeles or in the Salton Sea area. The plant will be equipped with two 500-megawatt generating plants. Sea water heating will require 90,000 kw plus all the waste heat produced in the generation of power. The remaining 910,000 kw will be marketed to help offset the cost of the flash distillation process. Fuel for power generation will be furnished either by oil or gas (available in California), coal (from Utah, New Mexico, or other Western States), or nuclear energy.

Mine-mouth power plants, with high-voltage transmission lines, will not be feasible because utilization of waste heat is part of the multistage flash distillation scheme. Thus the thermal plant will be constructed alongside the saline water conversion plant. Coal, if utilized, is not found in quantity in California and would therefore be transported to the conversion site by railroad or pipeline (powdered coal in a water or oil slurry).

In comparing fuel costs, delivered price per million British thermal units is the significant factor. It is estimated that for large contracts such as would prevail under the contemplated project Utah coal could be produced and sold for 15¢ to 17.5¢ per million Btu, f.o.b. mine. Current costs are on the order of 20¢ per million Btu. Transportation costs via coal-slurry pipeline have been estimated at 1.4 to 1.7 cents per million Btu per 100 miles. Thus coal from northeastern Utah could be delivered to a Los Angeles site at 23 to 25 cents per million Btu, probably nearer the latter figure. Cost at the Salton Sea site would be less. New Mexico coal could probably be delivered at the Los Angeles site for about the same price. Possible lower mining costs at the large but low-grade lignite deposits of Wyoming and the Dakotas might yield fuel as low as 14 cents per million Btu, f.o.b. mine. However, the additional transportation cost would increase the delivered price to approximately 40 cents per million Btu.

Transportation charges for unitized or integral train haulage of coal have been estimated at up to 12 to 13 percent higher than the coal-slurry transportation cost. Transportation charges for railroad haulage of coal based upon filed tariffs would be about 3.0 to 7.6 cents per million Btu per 100 miles (ref. 16), and about 1.4 to 1.7 cents per million Btu per 100 miles based on known unitrain rates.

The smog problem in southern California could conceivably preclude the utilization of coal as a fuel regardless of cost per million Btu.

The comparative prices of oil and gas in the Los Angeles area are 32.2 cents per million Btu and 34.3 cents per million Btu, respectively (see ref. 6). Increased demand for oil and gas, coupled with declining production and smog regulations could possibly set the stage for an all-nuclear electrical generating facility at the saline water conversion site.

BUREAU OF MINES STUDIES

Reservoir Site Examinations

The following reservoir site examinations have been completed, and detailed reports submitted to the Bureau of Reclamation, by the Bureau of Mines:

1. Bridge Canyon.................. Arizona
2. Marble Canyon.................. Arizona
3. Maxwell Reservoir.............. Arizona
4. River Mountains................ Nevada
5. Senator Wash................... California

The following reservoir sites are scheduled for examination in order to define possible mineral resources involvement:

1. Buttes......................... Arizona
2. Charleston..................... Arizona
3. Hooker......................... New Mexico
4. Lower Gunlock.................. Utah
5. Virgin City.................... Utah

The area to be involved in the Central Arizona Aqueduct System will also be examined by the Bureau of Mines.

Canal-Lining Research

Promising results have been obtained in the laboratory phase of canal-lining research now nearing completion at the Salt Lake City Metallurgy Research Center of the Bureau of Mines. If the technique developed proves as successful in field tests as in the laboratory, it can be applied at many places in the Lower Colorado River Basin with appreciable savings in first cost and annual charges.

Primary objective of the research, sponsored by the Missouri River Basin Project, was to find a low-cost means of reducing canal leakage and consequent waste of water and land. Bureau technicians attacked the problem through mineralogical and chemical channels. They found that adding certain salts to either coarse- or fine-grained materials containing some clay would reduce percolation rates sharply and make the mixtures relatively impervious. Many water-soluble salts were tried as sealants in controlled laboratory tests, and among the most effective was sodium carbonate. In permeability tests under both freezing and thawing conditions, the sodium-carbonate treatment also proved reasonably durable. Moreover, the method is relatively inexpensive: costs of sodium carbonate and its application are estimated at 1-1/2 to 2 cents per square year each, or a total of 3 to 4 cents per square yard treated.

During the current fiscal year, personnel of the Bureaus of Reclamation and Mines will utilize the laboratory results to design full-scale field tests of the treatment method. Canal-lining materials (soil samples) from seepage problem areas in Nebraska and New Mexico now are being tested in the laboratory, preparatory to selecting one or more field test sites.

Nevada Mineral Industry Water Requirements

In fiscal year 1964 the Bureau plans to study the water-use practices of the mineral industry in Nevada similar to the study performed in Arizona (ref. 9). Because the mineral industry (particularly copper) is such an important element in the economy of Nevada, the availability and utilization of water must be quantified. Water cost figures will be especially useful in interpreting costs of conservation practices such as recirculation. Similar studies in other water-starved States of the West, with emphasis on the effect of water shortage on mineral industries, should be an important Bureau effort in the future.

Other

The Bureau will continue to investigate, through cooperative agreements with California and Nevada, mineral occurrences of potential importance to the States' economies. Future exploration will help determine the availability and usability of the nonmetallic minerals such as clay, limestone, and barite, so necessary to the expanding population of the Lower Colorado River Basin.

Oil field reservoir data will be analyzed in an attempt to increase the accuracy of petroleum production forecasts to better determine the availability of fuel for the area.

Bureau research on pipeline transportation of coal (powdered coal, in a water-slurry), proceeding now in the East, may be of interest in future fuel transportation considerations in the basin.

CONCLUSIONS AND RECOMMENDATIONS

The highly important role of the mineral industry as a customer for water was clearly demonstrated by the Bureau of Mines study in Arizona (ref. 9). Similar studies for southern California and the remainder of the Lower Colorado River Basin should be made. Only in this manner can the estimate of water consumption (fig. 3) be refined to an accurate water requirement forecast.

Reserves of fossil fuels are more than adequate to satisfy future power demands (fig. 5 and table 5). Bituminous coal will be in such great demand for power generation by 2000, mostly in Arizona, that production from mines in the immense reserves of coal in Colorado, Utah, New Mexico, and Wyoming must be increased to satisfy that demand. Arizona alone will need 5.65 million tons a year by 1980 and 47.5 million tons a year by 2000. The magnitude of this requirement is realized when one compares it to the combined coal production of the four states for 1961—11.8 million tons.

Transportation of so great a tonnage probably will be the greatest problem confronting consumers of coal. Unit trains may be capable of moving only a part of it, and it is likely that a combination of means of transmitting energy—coal trains, EHV transmission, possibly pipeline (in special situations), and tie-ins of power-transmission lines will be used.

Only the most superficial investigation, and practically no study, could be given the subject of this report. The subjects' importance and magnitude require much more serious investigation, analysis, and evaluation than was possible in the little time available to them.

It is recommended that thorough studies be made of future need for water, fuels, minerals, transportation, and the other needs that the Lower Colorado River Basin development will create.

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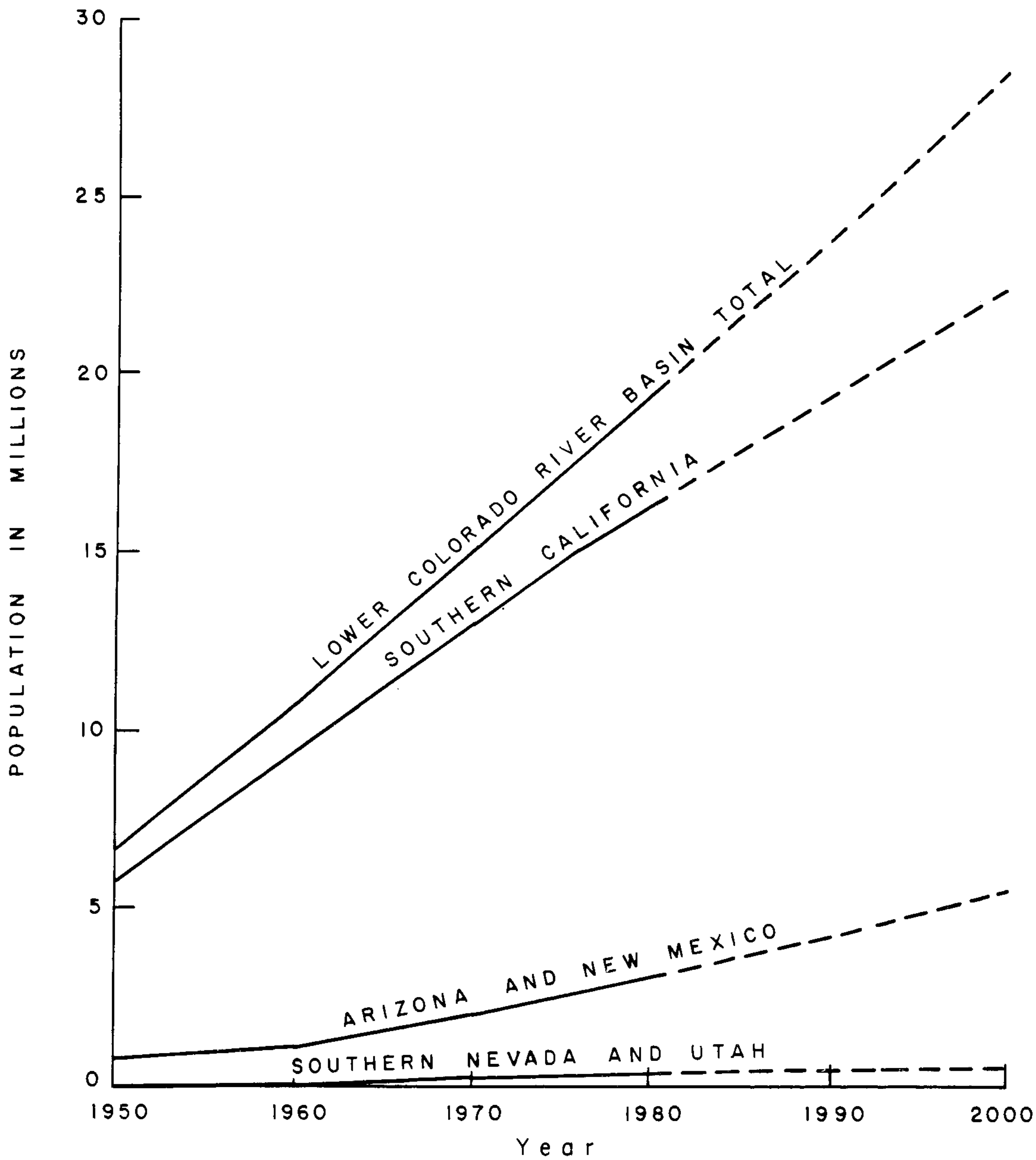

FIGURE 1.- POPULATION ESTIMATE, LOWER COLORADO RIVER BASIN

SOURCE OF DATA: REFERENCES NO. 5 AND NO. 4

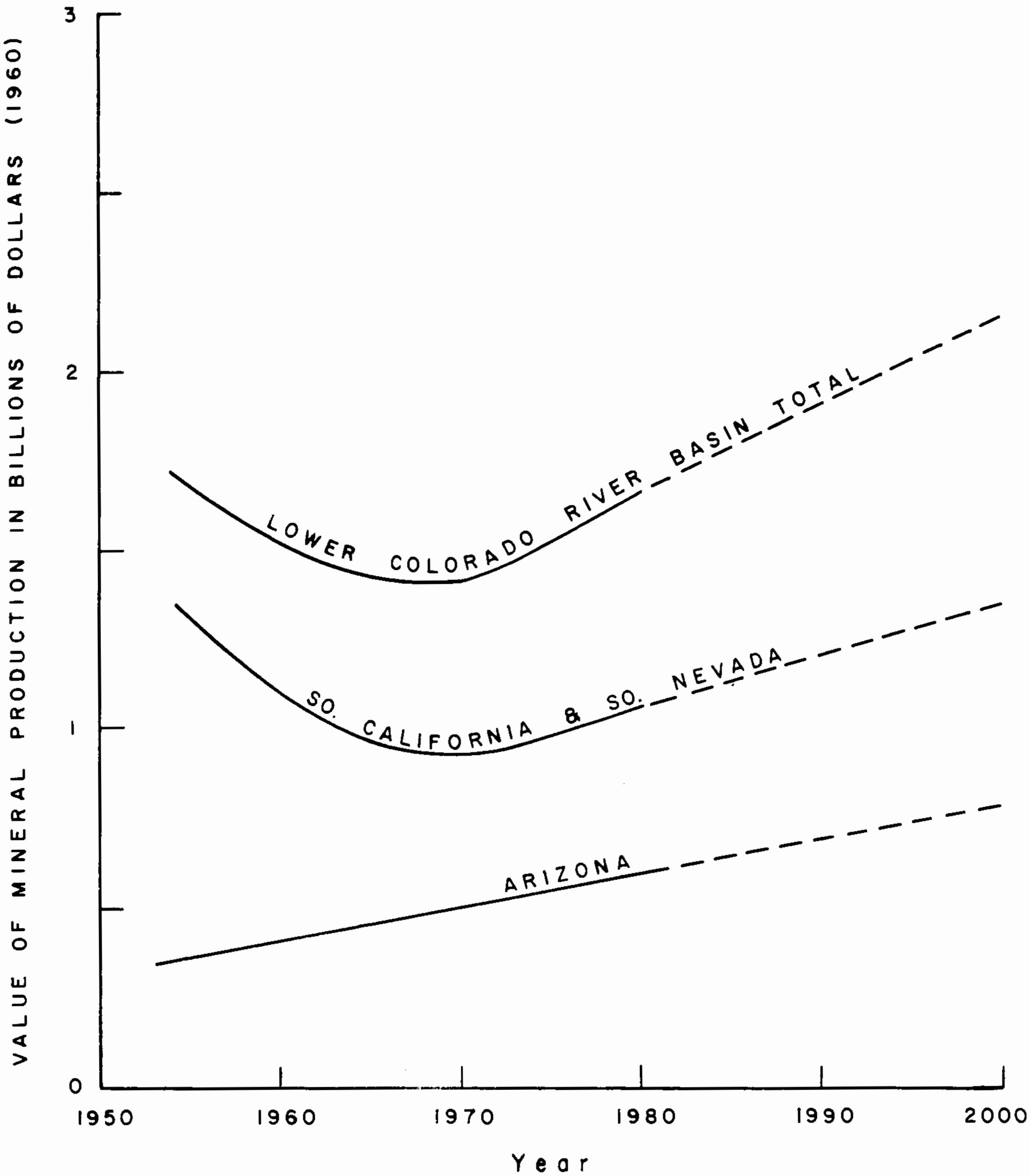

FIGURE 2.-ESTIMATE OF VALUE OF MINERAL PRODUCTION OF LOWER COLORADO RIVER BASIN.

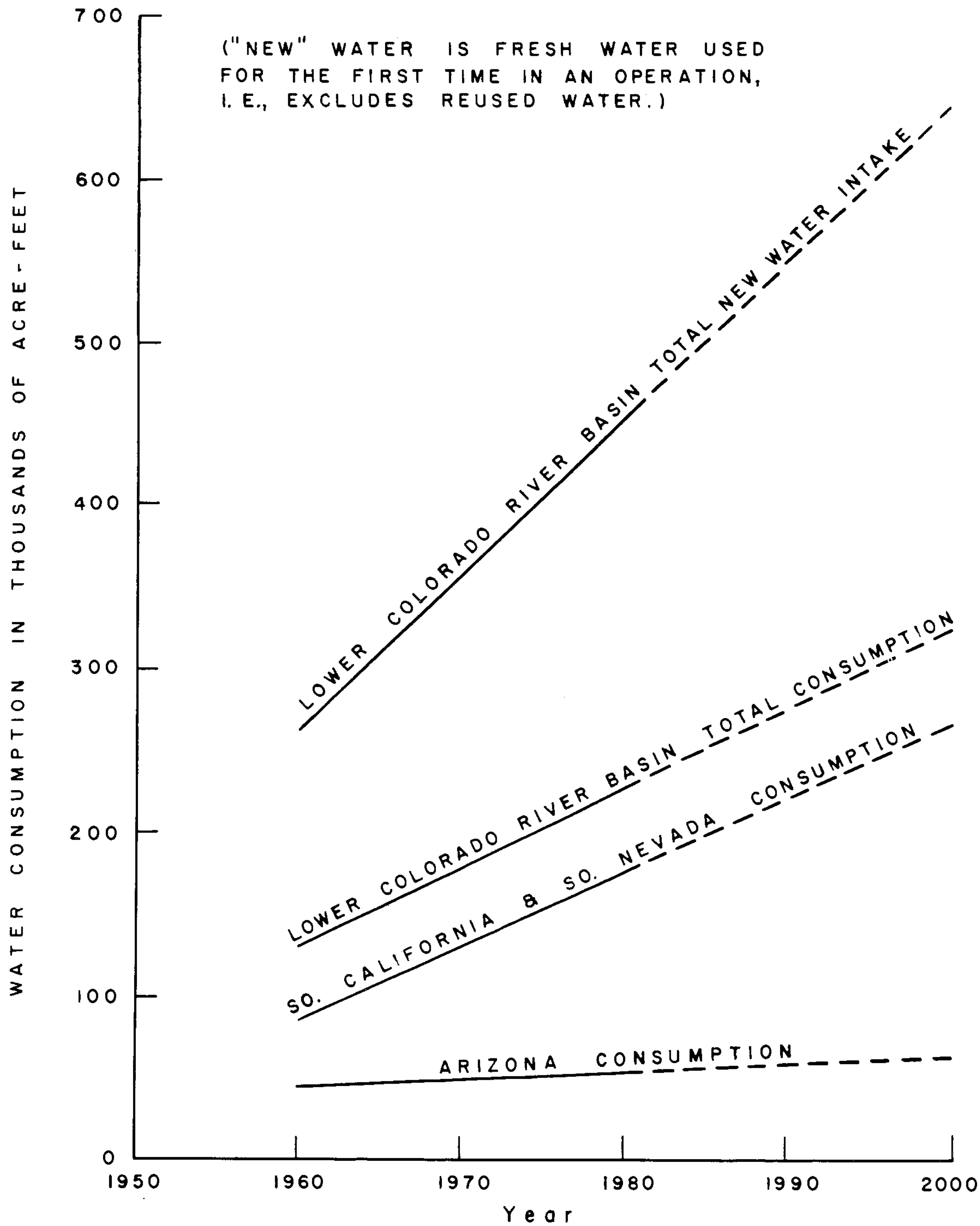

FIGURE 3. - PROJECTED NEW WATER INTAKE AND WATER CONSUMPTION, LOWER COLORADO RIVER BASIN MINERAL INDUSTRY

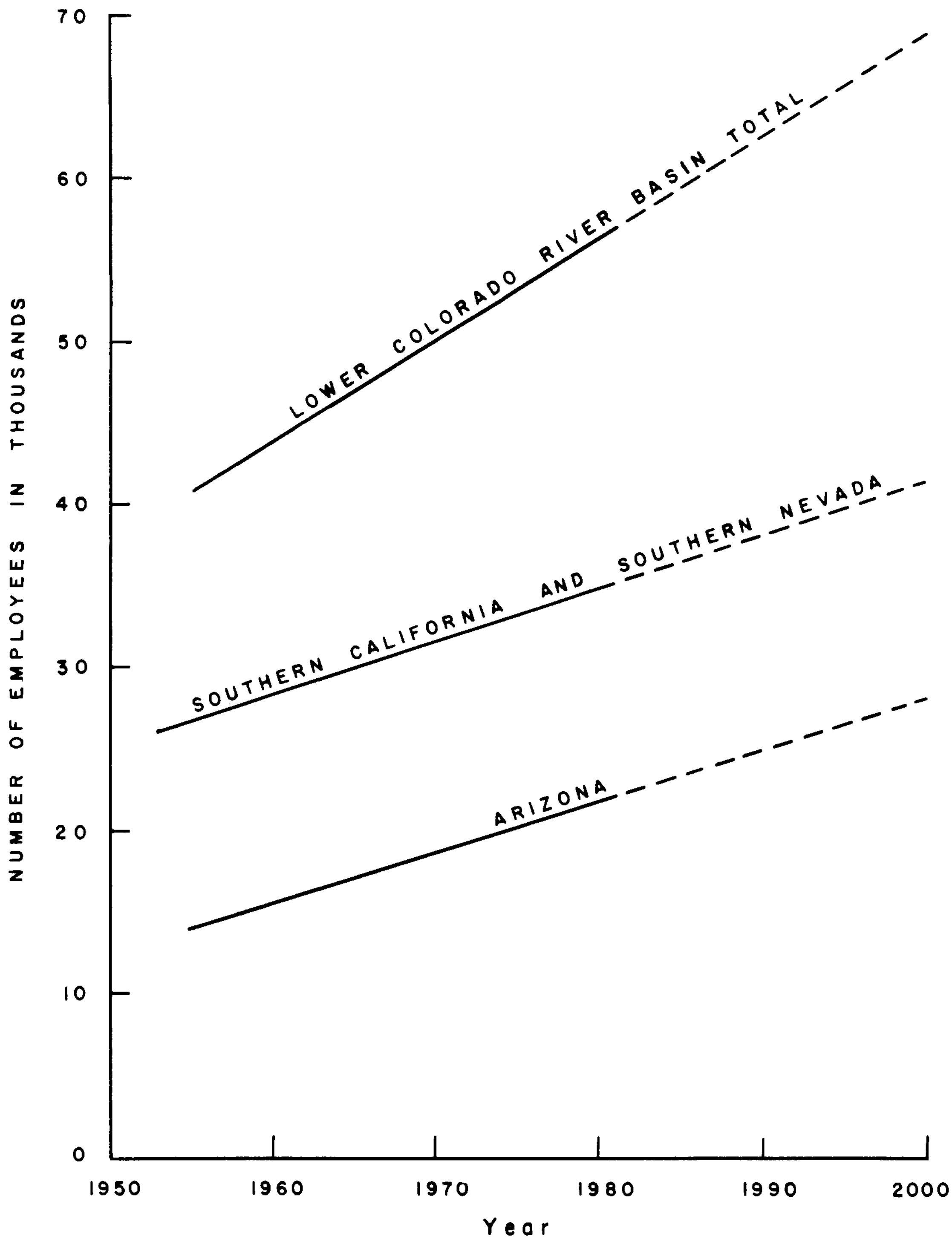

FIGURE 4.- ESTIMATE OF EMPLOYMENT IN LOWER COLORADO RIVER BASIN MINERAL INDUSTRY.

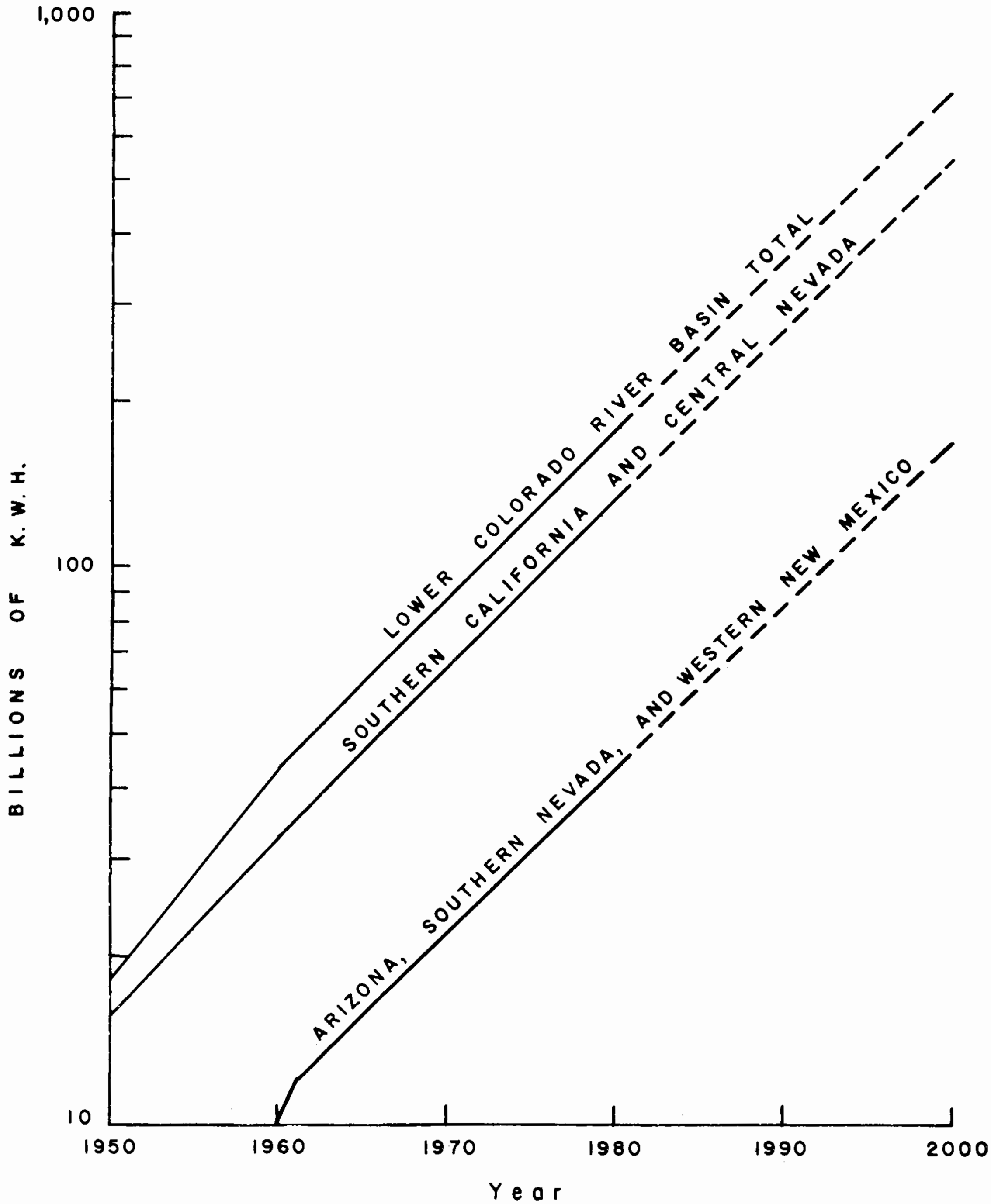

FIGURE 5-ESTIMATE OF ELECTRICAL REQUIREMENTS OF LOWER COLORADO BASIN

SOURCE OF DATA: REFERENCE NO. 12

TABLE 1. -Summary of mineral production, Arizona and southwestern New Mexico, 1953-62

Commodity	1953 Quantity	1953 Value (thousands)	1954 Quantity	1954 Value (thousands)	1955 Quantity	1955 Value (thousands)	1956 Quantity	1956 Value (thousands)	1957 Quantity	1957 Value (thousands)	1958 Quantity	1958 Value (thousands)	1959 Quantity	1959 Value (thousands)	1960 Quantity	1960 Valu (thous
Clay..........................thousand short tons..	198.6	$ 720.2	255.8	$ 820.6	258.0	$ 281.8	114.9	$ 180.1	119.4	$ 182.7	121.0	$ 187.2	(1)	(1)	(1)	(1)
Copper (recoverable content of ores)... short tons..	465,445	267,165.5	438,350	258,626.5	520,468	388,269.1	579,298	492,403.0	582,964	350,944.1	541,373	284,762.1	469,965	$ 288.558.1	605,869	$ 388,9
Gold (recoverable content of ore)......troy ounces..	115,430	4,040.0	118.221	4,141.2	129,498	4,532.5	149,272	5,224.6	155,644	5,447.9	146,350	5,122.0	127,760	4,471.7	148,467	5,1
Lead (recoverable content of ores)..... short tons..	12,351	3,235,9	9,269	2,539.7	13,078	3,897.2	17,985	5,647.4	17,729	5,070.3	13,007	3,048.4	10,828	2,490.6	10,491	2,4
Lime .... thousand short tons..	96.4	1,238.2	88.9	1,131.3	112.0	1,437.6	157.6	2,128,4	162.0	2,417.2	1,475	2,076.6	139.3	1,875.3	183.7	2,9
Pumice ....do...........	123.8	426.0	80.8	125.9	92.1	372.7	114.6	366.1	397	640	401	1,025.0	797.0	1,153.7	1,158.0	1,1
Sand and gravel......................do...........	3,463.4	2,696.4	3,851.8	3,161.5	7,862.8	6,593.8	8,278.8	6,527.8	11,325.7	9,989.3	17,520.5	12,501.5	14,577.2	13,070.9	14,747.2	14,4
Silver (recoverable content of ores) thousand troy ounces..	4,555.8	4,123.3	4,407.8	3,989.2	4,883.3	4,419.6	5,561.5	5,033.4	5,586.3	5,056.2	4,843.5	4,383.5	4,056.3	3,671.3	5,078.1	4,5
Stone.......................thousand short tons ..	443.8	623.7	(1)	(1)	1,659.6	2,431.3	(1)	(1)	24,807	3,582.8	1,588.8	2,826.2	2,502.5	4,042.7	4,326.3	5,1
Zinc (recoverable content of ores)......short tons..	40,893	9,405.4	21,467	4,637.1	37,917	9,327.6	60,512	16,580.2	66,585	15,447.8	37,566	7,663.9	41,961	9,651.3	49,581	12,7

1/ Figures withheld to avoid disclosing individual company confidential data.

Source: Department of the Interior, Bureau of Mines, Minerals Yearbooks.

TABLE 1. -Summary of mineral production, Arizona and southwestern New Mexico, 1953-62

1953		1954		1955		1956		1957	
Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
198.6	$ 720.2	255.8	$ 820.6	258.0	$ 281.8	114.9	$ 180.1	119.4	$ 182.7
465,445	267,165.5	438,350	258,626.5	520,468	388,269.1	579,298	492,403.0	582,964	350,944.1
115,430	4,040.0	118.221	4,141.2	129,498	4,532.5	149,272	5,224.6	155,644	5,447.9
12,351	3,235.9	9,269	2,539.7	13,078	3,897.2	17,985	5,647.4	17,729	5,070.3
96.4	1,238.2	88.9	1,131.3	112.0	1,437.6	157.6	2,128.4	162.0	2,417.2
123.8	426.0	80.8	125.9	92.1	372.7	114.6	366.1	397	640
3,463.4	2,696.4	3,851.8	3,161.5	7,862.8	6,593.8	8,278.8	6,527.8	11,325.7	9,989.3
4,555.8	4,123.3	4,407.8	3,989.2	4,883.3	4,419.6	5,561.5	5,033.4	5,586.3	5,056.2
443.8	623.7	(1)	(1)	1,659.6	2,431.3	(1)	(1)	24,807	3,582.8
40,893	9,405.4	21,467	4,637.1	37,917	9,327.6	60,512	16,580.2	66,585	15,447.8

1958		1959		1960		1961		1962	
Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
121.0	$ 187.2	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
541,373	284,762.1	469,965	$ 288.558.1	605,869	$ 388,967.3	666,610	$399,965.7	726,910	$ 447,776.
146,350	5,122.0	127,760	4,471.7	148,467	5,196.1	152,107	5,324.3	144,832	5,065.4
13,007	3,048.4	10,828	2,490.6	10,491	2,455.1	8,250	1,701.5	8,097	1,490.1
1,475	2,076.6	139.3	1,875.3	183.7	2,926.3	192.2	2,780.4	203.0	3,316.7
401	1,025.0	797.0	1,153.7	1,158.0	1,165.6	899.0	1,893.2	756.0	1,640.0
17,520.5	12,501.5	14,577.2	13,070.9	14,747.2	14,459.9	22,654.4	25,710.1	16,178.8	17,835.8
4,843.5	4,383.5	4,056.3	3,671.3	5,078.1	4,596.4	5,401.8	4,993.5	5,750.7	6,238.9
1,588.8	2,826.2	2,502.5	4,042.7	4,326.3	5,173.2	3,655.8	4,710.6	4,405.5	6,674.3
37,566	7,663.9	41,961	9,651.3	49,581	12,791.7	52,482	12,070.5	54,901	12,626.9

company confidential data.

:s, Minerals Yearbooks.

TABLE 2 - Mineral production in Arizona, 1953-62

Commodity	1953 Quantity	1953 Value (thousands)	1954 Quantity	1954 Value (thousands)	1955 Quantity	1955 Value (thousands)	1956 Quantity	1956 Value (thousands)	1957 Quantity	1957 Value (thousands)	1958 Quantity	1958 Value (thousands)	1959 Quantity	1959 Value (thousands)	1960 Quantity	1960 Value (thousands)
Beryllium concentrate.........short tons gross weight..	--	(1)	---	(1)	--	(1)	6	$ 2.6	5	$ 2	18	$ 10	--	--	--	(
Brucite...................................short tons..	100	$ 1.3	---	--	--	--	--	--	--	--	--	--	--	--	--	
Clays............................thousand short tons..	197.4	715.2	253.7	$ 814.2	254.4	$ 868.7	2/111.7	2/167.6	118	177	119	179	2/ 120	2/$ 179	2/ 173	2/ $
Coal (bituminous)................thousand short tons..	5.1	32.1	10.9	68.1	8.9	59.3	10.1	66.0	9	62	8	54	7	63	6	
Columbium-Tantalum conc......................pounds..	--	--	--	--	--	(1)	--	(1)	2,435	7	--	--	--	--	--	
Copper (recoverable content of ores)...... short tons..	393,524	225,883.4	377,927	222,976.9	454,105	338,762.3	505,908	430,021.8	515,854	310,544	485,839	255,551	430,297	264,202	538,605	345,
Fluorspar............................... short tons..	1,951	113.3	--	(1)	--	(1)	--	(1)	--	---	--	--	--	--	--	
Gem stones...	(3)	(1)	(3)	(1)	(3)	97	(3)	104	(3)	75	(3)	86	(3)	88	(3)	
Gold (recoverable content of ores)........troy ounces..	112,824	3,948.8	114,809	4,018.3	127,616	4,466.6	146,11	5,113.9	152,449	5,336	142,979	5,004	124,627	4,362	143,064	5,
Gypsum .... short tons..	13,484	43.8	--	(1)	--	(1)	95,66	366.1	---	(1)	--	(1)	--	--	--	
Iron Ore (usable).............long tons gross weight..	--	--	--	--	--	--	--	--	----	--	--	--	--	--	--	
Lead (recoverable content of ores).........short tons..	9,428	2,470.1	8,385	2,297.5	9,817	2,925.5	11,999.	3,767.7	12,441	3,558	11,890	2,787	9,999	2,300	8,495	1,
Lime............................ thousand short tons..	96.4	1,238.2	88.9	1,131.3	112.0	1,437.6	126.9	1,755.8	138	2,127	126	1,817	123	1,666	148	2,
Manganese ore and concentrate (35 percent or more Mn) short tons gross weight..	--	(1)	--	--	1,444	(1)	42,008	3,468.3	79,505	6,626	62,279	5,220	68,183	5,727	1,626	
Manganiferous ore and concentrate (5 to 35 percent Mn) short tons gross weight..	--	--	--	--	--	--	--	--	--	--	1,455	32	10,693	234	8,677	
Mercury................ ....76-pound flasks..	--	--	163	43.1	477	138.5	--	(1)	28	7	53	12	--	(1)	--	(1
Mica (scrap)...............................short tons..	--	(1)	1,682	17.8	1,353	8.7	--	--	1,650	17	1,717	25	3,069	55	--	(1
Molybdenum (content of concentrate)...thousand pounds..	1,446.6	1,425.6	1,538	1,524.9	1,497	1,510.5	2,392	2,670.5	2,385	3,071	2,320	2,827	3,181	4,019	4,359	5,
Natural gas ....million cubic feet..	--	--	--	--	--	(1)	21	3.0	--	--	--	--	--	--	--	
Perlite...................................short tons..	--	(1)	1,296	7.0	10,568	84.0	15,928	108.4	15,646	114	--	(1)	--	--	--	
Petroleum (crude)............thousand 42-gallon bbls..	--	--	--	--	--	--	--	--	--	--	--	(1)	25	(1)	73	(1
Pumice...........................thousand short tons..	123.8	426.0	80.8	125.9	92.1	372.7	114.6	366.1	397	640	401	1,025	487	1,153	703	1,
Rare earths (concentrates).....................pounds..	--	--	--	--	--	--	--	--	--	--	150	0.5	--	--	--	
Sand and gravel..................thousand short tons..	3,446.8	2,680.5	3,764.1	3,067.1	7,755.3	6,518.9	7,932.5	6,166.8	10,287	9,222	12,208	9,526	13,458	11,966	14,490	14,
Silver (recoverable content of ores) thousand troy ounces..	4,351.4	3,938.3	4,298.8	3,890.6	4,634.2	4,194.2	5,179.2	4,687.4	5,279	4,778	4,685	4,240	3,898	3,528	4,775	4,
Stone............................thousand short tons..	4/ 442.4	4/ 618.7	1,205.5	1,914.3	1,600.9	2,328.6	1,623.0	2,474.5	2,101	2,982	1,528	2,731	2,468	3,998	4,249	5,
Tungsten (60% WO_3 basis)..................short tons..	134	468.9	132	475.0	181	676.4	186	636.7	5	9	--	--	--	--	--	
Uranium Ore...............................short tons..	--	--	---	---	--	--	274,505	5,408	286,037	6,277	257,756	7,049	253,390	6,309	283,684	6,
Zinc (recoverable content of ore)..........short tons..	27,530	6,331.9	21,461	4,635.8	22,684	5,580.3	25,580	7,008.9	33,905	7,866	28,532	5,821	37,325	8,585	35,811	9,
Value of items not disclosed: Asbestos, barite, bentonite, cement, diatomite, feldspar, helium, nitrogen compounds, pyrites, silica, vanadium, vermiculite and values indicated by footnote 1.	--	6,165.5	--	8,171.6	--	9,201.4	--	17,900.6	--	10,441	--	11,734	--	9,811	--	15,

1/ Included in value of items not disclosed.
2/ Excludes bentonite.
3/ Weight not recorded.
4/ Excludes limestone for cement and lime.
5/ Not available.

TABLE 2 - Mineral production in Arizona, 1953-62

	1953		1954		1955		1956		1957		1958		1959		1960		1961		1962	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
eight..	--	(1)	---	(1)	--	(1)	6	$ 2.6	5	$ 2	18	$ 10	--	--	--	(1)	8	$ 4	1	$0.3
tons..	100	$ 1.3	---	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
tons..	197.4	715.2	253.7	$ 814.2	254.4	$ 868.7	2/111.7	2/167.6	118	177	119	1/9	2/ 120	2/$ 179	2/ 173	2/ $ 260	2/165	2/ 240	138	184.1
tons..	5.1	32.1	10.9	68.1	8.9	59.3	10.1	66.0	9	62	8	54	7	63	6	58	--	--	--	--
ounds..	--	--	--	--	--	(1)	--	(1)	2,435	7	--	--	--	--	--	--	--	--	--	--
tons..	393,524	225,883.4	377,927	222,976.9	454,105	338,762.3	505,908	430,021.8	515,854	310,544	485,839	255,551	430,297	264,202	538,605	345,784	587,053	352,232	644,424	396,853.1
tons..	1,951	113.3	--	(1)	--	(1)	--	(1)	--	---	--	--	--	--	---	--	--	--	--	--
....	(3)	(1)	(3)	(1)	(3)	97	(3)	104	(3)	75	(3)	86	(3)	88	(3)	120	(3)	119	(3)	119.5
unces..	112,824	3,948.8	114,809	4,018.3	127,616	4,466.6	146,11	5,113.9	152,449	5,336	142,979	5,004	124,627	4,362	143,064	5,007	145,959	5,109	137,207	4,802.0
tons..	13,484	43.8	--	(1)	--	(1)	95,66	366.1	---	(1)	--	(1)	--	--	--	--	--	--	--	(1)
eight..	--	--	--	--	--	--	--	--	----	--	--	--	--	--	--	--	246	(1)	--	(1)
tons..	9,428	2,470.1	8,385	2,297.5	9,817	2,925.5	11,999.	3,767.7	12,441	3,558	11,890	2,787	9,999	2,300	8,495	1,988	5,937	1,223	6,966	1,282.0
tons..	96.4	1,238.2	88.9	1,131.3	112.0	1,437.6	126.9	1,755.8	138	2,127	126	1,817	123	1,666	148	2,430	167	2,430	174	2,914.0
e Mn)																				
eight..	--	(1)	--	--	1,444	(1)	42,008	3,468.3	79,505	6,626	62,279	5,220	68,183	5,727	1,626	40	--	(1)	--	(1)
nt Mn)																				
eight..	--	--	--	--	--	--	--	--	--	--	1,455	32	10,693	234	8,677	190	--	--	--	--
lasks..	--	--	163	43.1	477	138.5	--	(1)	28	7	53	12	--	(1)	--	(1)	148	29	--	(1)
tons..	--	(1)	1,682	17.8	1,353	8.7	--	--	1,650	17	1,717	25	3,069	55	--	(1)	--	--	--	(1)
ounds..	1,446.6	1,425.6	1,538	1,524.9	1,497	1,510.5	2,392	2,670.5	2,385	3,071	2,320	2,827	3,181	4,019	4,359	5,211	4,878	6,232	4,412	5,864 0
feet..	--	--	--	--	--	(1)	21	3.0	--	--	--	--	--	--	--	--	--	--	--	--
tons..	--	(1)	1,296	7.0	10,568	84.0	15,928	108.4	15,646	114	--	(1)	--	--	--	--	--	(1)	--	(1)
bbls..	--	--	--	--	--	--	--	--	--	--	--	(1)	25	(1)	73	(1)	67	(1)	43	(1)
tons..	123.8	426.0	80.8	125.9	92.1	372.7	114.6	366.1	397	640	401	1,025	487	1,153	703	1,164	745	1,893	756	1,640.0
ounds..	--	--	--	--	--	--	--	--	--	--	150	0.5	--	--	--	--	--	--	--	--
tons..	3,446.8	2,680.5	3,764.1	3,067.1	7,755.3	6,518.9	7,932.5	6,166.8	10,287	9,222	12,208	9,526	13,458	11,966	14,490	14,235	21,953	24,706	15,579	17,404 0
unces..	4,351.4	3,938.3	4,298.8	3,890.6	4,634.2	4,194.2	5,179.2	4,687.4	5,279	4,778	4,685	4,240	3,898	3,528	4,775	4,322	5,120	4,733	5,454	5,917.0
tons..	4/ 442.4	4/ 618.7	1,205.5	1,914.3	1,600.9	2,328.6	1,623.0	2,474.5	2,101	2,982	1,528	2,731	2,468	3,998	4,249	5,107	3,582	4,626	4,333	6,616.0
tons..	134	468.9	132	475.0	181	676.4	186	636.7	5	9	--	--	--	--	--	--	--	--	15	14.0
tons..	--	--	---	---	--	--	274,505	5,408	286,037	6,277	257,756	7,049	253,390	6,309	283,684	6,219	228,225	4,965	143,196	3,047.0
tons..	27,530	6,331.9	21,461	4,635.8	22,684	5,580.3	25,580	7,008.9	33,905	7,866	28,532	5,821	37,325	8,585	35,811	9,239	29,585	6,804	32,888	7,564.0
	--	6,165.5	--	8,171.6	--	9,201.4	--	17,900.6	--	10,441	--	11,734	--	9,811	--	15,851	--	18,910	--	(5)

ı,

TABLE 3 --Mineral production in southwestern New Mexico, 1/ 1953-62

Commodity	1953 Quantity	1953 Value (thousands)	1954 Quantity	1954 Value (thousands)	1955 Quantity	1955 Value (thousands)	1956 Quantity	1956 Value (thousands)	1957 Quantity	1957 Value (thousands)	1958 Quantity	1958 Value (thousands)	1959 Quantity	1959 Value (thousands)	1960 Quantity	1960 Value (thousands)	1961 Quantity	1961 Value (thou[illegible])
Barite......................short tons..	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	4,441	$97.7	(2)	(2)	320	$6.4	492	$9.9	600	$1[illegible]
Clays.............thousand short tons..	1.2	$ 5.0	2.1	$ 6.4	3.6	$13.1	3.2	$12.5	1.4	5.7	2.0	$ 8.2	(2)	(2)	(2)	(2)	(2)	[illegible]
Coal (bituminous)..thousand short tons..	3	18.4	2.5	18.4	--	--	1.7	8.9	2.0	15.6	2.0	12.0	---	---	---	---	---	---
Copper (recoverable content of ores)																		
short tons..	71,920	41,282.1	60,423	35,649.6	66,363	49,506.8	73,390	62,381.2	67,110	40,400.1	55,534	29,211.1	39,668	24,356.1	67,264	43,183.3	79,557	47,73[illegible]
Fluorspar..................short tons..	(2)	(2)	(2)	(2)	(2)	(2)	---	---	--	---	---	---	200	6.9	---	---	---	---
Gem stones..............................	---	--	--	--	(3)	14.3	(3)	13.5	(3)	10.7	(3)	12.2	(3)	16.5	(3)	10.5	(3)	21
Gold (recoverable content of ores)		--	--	--	--													
troy ounces..	2,606	91.2	3,512	122.9	1,882	65.9	3,162	110.7	3,195	111.9	3,371	118.0	3,133	109.7	5,403	189.1	6,148	215
Iron Ore (usable) ..																		
thousand long tons, gross weight..	5.9	(2)	3.3	(2)	9.2	(2)	3.1	14.3	0.2	1.1	(2)	(2)	(2)	(2)	1.2	26.8	(2)	[illegible]
Lead (recoverable content of ores)																		
short tons..	2,923	765.8	884	242.2	3,261	971.8	5,986	1,879.7	5,288	1,512.3	1,117	261.4	829	190.6	1,996	467.1	2,323	478
Lime ....thousand short tons..	--	--	--	--	--	--	30.7	372.6	24.0	290.2	21.5	259.6	16.3	209.3	35.7	496.3	25.2	350
Manganese (35% +)..thousand short tons..	(2)	(2)	20.5	82.2	41.7	272.7	(2)	(2)	(2)	(2)	27.0	2,184.9	27.3	2,228.5	---	---	---	---
Manganiferous ore (5%-35%)																		
thousand short tons..	--	--	--	--	--	--	38.8	138.5	42.5	151.9	(2)	(2)	(2)	(2)	(2)	(2)	(2)	[illegible]
Molybdenum ....1,000 lbs..	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	602	684.0	705	845.8	(2)	(2)	(2)	[illegible]
Perlite....................short tons..	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	[illegible]
Pumice............thousand short tons..	--	--	--	--	--	--	--	--	--	--	--	--	210	0.7	455	106	154	0
Salt..............thousand short tons..	(2)	(2)	(2)	(2)	1.1	21.5	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.1	7
Sand and gravel....thousand short tons..	16.6	15.9	87.7	94.4	107.5	74.9	346.3	361.0	1,038.7	767.3	5,312.5	2,975.5	1,119.2	1,104.9	257.2	224.9	701.4	1,004
Silver (recoverable content of ores)																		
thousand troy ounces..	204.4	185.0	109.0	98.6	249.1	225.4	382.3	346.0	307.3	278.2	158.5	143.5	158.3	143.3	303.1	274.4	281.8	260[illegible]
Stone............ thousand short tons..	1.4	5.0	(2)	(2)	58.7	102.7	(2)	(2)	379.7	600.8	60.8	95.2	37.5	44.7	77.3	66.2	73.8	84[illegible]
Tungsten .... short tons..	--	--	(2)	1.4	(2)	1.6	(2)	0.4	--	--	--	--	--	--	--	--	--	--
Uranium Ore................ short tons..	--	--	--	--	--	--	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Zinc (recoverable content of ores)																		
short tons..	13,363	3,073.5	6	1.3	15,233	3,747.3	34,932	9,571.3	32,680	7,581.8	9,034	18,429	4,636	1,066.3	13,770	3,552.7	22,898	5,266[illegible]

1/ Catron, Socorro, Grant, Sierra, Luna, and Hidalgo Counties.
2/ Figures withheld to avoid disclosing individual company confidential data.
3/ Weight not recorded.

TABLE 3 --Mineral production in southwestern New Mexico, 1/ 1953-62

1953		1954		1955		1956		1957		1958		1959		1960		1961		1962		Ten Year Summary	
ntity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	4,441	$97.7	(2)	(2)	320	$6.4	492	$9.9	600	$10.2	252	$ 4.1	---	---
1.2	$ 5.0	2.1	$ 6.4	3.6	$13.1	3.2	$12.5	1.4	5.7	2.0	$ 8.2	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	---	---
3	18.4	2.5	18.4	--	--	1.7	8.9	2.0	15.6	2.0	12.0	---	---	---	---	---	---	---	---	---	---
,920	41,282.1	60,423	35,649.6	66,363	49,506.8	73,390	62,381.2	67,110	40,400.1	55,534	29,211.1	39,668	24,356.1	67,264	43,183.3	79,557	47,733.7	82,668	50.923.1	---	---
2)	(2)	(2)	(2)	(2)	(2)	---	---	--	---	---	---	200	6.9	---	---	---	---	---	---	25,020	$1,221.2
---	--	--	--	(3)	14.3	(3)	13.5	(3)	10.7	(3)	12.2	(3)	16.5	(3)	10.5	(3)	21.3	(3)	22.3	---	---
	--	--	--	--																	
,606	91.2	3,512	122.9	1,882	65.9	3,162	110.7	3,195	111.9	3,371	118.0	3,133	109.7	5,403	189.1	6,148	215.3	7,525	263.4	---	---
5.9	(2)	3.3	(2)	9.2	(2)	3.1	14.3	0.2	1.1	(2)	(2)	(2)	(2)	1.2	26.8	(2)	(2)	(2)	(2)	32.7	256.6
,923	765.8	884	242.2	3,261	971.8	5,986	1,879.7	5,288	1,512.3	1,117	261.4	829	190.6	1,996	467.1	2,323	478.5	1,131	208.1	---	---
--	--	--	--	--	--	30.7	372.6	24.0	290.2	21.5	259.6	16.3	209.3	35.7	496.3	25.2	350.4	29.0	402.7	---	---
2)	(2)	20.5	82.2	41.7	272.7	(2)	(2)	(2)	(2)	27.0	2,184.9	27.3	2,228.5	---	---	---	---	(2)	(2)	---	---
--	--	--	--	--	--	38.8	138.5	42.5	151.9	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	---	---
2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	602	684.0	705	845.8	(2)	(2)	(2)	(2)	(2)	(2)	7,313	8,092.0
2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	87	0.7	281,901	2,365.3
--	--	--	--	--	--	--	--	--	--	--	--	210	0.7	455	106	154	0.2	---	---	---	---
2)	(2)	(2)	(2)	1.1	21.5	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.1	7.1	(2)	(2)	12.1	165.9
16.6	15.9	87.7	94.4	107.5	74.9	346.3	361.0	1,038.7	767.3	5,312.5	2,975.5	1,119.2	1,104.9	257.2	224.9	701.4	1,004.1	599.8	431.8	---	---
204.4	185.0	109.0	98.6	249.1	225.4	382.3	346.0	307.3	278.2	158.5	143.5	158.3	143.3	303.1	274.4	281.8	260.5	296.7	321.9	---	---
1.4	5.0	(2)	(2)	58.7	102.7	(2)	(2)	379.7	600.8	60.8	95.2	37.5	44.7	77.3	66.2	73.8	84.6	75.2	58.3	---	---
--	--	(2)	1.4	(2)	1.6	(2)	0.4	--	--	--	--	--	--	--	--	--	--	--	--	---	---
--	--	--	--	--	--	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	10,419	267.7
,363	3,073.5	6	1.3	15,233	3,747.3	34,932	9,571.3	32,680	7,581.8	9,034	18,429	4,636	1,066.3	13,770	3,552.7	22,898	5,266.5	22,013	5,062.9	---	---

d Hidalgo Counties.
ividual company confidential data.

TABLE 4.--Value, water consumption, and employment of the mineral industry of southern California and Clark Co., Nevada, 1953-62

	Metals and Non-Metals Production 1/			Construction Materials 2/			Fuels 3/			Total		
Year	Value (thousands)	Water Cons. (acre-ft)	Number Employees	Value (thousands)	Water Cons. (acre-ft)	Number Employees	Value (thousands)	Water Cons. (acre-ft)	Number Employees (est.)	Value (thousands)	Water Cons. (acre-ft)	Number Employees
1953	$ 72,144	5,700	4,100 4/	$ 82,867	20,000	3,700 4/	$ 723,293	34,000	18,200	$ 878,304	60,000	26,000
1954	75,888	6,200	4,400 4/	107,412	28,000	4,200 4/	952,509	36,000	18,600	1,135,809	70,000	27,000
1955	106,899	8,200	4,700 4/	122,986	27,000	4,432	945,756	37,000	18,600	1,175,641	72,000	28,000
1956	119,124	10,400	5,000 4/	155,148	35,000	5,492	947,276	39,000	17,900	1,220,548	84,000	28,000
1957	160,291	7,700	5,447	101,703	30,000	5,352	1,050,695	41,000	18,000	1,312,689	79,000	29,000
1958	114,383	7,400	5,219	147,454	33,000	4,970	932,701	42,000	16,300	1,194,538	82,000	26,000
1959	123,382	7,300	5,242	162,434	35,000	5,210	833,591	44,000	17,000	1,119,407	86,000	27,000
1960	126,596	7,600	4,959	157,522	34,000	5,281	790,489	46,000	18,000	1,074,607	88,000	28,000
1961	143,672	8,900	5,356	145,816	37,000	5,267	778,682	47,000	18,000	1,068,170	93,000	29,000
1962	127,988	8,200	5,100 4/	177,424	41,000	5,500 4/	701,553	48,000	18,000	1,006,965	97,000	29,000

1/ Includes barite, boron minerals, bromine, calcium chloride, chromite, clay, copper, diatomite, feldspar, fluorspar, gem stones, gold, gypsum, iodine, iron ore, lead, lime, lithium minerals, magnesium compounds, manganese ore, mercury, mica, perlite, potassium salts, pumice, pumicite, volcanic cinders, rare earth metals, salt, sodium carbonate, sodium sulfate, sulfur, silver, strontium ore, talc, soapstone, pyrophyllite, tungsten, uranium ore, wollastonite, and zinc which have been grouped because the individual values of many of the commodities would disclose confidential company data.

2/ Includes stone, cement, and sand and gravel.

3/ Includes petroleum, natural gas, natural gas liquids, peat, and carbon dioxide.

4/ Extrapolated.

TABLE 5. --Electrical requirements of the Lower Colorado River Basin (in billion kwh)

Year	Southern California Central Nevada	Arizona Southern Nevada Western New Mexico	Total
1960	33.7	10.6	44.3
1961	36.4	12.0	48.4
1965	50.2	15.9	66.1
1970	70.4	22.6	93.0
1975	96.3	30.9	127.2
1980	129.5	42.0	171.5

Source of data: Reference No. 12

TABLE 6. --Electrical generation in California, by energy source (in billion kwh)

Year	THERMAL				Hydro	Total
	Natural gas	Oil	Coal	Nuclear		
1950	5.8	4.2	—	—	14.8	24.8
1955	16.3	11.6	—	—	14.6	42.5
1960	31.8	14.6	—	—	17.4	63.8
1965	54.7	15.8	—	0.5	21.8	92.8
1970	76.7	26.0	—	8.3	27.0	138.0
1975	89.0	24.0	3.0	50.0	31.0	197.0
1980	89	24	3	119	35	270
1985	91	24	3	194	39	351
1990	91	25	3	289	42	450
1995	82	25	3	408	44	562
2000	70	25	6	558	46	705
Total	697.3	219.2	21.0	1,626.8	332.6	2,896.9

Source of data: Reference No. 7

TABLE 7. --Water consumption (in acre-feet) of the Southern California and Clark County, Nevada, Mineral Industry

Year	Nonferrous metals	Ferrous metals	Nonmetals	Fuels	Total
1953	400	500	25,000	34,000	60,000
1954	800	800	32,000	36,000	70,000
1955	1,000	1,200	33,000	37,000	72,000
1956	2,000	1,700	41,000	39,000	84,000
1957	500	1,700	36,000	41,000	79,000
1958	200	1,300	39,000	42,000	83,000
1959	300	1,400	41,000	44,000	87,000
1960	100	1,500	39,000	46,000	87,000
1961	600	1,200	43,000	47,000	92,000
1962	200	1,800	47,000	48,000	97,000

UNITED STATES DEPARTMENT OF THE INTERIOR

LOWER COLORADO RIVER LAND USE OFFICE

APPENDIX

TO

PACIFIC SOUTHWEST WATER PLAN

THE INFLUENCE OF THE LOWER COLORADO RIVER LAND USE PLAN ON THE USE OF WATER IN THE STATES OF ARIZONA AND CALIFORNIA

Under the Lower Colorado River Land Use Plan covering the area between Davis Dam to the International Boundary, the largest portion of the proposed use of Federally-owned Reclamation withdrawn land will be for public recreation facilities integrated with the Bureau of Reclamation use of the land for reclamation functions such as water storage, conservation and delivery, channel control and flood protection. Consumptive use of water in support of these recreation facilities will be principally for domestic purposes. Ground water where available in sufficient quantity and of potable quality is a better source of this domestic water as it generally has a lower bacteria count, requires less processing and requires less investment in a distribution system than water from a surface source.

Under certain circumstances ground water sources tend to be self replacing. Sewage when processed and purified through underground facilities such as septic tanks returns to the ground water aquifer. Development under the Lower Colorado River Land Use Plan anticipates heavy use of septic tank facilities for disposal of sewage.

Portions of the area proposed for development under the Plan will have landscaping which requires irrigation water. Most of these areas are at present covered with heavy stands of phreatophytes, which preliminary study by Region 3 of the Bureau of Reclamation and other studies in the Rio Grande Valley, show to use an amount of water equal to or greater than the amount needed to maintain grass and other plant materials. Some landscaping near recreational facilities will be on lands currently used for agriculture. It is anticipated that the water requirement per unit of area for landscaping will be less than the amount used for crops.

A large portion of the Federally-owned land included in the Lower Colorado River Land Use Plan and currently used for agriculture is proposed for lease to State Wildlife management agencies for development as wildlife management areas. These agencies plan to continue, on a share cropping basis, farming the areas currently in agricultural production. Optimum juxtaposition of cover, feeding and nesting areas is a basic principle of game management and it is anticipated that the total area farmed by these agencies and using water will remain approximately equal to the present area. Fence rows and brush areas will remain with possible replacement by species of plants which provide comparable cover but do not use as much water as the existing phreatophytes. Use of water by the Bureau of Sport Fisheries and Wildlife on National Wildlife refuges has not been included in this report as that agency is submitting its own report for this comprehensive study.

Development of marinas, swimming and other water oriented facilities requires construction of quiet water lagoons. Surface evaporation from these lagoons will use some water.

The entire Southern California and Arizona region is a water scarce area. Studies of the recreational use on the Lower Colorado River show that the major portion of the people who visit the River are from the cities adjacent to the River and the Southern California and Phoenix-Tucson metropolitan areas. These areas are, when the Central Arizona Project is completed, heavy users of Colorado River water for domestic purposes. It appears that demand for Colorado River water for domestic purposes will be present regardless of whether it is present in the immediate River area or if it is present in one of the urban areas to which the water will be transported. Further, if there are no organized facilities available to accommodate this recreational use the area is likely to be used in an uncontrolled manner tending to create a River pollution problem.

Persons using the Lower Colorado River areas other than the Southern California and Phoenix-Tucson metropolitan areas, are drawn to the region by its unique climatic characteristics and demand facilities of all types. These people will come to the region as long as there are facilities in any portion of the region to accommodate them. If the facilities are not available in the immediate vicinity of the Lower Colorado River, they will go to other portions of the region where facilities are available and in many cases still use Colorado River water after it has been transported a considerable distance.

Recreational use of the lands included in the Lower Colorado River Land Use Plan at the present time is estimated to be 3.8 million visitor days.

Ultimate possible use, under the developments proposed in the Plan, is 34 million visitor days. The preponderance of facilities proposed for development under the Lower Colorado River Land Use Plan are in support of short term use by visitors. This type of use does not encourage the heavy per capita water consumption which is present in permanent residential areas.

An estimated average use per visitor day is 50 gallons. As the ultimate recreation use is reached, areas of Federally-owned land now in agriculture will be used to provide space for this recreation. This shifting of land use will result in less water consumption.

Permanent residential use on lands leased under the Lower Colorado River Land Use Plan will be limited. Townsites not on reclamation withdrawn land will provide homes for the majority of the people providing services for the visitors to the area and will also provide homes for those people who wish to live in an area where the recreation facilities on the River will be available without extensive travel from their homes. Except for one proposed townsite near Cross Roads, California, the proposed residential areas will be considerable distance from the River and will have to rely on ground water for domestic water supply in their early stages of development. When the population of these residential areas reach their ultimate size, it may be necessary for these proposed municipalities to install water systems to supplement this ground water source.

UNITED STATES DEPARTMENT OF THE INTERIOR

BONNEVILLE POWER ADMINISTRATION

APPENDIX

TO

PACIFIC SOUTHWEST WATER PLAN

UNITED STATES DEPARTMENT OF THE INTERIOR

BONNEVILLE POWER ADMINISTRATION

APPENDIX

TO

PACIFIC SOUTHWEST WATER PLAN

Bonneville Power Administration is the power marketing agency for 32 multipurpose federal dams existing, under construction, or authorized in the Columbia River Basin. This is the largest hydroelectric system in the United States and one of the largest in the world. Completion of hydroelectric projects presently authorized will raise the total nameplate rating of the system to over 10 million kilowatts.

As marketing agent for the federal dams, Bonneville Power Administration is required to construct, operate, and maintain a transmission system to carry the power from the generating plants to the load centers and to interconnect the federal power plants so that they can be hydraulically and electrically coordinated. The transmission grid which extends from Canada on the north to Southern Oregon on the south, and from the Pacific Coast to Western Montana, at present consists of nearly 9,000 miles of high voltage transmission line and over 200 substations.

Hydroelectric generation provides over 96 percent of the Pacific Northwest's electric energy requirements. Since there are insufficient storage reservoirs to completely control the large seasonal and annual variations in streamflow, power surplus to the regions' needs is frequently available.

The following tables show Pacific Northwest peak and energy power surpluses for the years 1967-68, 1969-70, 1974-75, 1979-80, and 1984-85. It should be noted that the estimated surpluses are after deducting Canadian peak and energy entitlement. It now appears possible that a large part of the Canadian entitlement may become available for sale in the United States outside the Pacific Northwest.

EXPLANATORY NOTES TO APPENDIX TABLES 1 THROUGH 6

The loads used in these analyses are based on the Pacific Northwest Area requirements included in the Federal Power Commission's National Power Survey. The area includes all of the states of Oregon, Washington, and Idaho (except for the service area of Utah Power and Light Company), Montana west of the Continental Divide, and the service area of Pacific Power and Light Company (Copco Division) in northern California.

Main stem hydro resources for the 1967-68 and 1969-70 levels of development are based on the BPA, Branch of Power Resources' adjusted 20-year regulation study 20-1 which includes High Arrow Lake and Duncan Lake storage in Canada. Hydro resources for the 1974-75, 1979-80, and 1984-85 levels of development are based on the Corps of Engineers' study C-1, which includes the full Canadian storage and U.S. Columbia River Power projects. Installations in the C-1 study have been adjusted for the three load levels.

The New Production Reactor was used as a dual purpose thermal source with 660,000 and 776,000 kilowatts for energy and peak, respeotively, at 1967-68 and 1969-70 levels of development.

Other resources of the area are included from summary data shown in the January 1961 report of the Power Planning Subcommittee, CBIAC, Power Resources of Hydroelectric Projects with Hydraulic Operations Independent of the Columbia River System, adjusted for minor changes in resource schedules.

ESTIMATED ENERGY SURPLUS - PACIFIC NORTHWEST AREA

Appendix Tables 1 through 6

Average surpluses represent the remainder of the total energy resources after deducting firm energy requirements, Canadian energy entitlement, and the replacement of the average energy in kilowatts of existing thermal resources, replacement of 50 percent of thermal resources for 1972-73 and thereafter, and serving interruptible load, all as indicated in the following table.

Level of Development	Canadian Entitlement Average mw	Existing Thermal Average mw	New Total Thermal Resources Average mw	Interruptible Load Average mw
1967-68	472	440	--	202
1969-70	489	467	--	202
1974-75	792	--	2,560 1/	--
1979-80	594	--	8,692 2/	--
1984-85	396	--	17,075 3/	--

1/ Includes 122 mw thermal energy reserves.

2/ Includes 414 mw thermal energy reserves.

3/ Includes 813 mw thermal energy reserves.

TABLE 1

Estimated Energy Surplus - Pacific Northwest Area
1967-68
(Thousands of Average Kilowatts at Point of Generation)

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1928-29	4356	1675	330	330	330	330	330	330	330	330	1320	2100
1929-30	3091	99	99	99	99	99	99	99	99	1122	1674	1724
1930-31	2300	99	99	99	99	99	99	99	692	692	692	692
1931-32	692	99	99	99	99	99	429	429	3311	3964	4502	5084
1932-33	4538	1479	1534	1298	1298	1298	1298	1298	2168	2903	4448	4903
1933-34	5052	3236	2879	3564	4031	4545	4667	3928	4354	4072	3544	3439
1934-35	2932	903	1024	1434	2625	2237	2029	1632	1775	1978	3333	4440
1935-36	4101	1646	297	297	297	297	297	297	297	2088	4034	4985
1936-37	2961	99	99	99	99	99	99	99	99	99	1894	2057
1937-38	3275	99	963	963	1491	1491	1491	1491	2736	3880	4671	4783
1938-39	4319	99	459	819	819	819	819	819	1258	2862	2942	3464
1939-40	3725	843	1052	1052	1052	1052	1052	1052	2898	2715	2888	2521
1940-41	2301	99	1110	1110	1110	1110	1110	1110	1110	604	99	99
1941-42	99	99	3340	3340	3340	3216	2067	1882	1614	2479	3541	4120
1942-43	4252	1521	1425	1425	2126	2126	2424	2424	2424	4980	4630	5289
1943-44	5624	2504	394	394	394	394	394	394	394	394	99	99
1944-45	99	99	99	99	99	99	99	99	99	99	2566	4406
1945-46	3803	99	99	1466	1466	2206	2510	2510	2510	3763	4872	4923
1946-47	4757	1526	2385	2424	2708	3776	2752	3136	3447	4042	3823	4391
1947-48	4175	1275	2112	3612	3364	2844	3027	2446	2619	3497	4633	4369
1948-49	4635	2689	1615	1615	1615	1615	1615	1615	3098	4092	5188	5123
1949-50	3262	99	1526	1526	2108	2108	2178	2677	3689	4620	5004	5451
1950-51	5071	3209	2527	3928	4165	4042	3857	5159	4638	5179	5143	4976
1951-52	4400	2441	2454	3398	2978	2902	2335	3109	3046	4394	4743	4497
1952-53	4617	1002	361	361	361	361	3317	3055	2608	2454	4121	5333
1953-54	5125	2101	2243	2455	2455	2455	2455	2590	2796	3762	4365	4751
1954-55	4670	3676	2966	2852	2487	1858	1746	1525	1007	1353	3276	4750
1955-56	4831	2387	2369	3439	3715	4316	3936	3059	3903	5020	5023	5344
1956-57	4940	2130	2207	2128	2128	2128	2128	2223	3262	3554	4576	4606
1957-58	4244	99	994	1888	1888	1888	1888	2950	2807	3832	4795	4990

Sending End Capacity			Average Monthly Surplus as Limited by Alternative Service Plans									Ave.
450 mw	427	310	366	378	378	378	392	392	404	421	427	427	392
600 mw	567	400	461	483	483	483	502	502	524	551	567	567	508
900 mw	840	578	651	690	690	690	719	719	767	794	840	840	735
1000 mw	930	631	713	755	757	757	789	789	834	874	930	930	807
1050 mw	975	656	741	787	790	790	824	824	871	914	975	975	844
1200 mw	1110	731	813	874	882	882	921	921	978	1031	1110	1110	947
1350 mw	1245	804	883	957	970	970	1014	1014	1080	1146	1244	1245	1048
1500 mw	1380	873	950	1031	1054	1054	1104	1104	1180	1256	1374	1380	1145
1800 mw	1650	975	1056	1146	1198	1209	1266	1253	1372	1476	1629	1647	1323
2250 mw	2055	1101	1200	1295	1383	1394	1459	1450	1640	1792	1993	2026	1566

TABLE 2

Estimated Energy Surplus - Pacific Northwest Area

1969-70

(Thousands of Average Kilowatts at Point of Generation)

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1928-29	4193	1345	0	0	0	0	0	0	0	0	1314	2163
1929-30	2839	0	0	0	0	0	0	0	0	944	1705	1666
1930-31	1948	0	0	0	0	0	0	0	261	261	261	261
1931-32	261	0	0	0	0	0	0	0	3087	4063	4770	5382
1932-33	4424	943	843	510	510	510	510	510	1651	2795	4728	4168
1933-34	4857	2825	2336	3019	3571	4238	4406	3541	4376	4179	3735	3187
1934-35	2537	251	306	702	1903	1398	1204	844	1179	1778	3526	4767
1935-36	3812	1110	0	0	0	0	0	0	0	1779	4245	5299
1936-37	2645	0	0	0	0	0	0	0	0	0	1905	1942
1937-38	2930	0	304	304	722	722	722	722	2405	3855	4934	5084
1938-39	4271	0	0	62	62	62	62	62	858	2907	3115	3438
1939-40	3457	210	285	285	285	285	285	391	2643	2644	3054	2576
1940-41	1946	0	456	456	456	456	456	456	456	0	0	0
1941-42	0	0	3528	3528	3528	2724	1360	1238	1099	2415	3763	4422
1942-43	4170	1025	768	768	1390	1390	1974	1974	1974	5150	4915	5617
1943-44	5888	2112	0	0	0	0	0	0	0	0	0	0
1944-45	0	0	0	0	0	0	0	0	0	0	2579	4741
1945-46	3682	0	0	729	729	1416	2912	2912	2912	3861	5146	5183
1946-47	4599	958	1815	1871	2112	3463	2126	2704	3231	4130	4094	4691
1947-48	4034	703	1518	3159	2811	2201	2462	1866	2203	3484	4882	4479
1948-49	4642	2317	921	921	921	921	921	921	2990	4204	5463	5454
1949-50	2973	0	1022	1022	1347	1347	1435	2179	3534	4690	5274	5686
1950-51	5275	2867	1952	3515	3691	3506	3292	5153	4524	5385	5388	5265
1951-52	4338	2034	1862	2958	2362	2258	1660	2629	2805	4491	5006	4815
1952-53	4608	431	0	0	0	0	2740	2540	2187	2256	4202	5623
1953-54	5295	1663	1659	1734	1734	1734	1734	2030	2378	3717	4650	4989
1954-55	4610	3342	2455	2278	1792	1028	920	724	319	1038	3380	5062
1955-56	4814	1948	1771	2847	3107	3918	3451	2521	3817	5163	5224	5553
1956-57	4878	1649	1583	1432	1432	1432	1432	1646	3071	3547	4843	4857
1957-58	4119	0	269	1206	1206	1206	1206	2578	2373	3863	5079	5277

Sending End Capacity	Average Monthly Surplus as Limited by Alternative Service Plans												Ave.
450 mw	414	255	264	292	297	297	312	315	349	369	414	414	333
600 mw	549	330	334	374	384	384	404	404	455	489	549	549	434
900 mw	819	473	468	517	542	548	578	574	663	729	819	819	629
1000 mw	909	517	505	558	589	599	629	621	730	807	909	909	690
1050 mw	954	536	522	577	613	623	654	644	763	845	954	954	720
1200 mw	1089	588	572	632	683	693	729	714	859	955	1089	1089	808
1350 mw	1224	638	622	682	748	758	795	781	949	1028	1223	1224	889
1500 mw	1359	683	672	730	802	806	850	847	1039	1175	1353	1359	973
1800 mw	1629	763	750	818	900	884	944	970	1214	1393	1609	1624	1125
2250 mw	2014	846	803	925	1003	987	1050	1119	1456	1693	1973	2001	1323

TABLE 3
Estimated Energy Surplus - Pacific Northwest Area
1972-73
(Thousands of Average Kilowatts at Point of Generation)

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
1928-29	5296	0	0	0	0	0	0	0	0	0	0	0	
1929-30	0	0	0	0	0	0	0	0	0	0	0	0	
1930-31	0	0	0	0	0	0	0	0	0	0	0	0	
1931-32	0	0	0	0	0	0	0	0	0	2337	4102	3347	
1932-33	4848	0	0	0	0	447	638	638	637	3859	4230	6751	
1933-34	6272	2723	931	1707	3511	5221	5308	4169	5034	5396	4751	4416	
1934-35	3070	0	0	0	0	1284	1433	1433	1432	2346	3653	4753	
1935-36	4841	0	0	0	0	0	0	0	0	4975	3916	4685	
1936-37	0	0	0	0	0	0	0	0	0	0	0	0	
1937-38	0	0	0	0	0	0	0	0	1799	5487	5772	6773	
1938-39	5414	0	0	0	0	0	0	156	529	4556	354	349	
1939-40	1411	0	0	0	0	0	0	1650	2543	4583	0	0	
1940-41	0	0	0	0	0	0	0	344	343	1705	0	0	
1941-42	0	0	0	0	0	0	0	1217	1217	3977	2229	2225	
1942-43	4720	0	0	0	0	1430	2325	3175	3179	6925	5885	6767	
1943-44	7778	704	0	0	0	0	0	0	0	0	0	0	
1944-45	0	0	0	0	0	0	0	0	0	0	1558	1555	
1945-46	0	0	0	0	0	0	0	0	2477	5442	6363	7166	
1946-47	5667	0	0	0	664	3458	3458	4396	4396	5486	4425	6346	
1947-48	5041	0	0	2167	2113	2113	2478	2478	2479	5074	6382	6533	
1948-49	5770	1650	0	0	0	0	0	2611	3113	5539	6264	5489	
1949-50	0	0	0	0	0	0	831	4054	5179	5955	3735	7282	
1950-51	7174	2242	128	1916	3292	4801	4351	5986	5274	6248	6984	7014	
1951-52	5601	922	160	1844	1844	1844	1844	3628	3627	6471	6180	5756	
1952-53	5341	0	0	0	0	0	0	3065	3066	3066	4968	6653	
1953-54	6656	422	0	0	162	1706	1865	3123	3123	5164	5155	6811	
1954-55	6224	3852	1244	518	518	518	518	518	519	986	3346	5814	
1955-56	6440	889	0	1095	1826	3999	3999	3999	5168	6842	6985	7480	
1956-57	6065	0	0	245	244	1153	1154	2825	2992	4883	5808	6838	
1957-58	3775	0	0	0	0	0	1281	3683	3699	4178	5646	6195	
Sending End Capacity			Average Monthly Surplus as Limited by Alternative Service Plans										Ave.
450 mw	300	119	40	98	119	180	210	287	326	360	342	342	227
600 mw	400	154	50	125	151	232	277	374	426	480	452	452	298
900 mw	600	217	70	175	203	332	396	535	608	720	672	672	433
1000 mw	667	231	74	192	220	365	433	589	668	800	745	745	477
1050 mw	700	238	76	200	228	382	451	615	698	838	782	782	499
1200 mw	800	258	81	222	253	431	505	695	788	953	892	892	564
1350 mw	900	278	82	242	278	473	552	771	873	1067	1002	1002	627
1500 mw	997	298	82	262	303	511	595	844	956	1183	1112	1112	688
1800 mw	1187	333	82	299	353	578	675	979	1116	1410	1324	1323	805
2250 mw	1472	378	82	316	396	650	769	1174	1341	1740	1638	1638	966

TABLE 4
Estimated Energy Surplus - Pacific Northwest Area
1974-75
(Thousands of Average Kilowatts at Point of Generation)

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
1928-29	5749	0	0	0	0	0	0	0	0	0	0	0	
1929-30	0	0	0	0	0	0	0	0	0	0	0	0	
1930-31	0	0	0	0	0	0	0	0	0	0	0	0	
1931-32	0	0	0	0	0	0	0	0	0	0	3231	4420	
1932-33	1675	0	0	0	215	0	3792	2836	1818	599	4565	7354	
1933-34	6135	1112	429	1699	4332	6075	6620	6154	4081	5935	4938	3831	
1934-35	493	0	0	0	0	962	2435	3440	0	0	4891	4927	
1935-36	4022	0	0	0	0	0	0	0	213	3691	6055	4534	
1936-37	0	0	0	0	0	0	0	0	0	0	0	0	
1937-38	0	0	0	0	0	0	23	333	3235	5190	6444	6593	
1938-39	4686	0	0	0	0	0	0	268	0	2412	2259	1860	
1939-40	0	0	0	0	0	0	0	3047	2625	79	1563	0	
1940-41	0	0	0	0	0	0	0	1528	0	0	0	0	
1941-42	0	0	0	0	0	0	1978	2870	0	805	3090	5707	
1942-43	2933	0	0	0	0	1355	6141	6516	4296	6811	4476	7903	
1943-44	8368	0	0	0	0	0	0	0	0	0	0	0	
1944-45	0	0	0	0	0	0	0	0	0	0	0	464	
1945-46	0	0	0	0	0	0	605	3173	4301	4577	6221	6996	
1946-47	4949	0	0	0	1128	5033	5161	7021	5693	4147	4331	4953	
1947-48	3248	0	0	3142	3518	2564	6241	5453	2753	3555	6838	7773	
1948-49	6291	972	0	0	86	0	345	4314	3623	4503	7272	5577	
1949-50	0	0	0	0	0	0	2293	6516	5426	4084	6562	9298	
1950-51	8497	1021	0	1947	4244	5631	6634	7651	4936	5841	7672	8242	
1951-52	6234	0	0	3330	1708	2778	4496	6040	3473	5974	7499	7143	
1952-53	3980	0	0	0	0	0	4788	6264	2428	776	5671	6783	
1953-54	5876	0	0	0	684	1285	4092	6472	3970	2278	6886	8036	
1954-55	7285	3003	2564	61	2019	1008	1810	4082	0	0	4794	5817	
1955-56	6112	0	0	1108	3220	5970	6864	5970	5535	7338	8473	9308	
1956-57	6626	0	0	268	71	1925	3355	5605	4902	3289	7091	7678	
1957-58	2882	0	0	0	0	0	3409	6323	3153	4067	7480	7394	
Sending End Capacity		Average Monthly Surplus as Limited by Alternative Service Plans											Ave.
450 mw	285	60	29	86	132	165	267	320	262	288	345	345	215
600 mw	376	80	34	111	172	220	352	420	347	383	460	455	284
900 mw	556	120	44	161	245	330	512	620	517	555	690	675	419
1000 mw	616	132	48	178	269	365	566	687	574	609	767	749	463
1050 mw	646	136	49	186	280	381	592	720	602	635	805	785	485
1200 mw	736	143	54	208	313	426	672	820	687	715	920	895	549
1350 mw	826	149	59	228	343	469	752	920	772	795	1035	1005	613
1500 mw	916	154	64	248	373	504	832	1020	857	875	1150	1115	676
1800 mw	1092	164	74	285	430	574	992	1211	1027	1035	1372	1335	799
2250 mw	1347	179	89	319	497	668	1209	1496	1268	1275	1702	1652	975

TABLE 5
Estimated Energy Surplus - Pacific Northwest Area
1979-80
(Thousands of Average Kilowatts at Point of Generation)

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
1928-29	5173	0	0	0	0	0	0	0	0	0	0	0	
1929-30	0	0	0	0	0	0	0	0	0	0	0	0	
1930-31	0	0	0	0	0	0	0	0	0	0	0	0	
1931-32	0	0	0	0	0	0	0	0	0	0	654	2100	
1932-33	0	0	0	0	0	0	788	189	0	0	2671	6607	
1933-34	5618	0	0	0	1704	4478	4965	4262	1147	4497	4091	2708	
1934-35	0	0	0	0	0	0	0	20	0	0	2707	2953	
1935-36	2436	0	0	0	0	0	0	0	0	711	3890	1974	
1936-37	0	0	0	0	0	0	0	0	0	0	0	0	
1937-38	0	0	0	0	0	0	0	0	0	2352	4463	4809	
1938-39	2659	0	0	0	0	0	0	0	0	0	0	0	
1939-40	0	0	0	0	0	0	0	0	0	0	0	0	
1940-41	0	0	0	0	0	0	0	0	0	0	0	0	
1941-42	0	0	0	0	0	0	0	0	0	0	426	3620	
1942-43	678	0	0	0	0	0	3331	4359	1052	4644	1965	6306	
1943-44	6900	0	0	0	0	0	0	0	0	0	0	0	
1944-45	0	0	0	0	0	0	0	0	0	0	0	0	
1945-46	0	0	0	0	0	0	0	0	1149	1823	4104	5151	
1946-47	3191	0	0	0	0	1674	2220	5062	3012	1484	2322	2782	
1947-48	1147	0	0	1299	410	0	4093	3287	0	703	5961	7153	
1948-49	5725	0	0	0	0	0	0	850	349	1654	6671	3577	
1949-50	0	0	0	0	0	0	0	4369	2645	1189	4553	8732	
1950-51	8311	0	0	0	1143	2622	4527	6058	1872	3458	6626	7763	
1951-52	5690	0	0	568	0	0	1109	3834	266	3327	6141	5386	
1952-53	1797	0	0	0	0	0	1850	3541	0	0	3259	5219	
1953-54	3791	0	0	0	0	0	745	4363	736	0	6048	7521	
1954-55	7074	1227	207	0	0	0	0	1509	0	0	2520	4220	
1955-56	5080	0	0	0	78	2784	4523	3643	2625	5350	7814	8774	
1956-57	5927	0	0	0	0	0	0	3289	1754	378	5575	6714	
1957-58	677	0	0	0	0	0	0	3249	0	1183	5821	6021	
Sending End Capacity			Average Monthly Surplus as Limited by Alternative Service Plans										Ave.
450 mw	255	15	7	30	46	60	150	217	156	208	314	315	148
600 mw	340	20	7	39	56	80	200	287	201	273	414	420	195
900 mw	495	30	7	49	76	120	291	425	285	390	606	630	284
1000 mw	545	33	7	52	83	133	318	469	312	426	669	700	312
1050 mw	570	35	7	54	86	140	331	490	325	445	701	735	327
1200 mw	643	40	7	59	94	160	390	555	357	499	796	840	370
1350 mw	713	41	7	62	99	180	403	620	382	544	891	945	407
1500 mw	783	41	7	62	104	200	438	685	407	588	986	1050	446
1800 mw	923	41	7	62	111	236	508	806	455	663	1176	1260	521
2250 mw	1118	41	7	62	111	281	599	986	503	754	1452	1561	623

TABLE 6
Estimated Energy Surplus - Pacific Northwest Area
1984-85
(Thousands of Average Kilowatts at Point of Generation)

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1928-29	2552	0	0	0	0	0	0	0	0	0	0	0
1929-30	0	0	0	0	0	0	0	0	0	0	0	0
1930-31	0	0	0	0	0	0	0	0	0	0	0	0
1931-32	0	0	0	0	0	0	0	0	0	0	0	0
1932-33	0	0	0	0	0	0	0	0	0	0	0	3840
1933-34	3081	0	0	0	0	551	661	2	0	1256	925	0
1934-35	0	0	0	0	0	0	0	0	0	0	0	0
1935-36	0	0	0	0	0	0	0	0	0	0	659	0
1936-37	0	0	0	0	0	0	0	0	0	0	0	0
1937-38	0	0	0	0	0	0	0	0	0	0	1255	1936
1938-39	0	0	0	0	0	0	0	0	0	0	0	0
1939-40	0	0	0	0	0	0	0	0	0	0	0	0
1940-41	0	0	0	0	0	0	0	0	0	0	0	0
1941-42	0	0	0	0	0	0	0	0	0	0	0	579
1942-43	0	0	0	0	0	0	0	156	0	1238	0	3443
1943-44	4127	0	0	0	0	0	0	0	0	0	0	0
1944-45	0	0	0	0	0	0	0	0	0	0	0	0
1945-46	0	0	0	0	0	0	0	0	0	0	942	2149
1946-47	122	0	0	0	0	0	0	984	0	0	0	0
1947-48	0	0	0	0	0	0	0	0	0	0	2891	4546
1948-49	3174	0	0	0	0	0	0	0	0	0	3706	452
1949-50	0	0	0	0	0	0	0	80	0	0	1228	6123
1950-51	5832	0	0	0	0	0	48	2095	0	0	3629	5095
1951-52	3234	0	0	0	0	0	0	0	0	0	3047	2514
1952-53	0	0	0	0	0	0	0	0	0	0	0	2358
1953-54	716	0	0	0	0	0	0	159	0	0	3229	4906
1954-55	4610	0	0	0	0	0	0	0	0	0	0	1299
1955-56	2305	0	0	0	0	0	62	0	0	1945	4944	6159
1956-57	3329	0	0	0	0	0	0	0	0	0	2486	3947
1957-58	0	0	0	0	0	0	0	0	0	0	2739	3178

Sending End Capacity	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Ave.
	Average Monthly Surplus as Limited by Alternative Service Plans												
450 mw	154	0	0	0	0	15	19	41	0	45	195	240	59
600 mw	204	0	0	0	0	18	26	51	0	60	260	314	78
900 mw	298	0	0	0	0	18	26	71	0	90	381	454	112
1000 mw	328	0	0	0	0	18	26	77	0	100	418	501	122
1050 mw	343	0	0	0	0	18	26	78	0	105	469	524	130
1200 mw	388	0	0	0	0	18	26	86	0	120	484	594	143
1350 mw	433	0	0	0	0	18	26	88	0	128	527	663	157
1500 mw	478	0	0	0	0	18	26	93	0	133	567	728	170
1800 mw	568	0	0	0	0	18	26	103	0	143	647	858	197
2250 mw	703	0	0	0	0	18	26	116	0	148	767	1039	235

ESTIMATED PEAK SURPLUS - PACIFIC NORTHWEST AREA

Appendix Tables 7 through 12

Pacific Northwest capacity surplus represents the remainder of total capacity of the area after deducting the estimated firm area peak load including reserves for maintenance and unscheduled outages, at 7 percent and 10 percent of peak loads for the periods August through March and April through July, respectively, Canadian dependable capacity entitlement, displacement of existing thermal capacity, and interruptible loads, all as indicated in the following table.

Level of Development	Canadian Dependable Capacity Entitlement mw	Existing Thermal mw	Interruptible Load mw
1967-68	942	585	205
1969-70	975	612	205
1974-75	1,397	--	--
1979-80	1,302	--	--
1984-85	1,173	--	--

TABLE 7

Estimated Peak Surplus - Pacific Northwest Area

1967-68

(Thousands of Kilowatts at Point of Generation)

Year	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1928-29	7692	8150	7673	6881	5340	4726	4295	4466	4596	4211	5190	6636
1929-30	8020	8026	5872	6882	5228	4681	4092	4466	4643	4297	5458	6585
1930-31	7740	7957	7629	6839	5274	4603	4196	4660	4455	4325	5284	6559
1931-32	7729	7838	7574	6694	5164	4554	4140	4597	4965	5099	5341	6555
1932-33	7896	8124	7823	6804	5503	4922	4506	5107	5164	4918	5319	6097
1933-34	7451	8056	7743	6747	5211	4814	4654	5250	5580	4693	5530	6617
1934-35	7929	7837	7525	6619	5374	4844	4461	4944	5317	4500	5357	6718
1935-36	7717	7987	7720	6725	5129	4486	4191	4418	4471	4781	5415	6620
1936-37	8029	7981	7857	6830	5166	4549	3969	4374	4154	3593	4844	6563
1937-38	7748	7929	7487	6467	5059	4558	4210	4688	4797	4422	5320	6287
1938-39	7588	8019	7618	6813	5257	4678	4295	4581	5011	4646	5336	6822
1939-40	7941	7997	7826	6827	5207	4679	4064	4666	5239	5064	5607	6586
1940-41	7776	7941	7618	6676	5373	4800	4444	4648	4798	4628	5383	6410
1941-42	7740	7813	7607	6787	5371	4883	4481	4771	4876	4672	5448	6706
1942-43	7853	8091	7851	6809	5381	4861	4399	4935	4992	4680	5256	6369
1943-44	7574	8159	7879	6908	5356	4747	4336	4848	4627	4188	4997	6446
1944-45	7789	7995	7816	6841	5280	4483	3917	4527	4746	4293	5189	6475
1945-46	7732	8024	7670	6676	5297	4673	4132	4700	5125	4572	5286	6403
1946-47	7832	8133	7850	6834	5310	4833	4540	5063	5465	5055	5291	6531
1947-48	7925	8172	7854	6922	5465	4850	4447	5178	5239	4980	4898	5257
1948-49	7796	8145	7880	6860	5348	4774	4237	4753	4757	4627	5263	6850
1949-50	8091	8008	7867	6824	5377	4787	4389	4846	5271	5327	5505	5755
1950-51	7223	8147	7869	6910	5568	5066	4733	5418	5904	5447	5477	6284
1951-52	7659	8155	7860	6896	5357	4823	4383	4974	5042	4564	5170	6456
1952-53	7973	8054	7871	6852	5289	4692	4422	5146	5250	4655	5431	6319
1953-54	7737	8164	7862	6837	5335	4798	4396	4851	5115	4838	5205	5942
1954-55	7129	8049	7870	6862	5382	4791	4371	4905	4948	4750	5300	6547
1955-56	7406	8154	7870	6916	5603	5053	4686	5284	5534	4729	4893	5917
1956-57	7741	8144	7860	6851	5333	4817	4333	4718	4906	4636	5110	6183
1957-58	8022	8019	7861	6841	5332	4818	4367	4735	4874	4811	5321	6499
Minimum Monthly Peak Surplus	7129	7813	5872	6467	5059	4483	3917	4374	4154	3593	4844	5257
Average Monthly Peak Surplus	7749	8042	7705	6808	5322	4755	4336	4817	4995	4667	5281	6400

TABLE 8

Estimated Peak Surplus - Pacific Northwest Area
1969-70
(Thousands of Kilowatts at Point of Generation)

Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1928-29	7401	7936	7748	6839	5071	4371	3887	4214	4421	3938	4815	6367
1929-30	7782	8495	6215	7110	5224	4593	3959	4484	4322	3830	5083	6316
1930-31	7502	8396	7975	7065	5280	4522	4060	4212	3883	3827	4890	6290
1931-32	7491	8307	7957	6934	5159	4359	3902	4145	4388	4602	4928	6245
1932-33	7632	7921	7535	6366	4832	4165	3706	4450	4585	4419	4918	5757
1933-34	7100	7853	7455	6310	4530	4050	3847	4587	4998	4074	5089	6275
1934-35	7670	7608	7178	6169	4693	4079	3653	4281	4735	3990	4949	6421
1935-36	7427	7784	7874	6755	4928	4199	3863	4236	4095	4255	5036	6330
1936-37	7791	8444	8216	7059	5159	4459	3836	4387	4247	3295	4414	6258
1937-38	7488	8398	7150	6028	4388	3805	3411	4033	4226	3896	4945	5975
1938-39	7331	8485	7510	6377	4587	3922	3495	3933	4448	4173	4961	6553
1939-40	7696	7791	7497	6385	4531	3918	3259	4007	4663	4562	5204	6317
1940-41	7538	8410	7308	6233	4698	4040	3640	3989	4222	4706	5179	6325
1941-42	8170	8282	7316	6345	4696	4125	3676	4112	4297	4172	5051	6427
1942-43	7582	7883	7530	6366	4707	4104	3604	4283	4485	4234	4881	6092
1943-44	7264	7950	7557	6484	4695	3997	3539	4197	4054	4253	4814	6382
1944-45	8223	8451	8153	7074	5284	4400	3789	4587	4844	3994	4792	6205
1945-46	7489	8481	7541	6265	4635	3925	3362	4085	4576	4130	4893	6058
1946-47	7559	7910	7509	6397	4642	4086	3767	4443	4922	4596	4895	6226
1947-48	7663	7954	7520	6501	4800	4099	3651	4531	4674	4508	4480	4762
1948-49	7521	7924	7544	6413	4662	4017	3465	4129	4229	4187	4871	6576
1949-50	7853	7784	7538	6380	4692	4019	3590	4210	4724	4893	5130	5385
1950-51	6853	7944	7530	6514	4912	4322	3958	4801	5362	5011	5055	5968
1951-52	7358	7952	7530	6507	4702	4077	3611	4358	4515	4104	4766	6169
1952-53	7715	7851	7975	6832	5030	4145	3621	4499	4690	4166	5056	6004
1953-54	7451	7961	7541	6396	4662	4040	3594	4212	4561	4404	4823	5575
1954-55	6728	7833	7549	6424	4709	4032	3567	4247	4374	4276	4907	6254
1955-56	7046	7935	7543	6473	4930	4302	3919	4683	4993	4253	4427	5521
1956-57	7457	7941	7541	6416	4657	4062	3534	4065	4350	4202	4710	5829
1957-58	7784	8488	7535	6431	4682	4083	3583	4111	4333	4377	4938	6181
Minimum Monthly Peak Surplus	6728	7608	6215	6028	4388	3805	3259	3933	3883	3295	4414	4762
Average Monthly Peak Surplus	7519	8078	7552	6528	4806	4144	3678	4284	4507	4244	4897	6101

TABLE 9

Estimated Peak Surplus - Pacific Northwest Area
1972-73
(Thousands of Kilowatts at Point of Generation)

Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1928-29	5884	6227	5710	4340	2222	1365	873	1870	2506	2622	3169	4764
1929-30	6127	6242	4703	4328	2140	1333	732	1936	2471	2527	3462	4850
1930-31	6120	6188	5661	4284	2167	1247	734	1729	2147	2337	3286	4738
1931-32	6026	6105	5560	4055	1798	758	60	514	745	1269	2387	4514
1932-33	6091	6195	5678	4259	2261	1443	970	1992	2636	2605	3030	4185
1933-34	5836	6172	5659	4244	2108	1380	1012	2132	2801	2647	3638	4666
1934-35	5999	6056	5388	4121	2167	1389	933	2002	2753	2655	3225	4701
1935-36	6048	6156	5588	4198	2047	1182	796	1844	2528	2909	3513	4821
1936-37	6111	6202	5676	4275	2077	1203	616	1594	1783	1690	2607	4558
1937-38	6075	6167	5576	4202	2164	1407	944	1993	2667	2761	3487	4761
1938-39	6063	6210	5680	4293	2162	1350	881	1956	2686	2728	3483	4859
1939-40	6100	6202	5649	4281	2110	1369	856	2031	2789	2770	3548	4846
1940-41	6123	6231	5683	4353	2224	1409	964	1963	2532	2528	3120	4576
1941-42	6040	6134	5588	4255	2229	1483	1000	2014	2608	2575	3160	4675
1942-43	6111	6239	5699	4301	2252	1476	970	2091	2766	2748	3476	4768
1943-44	6068	6233	5716	4377	2240	1470	893	1942	2549	2615	3339	4794
1944-45	6130	6232	5643	4314	2178	1171	578	1376	1649	1510	2472	4506
1945-46	6118	6228	5690	4327	2210	1404	971	2027	2754	2837	3606	4841
1946-47	6059	6221	5681	4329	2213	1451	1043	2122	2833	2915	3515	4809
1947-48	6099	6226	5695	4392	2278	1449	986	2187	2852	2838	3406	3523
1948-49	5977	6218	5706	4329	2209	1414	886	2010	2715	2907	3585	4903
1949-50	6153	6223	5702	4330	2227	1390	965	2135	2887	2920	3573	4341
1950-51	5655	6240	5696	4428	2353	1569	1138	2354	3144	3414	3758	4689
1951-52	5949	6238	5697	4427	2243	1444	957	2139	2792	2871	3537	4886
1952-53	6157	6241	5711	4318	2171	1351	982	2233	2881	2768	3115	4470
1953-54	6081	6241	5709	4324	2215	1419	964	2147	2820	2734	3304	4474
1954-55	5496	6195	5718	4338	2237	1401	923	2009	2716	2837	3048	4502
1955-56	5845	6221	5710	4384	2352	1547	1121	2247	2884	2971	3292	4192
1956-57	5966	6244	5711	4356	2210	1430	891	2040	2737	2640	3315	4638
1957-58	6116	6244	5708	4371	2241	1459	963	2127	2644	2732	3265	4785
Minimum Monthly Peak Surplus	5496	6056	4703	4055	1798	758	60	514	745	1269	2387	3523
Average Monthly Peak Surplus	6021	6206	5633	4304	2190	1372	887	1958	2576	2629	3291	4621

TABLE 10
Estimated Peak Surplus - Pacific Northwest Area
1974-75
(Thousands of Kilowatts at Point of Generation)

Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1928-29	6583	6857	6525	4955	2573	1638	1096	2326	3077	3391	3833	5175
1929-30	6740	6868	5519	4942	2491	1631	931	2103	2714	2838	3678	5198
1930-31	6732	6816	6474	4900	2517	1547	837	1691	2168	2412	3359	4986
1931-32	6595	6675	6300	4658	2127	885	0	59	534	1566	3392	5299
1932-33	6723	6824	6493	4874	2599	1710	1033	1857	2127	2196	3172	4881
1933-34	6651	6805	6474	4860	2464	1583	1115	2505	3433	3796	4211	5171
1934-35	6621	6682	6204	4735	2515	1663	1127	2395	3380	3697	4201	5292
1935-36	6684	6784	6402	4813	2391	1446	1007	2282	3170	3878	4209	5302
1936-37	6715	6827	6492	4889	2425	1490	753	1697	2262	2550	3512	5201
1937-38	6695	6793	6393	4817	2488	1625	1069	2233	3015	3396	4218	5298
1938-39	6701	6835	6493	4907	2507	1612	1086	2393	3357	3730	4229	5323
1939-40	6708	6828	6465	4896	2453	1632	1062	2454	3437	3743	4208	5312
1940-41	6729	6857	6499	4965	2568	1670	1170	2393	3204	3578	4071	5173
1941-42	6641	6757	6398	4866	2570	1730	1180	2388	3063	3503	4170	5287
1942-43	6731	6867	6514	4916	2598	1744	936	1943	2028	2753	3535	4919
1943-44	6711	6859	6532	4995	2583	1732	1104	2378	3177	3537	4136	5328
1944-45	6736	6846	6421	4874	2455	1441	804	1841	2200	2131	3028	4902
1945-46	6657	6787	6438	4877	2489	1593	958	1849	2030	2598	3424	5099
1946-47	6733	6846	6497	4946	2559	1730	1094	1979	2366	2456	3323	5170
1947-48	6752	6852	6509	5004	2626	1718	1011	1980	2224	2304	3260	4399
1948-49	6650	6846	6519	4947	2552	1679	1097	2421	2953	3721	4217	5383
1949-50	6760	6848	6515	4947	2574	1659	1025	2031	2593	2853	3471	4655
1950-51	6470	6869	6509	5044	2710	1842	1187	1977	2369	2833	3818	5124
1951-52	6665	6865	6513	5041	2590	1716	1010	1839	2108	2630	3863	5347
1952-53	6780	6866	6527	4935	2515	1611	1026	2112	2419	2387	3209	5007
1953-54	6740	6867	6525	4939	2557	1688	1022	2003	2437	2498	3364	4969
1954-55	6429	6855	6528	4957	2577	1664	984	1847	2366	2714	3059	4470
1955-56	6478	6850	6523	5000	2700	1819	1165	2084	2118	2879	3640	4835
1956-57	6690	6873	6526	4972	2557	1699	960	1941	2076	2414	3483	5148
1957-58	6726	6872	6521	4986	2583	1720	1163	2345	2884	3635	4261	5373
Minimum Monthly Peak Surplus	6429	6675	6204	4658	2127	885	0	59	534	1566	3059	4399
Average Monthly Peak Surplus	6674	6829	6442	4945	2530	1631	1000	2045	2576	2954	3718	5101

TABLE 11

Estimated Peak Surplus - Pacific Northwest Area

1979-1980

(Thousands of Kilowatts at Point of Generation)

Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1928-29	8244	8565	7939	5767	2503	1252	526	2275	3357	3848	4481	6270
1929-30	8410	8576	6933	5754	2421	1245	340	1987	2891	3196	4298	6304
1930-31	8402	8524	7888	5712	2447	1161	237	1550	2326	2764	3969	6086
1931-32	8272	8383	7714	5470	2057	469	0	0	568	1848	4022	6438
1932-33	8394	8532	7907	5686	2529	1321	429	1699	2238	2490	3732	5956
1933-34	8320	8513	7888	5672	2394	1190	535	2454	3739	4323	4947	6306
1934-35	8298	8390	7618	5547	2445	1277	557	2344	3686	4224	4937	6431
1935-36	8361	8492	7816	5625	2321	1060	437	2231	3476	4405	4945	6441
1936-37	8392	8535	7906	5701	2355	1104	151	1567	2454	2939	4159	6321
1937-38	8372	8501	7807	5629	2418	1239	499	2182	3321	3923	4954	6437
1938-39	8378	8543	7907	5719	2437	1226	516	2342	3663	4257	4965	6462
1939-40	8385	8536	7879	5708	2383	1246	492	2403	3743	4270	4944	6451
1940-41	8406	8565	7913	5777	2498	1284	600	2342	3510	4105	4807	6312
1941-42	8318	8465	7812	5678	2500	1344	610	2337	3369	4030	4906	6426
1942-43	8408	8575	7928	5728	2528	1358	338	1785	2139	3074	4118	5993
1943-44	8388	8567	7946	5807	2513	1346	534	2327	3483	4064	4872	6467
1944-45	8413	8554	7835	5686	2385	1055	217	1727	2374	2471	3594	5975
1945-46	8334	8495	7852	5689	2419	1207	360	1691	2141	2892	3988	6183
1946-47	8410	8554	7911	5758	2489	1344	496	1821	2477	2750	3906	6272
1947-48	8429	8560	7923	5816	2556	1332	412	1822	2335	2598	3843	5425
1948-49	8316	8554	7933	5759	2482	1293	527	2370	3259	4248	4948	6522
1949-50	8437	8556	7929	5759	2504	1273	427	1873	2704	3147	4041	5698
1950-51	8122	8577	7923	5856	2640	1456	589	1812	2480	3127	4201	6221
1951-52	8334	8573	7927	5853	2520	1330	412	1681	2219	2965	4524	6486
1952-53	8457	8574	7941	5747	2445	1225	428	1954	2530	2681	3766	6084
1953-54	8417	8575	7939	5751	2487	1302	424	1845	2548	2792	3944	6053
1954-55	8076	8563	7942	5769	2507	1278	386	1689	2477	3008	3562	5434
1955-56	8097	8558	7937	5812	2630	1433	567	1926	2229	3240	4288	5917
1956-57	8360	8581	7940	5784	2487	1313	362	1783	2187	2708	4054	6232
1957-58	8403	8580	7935	5798	2513	1334	593	2294	3190	4162	4997	6512
Minimum Monthly Peak Surplus	8076	8383	7618	5470	2057	469	0	0	568	1848	3562	5425
Average Monthly Peak Surplus	8345	8537	7856	5727	2460	1243	433	1937	2770	3352	4357	6204

TABLE 12
Estimated Peak Surplus - Pacific Northwest Area
1984-85
(Thousands of Kilowatts at Point of Generation)

Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1928-29	8794	9175	8476	5565	878	0	0	549	2044	2956	3888	6329
1929-30	8960	9186	7470	5552	796	0	0	256	1572	2296	3694	6363
1930-31	8952	9134	8425	5517	822	0	0	0	962	1817	3314	6094
1931-32	8783	8949	8199	5207	356	0	0	0	0	859	3352	6468
1932-33	8944	9142	8444	5484	904	0	0	0	902	1571	3115	6009
1933-34	8870	9123	8425	5470	769	0	0	728	2426	3430	4361	6356
1934-35	8846	9000	8155	5345	820	0	0	616	2373	3332	4342	6489
1935-36	8911	9102	8353	5423	696	0	0	505	2162	3523	4360	6500
1936-37	8942	9145	8443	5499	730	0	0	0	1113	2009	3528	6366
1937-38	8922	9111	8344	5427	793	0	0	439	1985	3007	4352	6495
1938-39	8928	9153	8444	5517	812	0	0	616	2350	3372	4379	6519
1939-40	8935	9146	8416	5506	758	0	0	677	2430	3385	4360	6510
1940-41	8956	9175	8450	5575	873	0	0	616	2196	3213	4211	6369
1941-42	8868	9075	8348	5475	875	0	0	611	2055	3138	4317	6485
1942-43	8958	9185	8465	5526	903	0	0	48	804	2171	3533	6050
1943-44	8937	9177	8483	5605	888	0	0	599	2163	3156	4263	6513
1944-45	8963	9158	8354	5455	720	0	0	0	964	1478	2901	5964
1945-46	8843	9072	8356	5454	761	0	-	0	798	1973	3381	6240
1946-47	8960	9164	8448	5556	864	0	0	82	1141	1831	3293	6329
1947-48	8979	9170	8460	5614	931	0	0	83	999	1679	3227	5425
1948-49	8863	9164	8470	5557	857	0	0	643	1946	3358	4349	6581
1949-50	8987	9166	8466	5557	879	0	0	145	1391	2255	3444	5717
1950-51	8655	9187	8460	5654	1015	0	0	76	1167	2236	3609	6272
1951-52	8884	9183	8464	5651	895	0	0	0	905	2073	3932	6542
1952-53	9007	9184	8478	5545	820	0	0	227	1216	1789	3170	6137
1953-54	8967	9185	8476	5549	862	0	0	106	1212	1873	3324	6100
1954-55	8614	9173	8479	5567	882	0	0	0	1163	2116	2966	5489
1955-56	8647	9168	8474	5610	1005	0	0	189	892	2318	3647	5928
1956-57	8909	9191	8477	5582	862	0	0	58	874	1817	3460	6283
1957-58	8953	9190	8472	5596	888	0	0	567	1876	3270	4405	6567
Minimum Monthly Peak Surplus	8614	8949	7470	5207	356	0	0	0	0	1478	2901	5425
Average Monthly Peak Surplus	8891	9144	8389	5521	830	0	0	281	1469	2443	3749	6250