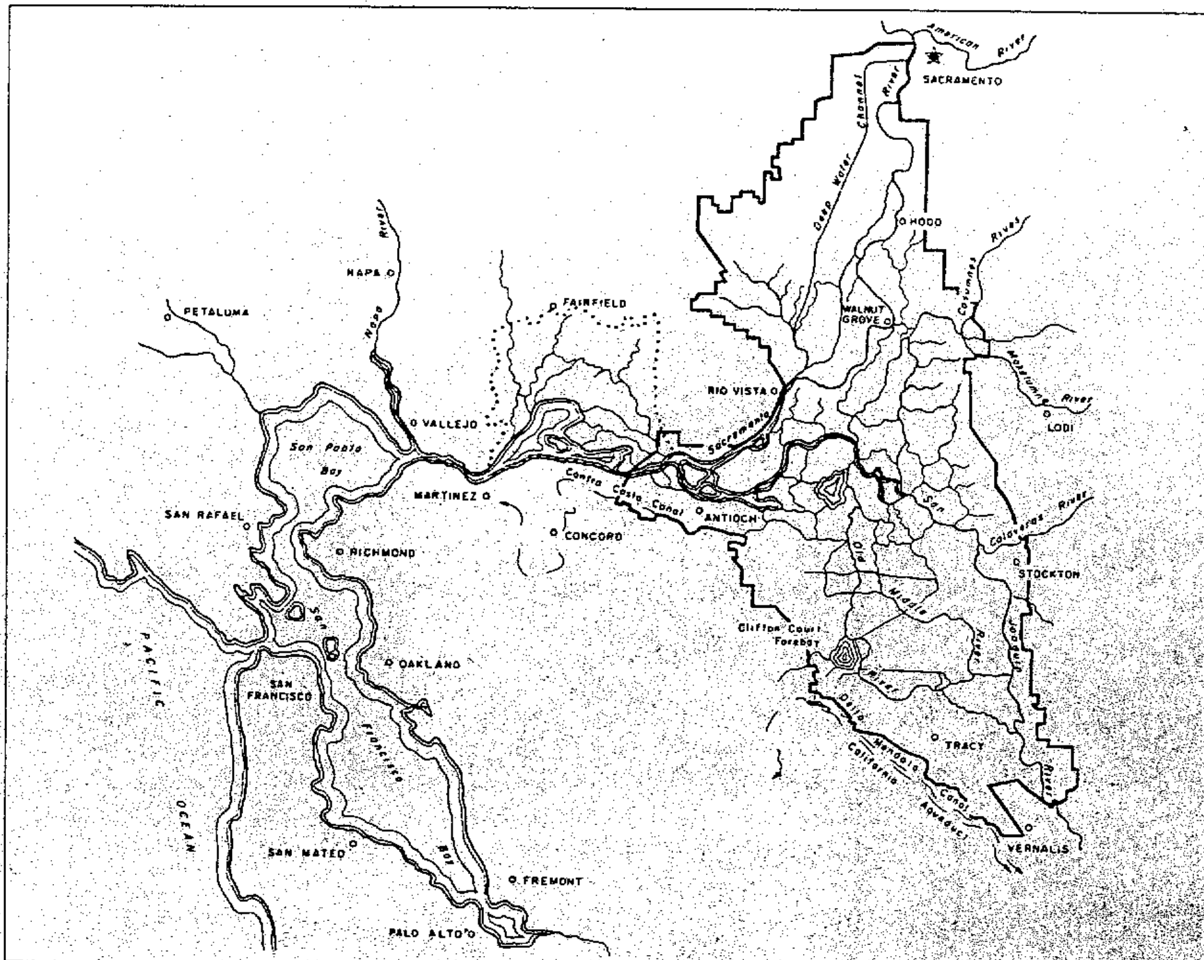


Technical Appendix

WATER QUALITY CONTROL PLAN FOR SALINITY

San Francisco Bay/ Sacramento - San Joaquin Delta Estuary

91-16WR

May 1991

WATER RESOURCES CONTROL BOARD
STATE OF CALIFORNIA

Technical Appendix

WATER QUALITY
CONTROL PLAN FOR SALINITY

San Francisco Bay/
Sacramento - San Joaquin
Delta Estuary

Report Number, 91-16 WR

May 1991

Prepared by the Bay-Delta Section
Division of Water Rights
WATER RESOURCES CONTROL BOARD
STATE OF CALIFORNIA

TECHNICAL APPENDICES

APPENDICES FIGURES

APPENDICES FIGURES (CONTINUED)

APPENDICES TABLES

APPENDICES TABLES (CONTINUED)

CITING INFORMATION

When citing evidence in the hearing record, the following conventions have been adopted:

Information derived from the TRANSCRIPT:

T,XIX,123:09-125:20

Ending page and line number (can be same as the starting page) - may be omitted if a single line reference is used
Beginning page and line number
Transcript Sequence Number (see Appendix G, Transcript Index)
Transcript

Information derived from an EXHIBIT SUBMITTED DURING PHASE I:

SWRCB,25,45

Page number, table number, graph number
Exhibit number
Identifying abbreviation of the information source (see Appendices A & B, Abbreviations/Symbols)

Information derived from an EXHIBIT SUBMITTED AFTER PHASE I:

P-CCWD-3,45

Page number, table number, graph number
Exhibit number
Identifying abbreviation of the information source (see Appendix A & B, Abbreviations/Symbols)
Phase of the proceedings
(WQCP = Water Quality Control Plan, 2/90-Present
EIRSP = Environmental Impact Report Scoping Phase)

When citing REFERENCES from outside of the hearing record, the following conventions have been adopted:

Information derived from published documents,
(a) in the text of the Plan:

Denton, 1985

Year of publication
Name of author or agency abbreviation

CITING INFORMATION (Continued)

(b) at the end of the appropriate Plan Chapter:

Denton, R.A. 1985. Currents in Suisun Bay. SWRCB, Publication No. 85-3wr. January 1985.

Complete publication source

Complete title of document cited

Publication date

Name of author or agency abbreviation

Information derived from Phase I closing <u>BRIEFS</u>:

(a) in the text of the Plan:

RIC,Brief,8

Page number

"Brief"

Identifying abbreviation of the information source

(b) at the end of the appropriate Plan Chapter:

Brief of the Rice Industry Committee on Pollutants in the Bay-Delta Estuary, pg. 8.

For a complete list of the abbreviations for information sources, citations and symbols used in this document, see Appendix A and B.

Appendix C is a Glossary of Terms; Appendix G is a Index of Transcripts listing Transcript Sequence Numbers.

APPENDIX 2.0

STATE BOARD AUTHORITY FOR REGULATION OF WATER IN THE BAY-DELTA ESTUARY

The State Board is responsible for formulating and adopting state policy for water quality control (WC Section 13140). The Water Code states that activities and factors which may affect the quality of waters of the state "...shall be regulated to attain the highest water quality which is reasonable considering all demands being made and to be made on those waters and the total values involved..."(WC Section 13000).

Through the basin planning process, the State and Regional Boards formulate and adopt Basin Plans specifying water quality objectives to ensure reasonable protection for designated beneficial uses of water (WC Sections 13170, 13240).

The Board's authority to conduct a new proceeding establishing water quality objectives for the Bay-Delta Estuary and to implement these objectives by amending water rights is affected by several statutes and court decisions. These include:

a. State Board authority to adopt water quality control plans. WC Section 13170.

b. Reserved jurisdiction, in permits of the CVP, SWP, and new appropriators since about 1965 within the watershed, to add specific terms and conditions.

c. Continuing authority to condition water rights. Cal. Const. Art. X, Section 2; Water Code Sections 100, 275, 1050; United States v. State Water Resources Control Board (1986) 182 Cal.App.3d 82, 129, 227, Cal. Rptr. 161.

d. Statutory authority to condition water rights for protection of all beneficial uses, for protection of the public interest, and for compliance with appropriate water quality control plans. Water Code Sections 1253, 1257 and 1258.

e. Continuing authority to reexamine water rights under the public trust doctrine. National Audubon Society v. Superior Court (1983) 33 Cal.3d 419, 447, 189 Cal.Rptr. 346.

f. The Delta Protection Act at Water Code Sections 12200-12220, the Watershed of Origin protections at Water Code Sections 11460-11463, the County of Origin protections at Water Code Sections 10505 and 10505.5, and the San Joaquin River Protection Act at Water Code Sections 12230-12233.

g. California Environmental Quality Act (CEQA) at Public Resources Code Section 21000 et seq.

h. The California Endangered Species Act at Fish and Game Code Section 2050 et seq.; the federal Endangered Species Act at 16 US Code Section 1531 et seq.

This Plan establishes or amends water quality objectives for three constituents of water in the Bay-Delta Estuary: salinity, temperature, and dissolved oxygen. In a water right proceeding that will follow adoption of this Plan, the Board will consider how and whether to implement these objectives by managing the water supply. Because of the relationship between the water quality objectives in this Plan and management of the water supply, a brief description of relevant water supply and water right laws is provided below.

In addition to general water right laws, four major water supply statutes affect the water supply to the Delta and the export of water from the Delta. These are the Delta Protection Act, the Watershed and the County of Origin provisions and the San Joaquin River Act. With the exception of the San Joaquin River Act, these statutes do not directly apply to water quality planning. However, they will affect the water right decision in which the Board will consider implementing the water quality objectives in this Plan.

The Delta Protection Act at Water Code Section 12200 et seq. provides that no water shall be exported from the Delta (1) which is necessary to provide salinity control and an adequate water supply for the users of water in the Delta (Section 12202), or (2) to which the users within the Delta are entitled (Section 12203). Section 12204. The Act contains a legislative finding that it is necessary to the peace, health, safety and welfare of the people of the state that an adequate water supply in the Delta be maintained that is sufficient to maintain and expand agriculture, industry, urban, and recreational development in the Delta area, and to provide a common source of fresh water for export to areas of water deficiency. Section 12201. The Act also allows substitution of a water supply to the Delta in lieu of the water supply that is provided as a result of salinity control, if substitution is in the public interest and the Delta users have no added financial burden as a result of the substitution. The delivery of water for Delta or export use is subject to the Watershed of Origin provisions and the County of Origin provisions. Sections 12201 and 12202.

The San Joaquin River Act at Water Code Section 12230 et seq. specifically protects the reach of the San Joaquin River between the Merced River and the Middle River. This law affects part of the southern Delta. While the Act focuses on the quality of water in the affected reach, the Act applies to both water quality and water rights decisions. It applies to all water diversions for which an application was filed after June 17, 1961. Section 12233. The Act declares state policy that nobody should divert water from the San Joaquin River to which the users along the protected reach are entitled. Section 12231. Further, the Act forbids the State Board and other state agencies from causing further significant degradation of the water quality in the specified reach. Section 12232.

The Watershed of Origin provisions at Water Code Sections 11460-11463 prohibit the State Water Project and the federal Central Valley Project from depriving "a watershed or area wherein water originates, or an area immediately adjacent thereto which can conveniently be supplied with water therefrom... " "... of the prior right to all the water reasonably required to adequately supply the beneficial needs of the watershed, area, or any of the inhabitants or property owners therein." Sections 11460 and 11128. While these provisions apparently have no direct effect upon the establishment of water quality objectives, they may affect the Board's implementation of the objectives in a water rights proceeding. Section 11462.

The County of Origin provisions at Water Code Sections 10505 and 10505.5 apply to water rights acquired pursuant to state-filed applications to appropriate water. The state filed numerous applications, generally with very early water right priority dates, for projects which may be needed to develop, used, or conserve the state's water resources. Section 10505, adopted 1927, provides: "No priority under this part shall be released nor assignment made of any application that will, in the judgement of the Board, deprive the county in which the water covered by the application originates of any such water necessary for the development of the county." Section 10505.5, adopted in 1969, provides that any subsequent permit issued on a state filed application shall provide that the permit and any license issued on the permit shall not authorize the use of any water outside the county of origin which is necessary for the development of the county. These provisions, like the Watershed of Origin provisions, have no direct effect upon the establishment of water quality objectives. However, they may affect implementation of the objectives in water rights proceeding.

In addition, during the Water Right Phase of these proceedings, the Board will consider the obligations of the various water right holders whose diversions and uses of water affect the beneficial uses of the waters to the Bay-Delta Estuary. In that consideration, the Board will have to take into account the existing water right priority system, which has been established by statutory and case law in California. However, as the Court of Appeal held in U.S. v. State Water Resources Control Board (1986) 227 Cal.Rptr. 161, 189, the State Board has authority to revise water right priorities to ensure that the requirements of California Constitution Article X, Section 2 are satisfied. The water right priority system, with a few exceptions, gives first priority to riparian right holders. All riparian right holders along a stream have equal rights with one another, and must share in any shortages. Appropriative right holders generally are junior in priority to riparian right holders. As an example, the CVP and the SWP are appropriative right holders. Appropriative right holders have a right to take water in accordance with their order of priority. To illustrate, if all of the appropriative right holders lined up at a water tank in their order of priority with buckets, each one would be able to fill a bucket in turn until the tank was empty. All of those whose priority was too low to reach the tank before it was empty would get no water. Under the modern appropriative rights system, water rights receive a priority according to the date when the appropriator filed an application to appropriate water. Water Code Sections 1450, 1455. The oldest appropriations, therefore, must be satisfied before newer appropriations can get water.

Implementation of Legal Authority

Recognizing uncertainties associated with proposed project facilities to be constructed and the need for additional information on the Bay-Delta ecosystem, the State Board limited the Delta Plan in 1978 to current and near-term conditions in the Delta. The State Board stated it would review the 1978 Water Quality Control Delta Plan in about ten years. This commitment as well as recent court decisions have called for the current hearing and have expanded the scope of its proceedings.

Specifically, in 1986, the State Court of Appeal, First District, issued a decision,[1/] also known as the Racanelli or Delta Water Cases decision, addressing legal challenges to D-1485 and the Delta Plan. The court directed the State Board to take a global perspective of water resources in developing water quality objectives: The State Board's duty in its water quality role is to provide reasonable protection for beneficial uses, considering all demands made on the water. The State Board's salinity control function in the Bay-Delta should not be solely related to its water right function. Furthermore, the decision recognized that an implementation program may be a lengthy and complex process that requires significant time intervals and action by entities over which the State Board may have little or no control.

In the State Board's view, the court's decision means that the State Board must consider all relevant factors in determining whether the protection afforded a beneficial use by the objectives is reasonable. For this Plan, these factors include not only the factors specifically listed in Water Code Section 13241, but also the unique role of the Bay-Delta Estuary in the State's water supply and environment. Because of the wide distribution of water from the Delta, the State Board in developing this Plan has carefully weighed the uses of the water both within and outside the Estuary to decide whether the objectives provide reasonable protection to the beneficial uses. Also in considering the objectives, the State Board has taken into consideration the legislative policies set forth in the Water Code at Section 13000 and the State Board's Statement of Policy with Respect to Maintaining High Quality of Waters in California, adopted in 1968 in Resolution 68-16. As applied to waters for which water quality standards are required under the federal Clean Water Act, Resolution 68-16 incorporates by reference the three-prong test set forth in the federal antidegradation policy at 40 CFR 131.12(a). Order No. WQ 86-17.

In the Water Right Phase, when it considers implementation of the water quality objectives in this Plan, the State Board will use an analytic process which will include water right holders in addition to the State Water Project and the federal Central Valley Project. As the Court of Appeal observed, the principal enforcement mechanism available to the

1/ *United States v. State Water Resources Control Board (1986) 182 Cal.App.3d 82, 227 Cal.Rptr.161*

State Board to control pollution from seawater intrusion is its regulation of water rights to control diversions which cause degradation of water quality. Id., at 227 Cal.Rptr. 184. Since 1928 when the voters approved California Constitution Article X, Section 2, all water users, riparians and appropriators alike, are subject to a universal limitation that water use must be reasonable and for a beneficial purpose. This "rule of reasonable use", according to the Court, is the cardinal principle in making water right decisions. Id., at 227 Cal.Rptr. 171. According to the Court, the State Board has broad power to strike the proper balance between the interests in water quality and the export of water, in deciding whether a particular activity is reasonable. Id., at 227 Cal.Rptr. 188. The determination of reasonableness is ordinarily a question of fact. Id.

Both the State Board's authority and the court's recent decision have guided the reassessment developed in this Plan.

California Environmental Quality Act (CEQA)

Pursuant to Section 15251(g) Title 14, California Code of Regulations (C.C.R.), the State Board's Water Quality Control (Basin) Planning Program is a "certified program" by the Secretary for Resources. As a certified program it is exempt from the requirements of preparing a separate environmental document. However, preparation of basin plans under the Program remains subject to other provisions in CEQA, including discussion of alternatives to the proposed objectives and mitigation measures to avoid or reduce any significant or potentially significant effects on the environment.

This Plan identifies the competing uses of Bay-Delta waters and provides, in terms of salinity and temperature, reasonable protection for each use; it identifies alternatives and mitigation measures to avoid or reduce any significant or potentially significant effects that this Plan might have on the environment. Therefore, this Plan is a substitute for a CEQA document as set forth in 14 C.C.R. Section 15252 (see Appendix F, Notice of Filing).

APPENDIX 3.0

BASIN DESCRIPTIONS

Precipitation in California

On the average, precipitation supplies about 193 MAF per year in California with another 6 MAF coming from out-of-state sources. About 58 percent of this water is used by native vegetation and unirrigated lands; about 25 percent flows to the sea, to salt sinks, and to Nevada; about 14 percent is diverted for offstream uses; and about 3 percent goes to the natural recharge of ground water basins (calculated from information in DWR Bulletin 160-83, pg.88).

Sacramento River Basin

Physical Description

The Sacramento River Basin, Basin 5A in Figure A3.0-1, includes the westerly drainage of the Sierra Nevada and the Cascade ranges, the easterly drainage of the Coast Range, and the valley floor. The Basin covers about 26,500 square miles (16,960,000 acres) and extends from the Goose Lake Basin at the Oregon border to the American River Basin (RWQCB 5, 1975). The Basin includes the watersheds of the following major tributaries: McCloud, Pit, Sacramento, Feather, Yuba, Bear, and American rivers, and Cottonwood, Stony, Cache, and Putah creeks.

The Sacramento Valley floor ranges from 30 to 45 miles wide in the central and southern parts, but narrows to five miles at its northern end; it slopes southward from about 300 feet above sea level at the north end near Red Bluff to sea level at Suisun Bay. The crestline of the Sierra Nevada generally ranges from 8,000 to 10,000 feet, while the crestline of the Coast Range extends from 2,000 to 8,000 feet. Due to the large snowpack at higher elevations in the Basin, the greatest volume of streamflow above the reservoirs occurs during snowmelt in the spring and early summer.

Hydrology

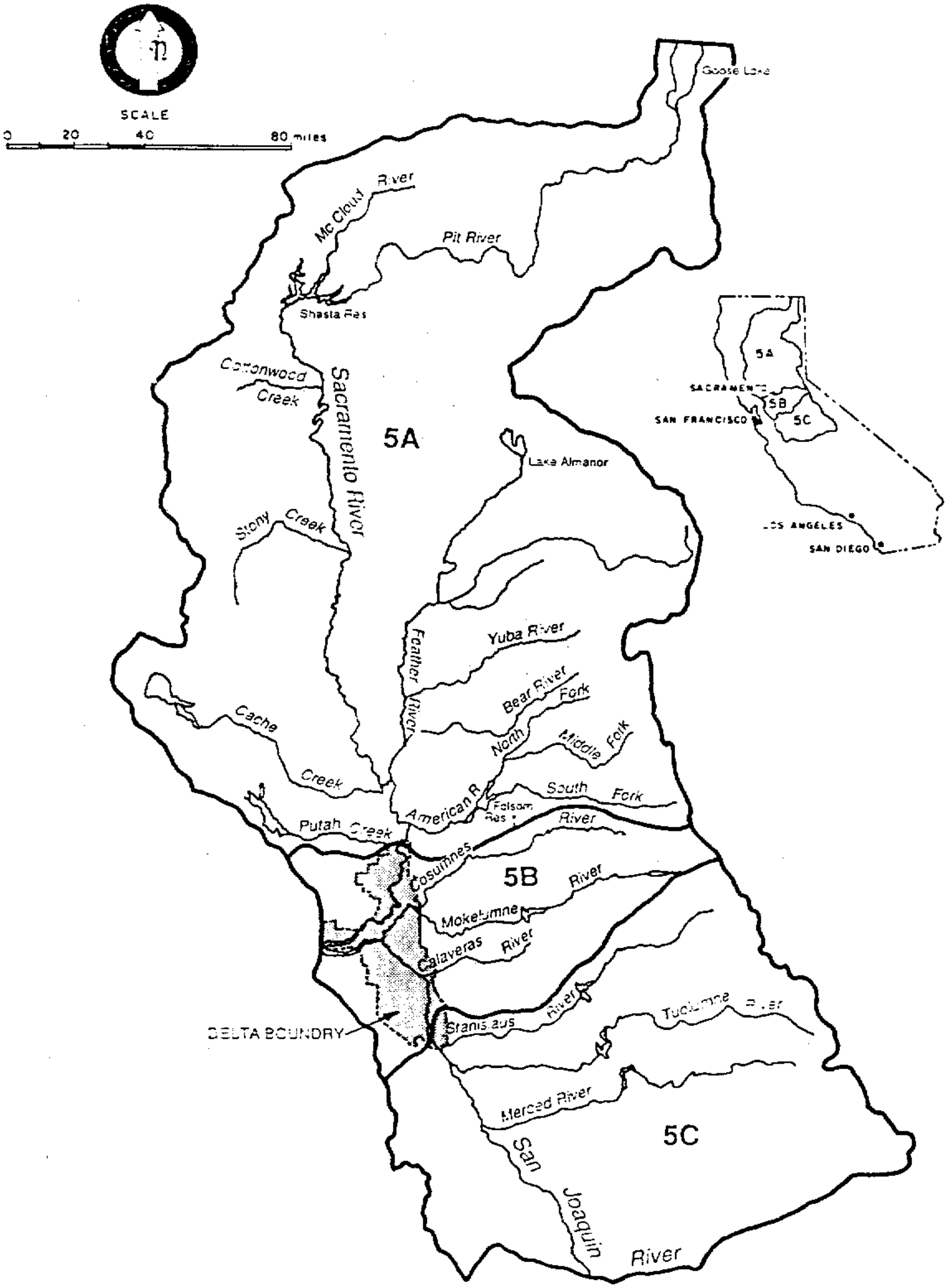
The Sacramento River Basin receives water transfers from other basins via the following projects:

- Trinity River
- Sly Park
- Little Truckee Ditch
- Echo Lake Conduit

The Basin exports water to other basins via the following projects:

- Putah South Canal
- Folsom South Canal
- Tule Lake Diversion
- North Fork Ditch
- Folsom Lake Diversion

FIGURE A3.0-1 Boundaries of the Sacramento River (5A), Central Sierra and Delta (5B), and San Joaquin (5C) Basins (From: RWQCB 5, 1975)



The amounts of these and other interbasin transfers are shown in Figure A3.0-2 (DWR,19). The basin boundaries in this figure differ somewhat from the boundaries defined in this Plan; however, it provides a good illustration of the magnitude of interbasin water transfers from the Sacramento River Basin to other areas in California.

Water from the Sacramento River Basin enters the Delta from two major waterways, the Sacramento River near Sacramento and the Yolo Bypass just west of Sacramento. Under present conditions and in years of normal runoff, the Sacramento River Basin contributes about 70 percent of the total runoff to the Estuary (Bay and Delta) (SWRCB,3,3).

Central Sierra Basin

Physical Description

Basin 5B in Figure A3.0-1 is referred to as the Central Sierra Basin (SWRCB,3,4). This Basin includes the watersheds of the Cosumnes, Mokelumne, and Calaveras rivers. This Basin encompasses about 3,800 square miles (2,432,000 acres).

Hydrology

Introduction

The Central Sierra Basin inflow to the Delta comes from three river systems, the Cosumnes, Mokelumne and Calaveras, sometimes called the "Eastside Streams." The Central Sierra Basin receives water from the Sacramento River Basin via the:

- o Folsom South Canal, and
- o the Folsom Lake Diversion.

Water is exported from the Central Sierra Basin via the following projects:

- o Mokelumne Aqueduct
- o Sly Park, and
- o South Bay Aqueduct.

In years of normal runoff, Basin 5B contributes about five percent of the total inflow to the Delta (SWRCB,3,3).

As of 1987, about 242,000 acre-feet of water (about one-third of the average annual Mokelumne River flow) were diverted into the Mokelumne Aqueduct for use in the east San Francisco Bay area (EBMUD,1,9).

San Joaquin River Basin

Physical Description

The San Joaquin River Basin, Basin 5C in Figure A3.0-1, encompasses over 11,000 square miles (7,040,000 acres) between the crests of the Sierra Nevada and Coast ranges, and stretches southward from the Delta to the drainage divide between the San Joaquin and Kings rivers. The valley

FIGURE A3.0-2 Interbasin water transfers for a 1980 level of development and the annual amounts in AF/YR (From: DWR, 19)

floor in the Basin measures about 50 miles wide by 100 miles long, and slopes from an elevation of about 250 feet at the southern end to near sea level at the northern end (RWQCB 5, 1975). In years of normal runoff, the San Joaquin River Basin now contributes about 15 percent of the total measured runoff to the Estuary (SWRCB,3,3).

The Kings River historically flowed into Fresno Slough and into the San Joaquin River. Due to upstream controls and diversions, this occurs now about once every three years (DWR,26,33). Due to this discontinuity, the Kings River is now considered to be part of the Tulare Lake Basin, Basin 5D, and not part of the San Joaquin River Basin.

Hydrology

The major tributaries in Basin 5C to the San Joaquin River are the Merced, Tuolumne, and Stanislaus rivers which originate in the Sierra Nevada. Peak streamflows above the reservoirs generally occur later in spring than the Sacramento Basin because the San Joaquin Basin mountain ranges are generally higher than those in the Sacramento Basin. Smaller tributaries, consisting of runoff from the Coast Range and/or agricultural drainage, include the following:

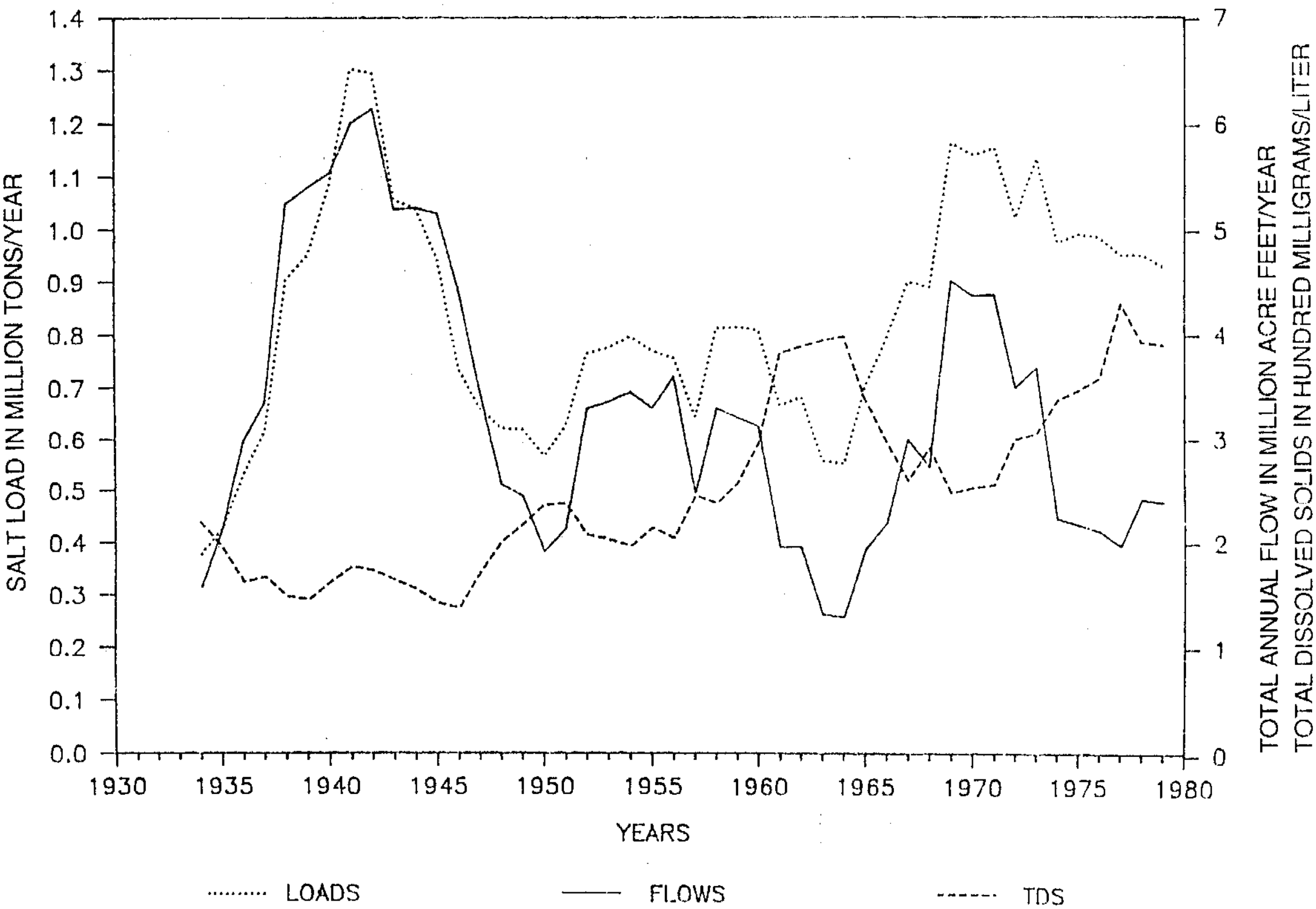
- Salt and Mud sloughs
- Panoche
- Little Panoche
- Los Banos
- Orestimba
- Del Puerto creeks

Water is imported into the San Joaquin River Basin from the Delta via the Delta-Mendota Canal (DMC) of the CVP and via the SWP (Oak Flat Water District). Water is exported from the Basin via the following projects (see Figure A3.0-2):

- Friant-Kern Canal (CVP),
- Hetch Hetchy Aqueduct, and
- San Felipe Unit (CVP).

About 77,000 acres in the San Joaquin River Basin have subsurface agricultural drainage systems which discharge to the San Joaquin River, primarily via Mud and Salt sloughs (EDF,11,I-1). During the irrigation season and occasionally following the flushing of agricultural drainage water from duck clubs in January and February, agricultural drainage makes up a significant portion of San Joaquin River flows and constituent loads (EDF,11,V-36,V-44,V-46&V-47). The San Joaquin River contains considerably higher concentrations of several constituents (including nitrates, selenium, arsenic, nickel and manganese) than the Sacramento River (AHI,302,219,231). Figure A3.0-3 shows that the salinity has increased since 1930. The salt load for a given flow has increased since 1985 primarily due to the bypassing of agricultural drainage around the Grassland Water District directly into the San Joaquin River.

FIGURE A3.0-3 Salinity, flow and salt load in the San Joaquin River near Vernalis
(5 Year running averages)(Adapted from Orlob, 1982 data)



The current water quality objective set by the Delta Plan for the San Joaquin River Basin is a monthly mean of 500 ppm TDS for the San Joaquin River near Vernalis (RWQCB,5, 1975). For the period of 1975 through 1987, the 500 ppm TDS objective was met in all but two critically dry water years, 1976 and 1977, as well as the beginning of Water Year 1978. However, this 12-year period was dominated by wet years -- six wet, two above normal, two dry, and two critical.

The operation of the Friant-Kern Canal and Delta-Mendota Canal units of the CVP began around 1950. The basin exchanges associated with these CVP units, as well as the consumptive use and reservoir storage aspects of these and other more recent projects on the eastside of the San Joaquin Valley, have significantly altered flow relationships for the San Joaquin River Basin. A comparison of this relationship for the pre-1950 period and the post-1950 period is shown in Figure A3.0-4 (EDF,11,II-30). The two regression lines in the figure are significantly different, indicating that the total amount of flow measured at Vernalis (the entry point of the San Joaquin River to the Delta) has decreased since 1950.

The Delta

Physical Description

The Delta is a roughly triangular area of about 1,150 square miles (738,000 acres) extending from Chipps Island near Pittsburg on the west to Sacramento on the north and to the Vernalis gaging station on the south (see Figure A3.0-5) (California Water Code Section 12220). This area includes those waterways above the confluence of the Sacramento and San Joaquin rivers which are influenced by tidal action, and about 800 square miles (512,000 acres) of agricultural lands which derive their water supply from these waterways. The total surface area of these waterways is over 75 square miles (48,000 acres), with an aggregate navigable length of about 550 miles. Major tributaries to the Delta include the Sacramento and San Joaquin rivers. Minor contributors include the eastside streams -- the Cosumnes, Mokelumne, and Calaveras rivers and Dry Creek -- and the Yolo Bypass.

Water is exported directly from the Delta at five major locations (identified by number on Figure A3.0-5):

- Tracy Pumping Plant (1)
- Clifton Court Intake (2)
- Contra Costa Canal at Pumping Plant No. 1 (3)
- City of Vallejo Intake at Cache Slough (4)
- North Bay Aqueduct Intake at Barker Slough (5)
  (The City of Vallejo, although it still maintains a standby intake at Cache Slough)

Hydrology

Background

In its original condition, the Delta was a vast, flat marsh traversed by an ever-changing network of channels and sloughs that divided the area into islands (SWC,262,A2-15). "During the flood season, the Delta became a great inland lake; when the floodwater receded, the network of sloughs

FIGURE A3.0-4 Unimpaired flows versus measured flows for the San Joaquin Basin

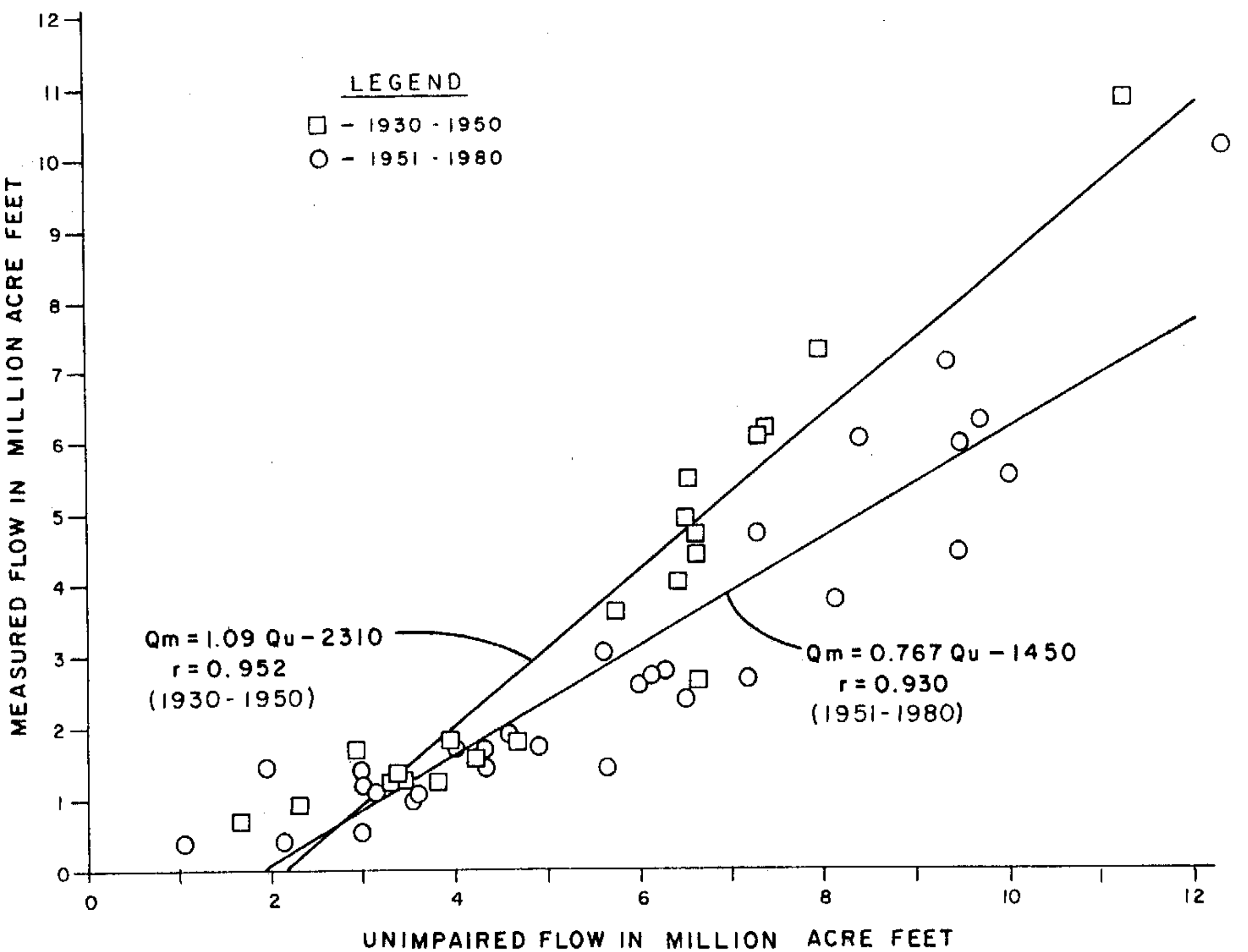
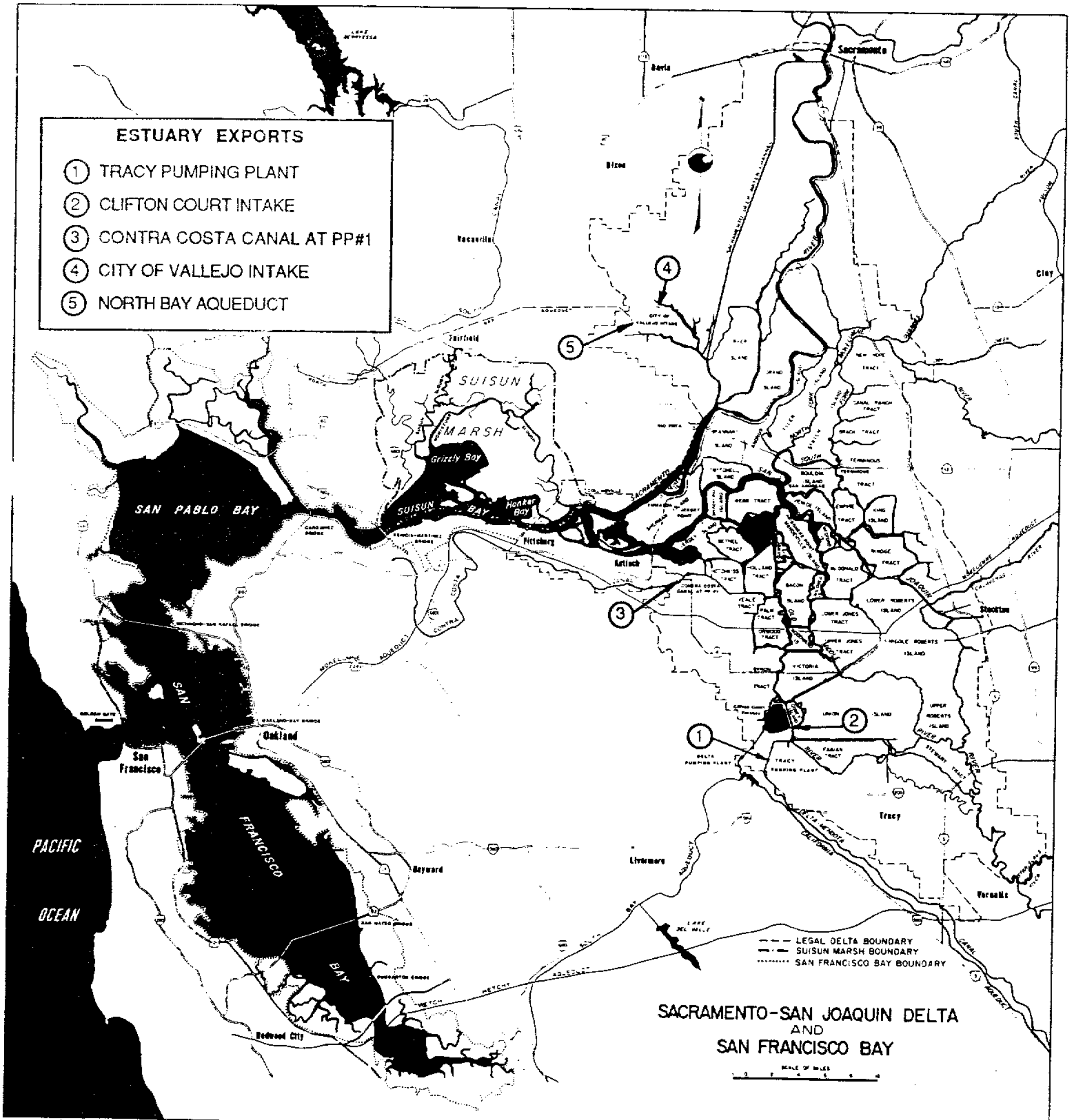


FIGURE A3.0-5 Boundary of the Bay-Delta Estuary and locations of Estuary exports
(From: SWRCB, 3, 5)



and channels reappeared throughout the marsh" (DWR,707,67). In the 1860s, reclamation began on low-lying areas, and local landowners undertook cooperative levee construction to allow the lands to be farmed. By the 1920s about 415,000 acres were completely reclaimed and in agricultural production (SWRCB,13,III-4); and "{m}any miles of entirely new channels had been dredged, and farmlands, small communities, highways and utilities were protected-- often tenuously--by 1,100 miles of levees, many of them built on peat soils" (DWR,707,67).

The export of water directly from the Delta first took place in 1940 with the completion of the Contra Costa Canal, a unit of the CVP. In 1951, water supplying the Delta-Mendota Canal began to be exported at the CVP's Tracy Pumping Plant (DWR,707,67). In the same year the Delta Cross Channel and control gates were constructed near Walnut Grove to allow a more efficient transfer of water to the Tracy pumps (SWRCB,13,III-6). With the start of operation of the State Water Project's (SWP) Harvey O. Banks Pumping Plant in 1967, Delta exports were again increased. By 1975, the combined deliveries of waters exported by both the CVP and SWP totaled 4.8 million acre-feet per year. The total CVP and SWP Delta exports are projected to reach 6.6 million acre-feet per year by the year 2000 (USBR,2,27).

Delta Flows

- Delta Inflow

  Freshwater flow into the Delta comes primarily from the Sacramento and San Joaquin rivers, with small contributions from the Mokelumne and Cosumnes rivers (SWRCB,13,III-7). Under present conditions, these river systems contribute approximately 85, 10, and 5 percent, respectively, of the average annual inflow to the Delta (not the Estuary) (DWR, 1987, from DWR '1990 Level of Development Operation Model Output').

- In-Delta Flow

  The flows in the Delta channels result from a combination of Delta inflows, Delta agricultural use, exports, and the counteracting force of the tides from the Pacific Ocean through the San Francisco Bay. The net flow is normally downstream, out of the Delta. However, many times the flows change direction and move back upstream on incoming tides. Tidally influenced flow reversals are a twice daily natural phenomena occurring throughout the Bay-Delta Estuary; it is only during extremely large flooding events that tidal forces are overcome throughout the tidal cycle. Such tidally-caused flow reversals occur over most of the Delta although they are often marked in parts of the Delta by the influence of Delta diversions, including export pumping (SWRCB,13,III-11). The distance of the upstream movement, and the extent of saline intrusion, vary depending on the flows in the Delta channels and the opposing force of (SWRCB,14,II-1).

- Delta Outflow

  The major factors affecting Delta outflow are the tides, stream runoff, upstream and Delta channel depletions, Delta exports, upstream use and upstream reservoir operations.

Delta outflow is highly seasonal and generally is characterized by large winter inflows from rainfall runoff generated by Pacific storms, and small, relatively steady inflows during the dry summers from reservoir releases. Delta outflow commonly exceeds 35,000 cfs from December through April, whereas it is usually less than 14,000 cfs from July through October (USGS,10,6).

Flow Measurement

The net Delta outflow at Chipps Island is not directly measurable since, at times, it may be less than five percent of the flows due to the tides (SWRCB,14,IV-7). However, an estimate of net Delta outflow is important for purposes of water quality control and water resource management (SWRCB,13,III-16). The net Delta outflow at Chipps Island is usually estimated by performing a water balance at the western boundary of the Delta, Chipps Island. The water balance involves adding the total Delta inflow and Delta precipitation runoff, then subtracting Delta channel depletions and Delta exports (DWR,47,2).

DWR has estimated the daily Delta outflow at Chipps Island for water years 1956 through 1985 using the flow accounting model, DAYFLOW. DAYFLOW is also used to estimate interior Delta flow at specified locations and fish-related parameters and indices (DWR,47). Figure A3.0-6 presents the means and standard deviations of Delta outflows computed by DAYFLOW for water years 1956 through 1985 (USGS,10,6).

Another commonly used estimate of Delta outflow, especially for the daily operation of the CVP and SWP, is the Delta Outflow Index (DOI). The DOI is similar to the DAYFLOW Delta outflow but does not include the flows from smaller peripheral streams entering the Delta, such as the Mokelumne and Calaveras rivers, or the Yolo Bypass flows. Because of these differences, the DOI is considered to be less representative than the DAYFLOW Delta outflow estimate (USBR,111,16).

Delta Channel Depletion, Exports and Reverse Flow

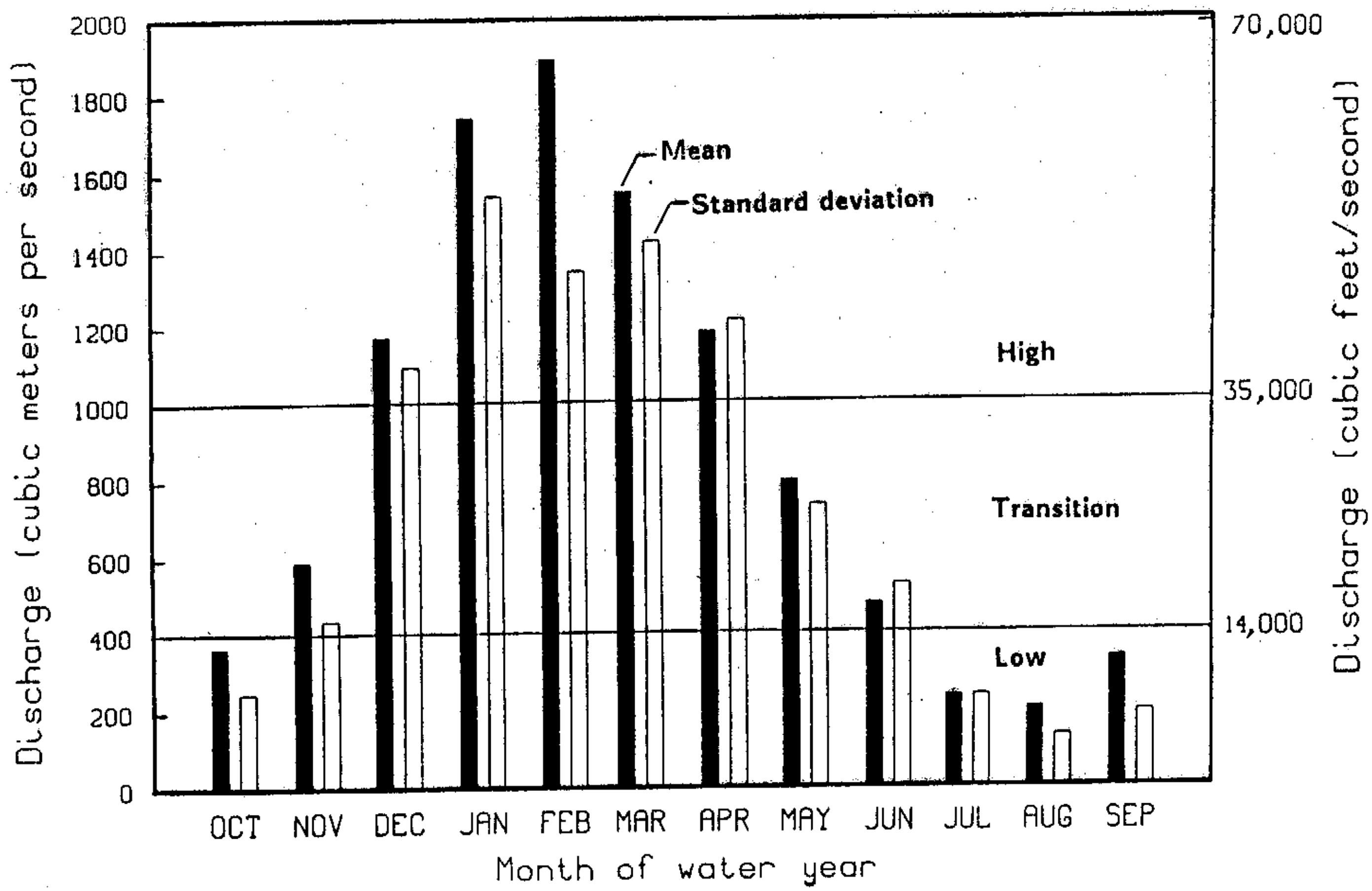
One of the critical factors in determining Delta outflow is Delta channel depletion, that is, "...the diversions of Delta channel waters via pumps, siphons, and subsurface seepage into the Delta uplands and lowlands for consumptive use by agriculture and native plants" (DWR,36,3-4)[1/]. The Delta channel depletions (not including precipitation) range from approximately 34 TAF in January to 278 TAF in July (DWR,1988,Operation Study). Currently, over 1,600 diversion locations have been identified within the Delta (T,II,189:17).

The locations of agricultural irrigation diversion and drainage return points are shown in Figures A3.0-7 (DWR,49,1) and A3.0-8 (DWR,64,1).

1/ *The consumptive use values used by the USBR and DWR to operate the CVP and SWP were fixed in the Federal-State Memorandum of Agreement dated April 9, 1969. The consumptive use values were based on: (1) a 1955 Delta land use survey; (2) estimates of consumptive use by identified crops; (3) changes in soil moisture; and (4) estimates of leaching requirements (SWRCB,13,III-16). While the consumptive use values are adjusted seasonally, they are not adjusted for water year types, thereby introducing error into the Delta outflow calculations (USBR,111,16).*

FIGURE A3.0-6

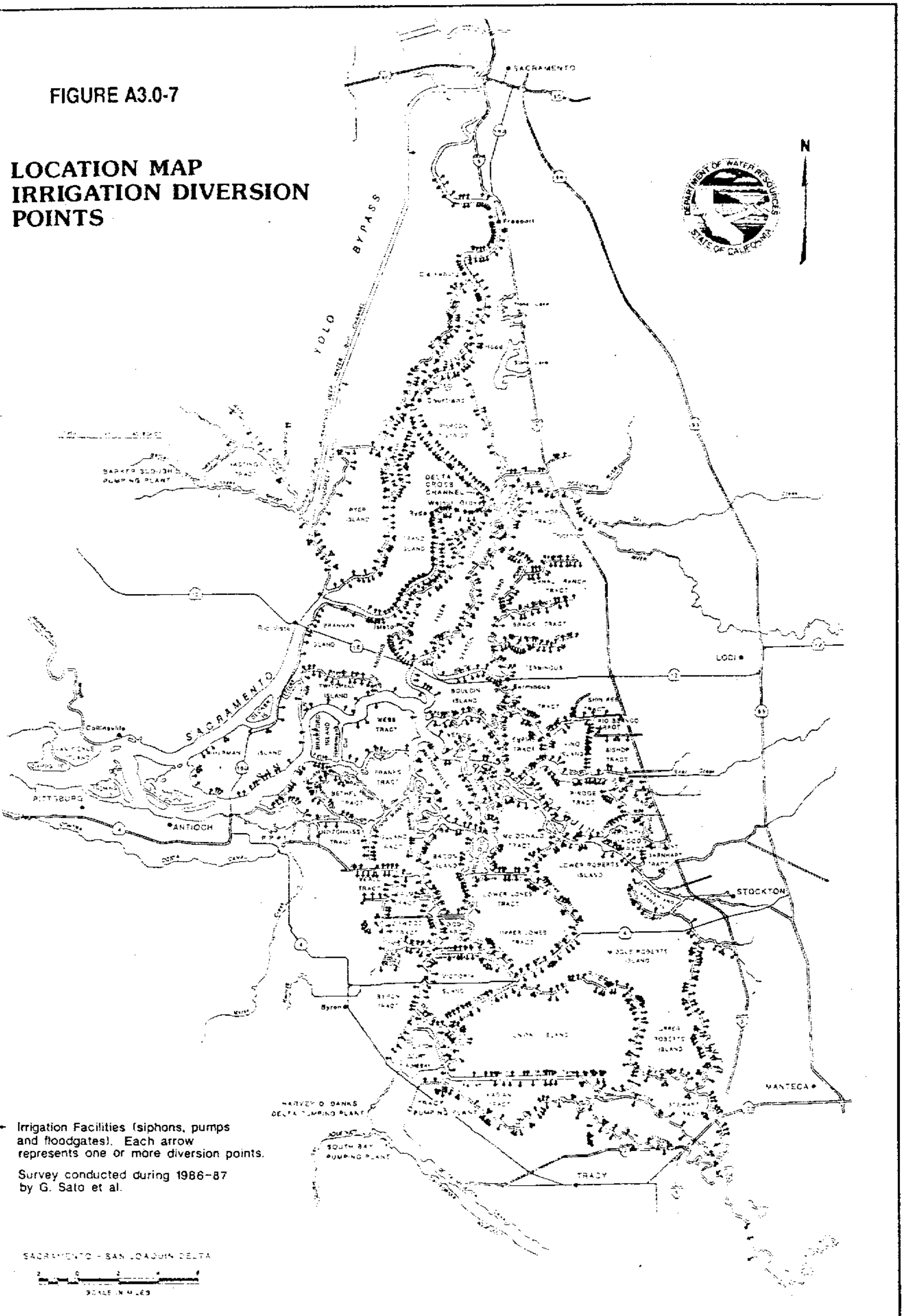
(FROM USGS EXHIBIT 10, PAGE 6)



--Means and standard deviations of net monthly discharges of the Sacramento-San Joaquin Delta into San Francisco Bay at Chipps Island, 1956-85 from estimates of the State of California (1986). Also shown are arbitrary divisions of the months into high (>1,000 m^3/s [35,000 ft^3/s]), transition (400-1,000 m^3/s [14,000-35,000 ft^3/s]), and low (<400 m^3/s [14,000 ft^3/s]) delta discharges.

FIGURE A3.0-7

LOCATION MAP IRRIGATION DIVERSION POINTS

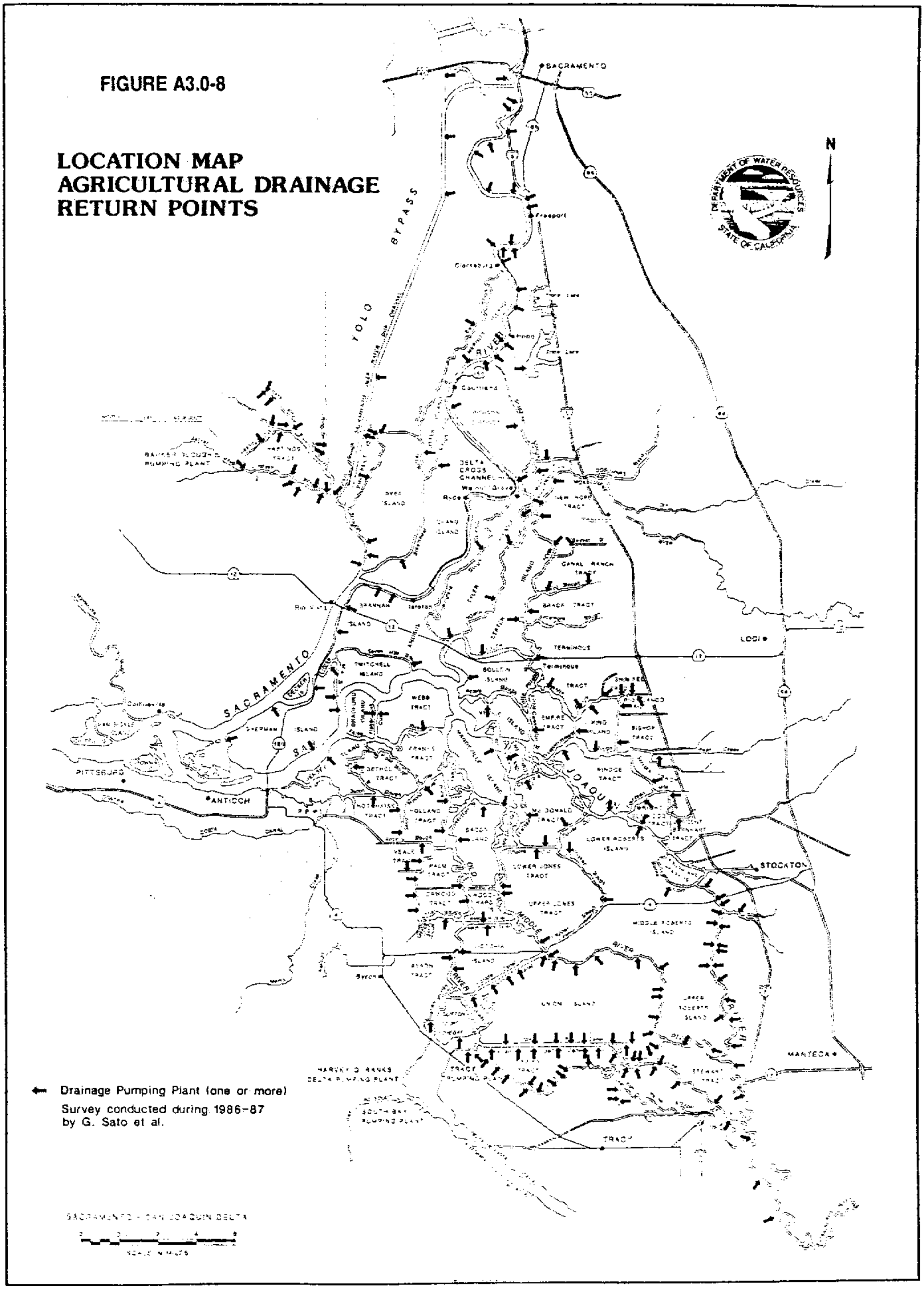


- Irrigation Facilities (siphons, pumps and floodgates). Each arrow represents one or more diversion points.

Survey conducted during 1986-87 by G. Sato et al.

FIGURE A3.0-8

LOCATION MAP AGRICULTURAL DRAINAGE RETURN POINTS



← Drainage Pumping Plant (one or more)
Survey conducted during 1986-87 by G. Sato et al.

Water supplies for export by the CVP and SWP are obtained from surplus Delta flows, when available, and from upstream reservoir releases, when Delta inflow is low and surplus flows are unavailable. Upstream reservoir releases from the Sacramento River Basin enter the Delta via the Sacramento River and Yolo Bypass. A portion of this water is then used within the Delta to meet agricultural needs, a portion is exported by various projects, and the remainder flows into San Francisco Bay as Delta outflow. Some of these releases are drawn to the CVP and SWP pumps through interior Delta channels facilitated in part by the CVP's Delta Cross Channel at Walnut Grove (DWR,707,69).

When export rates are high, the net flow of water can move in an upstream direction toward the export pumps (SWRCB,13,III-II). This is known as reverse flow. During periods of high Delta inflow and high export, there is some reverse flow, but enough water is available from the San Joaquin River, eastern Delta tributaries (Central Sierra Basin) and water transported from the Sacramento River via the Delta Cross Channel to meet export demands (Figure A3.0-9).

When there are high exports, low San Joaquin River inflows and high Delta consumptive uses, however, the normal water path changes, causing a reversal of flows around the western end of Sherman Island where the Sacramento River and the San Joaquin River meet (SWRCB,13;III-23) (Figure A3.0-10). As water travels around Sherman Island, it mixes with saltier ocean water entering as tidal inflow and is drawn upstream into the San Joaquin River and other channels by the CVP and SWP pumping plants (DWR,707,69). Figures A3.0-11 through A3.0-13 show other typical Delta flow patterns (DWR,51a-e).

Delta Flow and Salinity

Salinity is one of the major water quality factors affecting the beneficial uses of Delta water. Figure A3.0-14 shows the relationship between flow and salinity at Collinsville in the western Delta 1/. The form of the relationship is typical of the flow-salinity relationships in the western Delta.

Upstream storage facilities, in-basin depletions, and Delta exports have reduced winter and spring Delta outflows. Releases from upstream storage facilities, on the other hand, have increased summer and fall Delta outflows (SWRCB,14,II-1). These changes in flows have correspondingly changed the extent and timing of salinity intrusion into the Delta. Figure A3.0-15 shows the maximum annual salinity intrusion into the Delta from 1920 through 1977 (DWR,60). Supplemental releases due to storage facilities since the 1940s have generally kept salinity intrusion, as indicated by the 1000 ppm chloride line in the Delta, at a point farther west, or downstream, than had been the case before that period.

1/ *Historically, the salinity of the waterways in the Delta has been expressed in chlorides (Cl) or total dissolved solids (TDS) concentrations, and, more recently, in electrical conductivity (EC). However, sometimes it is necessary to convert one unit of salinity to another. Consequently, "Unit Conversion Equations" are used to convert any one of the parameters to any of the others at various locations in the Delta using specific formulas for geographic location and water year type (DWR,61,1).*

FIGURE A3.0-9

DWR-51E

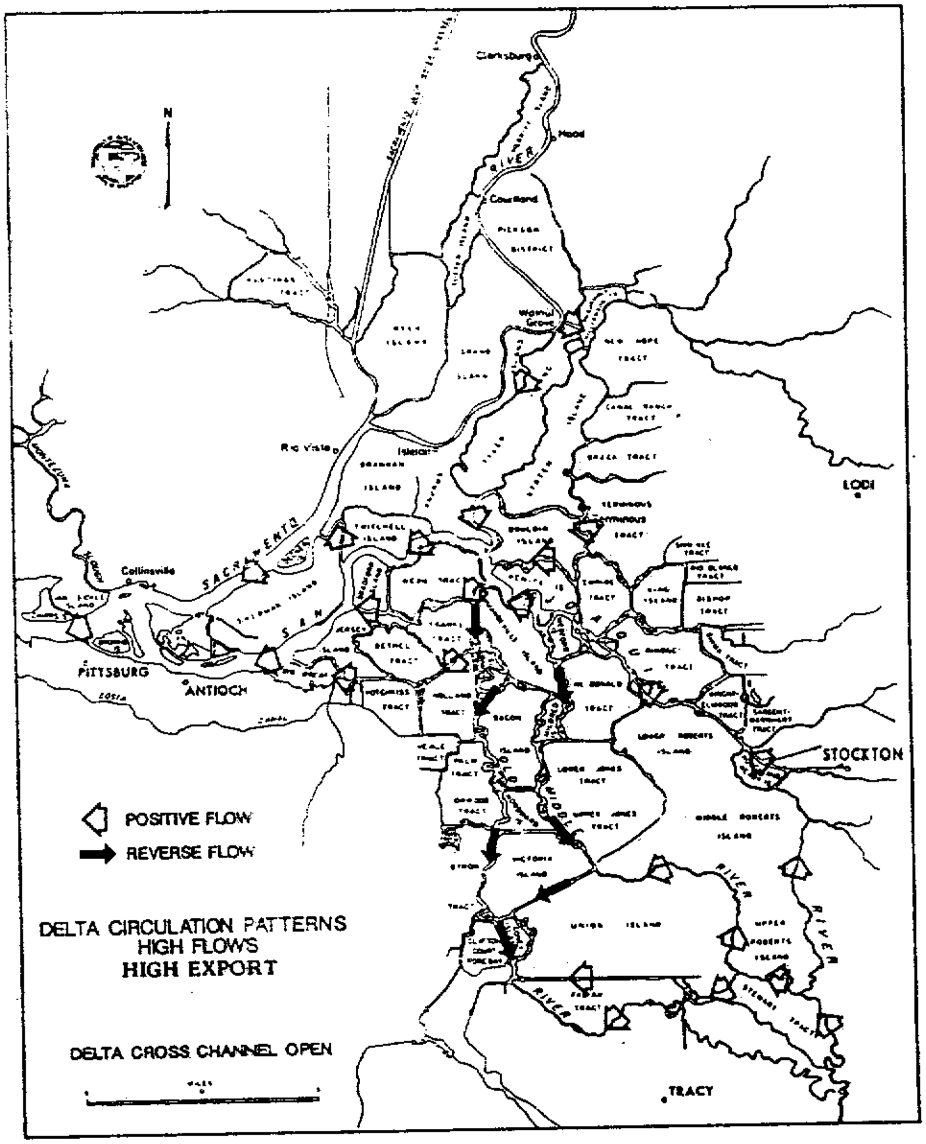


FIGURE A3.0-10

DWR-51D

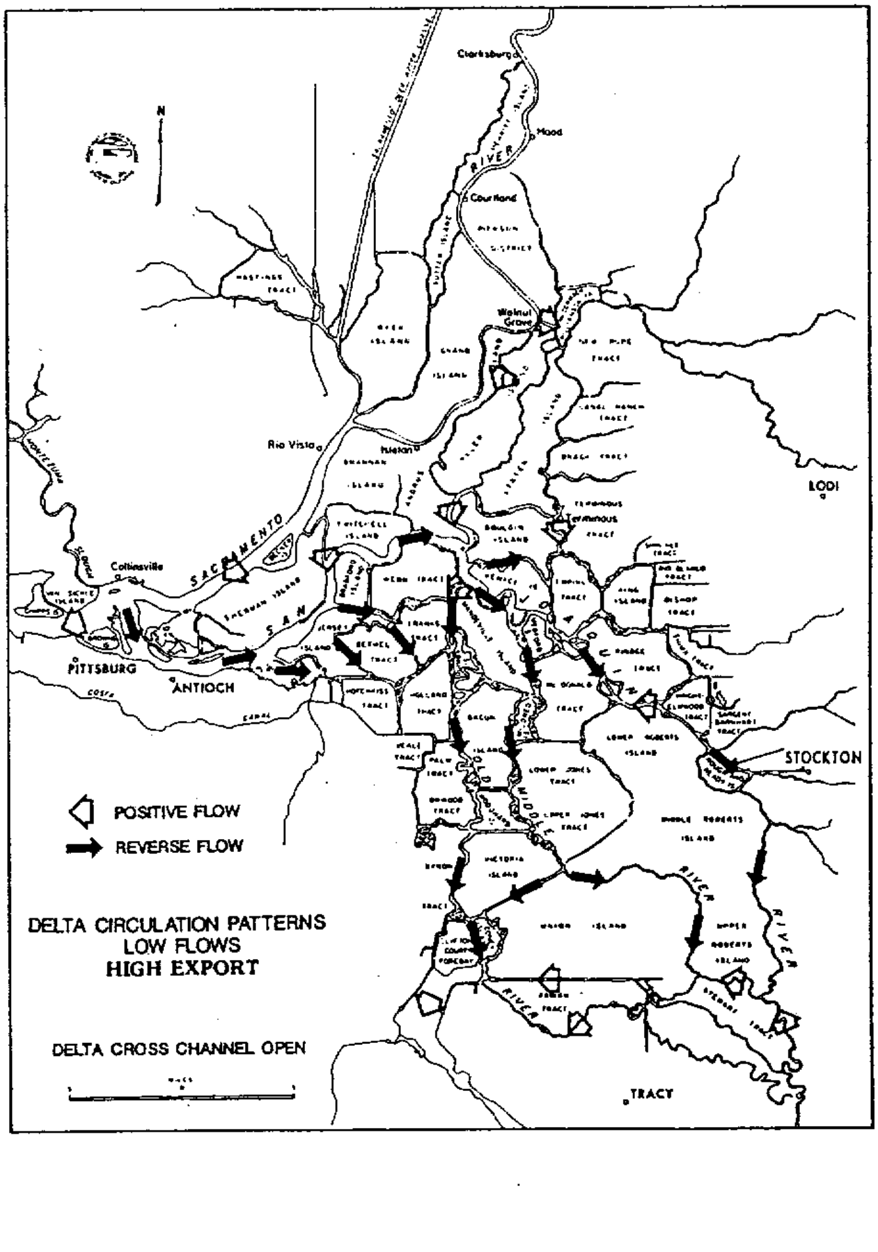


FIGURE A3.0-11

DWR-51A

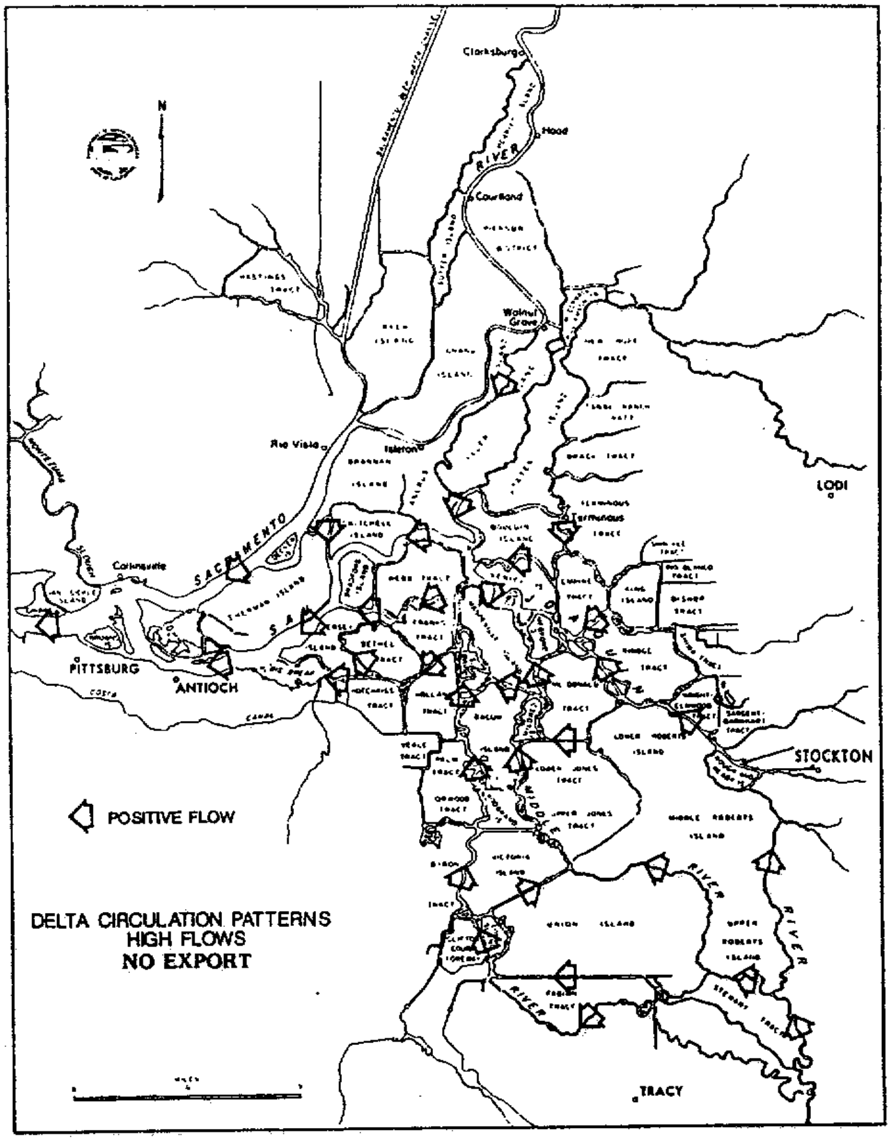


FIGURE A3.0-12

DWR-51B

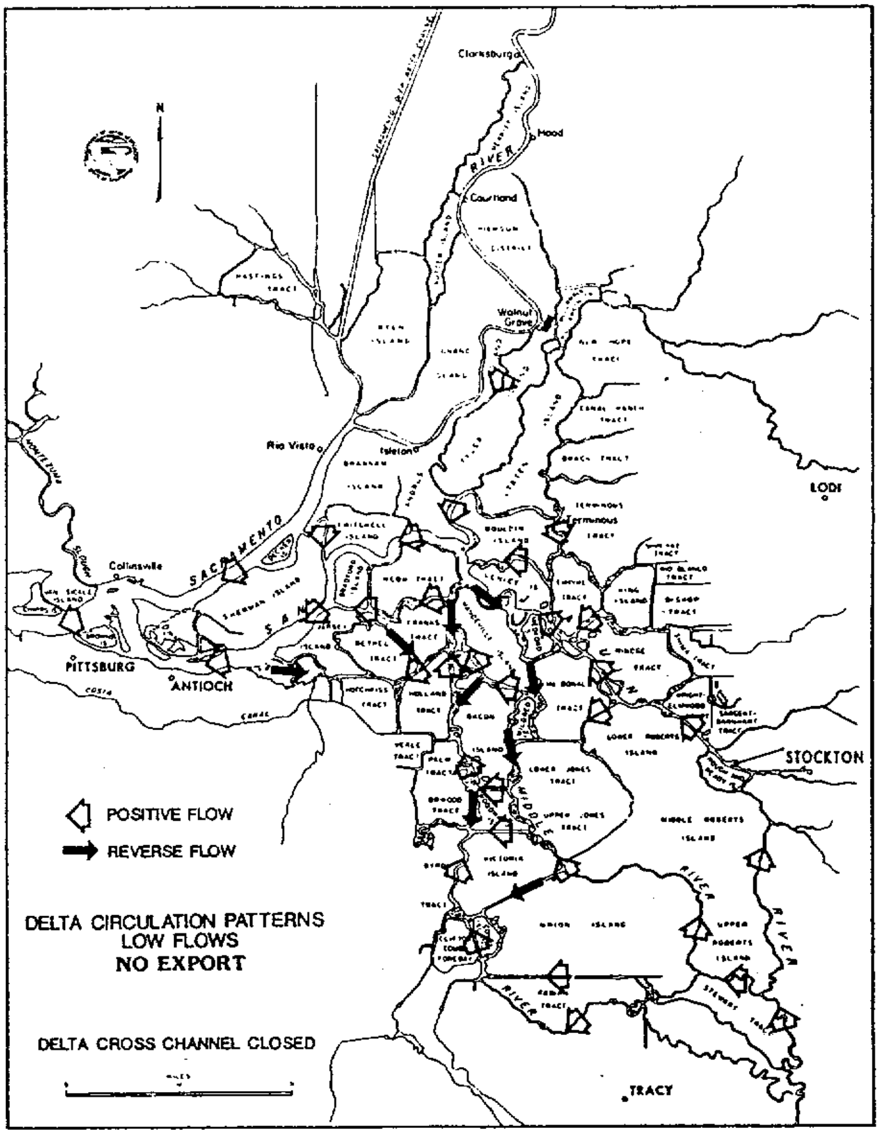


FIGURE A3.0-13

DWR-51C

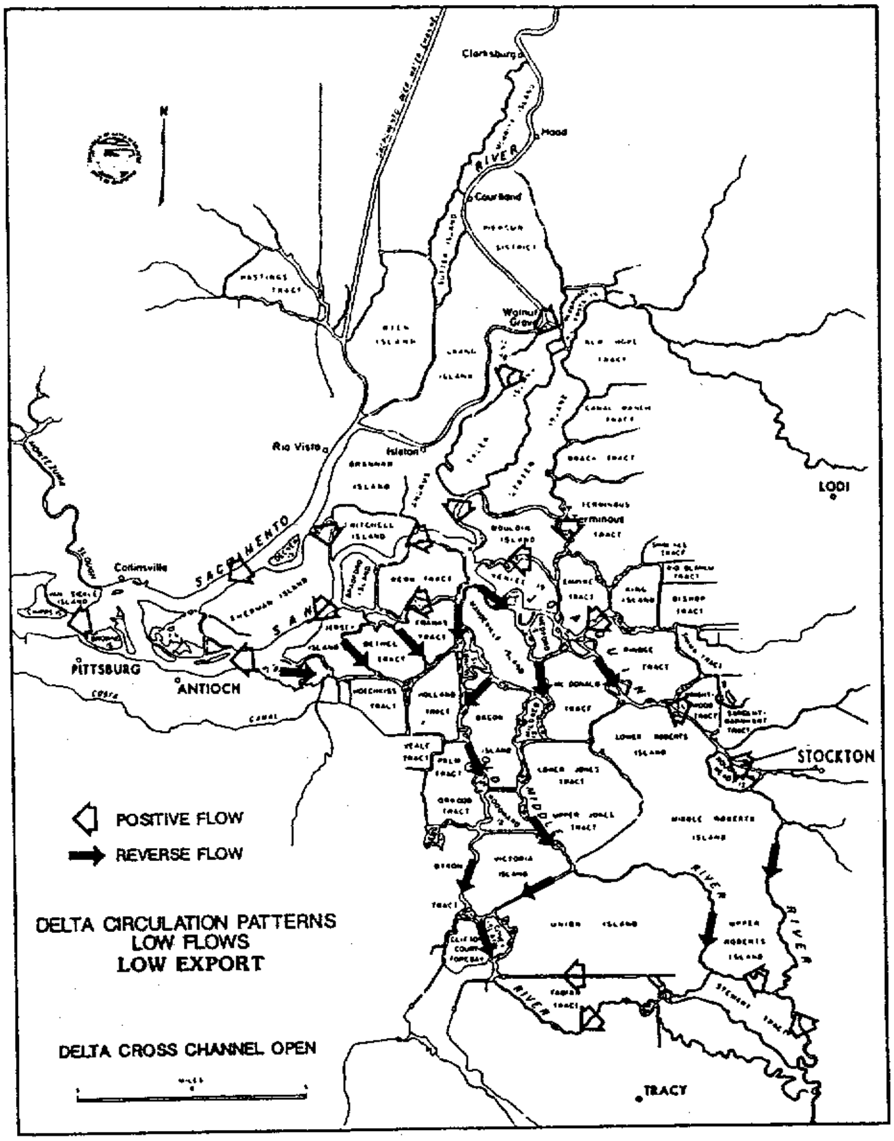
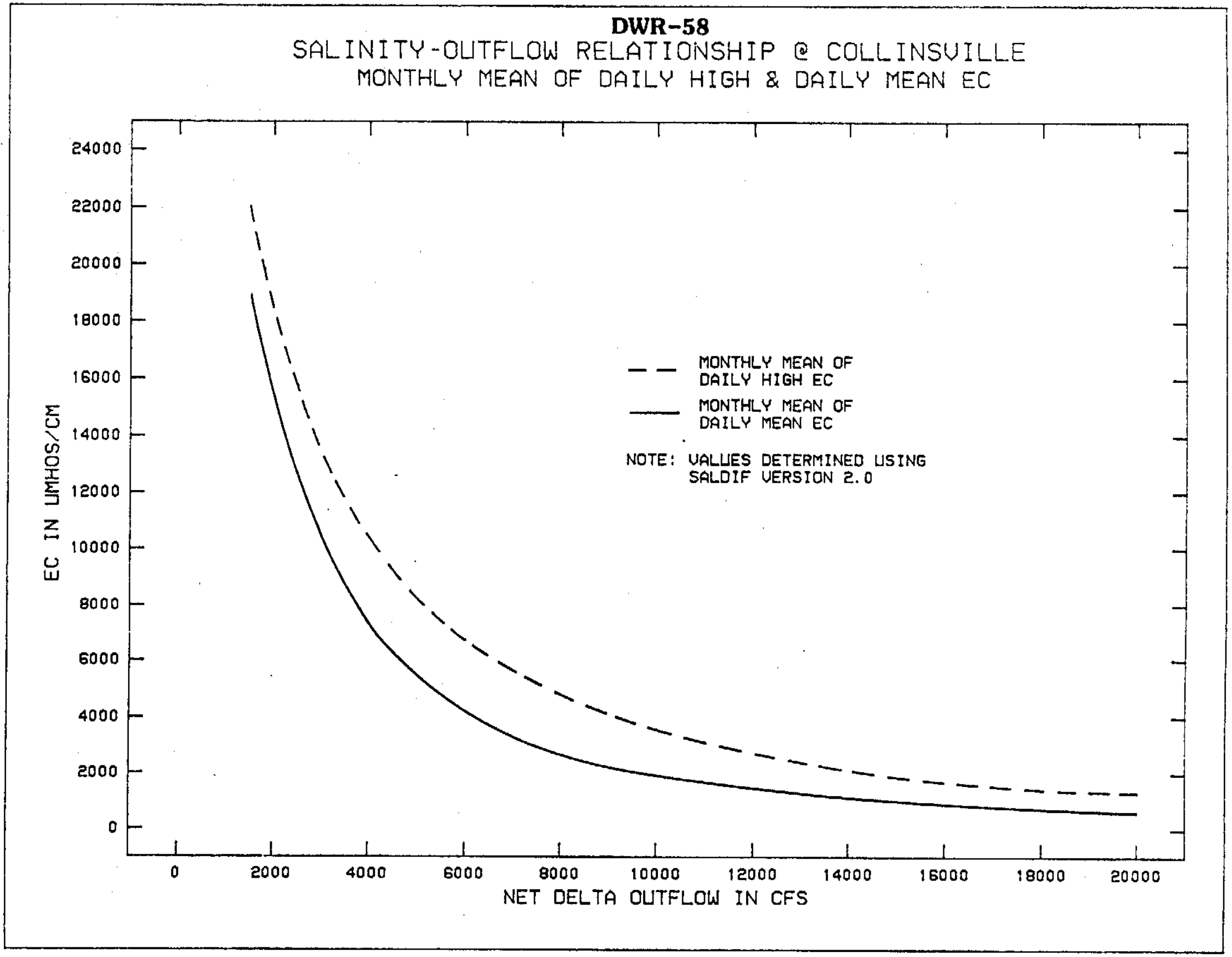
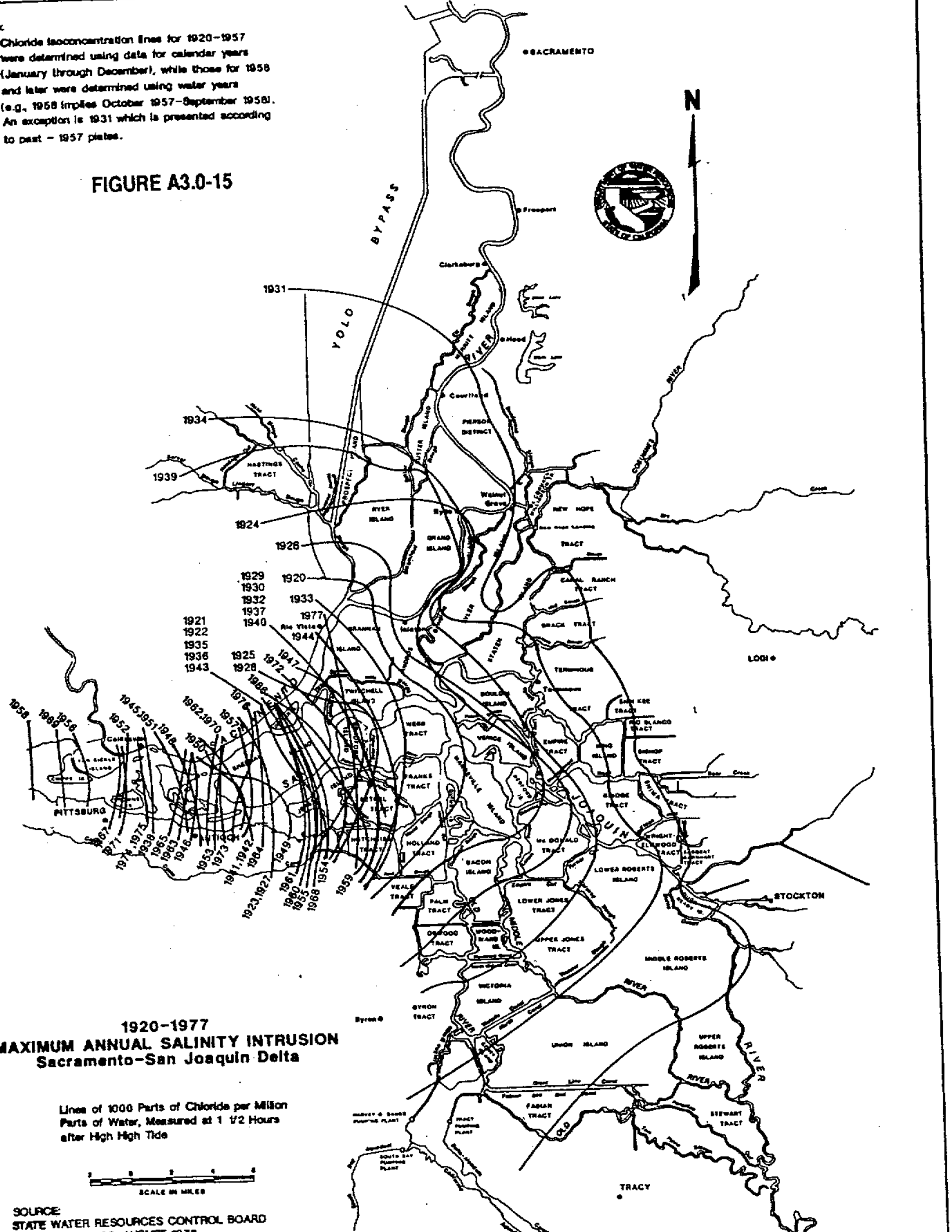


FIGURE A3.0-14



Note:
Chloride isoconcentration lines for 1920-1957 were determined using data for calendar years (January through December), while those for 1958 and later were determined using water years (e.g., 1958 implies October 1957-September 1958). An exception is 1931 which is presented according to past - 1957 plates.

FIGURE A3.0-15



1920-1977
MAXIMUM ANNUAL SALINITY INTRUSION
Sacramento-San Joaquin Delta

Lines of 1000 Parts of Chloride per Million Parts of Water, Measured at 1 1/2 Hours after High High Tide

SCALE IN MILES

SOURCE:
STATE WATER RESOURCES CONTROL BOARD
FINAL EIR D-1485, AUGUST 1978

The Delta Plan currently requires only the CVP and SWP to meet specified flow and salinity standards within the Delta and Suisun Marsh (SWRCB,15,5). Figure A3.0-16 shows the estimated average monthly Delta outflows under the present level of development (DWR,30); the present level of Delta outflow is composed of three factors: minimum amounts required by D-1485 standards, carriage water, and surplus Delta outflow. Estimates of the component required by D-1485 standards are given in Table A3.0-1.

San Francisco Bay and Basin

Physical Description

The boundary of San Francisco Bay (SWRCB,3,3) extends from the Golden Gate Bridge on the west to the Delta on the east and includes areas subject to tidal action up to mean high tide, areas 100 feet landward of the mean high tide shoreline, saltponds, and managed wetlands. This definition includes the entire Suisun Marsh as part of San Francisco Bay. Suisun Marsh, as defined by Section 29101 of the Public Resources Code, includes the waterways north of Suisun, Grizzly, and Honker bays which are subject to tidal action and the adjacent lands whose management is dependent on tidal action of these waters. This definition generally follows the San Francisco Bay Conservation and Development Commission (BCDC) boundary as defined in Government Code Sections 66610 and 66611.

San Francisco Bay consists of about 805 square miles (515,000 acres) (BCDC,1982) including: 420 square miles (269,000 acres) of open water (470 square miles when saturated mud flats are included), 125 square miles (80,000 acres) of tidal marshes; 110 square miles (70,000 acres) of Suisun Marsh; 80 square miles (51,000 acres) of diked historic baylands; and 70 square miles (45,000 acres) of saltponds and other managed wetlands.

The San Francisco Bay Basin (Figure A3.0-17) is defined as the area contributing local runoff to the Bay. This description differs somewhat from the Basin Plan boundary of Region 2 (RWQCB 2, 1986), which includes the entire San Francisco Bay Basin as well as coastal area from Dillon Beach to San Gregorio. The total area of the San Francisco Bay Basin is about 3,870 square miles, or 2,477,000 acres (SWRCB,3,Appendix F). The major streams contributing to local runoff to the Bay are the Napa, Petaluma, and Guadalupe rivers, and the Alameda, Coyote, Sonoma and Walnut creeks. Water is imported to the Basin via the following water projects (see Figure A3.0-2): Mokelumne Aqueduct, Hetch Hetchy Aqueduct, South Bay Aqueduct, Contra Costa Canal, Putah South Canal, Sonoma Petaluma Aqueducts, and North Bay Aqueduct.

In years of normal runoff, the San Francisco Bay Basin contributes about ten percent of the total flow, including Delta outflow, to the San Francisco Bay (SWRCB,3,3). From 1970 through 1982, the runoff into the Bay from rainfall averaged about 57 percent of the total San Francisco Bay Basin local runoff, with the rest being municipal and industrial discharges (SWRCB,3,35; Appendix R).

FIGURE A3.0-16

PRESENT LEVEL DELTA OUTFLOW

USING 1922-1978 MONTHLY AVERAGE HYDROLOGY

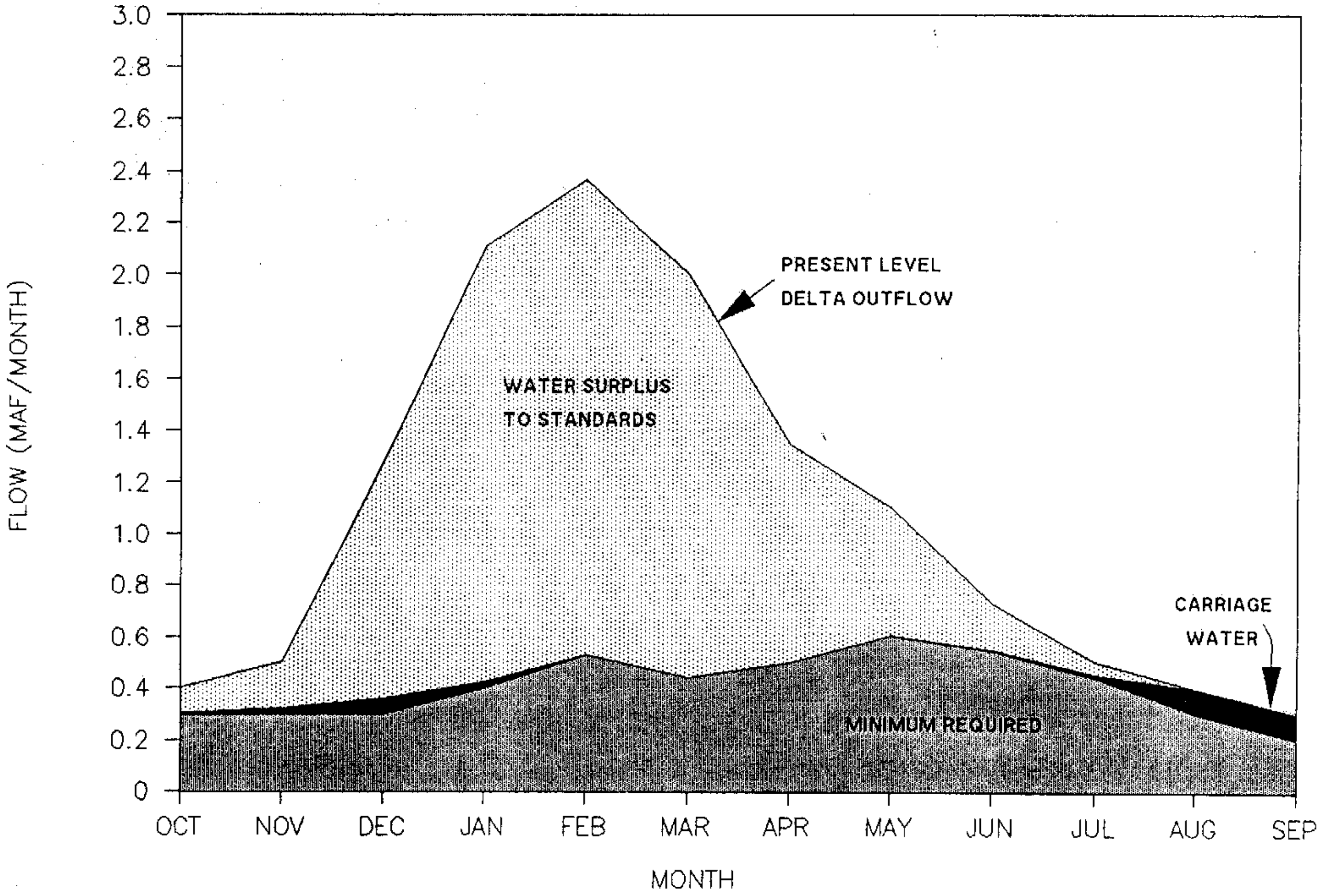


TABLE A3.0-1

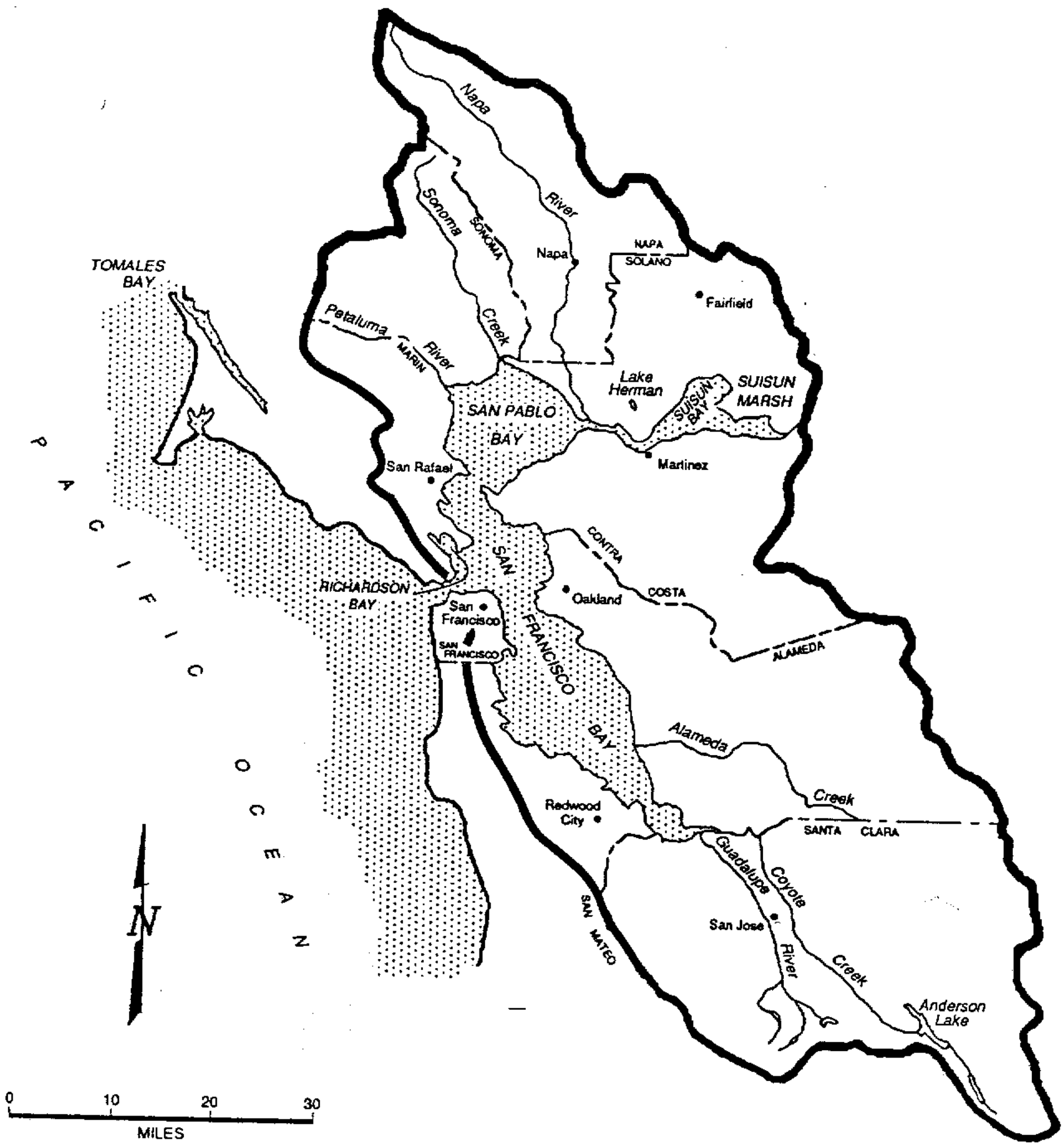
ESTIMATED DELTA OUTFLOW REQUIREMENTS OF THE 1978 DELTA PLAN

Time Period	Delta Outflow Requirements in cfs (acre-feet)									
	Wet		Above Normal		Below Normal		Dry		Critical	
	Lower Require-ments	Upper Require-ments	Lower Require-ments	Upper Require-ments	Lower Require-ments	Upper Require-ments	Lower Require-ments	Upper Require-ments	Lower Require-ments	Upper Require-ments
January	4,500[2] (276,700)	6,600[1] (405,800)	4,500[2] (276,700)	6,600[1] (405,800)	4,500[2] (276,700)	6,600[1] (405,800)	4,500[2] (276,700)	6,600[1] (405,800)	4,500[2] (276,700)	6,600[1] (405,800)
February	10,000 (555,400)	10,000 (555,400)	4,500[2] (249,900)	12,000 (666,500)	4,500[2] (249,900)	12,000 (666,500)	4,500[2] (249,900)	6,600[1] (366,600)	4,500[2] (249,900)	6,600[1] (366,600)
March 1-17	10,000 (337,200)	10,000 (337,200)	4,500[2] (151,700)	12,000 (404,600)	4,500[2] (151,700)	12,000 (404,600)	4,500[2] (151,700)	6,600[1] (222,500)	4,500[2] (151,700)	6,600[1] (222,500)
March 18-31	10,000 (277,700)	10,000 (277,700)	4,500[2] (125,000)	12,000 (333,200)	4,500[2] (125,000)	12,000 (333,200)	4,500[2] (125,000)	6,600[1] (183,300)	4,500[2] (125,000)	6,500[1] (183,300)
April	10,000 (595,000)	10,000 (595,000)	7,600 (452,200)	7,600 (452,200)	7,600 (452,200)	7,600 (452,200)	7,600 (452,200)	7,500 (452,200)	4,500[3] (267,800)	6,700[3] (398,700)
May 1-5	10,000 (99,200)	10,000 (99,200)	7,600 (75,400)	7,600 (75,400)	7,600 (75,400)	7,500 (75,400)	7,600 (75,400)	7,500 (75,400)	4,500[3] (44,600)	6,700[3] (66,400)
May 6-31	7,600 (391,900)	14,000[4] (722,000)	7,600 (391,900)	14,000[4] (722,000)	7,600 (391,900)	11,400[4] (587,900)	7,600 (391,900)	7,600 (391,900)	3,900 (201,100)	3,900 (201,100)
June 1-15	7,600 (226,100)	14,000[4] (416,500)	7,600 (226,100)	10,700[4] (318,400)	7,600 (226,100)	9,500[4] (282,600)	7,600 (226,100)	7,600 (226,100)	3,900 (116,000)	3,900 (116,000)
June 16-20	7,600 (75,400)	14,000[4] (138,800)	7,600 (75,400)	10,700[4] (106,100)	7,600 (75,400)	9,500[4] (94,200)	4,700 (46,600)	4,700 (46,600)	3,900 (38,700)	3,900 (38,700)
June 21-30	7,600 (150,700)	14,000[4] (227,700)	7,500 (150,700)	10,700[4] (212,200)	5,400 (107,100)	9,500[4] (188,400)	4,700 (93,200)	4,700 (93,200)	3,900 (77,400)	3,900 (77,400)
July	7,600 (467,300)	10,000[4] (614,900)	6,700 (412,000)	7,700[4] (473,500)	5,400 (332,000)	6,500[4] (399,700)	4,700 (289,000)	4,700 (289,000)	3,900 (239,800)	3,900 (239,800)
August 1-15	7,600 (226,100)	7,600 (225,100)	6,700 (199,300)	6,700 (199,300)	5,400 (160,700)	5,400 (160,700)	4,700 (139,800)	4,700 (139,800)	3,900 (116,000)	3,900 (116,000)
August 16-31	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)	2,500 (79,300)
September	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)	2,500 (148,800)
October	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	3,500[5] (215,200)	4,500 (276,700)	3,500[5] (215,200)	4,500 (276,700)
November	4,500 (267,800)	4,500 (267,800)	4,500 (267,800)	4,500 (267,800)	4,500 (267,800)	4,500 (267,800)	3,500[5] (208,300)	4,500 (267,800)	3,500[5] (208,300)	4,500 (267,800)
December	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	4,500 (276,700)	3,500[5] (215,200)	4,500 (276,700)	3,500[5] (215,200)	4,500 (276,700)
Total in 1000s acre-feet	4,728	5,566	3,836	5,418	3,673	5,100	3,384	3,942	2,772	3,482

1 When the storages at any two of Shasta, Oroville and Folsom Reservoirs are encroached in their flood control reservation.
2 If storages are encroached (see No. 1) then 6,600.
3 If SWP and CVP users are taking deficiencies in firm supplies then 4,500 cfs for critical year.
4 If subnormal snowmelt then use lower limit.
5 When project users (CVP and SWP) are taking deficiencies, otherwise 4,500 cfs.

Department of Water Resources
Division of Operations and Maintenance
March 1986

FIGURE A3.0-17 Boundary of the San Francisco Bay Basin
(From: SWRCB, 3, 12)



MAP0022

Hydrology

San Francisco Bay, excluding the Delta, but including saturated mudflats, has a total water surface area of approximately 300,000 acres or 470 square miles at mean lower low water (MLLW). The area, mean depth and volume of the subregions of the Bay are summarized in Table A3.0-2 (Cheng and Garner, 1984). The locations of the Bay's subregions are shown in Figure A3.0-18. These subregions differ from the description in the Region 2 Basin Plan (RWQCB,2,1986) and are based solely on hydrodynamics.

Table A3.0-2
BATHYMETRIC DATA FOR SAN FRANCISCO BAY
(Adapted from Cheng and Gardner, 1984)

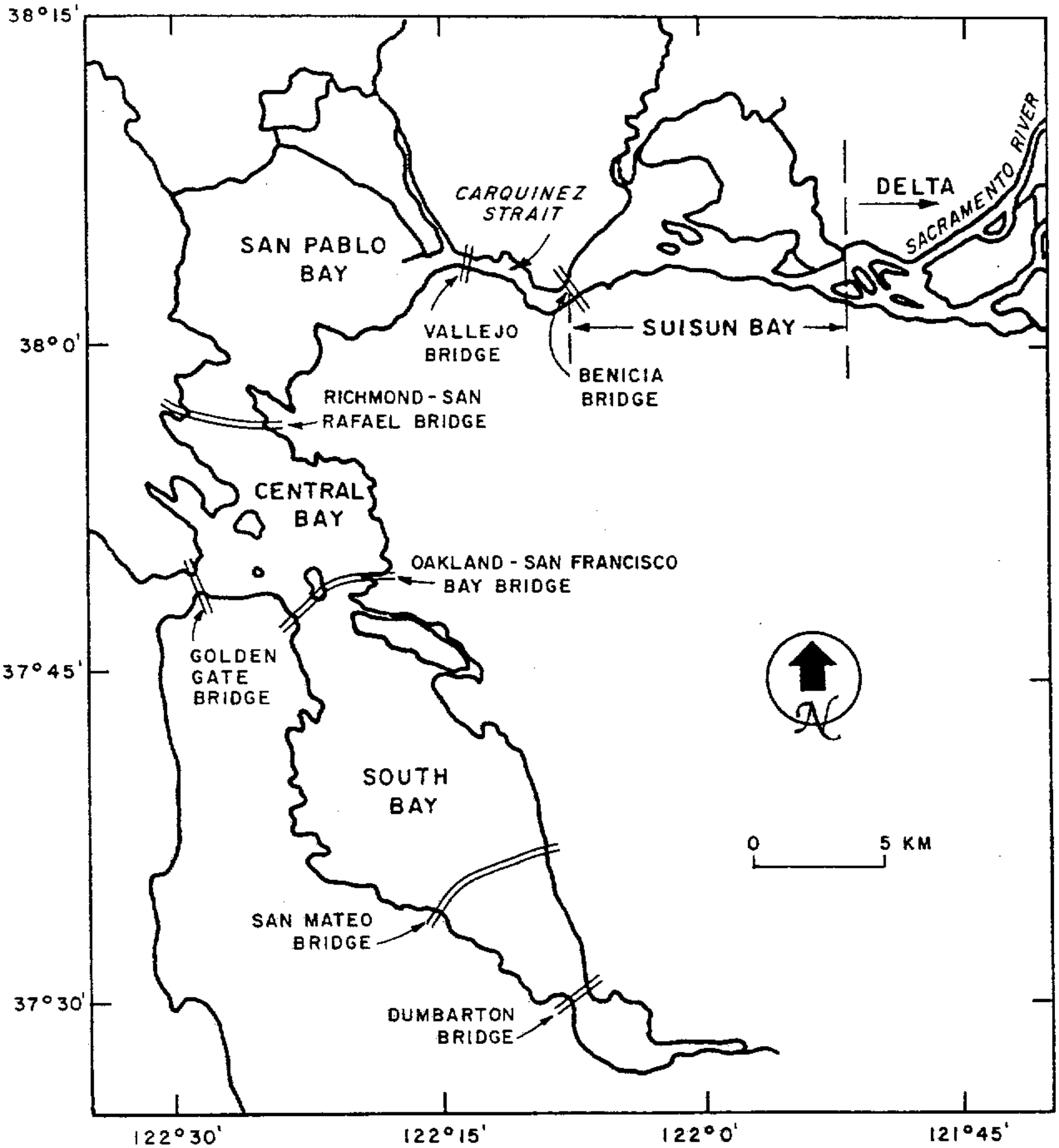
Region	Surface Area at MLLW (sq mi)	Mean Depth (ft)	Mean Volume (AF)
Central Bay	103	35	2,307,000
San Pablo Bay	105	9	605,000
Carquinez Strait	12	29	223,000
Suisun Bay	36	14	323,000
South Bay	214	11	1,507,000
San Francisco Bay (Total)	470	17	4,965,000

San Francisco Bay is unique among American estuaries in having two arms or reaches, the northern including San Pablo and Suisun bays, and the southern extending from the Oakland-Bay Bridge to Mountain View. The northern reach receives discharge from the Sacramento-San Joaquin Delta, approximately 90 percent of the freshwater inflow to San Francisco Bay. The southern reach primarily receives local runoff, storm drain and treatment plant discharges and Delta outflow in very high flow events. Between the two reaches is the Central Bay bounded by the Richmond-San Rafael, Oakland-Bay, and Golden Gate bridges. The Central Bay is deeper than either of the two reaches (SWRCB,431,18-19).

o Freshwater Inflow

Excluding water from the Delta, freshwater inflows come into the Bay primarily via the Napa and Petaluma rivers which provide local drainage to the northern part of San Pablo Bay; via Walnut Creek and Suisun Slough which enter Suisun Bay; via Pinole and Novato creeks which enter the San Pablo Bay; and via San Lorenzo, Matadero and Coyote creeks which enter the South Bay. In addition, many municipal and industrial wastewater treatment plants and combined sewer overflows contribute to the Bay inflows (SWRCB,3,11-16). Because these freshwater inflows into the Bay are small compared to Delta outflow, they are often ignored in calculations of total inflow to the Bay. In the southern portion of the South Bay, all tributary streams have intermittent, local runoff (excluding effluent) (BISF,6,56-59).

FIGURE A3.0-18 Location map of San Francisco Bay showing the four sub-regions and the Sacramento-San Joaquin Delta.
(Source: Denton and Hunt, 1986)



o Tidal Exchange

Immense flows are exchanged between the bay and the ocean on tidal currents driven by the gravitational attraction between the earth, the sun and moon. Their exact size is not known (USGS,3 updated,5), but tidal flows entering San Francisco Bay at the Golden Gate Bridge have been estimated to average greater than 2.5 million cfs (BISF,6,51). Because of complex circulation eddies outside the entrance to the Bay, only a portion the water flooding in from the ocean is "new" water, i.e., water which has not entered the Bay for at least several tidal cycles (Denton and Hunt, 1986).

- Central Bay

Flood tides first entering the central Bay pass on either side of Alcatraz Island, through Raccoon Strait between the Tiburon Peninsula and Angel Island; tides then flow northwards through San Pablo Strait into San Pablo Bay and southwards beneath the Oakland-Bay Bridge into south Bay (Figure A3.0-19).

- San Pablo Bay

The main tidal flows in San Pablo Bay pass along a natural channel that runs between San Pablo Strait, then across the shallow Pinole Shoal and through Carquinez Strait to the east (Figure A3.0-20). The maximum depth in the two straits is about 83 feet, decreasing to about 20 to 25 feet over Pinole Shoal. A 600-foot-wide shipping channel, dredged to a depth of 35 feet across the shallow Pinole Shoal, provides shipping access to the Mare Island Naval Shipyard and the ports of Sacramento and Stockton. The areas north and south of the shipping channel are very shallow; one-half of the area of San Pablo Bay has a depth of less than six feet.

- Suisun Bay and Marsh

Having the smallest surface area of the four embayments, Suisun Bay is situated in the northeastern reach of San Francisco Bay between the cities of Benicia and Antioch (Figure A3.0-21). The entire Suisun Bay and Marsh area, including two subbays, Grizzly and Honker, consists of 84,190 acres, of which about 26,880 acres are bays and sloughs. The remaining 57,310 acres are diked and managed wetlands. (Approximately 45,710 acres of managed wetlands are privately-owned and used primarily for duck hunting; 10,490 acres are owned by the State of California as a waterfowl management area, wildlife refuge and public recreation area; and 1,110 acres are controlled by the U.S. Navy (SWRCB, 1978)).

The main tidal flows are along a few well-defined channels separated by islands and shallow gravel banks. During most periods of outflow from the Delta, Suisun Bay is the usual location of the estuary's 'null zone' (defined as the region in a partially or well-mixed estuary where the residual bottom currents are effectively zero). Upstream of this area there is a net downstream, or seaward, residual velocity along

FIGURE A3.0-19 Map of the Central Bay and the region immediately outside Golden Gate. The dotted line shows the 60 ft depth contour and the dashed line is the 18 ft contour. (Source: Denton and Hunt, 1986)

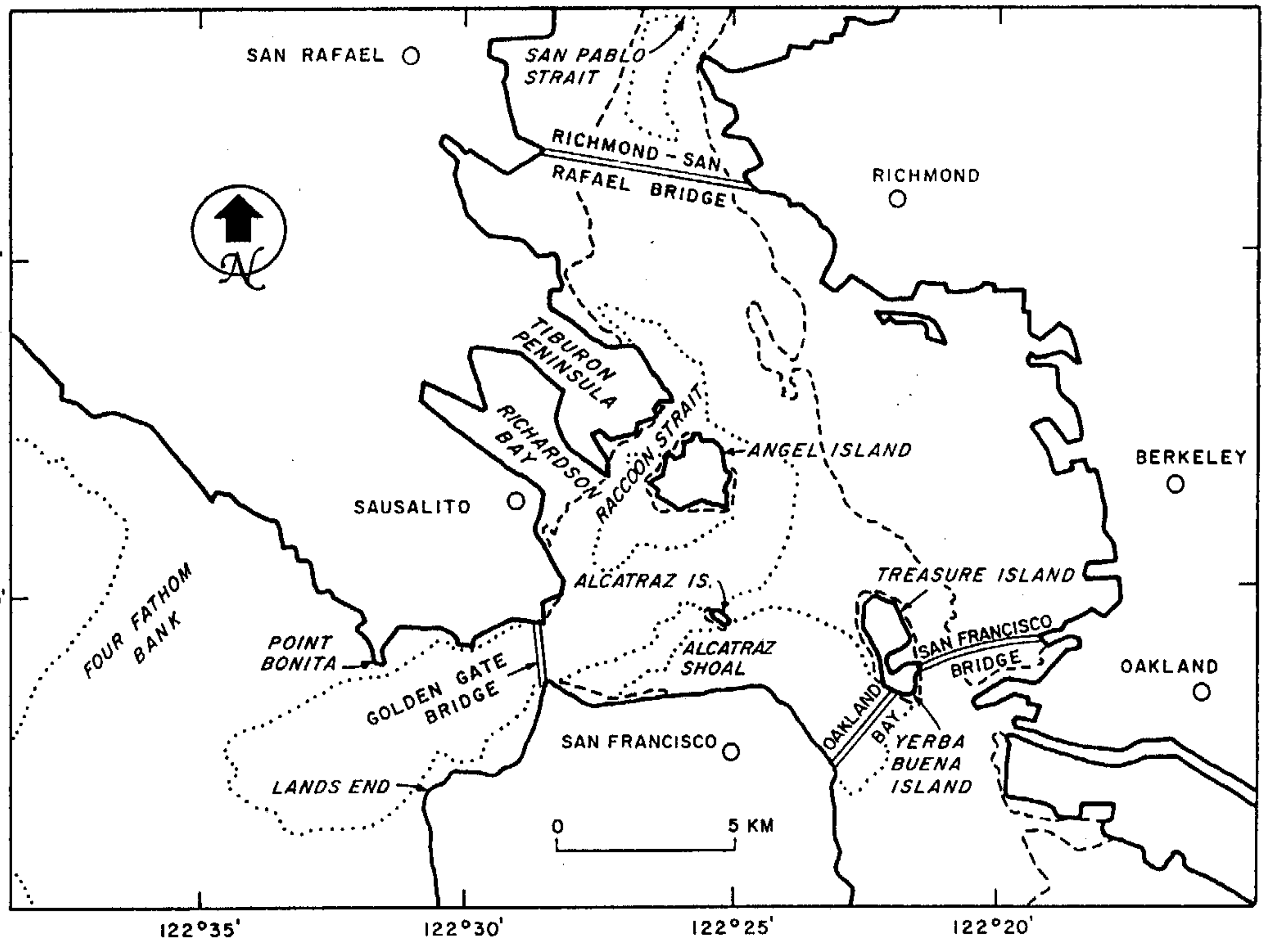


FIGURE A3.0-20 Map of San Pablo Bay. The 18 ft (5.5) depth contour is plotted as a dashed line and indicates the location of the main channel. The dotted line shows the extent of the mudflats around the bay. (Source: Denton and Hunt, 1986)

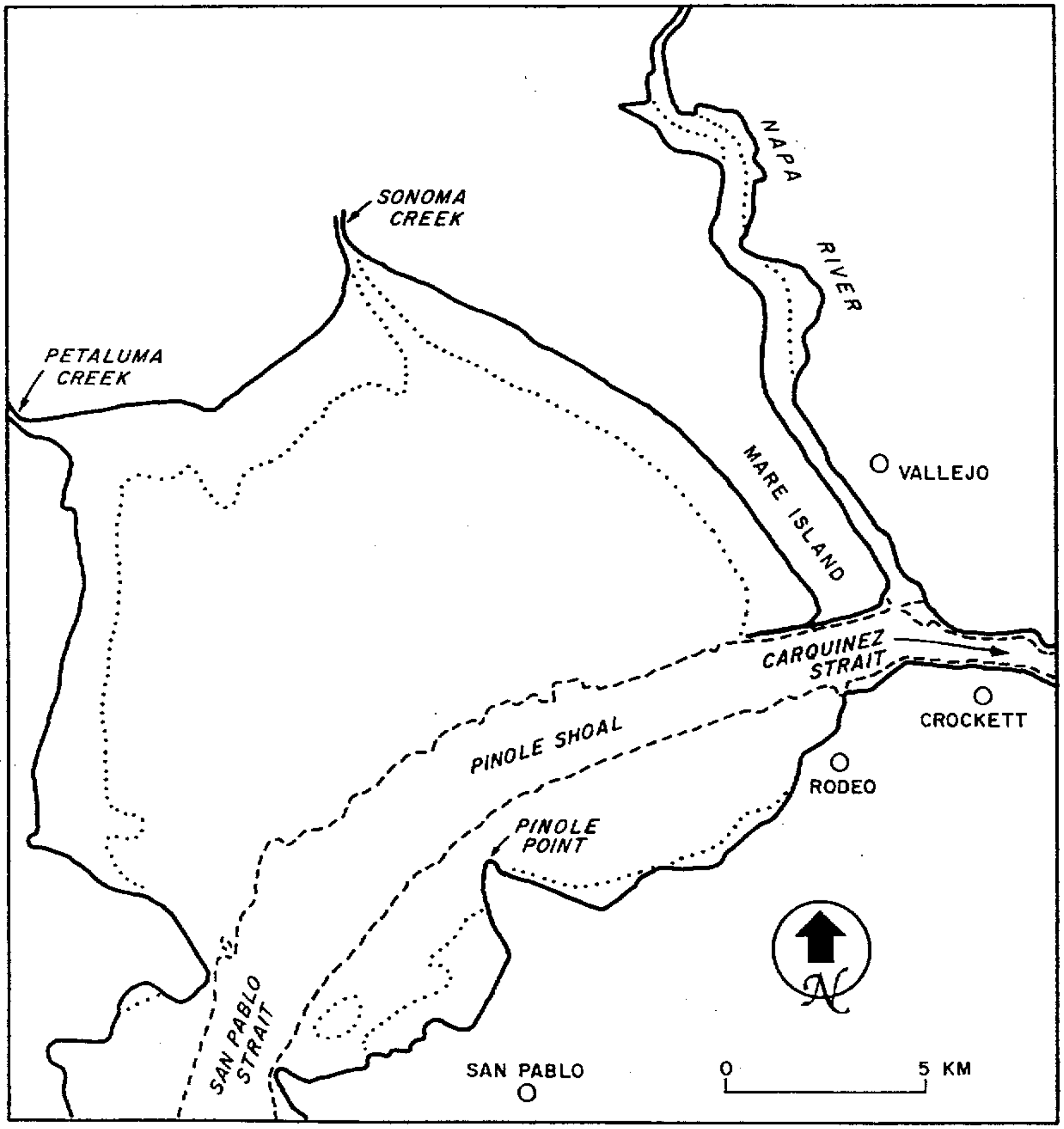
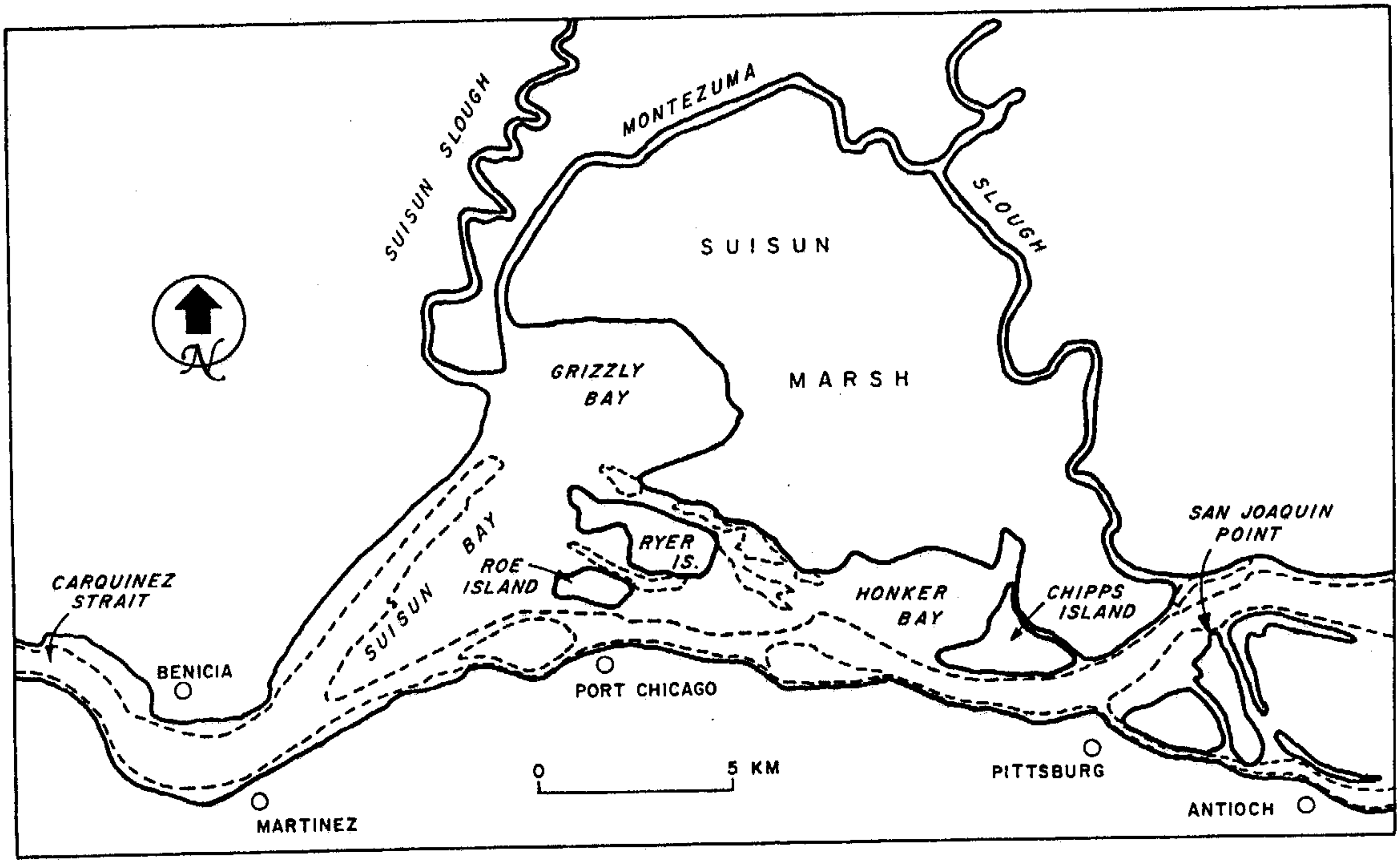


FIGURE A3.0-21 Map of Suisun Bay. The dashed line shows the 18 ft (5.5) depth contour. (Source: Denton and Hunt, 1986)



the bottom caused by river inflow. Seaward of the null zone, gravitational circulation produces a transport, for the most part toward land, of denser more saline water along the bottom. The null zone is significant because it is the theoretical upstream boundary of the entrapment zone, the area in the estuary where suspended materials, including biota, accumulate (USBR,112,407). Figure A3.0-22 is a diagram of estuarine circulation for a partially mixed estuary such as Suisun Bay; it illustrates the relationships between flows, salinities, and the null and entrapment zones (CCCWA/EDF,1,56).

The salinity of water within Suisun Bay varies seasonally with the volume of freshwater outflow from the Delta. Salinities of the water in Montezuma Slough are lower than in Suisun Bay itself for a longer period of time each year because the Slough lies further upstream and receives freshwater inflow from the Sacramento River and other tributary channels first. For the most part, low salinity water stays in the Suisun Marsh channels later in the spring and early summer, but higher salinity water remains later in the fall before the Marsh channels are flushed by increasing Delta outflows (SWRCB,1978).

By most definitions, Suisun Bay includes Suisun Marsh, located to the north of the main body of the Bay. The Marsh was a natural fresh to brackish water marsh prior to widespread reclamation for agricultural purposes in the early 1900s. However, because of increasing problems with salinity in the 1930s, the reclaimed marsh lands were gradually converted to private duck clubs and state Wildlife Management Areas.

- South Bay

The entrance to the South Bay from the Central Bay is separated by Treasure and Yerba Buena islands into two passages, one to the east that is 30 to 35 feet deep and one to the west that is 70 feet deep at the Oakland-San Francisco Bay Bridge (Figure A3.0-23). Because the South Bay receives only minor amounts of local freshwater inflows, it is essentially a tidal lagoon. Tidal currents in South Bay are greatest along the main channel on the western side of the Bay. In the South Bay, evidence suggests three distinct mixing zones exist: (1) between the Oakland-San Francisco Bay Bridge and San Bruno Shoal, a relatively shallow area with water depths of about 11 to 26 feet between Bay Farm Island and Oyster Point; (2) between the San Bruno Shoal and the San Mateo Bridge; and (3) in the area south of the San Mateo Bridge. A navigation channel, 500 feet wide and 29 feet deep, is maintained across the San Bruno Shoal.

The salinity of the South Bay remains close to the level of the ocean (33 to 35 parts per thousand) throughout most of the year, except during periods of high Delta outflow. During particularly hot, dry periods when evaporation rates are high, the South Bay can act as a "negative" estuary where salinity levels actually increase in the southern extremities (Denton and Hunt, 1986).

FIGURE A3.0-22 Diagram of Estuarine Circulation for a Partially Mixed Estuary (Source: CCCWA/EDF, 1, Figure 12)

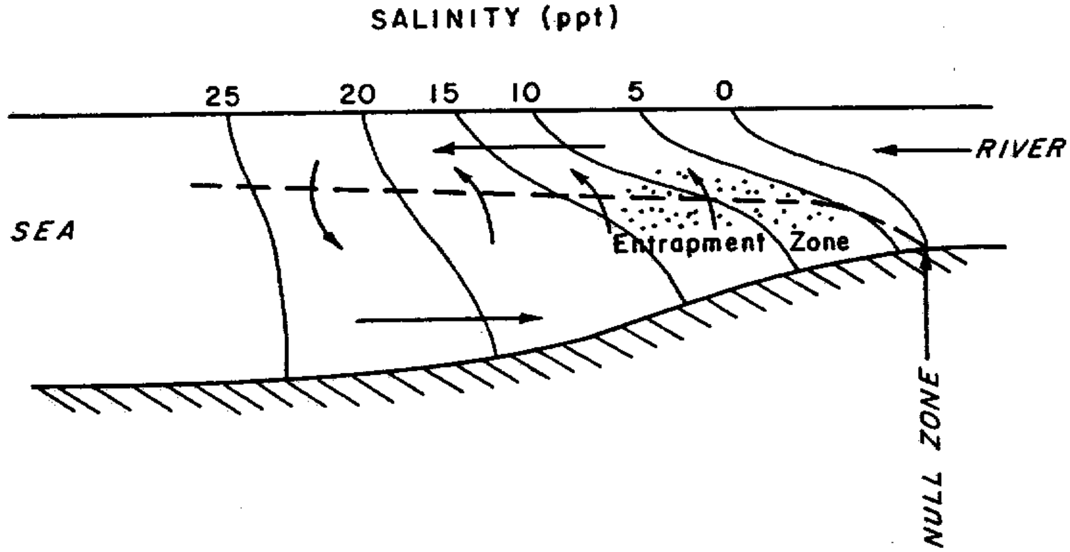
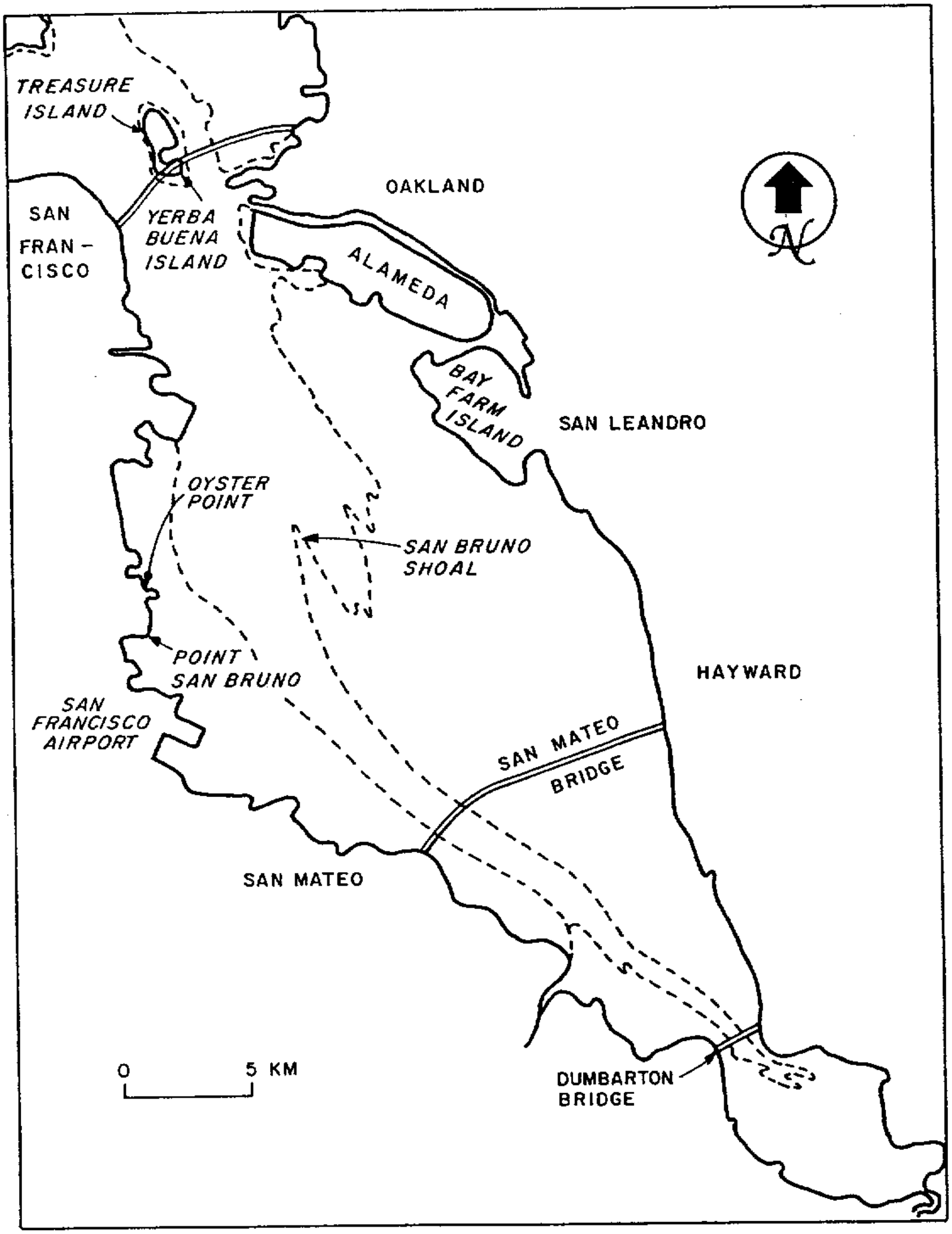


FIGURE A3.0-23 Map of the South Bay. The dashed line shows the 18 ft depth contour. (Source: Denton and Hunt, 1986)



Currents differ in the South Bay according to Delta outflows. From analyses of current data for summer wind conditions and low Delta discharges, the USGS has concluded that net currents in South Bay north of San Bruno Shoal are southward along the eastern side and northward along the western side of the Bay (USGS,3,25). Following high outflow pulse events, a lens of freshwater can spread southwards, depending on wind and tide conditions, into the Central and South Bays over more saline water that is flowing toward the ocean. This process, which is known as gravitational overturn, allows large volumes of freshwater to enter the South Bay (Denton and Hunt, 1986). The significant density difference between the two flows acts to inhibit vertical mixing. When Delta outflow subsides, reintrusion of ocean water raises the salinities in Central Bay above those in South Bay, and the direction of circulation reverses; that is, surface waters again flow seaward (USGS,3,26).

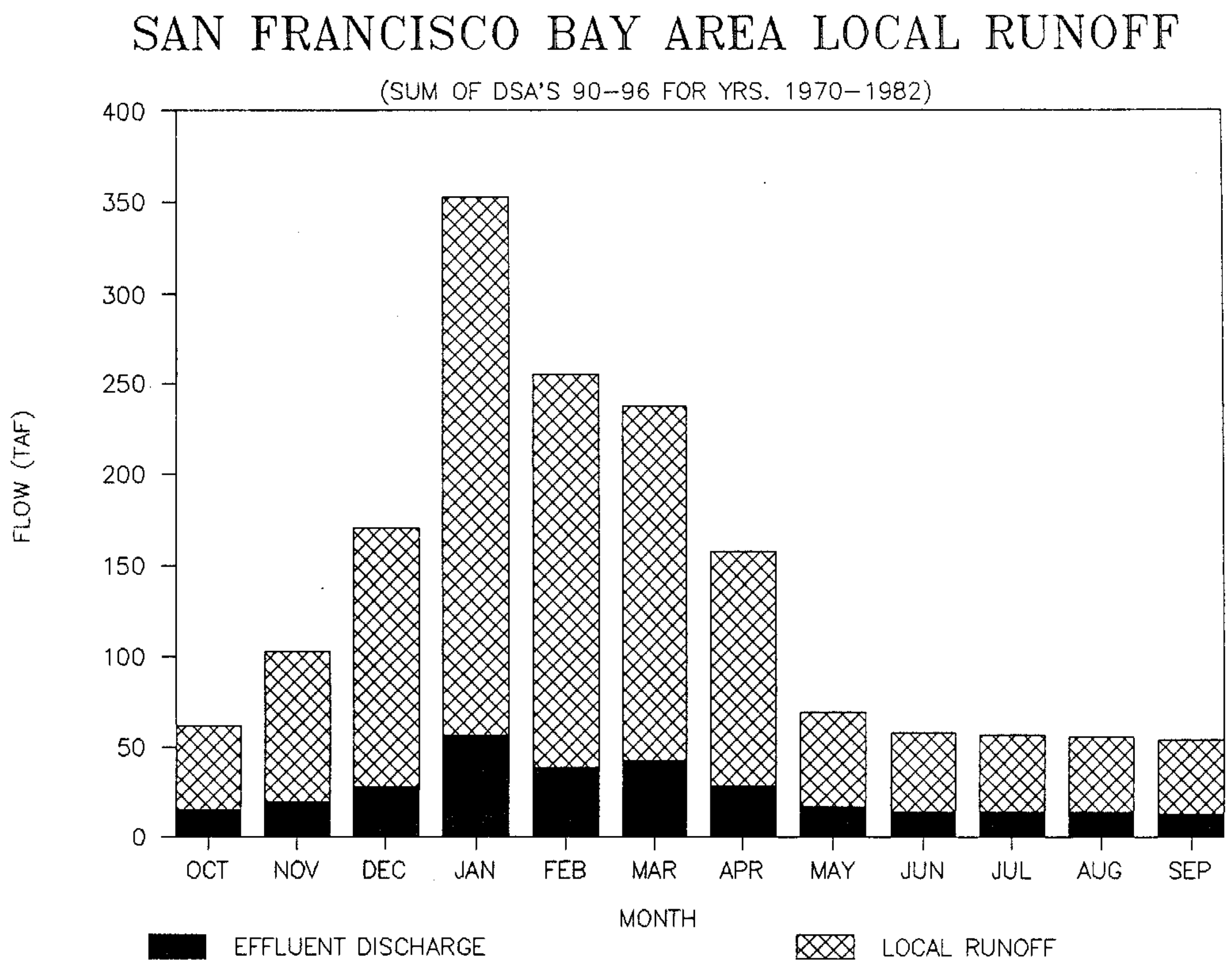
o Local Runoff

In the San Francisco Bay Basin, almost all of the local runoff comes from rainfall, with minor amounts from snowmelt runoff and groundwater depletion. However, the local runoff is somewhat depleted due to infiltration, evapotranspiration, and storage in reservoir impoundments. Unlike the areas upstream of the Bay Basin with considerable snowfall, the precipitation runoff in the Bay Basin occurs almost immediately after the precipitation events.

Upstream storage and regulated releases required by the Delta Plan have provided higher levels of inflow from the Delta in most of the summer months, especially in dry and critically dry years. Significant amounts of effluent from industrial and municipal sources are discharged into the Bay, but the effects of these additional flows are not known.

A variety of factors have altered the effects of Bay Basin local runoff. These include upstream reservoirs, the change in land use patterns from native vegetation to agricultural vegetation, impermeable surfaces such as concrete or asphalt, and the effects of ground water pumping. For example, the extensive expansion of streets, parking lots, and drainage conduits allow less rainfall to reach the ground water and subsequently greater amounts to flow directly into the Bay. Wastewater treatment plant discharges and water imports into the Bay Basin have also changed the locations and greatly increased the quantity of local inflows to the Bay. DWR developed a local runoff survey for separate Bay Basin hydrologic areas and a summary of wastewater discharge for the period of water years 1970 through 1982 (Figure A3.0-24) (SWRCB,3,Appendix R).

FIGURE A3.0-24



APPENDIX 3.1

DESCRIPTION OF VARIOUS COMPONENTS OF THE NEW WATER YEAR CLASSIFICATION 40-30-30 INDEX

The new water year classification, the 40-30-30 Index, is described in the main text of the Water Quality Control Plan. This appendix provides a detailed description of the following steps taken to develop this index:

- o Determination of Weighting Coefficients
- o Results of Regression Analysis
- o Determination of Water Year Classification Breakpoints
- o Verification Process
- o Adjustments to Water Year Classification, and
- o Source of Database

o Sacramento Basin Index (40-30-30 Index)

The modified classification splits the index into three terms. The form of the index equation is as follows:

Index = C1*X + C2*Y + C3*Z

Where: C1, C2, and C3 are weighting coefficients of 0.4, 0.3 and 0.3, respectively.

And: X = April through July Four River Unimpaired Flow (MAF)
Y = October through March Four River Unimpaired Flow (MAF)
Z = Previous year's WY Index (MAF) having a maximum cap value of value of 10 MAF.

o Determination of Weighting Coefficients

The weighting coefficients set the relative importance of each term, and so essentially control the accuracy of the index. To determine the optimal values for these coefficients, a statistical analysis was performed to establish an index equation that produced the highest correlation to water availability. Increasing the second and third term's weighting coefficients with respect to the first improved the correlation. This improvement reached a plateau after a relatively small increase and remained at that level over a wide range of weighting coefficient combinations. Choice of 0.4, 0.3, and 0.3 for the weighting coefficients, C1, C2, and C3 respectively, was based on obtaining a high degree of correlation, and a final condition that the coefficients be simple numbers so that the index would remain relatively easy to work with.

o Results of Regression Analysis

Table A3.1-1 lists some of the regression results of these statistical analyses made to determine the optimal weighting coefficients and also lists the results of regressing the water availability against Delta Plan classification availability. This comparison indicates that breaking the index into two separate hydrologic periods and adding the effect of the previous year's hydrology enhances the index's reliability.

TABLE A3.1-1
Selected Results of the Statistical Analyses to Determine Optimal Weighting Coefficients

Classification	Weighting Coefficients(%)	R Squared Value
Proposed Modified	40 -- 30 -- 30 w/cap.1/	0.852/
Selected Alternatives	40 -- 20 -- 40	0.88
	40 -- 30 -- 30	0.87
Delta Plan w/new BP3/	33 -- 67 -- 00	0.74
April through July	100 -- 00 -- 00	0.66

Figure A3.1-1 shows a plot of the Sacramento Basin Water Year (WY) Index vs. July Water Availability with the regression curve for 57 years of data, 1922 through 1978, for the optimal weighting coefficients.

- Determination of Water Year Classification Breakpoints

The Delta Plan Water Year classification defines the boundaries of five water year types: wet, above normal, below normal, dry, or critically dry. This classification defines normal Sacramento Valley inflow, the boundary between above normal and below normal, as the logarithmic mean, or fiftieth percentile, of the Sacramento Basin's Four River Index for the period 1922 through 1971. In other words, there is an equal chance that Sacramento Basin Index will either exceed or not exceed the logarithmetic mean of 15.7 million acre feet (MAF). The boundary between an above normal year and a wet year is set at the 70 percent probability, 19.6 MAF. The boundaries for dry and critically dry years, 30 percent (12.5 MAF) and 15 percent (10.2 MAF) probability, respectively, were developed by identifying the Sacramento Basin Four River Index flows which had a potential for water supply shortages or critical water supply shortages for project operations. The years DWR identified as having a potential for shortages are (DWR,1,1978 Delta Plan hearing exhibit):

- Shortages: 1926, 1930, 1932, 1944, 1947, 1949, 1955, 1959, 1960, 1961, and 1964.
- Critical Shortages: 1924, 1929, 1931, 1933, 1934, and 1939.

The drought years 1976 and 1977 occurred after this analysis was completed and so were not included as years of critical shortage.

The methodology used to determine the index breakpoints that define the boundaries of the five water year types in the Delta Plan classification, was also used to determine the breakpoints for the new classification. An updated database was used with this methodology. Changes in the database are:

1/ This classification has a cap of 10 MAF on the third term.

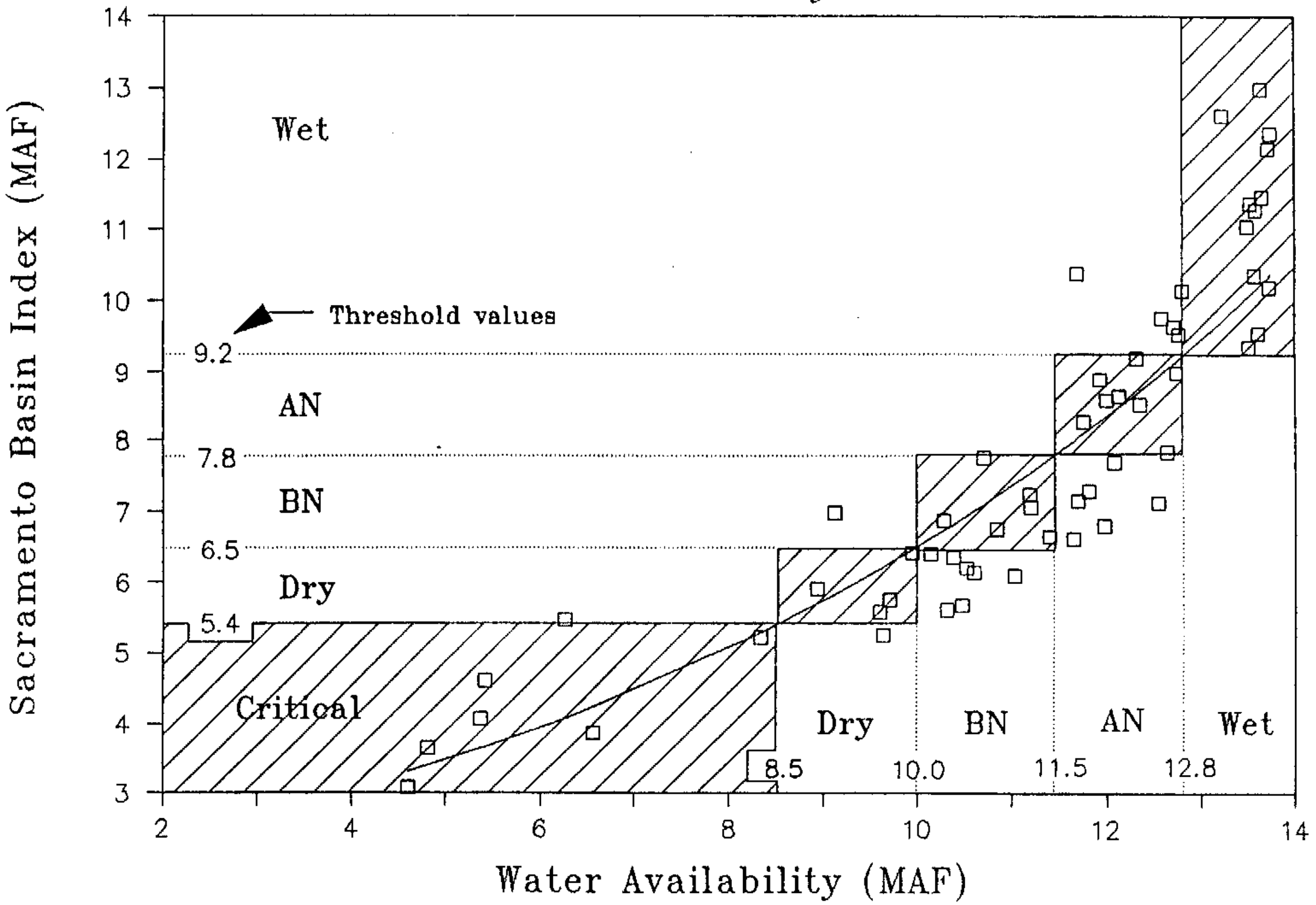
2/ The R squared value for the Proposed Modified and Selected Alternatives classifications are very similar, with the values for the latter being slightly higher. It was the consensus of the subworkgroup that the 40-30-30 w/cap Index was the preferable index.

3/ Breakpoint (BP), or threshold values are revised to reflect 1906 -- 1987 hydrology.

FIGURE A3.1-1

PLOT OF DATA POINTS, REGRESSION CURVE AND INDEX THRESHOLD VALUES FOR MODIFIED WATER INDEX 40-30-30 W/CAP

Month of July



Note: Shade areas indicate ranges where index correctly estimates water availability.
Area above shaded area indicates index over predicts amount of water availability.
Area below shaded area indicates index under predicts amount of water availability.

- An extended database, 1906 -- 1988 -- was used, and
- Two additional years with the potential for project shortages were included, 1939 and 1985.

New threshold flow levels and the percentage distributions were developed. Figure A3.1-2 shows a plot of the probability that the index value will be equal to or less than a particular value. The Delta Plan and the new classification threshold values and year type distributions are shown in Table A3.1-2.

Table A3.1-2

SACRAMENTO BASIN WY CLASSIFICATION
THRESHOLD VALUES AND YEAR TYPE DISTRIBUTION

Delta Plan Classification[1/]

Year Type	Threshold Value (MAF)	1906 -- 1988 Expected %	Expected No. Years	Actual %	Actual No. Years
W	Greater than 19.6	30	25	41	34
AN	Less than 19.6, greater than 15.7	20	17	12	10
BN	Less than 15.7, greater than 12.5	28	23	18	15
D	Less than 12.5, greater than 10.2	11	9	16	13
C	Less than 10.2	11	9	13	11

New Classification -- 40-30-30 Index

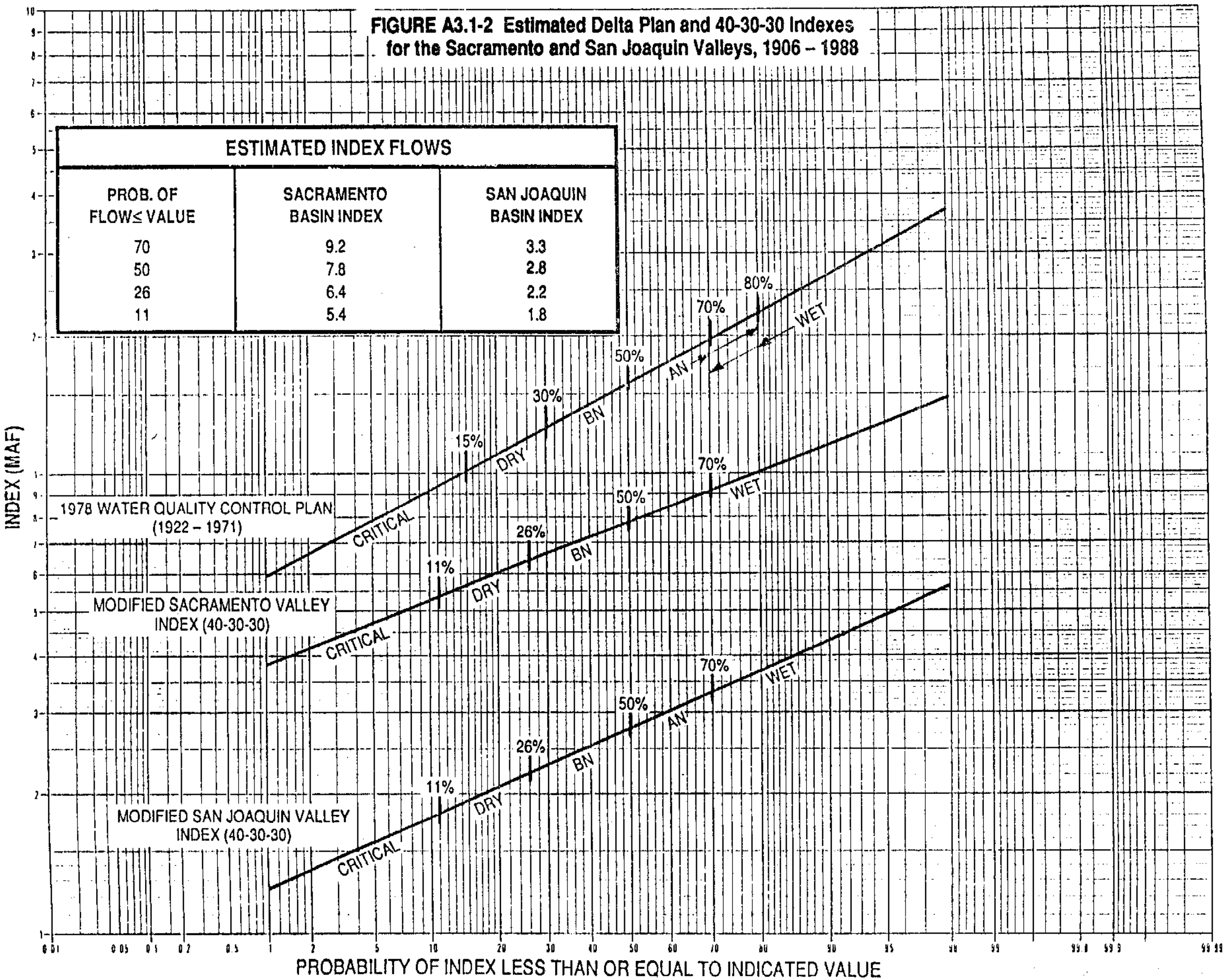
Year Type	Threshold Value (MAF)	1906 -- 1988 Expected %	Expected No. of	Actual %	Actual No. of
W	Greater than 9.2	30	25	35	29
AN	Less than 9.2, greater than 7.8	20	17	13	11
BN	Less than 7.8, greater than 6.5	26	21	20.5	17
D	Less than 6.5, greater than 5.4	13	11	20.5	17
C	Less than 5.4	11	9	11	9

o Verification Process

A study was performed to analyze how well the predicted water year type reflected the water availability for that year. Tables A3.1-3, A3.1-4 and A3.1-5 show the results of this study. The first step in this study was to determine the threshold values for water availability volume that corresponded to the threshold flow volume levels. Regression curves, one of which is shown in Figure A3.1-1 were used to calculate these amounts. Figure A3.1-1 is a plot of WY Index vs. July water availability for 57 years of data, 1922 through 1978; included is the regression curve for the plotted points. Figure A3-1.1 also illustrates the verification by showing the areas where the WY Index predicts water availability correctly and the distribution of the 57 years of index values in regard to these areas.

1/ *Adjustments for subnormal snowmelt and year following critical year condition are not included in the Delta Plan classification data.*

FIGURE A3.1-2 Estimated Delta Plan and 40-30-30 Indexes for the Sacramento and San Joaquin Valleys, 1906 – 1988



ESTIMATED INDEX FLOWS		
PROB. OF FLOW≤ VALUE	SACRAMENTO BASIN INDEX	SAN JOAQUIN BASIN INDEX
70	9.2	3.3
50	7.8	2.8
26	6.4	2.2
11	5.4	1.8

TABLE A3.1-3
Sacramento WY Classification
40-30-30 W/CAP
April Verification

SACRAMENTO BASIN: BREAK PT.	WATER YEAR	SAC INDEX 40-30-30	Apr Total Available (TAF)	BREAK PT	YR TYPE	DIFF	VARIANCE
	1974	12992	18188				
	1938	12624	19437				
	1952	12383	21473				
	1958	12157	19586				
	1941	11469	18473		WET		
	1956	11376	17991				
	1942	11272	18629				
	1969	11045	19276				
	1970	10402	15060 *			-1968	11.56%
	1971	10373	17882				
	1967	10197	19284				
	1965	10153	17119				
	1943	9768	16174 *			-854	5.02%
	1963	9634	18605				
	1953	9553	17730				
	1927	9525	17113				
	1975	9353	17478				
9200				17028			
	1951	9184	15755				
	1922	8974	17518 **			490	2.88%
	1940	8879	15025 *			-248	1.46%
	1978	8630	16027		AN		
	1973	8581	15686				
	1954	8514	16442				
	1928	8272	14620 *			-653	4.27%
	1957	7832	15818				
7800				15273			
	1936	7751	13706				
	1946	7697	15658 **			385	2.26%
	1972	7292	15413 **			140	0.82%
	1968	7243	14406				
	1966	7162	15098				
	1948	7120	14732		BN		
	1923	7062	14630				
	1935	6978	11819 *			-1516	8.90%
	1937	6870	13105 *			-230	1.35%
	1945	6800	14980				
	1959	6754	14401				
	1962	6649	15127				
	1950	6618	14750				
6500				13335			
	1964	6409	13657 **			322	1.89%
	1925	6395	13180				
	1944	6347	13635 **			300	1.76%
	1960	6201	13970 **			635	3.73%
	1955	6136	13819 **			484	2.84%
	1949	6090	14104 **			769	4.51%
	1930	5899	12000		DRY		
	1926	5747	12451				
	1961	5677	13839 **			504	2.96%
	1947	5611	13588 **			253	1.48%
	1939	5583	12951				
	1932	5475	9436 *			-1928	11.32%
5400				11364			
	1976	5258	12612 **			1248	7.33%
	1929	5216	11370 **			6	0.03%
	1933	4626	7775				
	1934	4074	7578		CRIT		
	1924	3873	9110				
	1931	3660	7386				
	1977	3095	6412				
						AVG.	4.02%

* Water availability less than expected from index
** Water availability greater than expected from index

TABLE A3.1-4
Sacramento WY Classification
40-30-30 W/CAP
July Verification

SACRAMENTO BASIN: BREAK PT	WATER YEAR	SAC INDEX 40-30-30	July Total Available (TAF)	BREAK PT.	YR. TYPE	DIFF.	VARIANCE
	1974	12992	13637				
	1938	12624	13216				
	1952	12383	13738				
	1958	12157	13718				
	1941	11469	13641		WET		
	1956	11376	13517				
	1942	11272	13578				
	1969	11045	13480				
	1970	10402	11678 *			-1099	8.60%
	1971	10373	13560				
	1967	10197	13722				
	1965	10153	12790				
	1943	9768	12567 *			-210	1.64%
	1963	9634	12698 *			-79	0.62%
	1953	9553	13613				
	1927	9525	12760 *			-17	0.13%
	1975	9353	13503				
9200				12777			
	1951	9184	12301				
	1922	8974	12726				
	1940	8879	11922				
	1978	8630	12116		AN		
	1973	8581	11999				
	1954	8514	12338				
	1928	8272	11754				
	1957	7832	12623				
7800				11454			
	1936	7751	10705				
	1946	7697	12073 **			619	5.40%
	1972	7292	11806 **			352	3.07%
	1968	7243	11178				
	1966	7162	11694 **			240	2.10%
	1948	7120	12536 **		BN	1082	9.45%
	1923	7062	11200				
	1935	6978	9116 *			-877	8.78%
	1937	6870	10270				
	1945	6800	11976 **			522	4.56%
	1959	6754	10833				
	1962	6649	11399				
	1950	6618	11646 **			192	1.68%
6500				9993			
	1964	6409	9936				
	1925	6395	10132 **			139	1.39%
	1944	6347	10370 **			377	3.77%
	1960	6201	10509 **			516	5.16%
	1955	6136	10592 **			599	6.00%
	1949	6090	11022 **			1029	10.30%
	1930	5899	8933		DRY		
	1926	5747	9698				
	1961	5677	10466 **			473	4.73%
	1947	5611	10308 **			315	3.15%
	1939	5583	9599				
	1932	5475	6251 *			-2256	26.52%
5400				8507			
	1976	5258	9624 **			1117	13.13%
	1929	5216	8330				
	1933	4626	5411				
	1934	4074	5364		CRIT		
	1924	3873	6557				
	1931	3660	4813				
	1977	3095	4605				
						AVG.	6.01%

* Water availability less than expected from index
** Water availability greater than expected from index

TABLE A3.1-5
Sacramento WY Classification
40-30-30 W/CAP
October Verification

SACRAMENTO BASIN: BREAK PT.	WATER YEAR	SAC INDEX 40-30-30	Oct Total Available (TAF)	BREAK PT.	YR. TYPE	DIFF.	VARIANCE
	1974	12992	9919				
	1938	12624	9553				
	1952	12383	10133				
	1958	12157	9959				
	1941	11469	9445		WET		
	1956	11376	9563				
	1942	11272	9554				
	1969	11045	9906				
	1970	10402	7873 *			-1062	11.89%
	1971	10373	9699				
	1967	10197	10137				
	1965	10153	8950				
	1943	9768	8538 *			-397	4.45%
	1963	9634	8738 *			-197	2.21%
	1953	9553	9676				
	1927	9525	8613 *			-322	3.61%
	1975	9353	9869				
9200				8935			
	1951	9184	8510				
	1922	8974	8793				
	1940	8879	7732 *			-104	1.32%
	1978	8630	8742		AN		
	1973	8581	8329				
	1954	8514	8571				
	1928	8272	7712 *			-124	1.58%
	1957	7832	8890				
7800				7836			
	1936	7751	6728				
	1946	7697	8122 **			286	3.65%
	1972	7292	8226 **			390	4.98%
	1968	7243	7695				
	1966	7162	7934 **			98	1.25%
	1948	7120	8593 **		BN	757	9.66%
	1923	7062	7684				
	1935	6978	5440 *			-1181	17.84%
	1937	6870	6608 *			-13	0.20%
	1945	6800	8220 **			384	4.90%
	1959	6754	7398				
	1962	6649	7917 **			81	1.04%
	1950	6618	7972 **			136	1.74%
6500				6621			
	1964	6409	6475				
	1925	6395	6702 **			81	1.22%
	1944	6347	6699 **			78	1.18%
	1960	6201	6889 **			268	4.05%
	1955	6136	7146 **			525	7.93%
	1949	6090	7613 **			992	14.98%
	1930	5899	5514		DRY		
	1926	5747	6097				
	1961	5677	6997 **			376	5.68%
	1947	5611	6659 **			38	0.57%
	1939	5583	6049				
	1932	5475	3489 *			-1897	35.22%
5400				5386			
	1976	5258	6422 **			1036	19.24%
	1929	5216	5229				
	1933	4626	3097				
	1934	4074	3066		CRIT		
	1924	3873	4205				
	1931	3660	2538				
	1977	3095	2577				
						AVG.	6.68%

* Water availability less than expected from index
** Water availability greater than expected from index

These water availability threshold levels define the range of water availability for each year type. If a given year's water availability fell outside its respective water availability range, then it was assumed that the water year index incorrectly predicted the water year type.

TABLE A3.1-6

Sacramento Basin WY Classification
Comparison of Verification Results for
Selected Classifications

Classification	Month	No. of Correct Predictions	No. of Incorrect Predictions	Average Variance(%)
40-30-30 Index	April	38	19	4.0
(40-30-30)	July	37	20	6.0
	October	33	24	6.7
Delta Plan WY	April	31	26	7.4
(33-67-00)	July	27	30	7.2
	October	27	30	9.6
April -- July	April	30	27	10.2
(100-00-00)	July	29	28	10.8
	October	27	30	12.8

Table A3.1-6 compares the results of the proposed new classification with other alternative classifications. The results indicate that the new classification has significantly fewer incorrect predictions and the degree of error is significantly smaller than with the Delta Plan classification.

o Adjustments to Water Year Classification

In the Delta Plan classification, two adjustments were created to account for unusual hydrologic conditions; a second classification for a year which follows a critical year, and a sub-normal snowmelt adjustment. The "year following critical year" classification was developed to account for the effects that depleted reservoir and ground water storage have on the ability of project operations to meet their demands. In this secondary classification the boundary of a wet year is raised to 22.5 MAF, an 80 percent probability of occurrence. The boundary for an above normal year remains the same at 15.7 MAF. The below normal year classification is eliminated, and the boundary between a dry and a critically dry year is raised to 12.5, the previous boundary for a below normal year. The "year following critical year" classification applies only to fish and wildlife objectives.

The sub-normal snowmelt adjustment was developed to account for unusual deficiencies in snowpack storage. This adjustment is made in years where the percentage of precipitation, in the form of snowfall, is much less than expected. Under normal conditions, a great proportion of winter precipitation is stored in the snowpack and released over a long period of time as the snowpack melts. Under sub-normal snowmelt conditions, a greater proportion of the precipitation falls in the form of rainfall and cannot be stored in the snowpack nor reservoirs and is released as uncontrolled or surplus flow. The sub-normal snowmelt adjustment applies only to the fish and wildlife objectives.

The adjustments that were necessary in the Delta Plan classification are less important in this modified classification system.

Because the effects of previous year's conditions are included in the third term of the index, the "year following critical year" modification is not necessary.

The subnormal snowmelt modification, to a large extent, is accounted for with the inclusion of the third term and with the difference in weighting coefficients between the first and second terms. DWR has identified the following years, between the period 1922 - 1978, as subnormal snowmelt years:

- Subnormal snowmelt years: 1928, 1951, 1960, 1966, 1968, 1970, and 1972.

Table A3.1-4 shows that for the month of July, after spring snowmelt has finished, the modified index correctly predicts the amount of water available during subnormal snowmelt years three out of seven times, and under-predicts the amount of water available three out of seven times. Therefore, the index does not predict more water than is available six out of seven of the subnormal snowmelt years. Only 1970's index overpredicts water availability. This indicates that subnormal snowmelt conditions are highly accounted for in the index.

A modification for subnormal snowmelt would be beneficial if it could account for unusual hydrologic conditions not predicted in the index, and not cause other errors while accomplishing this. However, the current subnormal snowmelt modification causes the 40-30-30 Index to be less accurate, and therefore is not included as an adjustment to the index.

o Source of Database

The source of the database used to develop water availability for this analysis was DWR operation study run number 62B. This operation study assumed 1990 level demands and conditions, D-1485 Delta flow and water quality standards, and the amended D-1485 Suisun Marsh standards with no facilities.

APPENDIX 3

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- SWRCB. 1978. Final Environmental Impact Report for the Water Quality Control Plan and Water Right Decision, Sacramento-San Joaquin Delta and Suisun Marsh, August 1978. Sacramento, California.

- 1906 through 1920--DWR Division of Planning Statewide Planning Branch, 4/14/80; 1921 through 1978--DWR Exhibit 7, except as stated below; 1969 through 1983 Sacramento River near Red Bluff--DWR California Data Exchange Center, 1/15/88; 1984 through 1987--DWR California Data Exchange Center, 1/15/88.

APPENDIX 4.0

BENEFICIAL USES OF BAY-DELTA ESTUARY WATER

Conclusions: CURRENT AND FUTURE WATER SUPPLY CONDITIONS

- The majority of surface water in California (about 55 percent) flows to the sea, into salt sinks or into Nevada.
- The watershed of the Bay-Delta is a major source of supply critical in satisfying the water needs of the entire State.
- The Bay-Delta watershed is influenced by water diversion and control. On the average about 40 percent of the flows entering the Delta are unmanaged. However, in dry years less than five percent is unmanaged.
- As California's population grows to over thirty-six million people by 2010, the adequacy of currently developed water supplies to meet the needs of a growing population, expanding economy, and the aquatic environment will diminish.
- There are about 9.2 million acres of irrigated agricultural land in California.
- Agricultural acreage is not expected to increase in the Central Valley.
- Currently developed surface water supplies do not meet existing agricultural water requirements. This is demonstrated by the fact that agricultural demands are partially being met by groundwater overdraft in the San Joaquin Valley.
- Agricultural water conservation in areas that receive water from the Delta is important but will not satisfy the State's water needs since less than 20 percent of the agricultural water demand is met by water exported from the Delta.
- Planning for municipal and industrial water needs must focus on the primary requirements of a reliable supply of drinking water.
- Reductions in reliable water supplies will have adverse impacts on the economy of the state.
- Conservation, reclamation and maximum conjunctive use of local ground water basins are important components of reliable water supplies.
- California water supplies have been affected by recent court decisions. The state's share of water from the Colorado River has been reduced to 4.4 MAF, an amount the courts will likely limit still further. Interim court decisions have reduced the city of Los Angeles' water supply from tributaries in the Mono Lake Basin by 50 to 65 TAF. Also, court decisions have limited export of ground water from the Owens Valley Basin to levels lower than originally anticipated by the City.

- **Water conservation by the Imperial Irrigation District consistent with State Board Order 88-20 could make water available for use in other parts of the state by 100,000 AF in the early 1990s, with a long-term goal of about 368,000 AF.**

- **Ground water is a resource upon which the state relies. Factors limiting the availability of that resource include toxics, overdraft, salt water intrusion and land use practices.**

4.0.1 Introduction

"'Beneficial uses' of the waters of the state that may be protected against degradation include, but are not necessarily limited to, domestic, municipal, agricultural and industrial supply; power generation; recreation; esthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves" (Porter-Cologne Water Quality Control Act, Water Code Section 13050(f)).

This chapter discusses the many beneficial uses made of Bay-Delta waters which were addressed during the Phase I hearings. Only after beneficial uses have been properly identified can appropriate water quality objectives and other control policies be established. A clear understanding of each beneficial use provides a foundation for establishing the levels of protection needed.

This Plan complements specific beneficial uses in the Basin Plans of the San Francisco Bay and Central Valley Regional Water Quality Control Boards. There are additional beneficial uses made of these waters as addressed in these Basin Plans. The beneficial uses discussed in this Plan are not therefore meant to be exclusive.

The discussion of beneficial uses has been separated into estuary and export uses. Estuarine habitat is also a specific beneficial use discussed in the Basin Plan of the San Francisco Bay Regional Water Quality Control Board. During Phase I of the proceedings, information was submitted on specific subtopics, e.g., striped bass, Chinook salmon, various human uses of the habitat. These issues are addressed here in a similar fashion. Habitat is separated into the Delta's water, generally fresh, and the Bay's waters, generally brackish and saltwater habitats, to help identify the general salinity conditions.

4.0.2 Uses of Estuary Water for Municipal and Domestic Supply Purposes Within the Estuary

Municipal and Domestic Supply (MUN) includes established uses in community or military water systems as well as domestic uses from private systems (RWQCB 5, 1975).

Current and projected MUN water use of Delta surface water is presented in Table A4.0-1. Delta cities that rely on this water are Antioch, Pittsburg, Tracy and Oakley. Pittsburg and Oakley obtain water supplies from Rock Slough via the Contra Costa Canal; Tracy obtains its supply from Old River via the Delta-Mendota Canal. Antioch diverts directly from the San Joaquin River during high flow periods when water quality is satisfactory and at other times obtains part from the Contra Costa Canal. The City of Sacramento maintains a standby diversion facility on the Sacramento River in the upper Delta, but usually diverts from two other facilities on the American and Sacramento rivers upstream of the Delta. The cities of Stockton, Tracy, Rio Vista, and other Delta communities rely to various degrees on ground water for MUN water supplies (SWRCB 5, 1978).

TABLE A4-1

MAJOR MUNICIPAL WATER DEMANDS

	1986 Population	**Water Demands (AF)**
City of Tracy	25,300	7,822 (1986)
Antioch	40,734	9,073 (1985)
Pittsburg	53,125	7,729 (1985)
Oakley County W.D.	8,436	2,128 (1985)

	Year 2000 Population	**Year 2000 Water Demands (AF)**
City of Tracy	33,000 (1990)	10,400 (1990)
Antioch	78,900	14,338
Pittsburg	59,100	12,994
Oakley County W.D.	N/A	5,153

(Table adapted from information found in City of Tracy (CT), Exhibit Nos. 2 & 3; Contra Costa Water District (CCWD), Exhibit Nos. 7, 24 & 25).

4.0.3 Industrial Beneficial Uses

Industrial use is comprised of three separate beneficial uses:

- o Industrial Service Supply (IND) "includes uses which do not depend primarily on water quality such as mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization".
- o Industrial Process Supply (PROC) "includes process water supply and all uses related to the manufacturing of products".
- o Hydroelectric Power Generation (POW) "is that supply used for hydropower generation" (RWQCB 5, 1975).

Very little information on Bay-Delta industrial use was presented in Phase I of the proceedings. Two Bay-Delta industries, Fibreboard Louisiana-Pacific Corporation (Fibreboard) and Shell Oil Company, presented testimony, but no exhibits. Contra Costa Water District (CCWD) and DWR presented exhibits and testimony, but of a limited scope. The total amount of water delivered from the Contra Costa Canal to major industrial water users in the Delta totaled 22,733 acre-feet in 1985 and 15,519 acre-feet in 1986 (CCWD,26).

4.0.3.1 Antioch-Pittsburg Area

Fibreboard, a large kraft paper mill located on the south shore of the San Joaquin River approximately five miles east of Antioch, produces linerboard, corrugating medium, and fiber board from wood chips (hearing for D-1485,RT,Vol.XVII,p.135). Fibreboard presented the only testimony supporting the need for process water with not more than 150 ppm chloride for the production of corrugated box linerboard (T,IV,92:25-93:6; T,IX,75:23,81:23). To keep the chlorinity in their linerboard (used in corregated boxes) at levels which will not corrode canned goods, Fibreboard maintains the salinity of their process water below 150 mg/l chloride (T,IX,75:23-81:23).

Fibreboard has two main sources of water, direct pumping from the San Joaquin River and CCWD. When the chlorinity in the San Joaquin River supply is higher than 150 ppm, a partial supply of water is purchased from CCWD; when the chlorinity level reaches 250 ppm, the entire supply is taken from the Contra Costa Canal (T,IX,77:23-78:6). A third, relatively minor source is ground water from two wells that provide between 500,000 and 800,000 gallons per day.

4.0.3.2 Industries Outside of the Antioch-Pittsburg Area

Shell Oil Company in Martinez, which obtains most of its water supply from the Contra Costa Canal, was the only Bay-Delta industry located outside the Antioch-Pittsburg area to present testimony during Phase I (T,IX,41:11-14). Shell Oil Company's testimony was related to reliability of supply (T,IX,46:12-13). Three other industries near Tracy, H. J. Heinz Company, Laprino Cheese and Laura Scudders, which obtain their water supply from the DMC or local ground water supplies, were identified but did not present testimony (T,IX,11:4-12; T,IX,21:21-25).

4.0.4 Estuary Agriculture Beneficial Uses

Agricultural uses include crops, orchards, and pasture irrigation, stock watering, support and vegetation for range, grazing and all uses in support of farming and ranching operations (RWQCB 5B, 1975).

4.0.4.1 Delta Agriculture

About three-quarters of the Delta land area (515,000 acres) is farmed with water from the channels and sloughs adjacent to each individual island in the Delta (DWR,304). The Delta's climate and soil permit a wide variety of crops to be grown; corn and grain are the predominant crops.

Soils in the Delta fall generally into two categories, organic and mineral. Farmed organic soils constitute 68 percent of the total cropped area and mineral soils the remaining 32 percent. Organic soils are usually found in the Delta lowlands, that is, the land area below an elevation of +5 feet mean sea level. Delta uplands are those areas above +5 feet mean sea level. Mineral soils are found in both the Delta lowlands and uplands.

Delta Organic Soils

The Delta's organic or peat soils were formed in a wetland environment that existed prior to the area's reclamation for agriculture. These peat soils were formed through the biological decomposition of marsh plants and grasses under anaerobic conditions. Current land use is constantly reducing the amount of Delta organic soils. Organic materials are no longer being deposited, while increased decomposition and oxidation from natural processes and farm practices are occurring at high rates. High winds also transport dried organic soils out of the Delta. Consequently, many of the lowland Delta islands are sinking at the rate of one to three inches per year and the actual acreage of the organic soils is also being reduced (T,LV,82:20-25).

The high permeability of organic soils and their low surface elevation compared to surrounding waterways produces high ground water table conditions. The high ground water table, along with problems associated with uneven decomposition and settlement of organic soils, makes subirrigation the primary method of water application for crop production. (Subirrigation is an irrigation technique by which water is delivered to the crop root zone by horizontal flow through the soil from the spud ditches.)

The quality of irrigation water, and the effects of rainfall and other farm practices including, possibly, winter ponding[1/], all reduce the need for leaching.

Delta Mineral Soils

Delta mineral soils were formed through deposition of sands and minerals eroded from the Sierra Nevada by various streams tributary to the Delta. These soils are generally found in the Delta uplands.

On mineral soils, the area in Figure A4-1 which is not designated as organic soil, surface irrigation is the common irrigation method. Water is applied to the soil surface, usually through furrow, sprinkler, or flood irrigation. Unlike organic soils, salts in the surface-irrigated mineral soils are brought into the soil column from the surface with the applied water. Excess salts are removed during irrigation and after harvest by applying irrigation water to flush the salt into the lower ground water table. Some leaching may also be accomplished with winter rainfall.

Delta Crop Production

Agriculture was introduced into the Delta in the 1860s and was well established by the turn of the century; it has maintained its current level since the 1920s (see Figure A4-2). Delta agriculture is important economically at both the regional and statewide level.

1/ Winter ponding, currently in use in the Delta, is the practice of flooding large agricultural field areas for the purpose of controlling weeds, and reducing salt in the upper region of the soil profile. Other benefits are recreation, and possibly salt leaching.

FIGURE A4-1 Sacramento - San Joaquin Delta
Approximate Location Of Organic Soils
(Soils With Greater Than 25% Organic Matter)
Source: DWR Bulletin 192-82, Delta Levees Investigation Dec. 1982 also DWR Exhibit 303

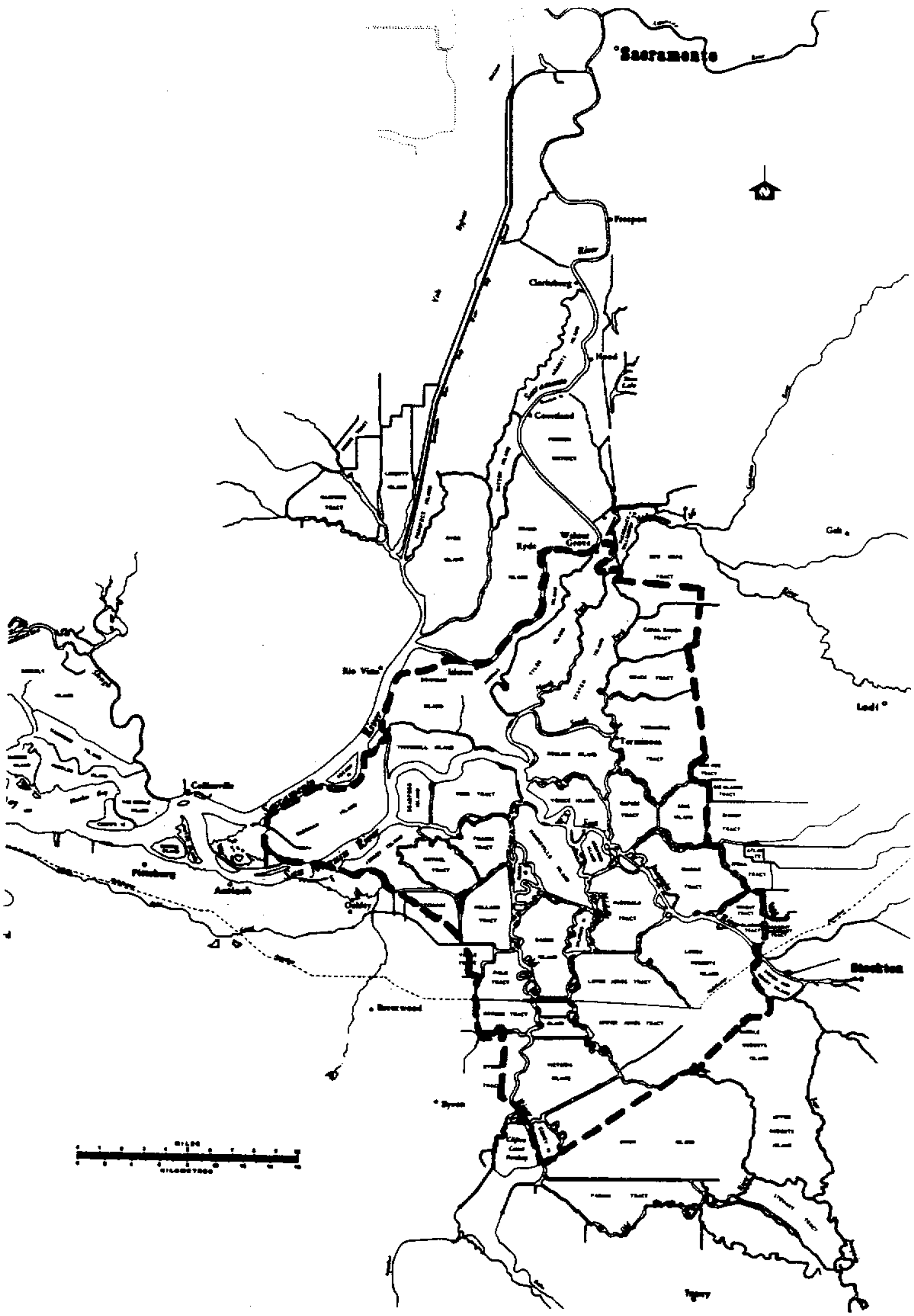

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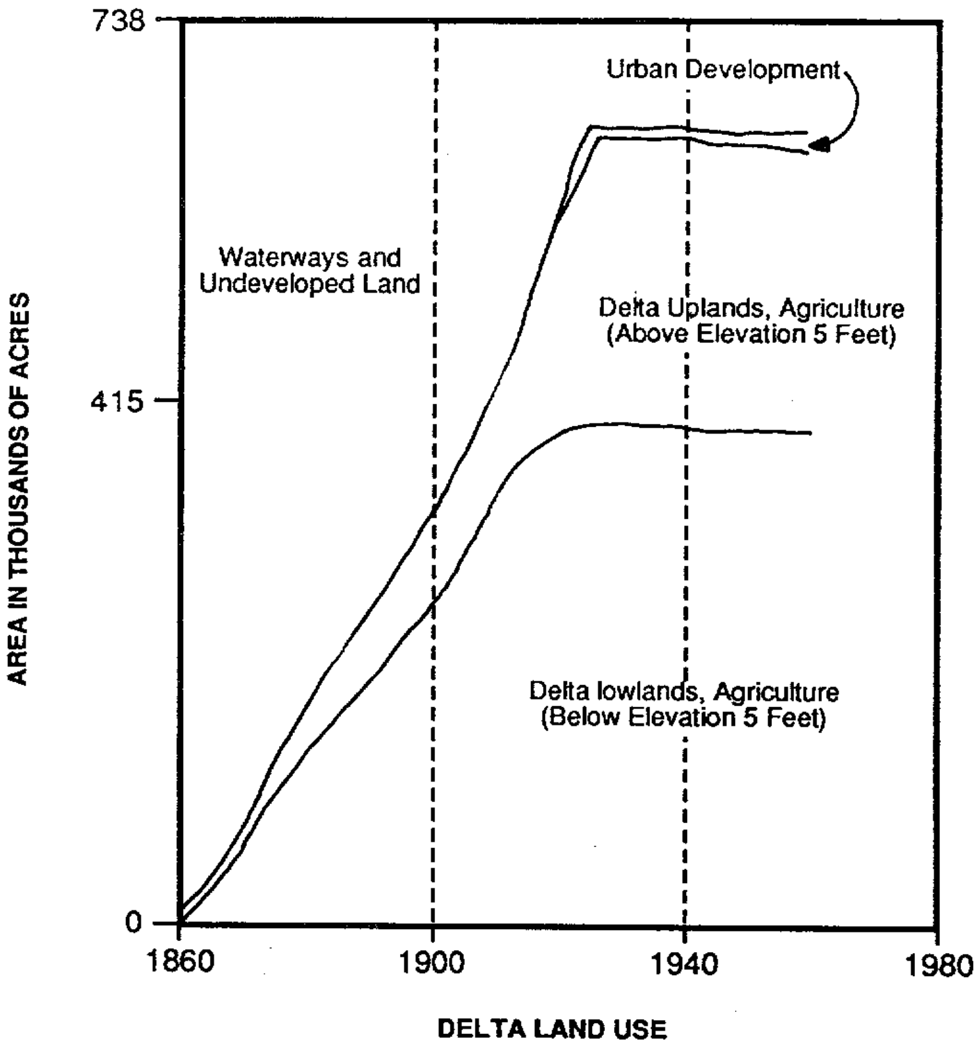
FIGURE A4-2
Delta Land Use and Dedicated Acreage



Adapted from: Bulletin 76 – **Delta Water Facilities**, December 1960

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Crop production information was presented by DWR for the Delta lowlands and uplands (DWR,304). Corn was the predominant crop grown in the Delta during the period 1977-84, accounting for 25.8 percent of the total cropped acreage (Table A4-2). Grain is grown on an additional 21.5 percent of the cropped acreage, followed by tomatoes, alfalfa and mixed pasture; other crops such as sugar beets, deciduous trees and safflower account for most of the remainder. Crop and livestock production in the Delta has a gross sale value of approximately $500 million (Table A4-3), with field and truck crops making up 57 percent of that total.

4.0.4.2 Bay Agriculture

Very little information was presented in the hearing sessions on agriculture outside of the legal limits of the Delta but within the boundaries of San Francisco Bay Region. Contra Costa Water District presented records showing crop production for their district (CCWD,48) (Table A4-4).

4.0.5 Beneficial Uses Made of the Estuary's Aquatic Habitat

This section discusses some of the specific data presented during Phase I as they relate to the following five major beneficial uses addressed in the current Water Quality Control Plans (Basin Plans) of the San Francisco Bay and Central Valley Regions:

- Freshwater Habitat -- which provides habitat to sustain aquatic resources for cold water (COLD) and warm water (WARM) species.

- Fish Migration (MIGR) -- which provides a migration route and temporary aquatic environment for anadromous and other fish species. This beneficial use is also subdivided for warm and cold water species.

- Fish Spawning (SPWN) -- which provides a high quality aquatic habitat suitable for fish spawning.

- Wildlife Habitat (WILD) -- which provides a water supply and vegetation habitat for the maintenance of wildlife. The two most important types of wildlife habitat are riparian and wetland habitats.

TABLE A4-2

CROP ACREAGES AND PERCENTAGES[1/] BASED ON DATA COLLECTED DURING THE PERIOD 1977--1984 FOR THE SACRAMENTO-SAN JOAQUIN DELTA (From DWR, 304)

Crop	Lowlands & Uplands		Lowlands		Uplands	
	Acre	Percent	Acre	Percent	Acre	Percent
Field Corn	132,770	25.8	107,480	30.6	25,290	15.6
Grain	110,900	21.5	81,960	23.4	28,940	17.8
Tomatoes	43,100	8.4	25,370	7.2	17,730	10.9
Alfalfa	39,770	7.7	24,350	6.9	15,420	9.5
Mixed Pasture	36,020	7.0	17,730	5.0	18,290	11.3
Sugar Beets	27,650	5.4	15,240	4.3	12,410	7.6
Deciduous	25,960	5.0	9,240	2.6	16,720	10.3
Safflower	23,530	4.6	21,060	6.0	2,470	1.5
Asparagus	23,400	4.5	21,840	6.2	1,560	1.0
Beans	17,580	3.4	4,690	1.3	12,890	7.9
Sunflower	6,630	1.3	6,050	1.7	580	0.4
Vineyard	4,870	1.0	4,150	1.2	720	0.5
Sorghum	4,580	0.9	3,600	1.0	980	0.6
Cole Crops[2/]	4,140	0.8	3,610	1.0	530	0.3
Melons	2,430	0.5	250	0.1	2,180	1.4
Sudan	2,180	0.4	710	0.2	1,470	0.9
Potatoes	2,160	0.4	2,160	0.6	0	0.0
Rice	1,810	0.4	480	0.1	1,330	0.8
Native Pasture	1,130	0.2	140	0.0	990	0.6
Misc. Truck	1,120	0.2	750	0.2	370	0.2
Lettuce	1,110	0.2	0	0.0	1,110	0.7
Onions	590	0.1	370	0.1	220	0.1
Misc. Field	510	0.1	460	0.1	50	0.0
Clover	450	0.1	440	0.1	10	0.0
Carrots	300	0.1	300	0.1	0	0.0
Peppers	250	0.0	50	0.0	200	0.1
Nursery	60	0.0	0	0.0	60	0.0
Total	515,000	100.0	352,480	100.0	162,520	100.0

1/ Percentages computed by State Board staff.

2/ Cole crops include those from the cabbage family.

TABLE A4-3

1985 ECONOMIC VALUE OF DELTA CROPS AND LIVESTOCK
(From DWR, 340)

Gross Value of Delta Area ($Million)

Agricultural Category	Lowland	Upland	Total
Field Crops	100.4	67.2	167.6
Truck Crops	76.9	34.6	111.5
Tree Fruit/ Nut & Vine	25.1	18.2	43.2
Seed & Nursery	7.9	1.8	9.7
Livestock	9.9	144.5	154.5
TOTAL	$220.2	$266.3	$486.5

TABLE A4-4

CROPS PRODUCED IN CONTRA COSTA WATER DISTRICT, 1986

Crop	Acres
Corn	10
Alfalfa	20
Irrigated Pasture	30
Other miscellaneous field crops	60
Apricots	10
Grapes*	500
Almonds*	700
Walnuts	10

* Not irrigated in 1986

o Preservation of Rare, Threatened and Endangered Species (RARE) -- which provides an aquatic habitat necessary, at least in part, for the survival of certain species established as being rare, threatened or endangered under the California Endangered Species Act (CESA).

The fishery resources of the Estuary depend upon complex ecosystems for a variety of purposes during different life stages and in different seasons and water year types. The Estuary provides habitat for the entire life cycle, or a critical portion of the life cycle, for close to 150 fish species and a vast aquatic food web of invertebrates, including shellfish and crustaceans, and planktonic organisms. The fishery provides valuable resources for many other terrestrial and aquatic wildlife species as well.

The relationship between aquatic habitat and water quality requirements has been documented for relatively few species. Studies normally focus on important commercial and recreational species such as Bay shrimp, Dungeness crab, Chinook salmon, striped bass, and American shad. There is still much debate about the relationship between water quality and quantity and the changes in fishery resources even for the well studied species.

Sections 4.0.5.1 and 4.0.5.2. summarize available information on fish, invertebrates and rare, threatened and endangered animals and plants in the Estuary. There are two major subdivisions: Section 4.0.5.1 discusses fishery habitat for species which mostly use freshwater habitat; Section 4.0.5.2 discusses those which mostly use estuarine habitat.

4.0.5.1 Delta Habitat

This section considers the habitat for species that primarily use the freshwater of the Delta upstream of Chipps Island. Suisun Bay and the other downstream estuarine areas (San Pablo, San Francisco and South bays) are discussed in Section 4.0.5.2.

Phytoplankton and Zooplankton

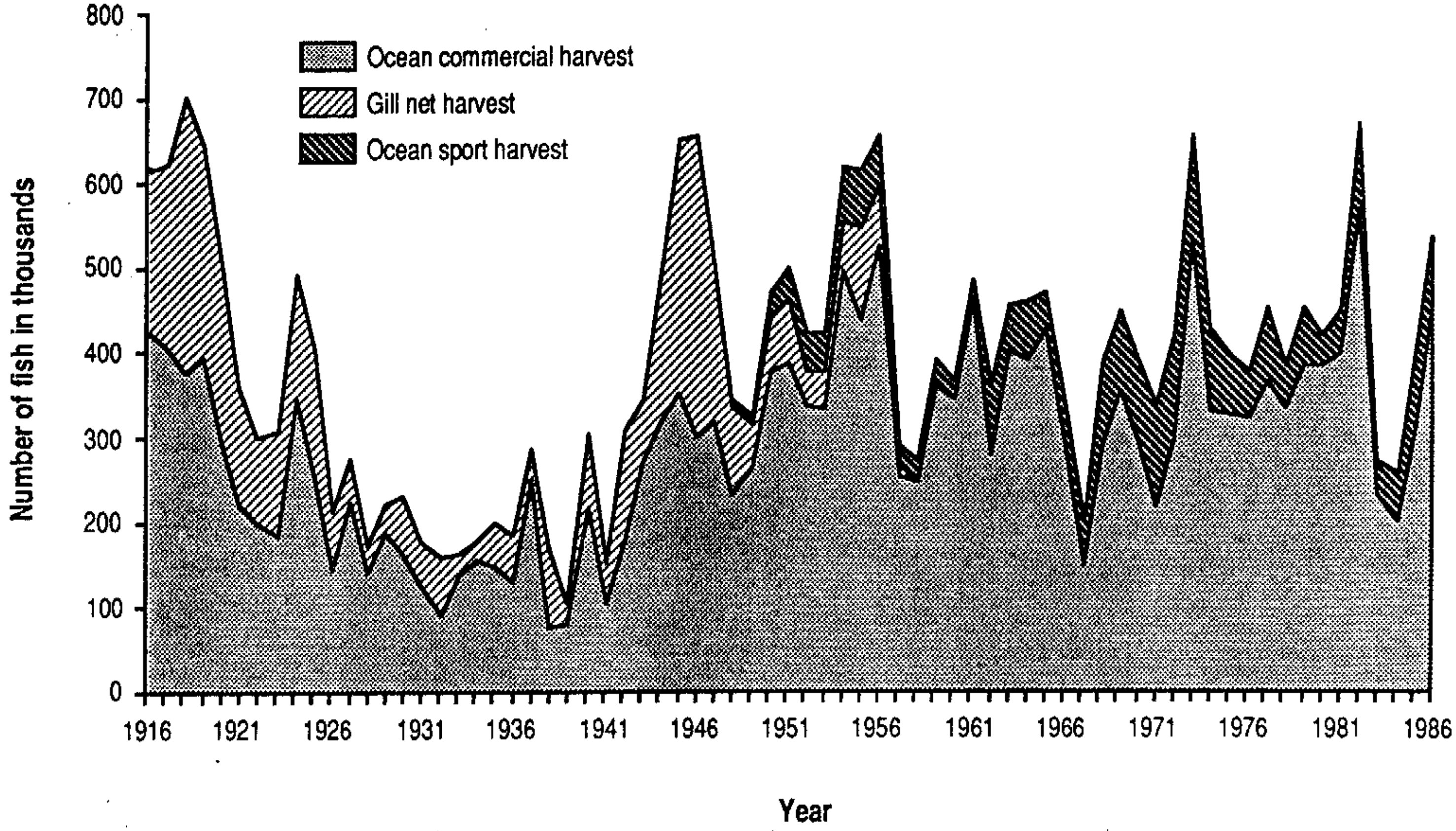
The importance of phytoplankton and zooplankton (including the opossum shrimp, Neomysis mercedis) and their place in the food chain of fish and larger invertebrates was discussed at length in Phase I of the proceedings (see, for example, DFG,28,14; T,XXXIX,15:16-19,28:13-29:14,70:19-71:8; T,XLI,52:19-53:5,59:1-4). The young of striped bass and other game fish, and all life stages of forage fish, feed on zooplankton and Neomysis (DFG,28,1), which in turn feed on smaller zooplankton and phytoplankton (DFG,28,1-4). Phytoplankton abundance is itself dependent on light, flow, salinity and nutrients. The complex interactions of these components are discussed in the hearing record.

Chinook Salmon

o Races and Migration

Chinook, or king salmon, Oncorhynchus tshawytscha, is a native, coldwater, anadromous species of major commercial and recreational importance in California. From about 1955 through 1965, Sacramento Basin Chinook salmon escapement averaged above 250,000 fish. Over the last 20 years the total number of naturally produced adult salmon has declined to around 100,000 fish while escapement of hatchery reared fish has increased to about 90,000 fish (DWR,559,74) (Figure A4-3). Annual Sacramento Basin escapement and commercial ocean harvest have become relatively stable in the last 20 years (DWR,559,47-74; USFWS,31,2). The estuarine gill net fishery for salmon was outlawed in 1957. Since then the ocean commercial troll harvest of Central Valley salmon has averaged about 324,000 fish, approximately 57 percent of all Chinook harvested in California. The ocean recreational catch has averaged close to 60,000 fish and the inland sport harvest is estimated to be about 35,000 fish (USFWS,31,103,176-179; DWR,56,57-59).

FIGURE A4-3 Estimate of annual ocean harvest of Central Valley Chinook salmon
(After DWR, 561, 2, Figure III-3)



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Adult Chinook salmon migrate through the Estuary from the ocean to spawning areas in the upper Sacramento-San Joaquin River basins. Four races, all believed to be genetically distinct (USFWS,31,109), spawn in the upper Sacramento Basin (USFWS,29,4). Each race is named for the time of year when the upstream migration (run) occurs. There are fall-, late fall-, winter- and spring-runs. Some hybridization between runs, especially spring and fall runs, may have occurred due to the fact that the timing of spawning overlaps and there is less suitable spawning habitat than was historically available. The two remaining areas where significant numbers of genetically pure strains of spring-run Chinook exist are in Mill and Deer Creeks (USFWS,29,6). Because the spawning runs of the four races overlap in the upper Sacramento River, all life stages may be found in all months (see Figure A4-4). The USFWS stated that the occurrence of four races of Chinook salmon in a single river basin is unique in the United States (T,XXXV,16:24-17:1).

The fall-run, comprising up to 90 percent of all Chinook spawning in the Central Valley, migrates upstream from about late July through December (USFWS,29,5). Smaller populations of late-fall, winter-, and spring-run fish spawn in the upper Sacramento River (see Figure A4-5). The winter-run was formerly the second largest but today is the smallest (T,XXXV,22:6-14) and is now designated as an "endangered" species under the California Endangered Species Act and a "threatened" species under the federal Endangered Species Act.

The Sacramento River and its tributaries produce at least 80 percent of all Central Valley Chinook salmon (USFWS,31,1). During the years 1953-1986, the San Joaquin River Basin contributed at least 10 percent of the Central Valley salmon produced for 13 years and at least 17 percent for three years (DFG,15,Appendix 1). Prior to the closure of Friant Dam on the San Joaquin River, there was a spring-run in the upper river (DFG,15,8). Today, only the fall-run spawns in the Merced, Tuolumne and Stanislaus rivers (DFG,15,4). There are also small runs in the Mokelumne and Cosumnes Rivers (SWRCB,435,35).

o Development and Migration

The developmental stages and habitat requirements for each stage are generally the same for the four races of Chinook salmon in the Central Valley. However, the different life stages use different locations and require different habitat conditions as they develop within the Sacramento-San Joaquin River basins (see Table A4-5).

Spawning and incubation take place upstream of the Delta. Juveniles and occasionally fry rear in the Delta. While rearing, young salmon feed for about two months or more on a diet of aquatic and terrestrial insects and zooplankton (USFWS,29,4;USFWS,31,14;SWRCB,450,5-4). Peak fry abundance occurs in the Delta in February and March (USFWS,31,7). As they grow and move into the Bay habitat, Neomysis (opossum shrimp), Corophium (an amphipod) and Crangon (Bay shrimp) become important prey items (SWRCB,433,113).

FIGURE A4-4 Timing of life history stages for the four races of Chinook salmon in the Sacramento River Basin (After USFWS, 29, 5, Figure 2)

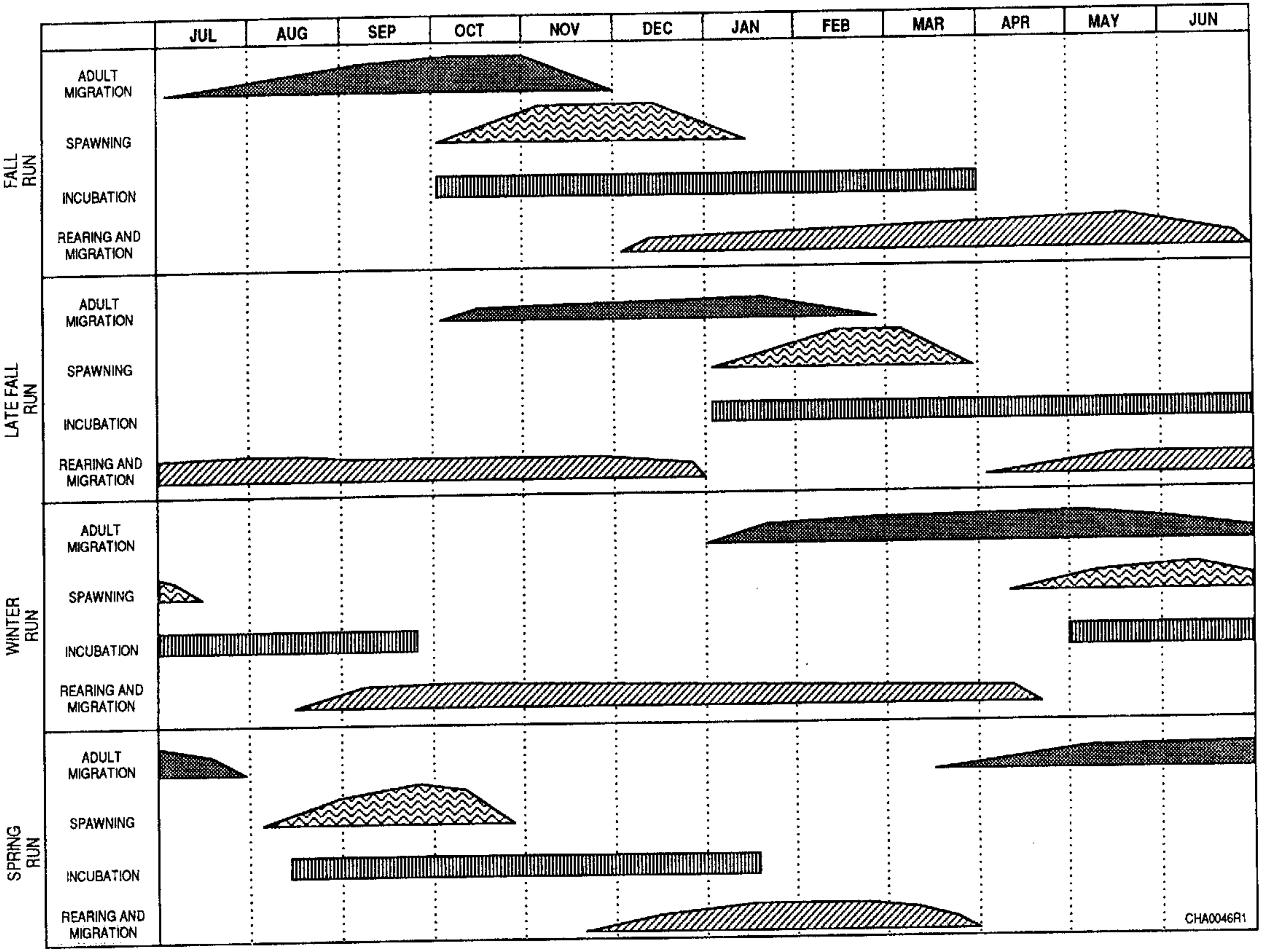
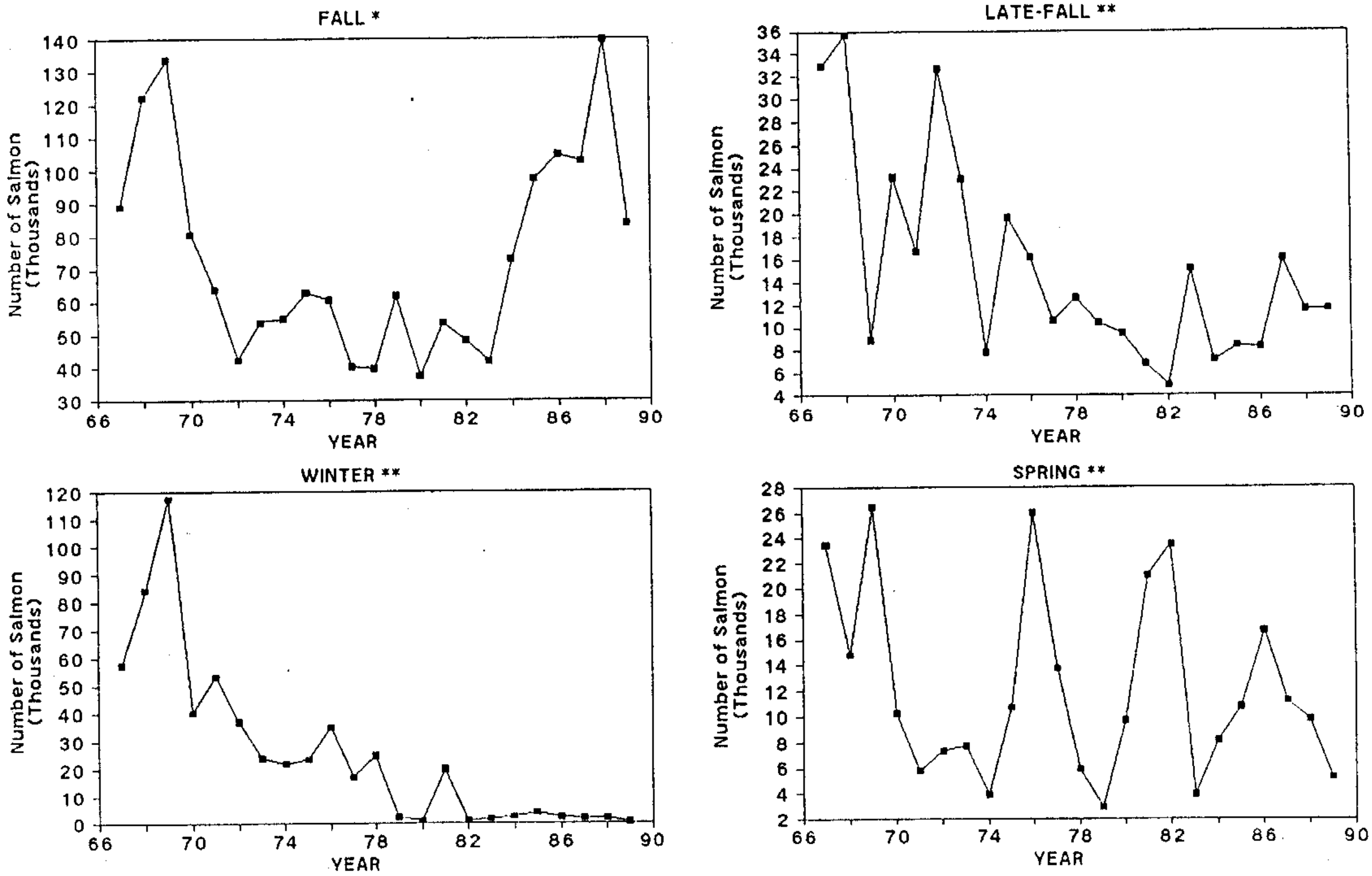


FIGURE A4-5 **Spawning escapement of the four races of Chinook Salmon in the Upper Sacramento River Basin**

(After USFWS, 29,7-10,Figures 3-6, & update from D. Painter, DFG)



* Upper Sacramento River 1967-1989

** Chinook Salmon Counts Past Red Bluff Diversion Dam 1967-1989

TABLE A4-5 Chinook Salmon Environmental Requirements and Life History Stages

Life Stage	Location	Duration (race)	Flow	Water Quality	Other
Adult Migration	Pacific Ocean Bay-Delta to upstream	July-Dec (fall) Oct-Mar (Late-Fall) Jan-June (winter) mid Mar-Aug (spring)	Adequate flow of home stream water to locate spawning grounds and cover redds	Temperature Chinook Migration Range Optimum: 49-57.5°F Dissolved Oxygen ≥6 mg/l	
Spawning	Upper reaches of all major rivers and streams in Sacramento-San Joaquin River Basins below dams	Oct-mid Jan (fall) Jan-Apr (late fall) Apr-mid July (winter) Aug-Nov (spring)	Stable flow without extreme fluctuation sufficient to cover and aerate redds	Temperature Chinook Gen'l Spawning Range Lower Threshold: 42°F Upper Threshold: 58°F Dissolved Oxygen ≥7 mg/l	Clean gravel substrate with good circulation through redd
Incubation (Egg-Alevin)	Spawning grounds (see above)	Oct-Apr (fall) Jan-Jul (late fall) May-Oct (winter) mid Aug-mid Jan (spring)	same as above	same as above	same as above
Rearing (Fry-Junvenile)	Upstream, Delta, and upper estuary	Dec-Mar (fall) Apr-Aug (late fall) mid Aug-Nov (winter) late Nov-Jan (spring)	Stable flow to prevent stranding Can tolerate greater flows and velocities as they mature and move into deeper water	Temperature Chinook Optimum Range Lower Lethal: 32°F Upper Lethal: 79°F Preferred Range: 45-58°F Dissolved Oxygen ≥6 mg/l	Diet of aquatic and terrestrial insects, crustaceans
Smolt Migration	Downstream to Bay-Delta Estuary to Pacific Ocean	Apr-June (fall) Aug-Jan (late fall) Nov-late Apr (winter) Feb-Apr (spring)	Tolerate higher flows typical of spring snow melt or rainy season. Helps move smolts downstream	same as above (Water Quality data from Bell 1973)	Diet of Neomysis Crangon, Corophium, and aquatic and terrestrial insects (SWRCB,433,133)

Including naturally-produced fish and hatchery-reared salmon released in or above the Delta (USFWS, 31,27), the annual fall smolt run that passed Chipps Island between 1978 and 1985 was estimated to range from 10 to 50 million fish (USFWS,31,25). On the average, it takes an individual fall-run smolt three weeks to emigrate from the upper Sacramento to the ocean (one week to reach the Delta and about two weeks to pass through the Delta and Bay) (USFWS, 31,32). Smolt emigration through the Delta usually peaks in May (Figure A4-4) (USFWS,31,22). However, smolts from different tributaries leave their natal streams and move into the Delta at different times and there are year-to-year variations in the timing of emigration (USFWS,31,23). The fall run emigration from April through June (USFWS,31,17) coincides with historical flow increases caused by snow melt (DWR,561,6). Fall-run fry tend to enter the Delta with high flows following winter storms (memo from D. Stevens to H.K. Chadwick, June 19, 1989). The USFWS has determined through mark-recapture studies that fry released upstream survive better than those released in the Delta in wet years (USFWS;3,35; USFWS,2,27). San Joaquin River Basin fall-run smolts emigrate somewhat earlier during this period than Sacramento River Basin smolts (USFWS,31,23). The increase in Delta smolt abundance observed in October and November is probably the late-fall race or yearling, fall-run salmon. The winter- and spring-runs emigrate from January through March.

Peak abundance of salmon salvaged at the state's Delta pumping plant confirm this seasonal pattern of young salmon abundance in the Delta (see Figure A4-6).

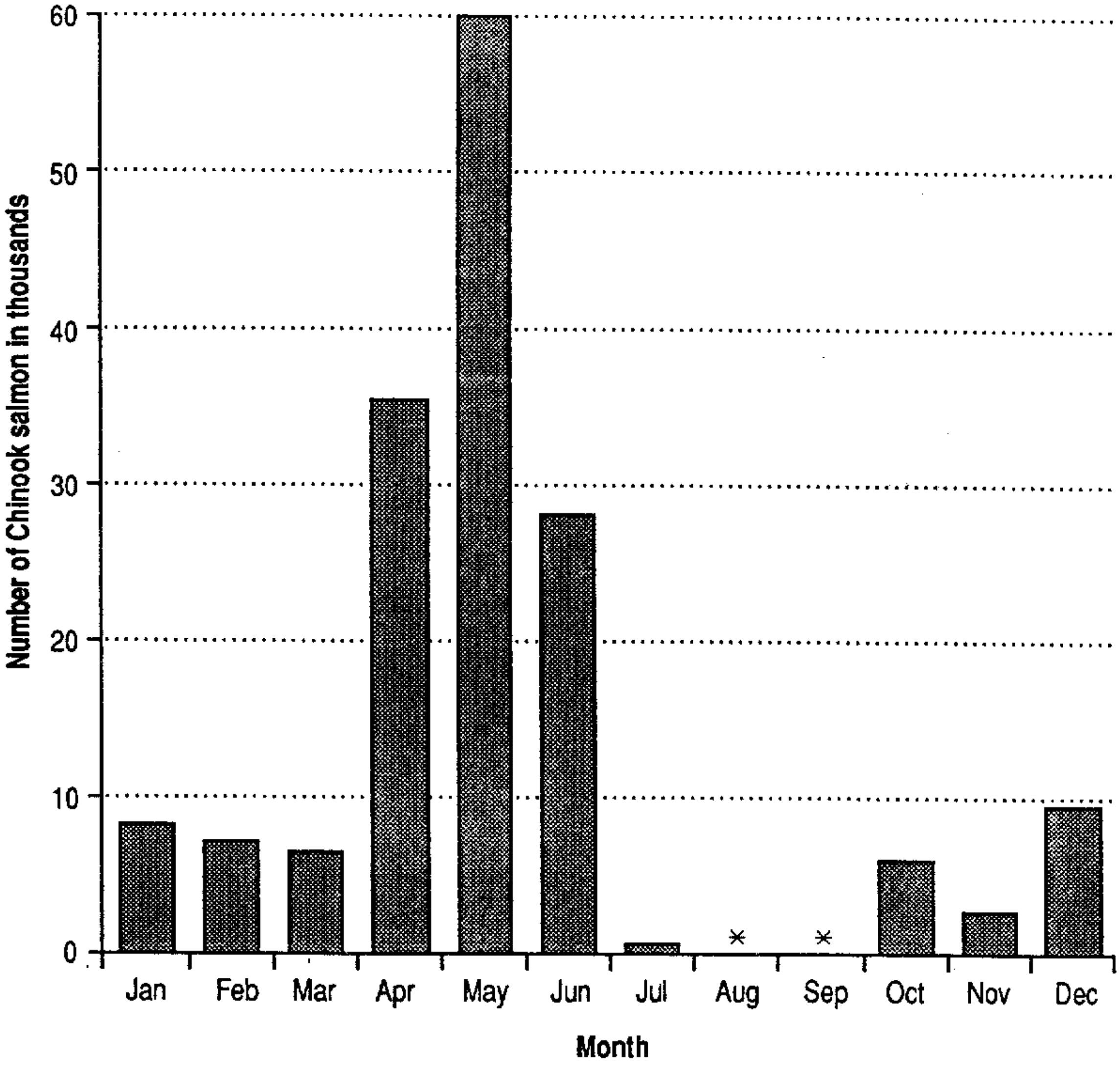
o Survival and Abundance

Smolts migrate downstream to the ocean where they mature for two or more years. Recoveries of adults in the ocean, tagged as smolts and released in Suisun Bay, indicate that only about two percent survive. Thus, 10 to 50 million smolts would produce 200,000 to 1,000,000 fish available to the ocean fishery (i.e., 10,000,000 x .02 = 200,000 adults or 2 percent survival rate from smolt entering salt water to attaining adulthood) (USFWS,31,27). The commercial harvest of Central Valley Chinook is about 350,000 to 450,000 fish (see Figure A4-3). The number of fish escaping harvest and mortality and returning to the spawning grounds each year is known as annual escapement. Survival from eggs to returning adults in a stable population was reported to average 0.04 percent (DWR,561,3). No detailed evidence was presented regarding overall survival rates for Sacramento-San Joaquin Basin Chinook salmon.

o Salmon Harvest and Economic Value

Table A4-6 shows the average estimated ocean commercial and sport catch of Central Valley Chinook salmon in California and an estimate of the proportion supported by hatchery production (DWR,559,45). The estimated 1977-1986 California commercial harvest of Chinook salmon from the Central Valley averaged well over 300,000 fish per year (USFWS,31, 177,Appendix 32), representing almost 60 percent of the total ocean catch of Chinook salmon in California during this period.

FIGURE A4-6 Mean monthly salvage of Chinook salmon at the State Water Project fish protective facility, 1968 - 1986 (From DFG, 17, Appendix , Table 4)



* about 100 fish

TABLE A4-6

Estimated Average Annual Harvest of Chinook Salmon and the Hatchery Contribution to the Catch of Central Valley Salmon

Year	Ocean Commercial Catch 1/ (1)	Commercial Catch of Central Valley Chinook 1/ (2)	Percent of Ocean Catch from Central Valley Chinook (2/1) (3)	Ocean Sport Catch of Central Valley Chinook 2/ (4)
1952-1970	558,282	320,982	57	52,157
1971-1977	564,796	309,402	55	91,608
1978-1986	560,711	333,160	59	63,866

Year	Sport + Commercial Catch of Central Valley Chinook (2+4) (5)	Ocean Commercial + Sport Catch of Hatchery Chinook 3/ (6)	Percent Hatchery Chinook in Central Valley Catch (6/5) (7)
1952-1970	373,139	7,407	2.0
1971-1977	401,010	88,603	22.1
1978-1986	397,026	141,291	35.6

1/ From DWR,561,57, Appendix A-3.

2/ From DWR,561,58-60, Appendix A-4.

3/ From DWR,559,44-45, Table III-4. The period of time covers 1957-1970 for the American River hatchery alone. Subsequent years include the Feather River hatchery production through 1984. Contributions by other Central Valley hatcheries were not determined.

The five-year average price per salmon purchased "off the boat" was estimated to be $26 in 1987. The average commercial catch for 1982-1986 was about 315,500 fish (USFWS,31,177), which translates to an average annual value of about $8.2 million per year for the commercial fishery. The ocean sport harvest averages about 60,000 fish per year (see Figure A4-3). It is estimated that $72 per day is spent for about 100,000 days of ocean recreational fishing, primarily party boat rentals, for an estimated annual value of $7.2 million (Huppert and Thomson, 1984) (BISF,40,15). USFWS presented an estimate for the inland sport harvest of Chinook salmon of 35,000 fish (USFWS,31,103). However, Meyer Resources (1985) reported the inland catch is estimated to be ten percent of the ocean sport catch (BISF,40,15), or about 6,000 fish. At a catch rate of 0.2 fish per day (USFWS,1984), the estimated angler days per year range from a high of 175,000 days (for 3,500 fish) to a low of 30,000 days (for 24,000 fish). Catch rates are highly variable. Fishing success rates may vary from an average of 0.01 fish per hour effort from carquinez Strait to Sacramento, to an average of 0.09 fish per hour from Red Bluff to Keswick Dam. The success rates range from 0.08 to 0.72 fish per assumed 8-hour outing with the majority of the Sacramento River fish being caught on the upper portions of the river. Based on cost estimates for shore fishing ($31 per day) to boat rental (about $48/day) (BISF,40,15) the estimated annual value of the inland recreational Chinook fishery ranges from $930,000 to 1.4 million (for 30,000 angler days) and from $5.4 to $8.4 million (for 175,000 angler days). The value of Central Valley Chinook salmon harvested in California's inland and coastal waters is estimated to range from a minimum of approximately $15.8 million to a maximum of approximately $23.8 million (see Table A4-7).

Table A4-7

ESTIMATED DOLLAR VALUE OF CHINOOK SALMON
CAUGHT IN CALIFORNIA

Commercial Fishery (million $)	**Sport Fishery1/ (million $)**	**Total (million $)**
	Inland	Ocean
	.387-.60	15.8-16.0
8.2		7.2
	5.4-8.4	20.8-23.8

1/ Estimates of the size of the inland fishery vary widely from 6,000-35,000 fish. Therefore the estimated dollar value was calculated for both these estimates (derived from values in BISF,40).

Striped Bass

Striped bass, Morone saxatilis, were successfully introduced into the Estuary at Martinez with the planting of about 140 fish from the Navesink River, New Jersey, on June 18, 1879. A second planting of 300 fish occurred in 1882 (BISF,58,2). The stock expanded quickly and before 1890 supported a commercial fishery that was terminated in 1935 due to a population decline (BISF,47,27). While an important recreational fishery continues to the present, recent declines have caused concern.

o Migration and Spawning

The striped bass is a warm water, anadromous fish. Most of its adult life is spent in San Francisco Bay and adjacent ocean areas (T,XLI,67:1-7). In the fall the adults migrate upstream and spend the winter in Suisun Bay and the western Delta. In spring the adults move farther upstream to spawn in the Sacramento River between Sacramento and Colusa and in the western and central Delta portion of the San Joaquin River between Antioch and Venice Island (T,XLI,67:1-16). Spawning typically occurs in the Delta from late April through May and in the Sacramento River from mid-May to mid-June (T,XLI,67:22-25). About one-half to two-thirds of the eggs that are spawned are produced in the Sacramento River, with the remainder in the Delta (T,XLI,67:20-22).

About 3 mm in diameter, striped bass eggs drift with the currents and hatch in two to three days (T,XLI,69:11-13). The larvae first subsist on the remainder of their yolk sacs and oil droplets and continue to drift until they are about six mm in length, when they start feeding on zooplankton (copepods and cladocerans) (BISF,47,35). They soon consume larger organisms, especially the opossum shrimp, Neomysis mercedis, which remains the dominant food organism through the first two years of life before the bass shift to larger food, including Bay shrimp and forage fish (T,XLI,70:1-8).

The majority of bass larvae tend to concentrate in the entrapment zone in Suisun Bay and the western Delta, although in very high flow years the entrapment zone and the larvae may be found farther down the Estuary (T,XLI,69:15-24). The lower San Joaquin River appears to be a less desirable nursery area than in former years. Higher larval mortalities here appear to be the cause for the decline of the Delta portion of the Striped Bass Index (SBI) (T,XLIII,30:17-23,31:11-15).

Striped bass represent a substantial resource throughout the Estuary, upstream on the Sacramento River, in coastal waters and in export canals and reservoirs (see Appendix Sections 4.0.9.3 and 4.0.9.5). From 1983 to 1985, sales of striped bass stamps (required by law for fishing) averaged over 560,000 per year (NOAA,1986). Annual recreational catches of striped bass (excluding reservoirs and aqueducts) vary from 100,000 to 400,000 fish (T,XLI,70:17-18), and are taken mainly from private boats or along the shoreline. Charter boats take 10 to 15 percent of the catch (T,XLI,70:25-71:17). Apart from the fishery, striped bass are valuable in the food chain of the Estuary.

Their eggs and small larvae serve as food for other fish and invertebrates. Being principal predators in the river and estuarine food chains, larger bass contribute to the control of the size of forage fish populations.

American Shad

American shad, Alosa sapidissima, is a warm water, anadromous fish species. Shad were introduced to the Delta from the east coast in the late 1800s and within ten years a commercial gill net fishery developed. Over one million pounds (lbs) per year were regularly harvested. DFG estimated that in 1917, at an average weight of three lbs per fish, almost two million shad were caught, representing about 5.8 million lbs (DFG,23,16). By the late 1940s the fishery declined, and by 1957 commercial fishing of shad ended when gill netting was prohibited to protect other fisheries (DFG,23,1; SWRCB,405,42).

Estimates from a 1976-1977 survey indicate a population of about three million American shad spawners (T,XXXIX,13:11-12; DFG,23,15). A popular shad sport fishery exists in the Sacramento, San Joaquin, American, Feather, and Yuba rivers and in the Delta. Surveys in the late 1970s indicate that between 35,000 and 55,000 angler days were spent in catching about 79,000 to 140,000 shad (DFG,23,1-2). No specific data on the value of the shad fishery are available. However, if shore fishing expenditures average about $31 per angler day (Thomson and Huppert, 1987), the total annual value ranges from $2.4 to $4.3 million.

The life history stages and habitat requirements of American shad are shown in Table A4-8. Adult shad spend three to five years in the ocean before they reach maturity (SWRCB,450,33) and enter the lower Estuary in the fall; they migrate through the Delta from about March through May to upstream spawning grounds (T,XXXIX,13:23-24), actively feeding on copepods and cladocerans, as well as Neomysis and Corophium (DFG,23,12; SWRCB,433,100). Peak adult numbers occur in the upper Delta in May (DFG,23,5).

Historically, spawning occurred throughout the tidal fresh water reaches of the San Joaquin and Sacramento rivers and upstream from about May through July. Today, the lower San Joaquin River no longer supports significant spawning activity (T,XXXIX,14:3-23). Spawning occurs primarily from May to June in the north Delta, the Sacramento River above Hood up to the Red Bluff diversion dam, and the major tributaries of the Sacramento River (DFG,23,2-4; SWRCB,450,3-3; DFG,13,21; SWRCB,405,41).

After shad spawn, the fertilized eggs sink and drift with the current until hatching about 4 to 6 days later (SWRCB,405,41). When river flows are high, more shad eggs are carried further downstream and the importance of the Delta as rearing habitat increases (T,XXXIX,15:13-15). The major shad nursery areas are located in the Feather River below the mouth of the Yuba River, the lower American River, the Sacramento River from Colusa to Sacramento, and the north Delta (DFG,23,8;T,XXXIX,15:3-15:6). Shad nursery habitat is mostly upstream from striped bass nursery habitat (T,XXXIX,49:1-49:3) and overlaps with

TABLE A4-8 --American Shad Environmental Requirements and Life History Stages
(from DFG,23;DFG,13;SWRCB,405;SWRCB,433)

Life Stage	Location	Period	Flow	Water Quality	Other
Adult Migration	from Pacific Ocean through Bay-Delta to upstream freshwater tributaries	March-May	low flows reduce size of run in tributaries	temperature 57-75° F	diet is *Neomysis* and other zooplankton
Spawning	upper Sacramento River to Red Bluff Diversion Dam and major tributaries, North Delta, Mokelumne and Old River. Formerly San Joaquin R.	April-early July	higher flows increase numbers spawning in tributaries	63-75° F optimum = 60-70° F	spawn over sand or gravel
Egg Incubation	lower Sacramento R. below Colusa, Feather and American Rivers, Delta	May-July	higher flows carry more eggs into Delta		
Rearing	same as above	June-Sept	more juveniles produced when flows are higher		feed on terrestrial insects, zooplankton
Juvenile Emigration	Delta-Estuary to Bay or Pacific Ocean	late June-December			diet is *Neomysis*, *Corophium*, larval fish, copepods

Chinook salmon rearing areas. In rearing areas upstream from the Delta, young shad concentrate near the water surface, feeding on terrestrial insects that drop into the water from riparian vegetation (SWRCB,433,101). From about June through August in the Delta, young shad feed on zooplankton before emigrating as juveniles during September to December (DFG,23,11; SWRCB,450,3-3). Most shad emigrate by the end of their first year (DFG,23,10). However, some may remain in San Francisco, San Pablo, and Suisun bays and Suisun Marsh for a second year or may not emigrate to the ocean at all (DFG,23,10-11). According to DFG relatively few yearling shad use the Suisun Marsh channels (T,XXXIX,46:1-5).

Other Resident and Anadromous Fish

There are over 30 species of resident, warm water fishes in the Estuary (DFG,24,2), more than half of which were introduced. Most resident fish are members of one of three families: Centrarchidae, sunfish; Cyprinidae, minnows; and Ictaluridae, catfish.

o Background

These families support popular recreational fisheries in the Delta, where white catfish, Ictalurus catus, are the most commonly caught resident game fish, followed by largemouth bass, Micropterus salmoides, and then other sunfish. Statewide, sunfish, catfish and largemouth bass are the second, third, and fourth most commonly caught game fish (DFG,24,5). Non-game resident fish are important components in the estuarine food web both as predators and prey (DFG,24,6). An important introduced forage species, the threadfin shad, Dorosoma petenense, is consumed by striped bass, largemouth bass and other sunfish (SWRCB,450,3-10). Table A4-9 lists the resident species of the Estuary. Only fish of specific interest or concern are discussed below.

o Catfish

Of the four species of introduced catfish (see Table A4-9), the white catfish, by far the most numerous (DFG,24,4), supports a significant recreational fishery. In the southern Delta where EC and turbidity were greater, white catfish were the most numerous resident fish species (DFG,24,28).

o Other Anadromous Species

Several other native, anadromous fish use the Delta as a migration corridor and nursery habitat. They are the green sturgeon, Acipenser medirostris; the white sturgeon, Acipenser transmontanus: and the steelhead rainbow trout, Oncorhynchus mykiss (formerly Salmo gairdneri gairdneri) (SWRCB,405,38)(WQCP-DFG-1). Other than information presented in SWRCB exhibits, no testimony or recommendations were made in Phase I of the proceedings regarding these species' uses of the Delta.

TABLE A4-9 Fishes of the Delta
(from DFG,24 and SWRCB,450)

Cyprinidae - Minnows

Carassius auratus
goldfish (I) * +
Cyprinus carpio
common carp (I) +
Lavinia exilicauda
hitch (N) +
Mylopharadon conocephalus
hardhead (N) +
Notemigonus crysoleucas
golden shiner (I) +

Orthodon microlepidotus
Sacramento blackfish (N) +
Pimephales promelas
fathead minnow (I)
Pogonichthys macrolepidotus
splittail (N) + 1/
Ptychocheilus grandis
Sacramento squawfish (N) +

Ictaluridae - Catfish

Ictalurus catus
white catfish (I) +
Ictalurus melas
black bullhead (I) +

Ictalurus nebulosus
brown bullhead (I) +
Ictalurus punctatus
channel catfish (I) +

Centrarchidae - Sunfish

Lepomis cyanellus
green sunfish (I) +
Lepomis gibbosus
pumpkinseed (I) +
Lepomis gulosus
warmouth (I) +
Lepomis macrochirus
bluegill (I) +
Lepomis microlophus
redear sunfish (I) +

Micropterus dolomieui
smallmouth bass (I) +
Micropterus punctulatus
spotted bass (I) +
Micropterus salmoides
largemouth bass (I) +
Pomoxis annularis
white crappie (I) +
Pomoxis nigromaculatus
black crappie (I) +

Others

Catostomus occidentalis
Sacramento sucker (N) +
Hysterocarpus traski
tule perch (N) +
Menidia beryllina
inland silversides (I) +
Dorosoma petenense
threadfin shad (I) +
Percina macrolepida
bigscale logperch (I) +
Morone saxatilis
striped bass (I) +
Alosa sapidissima
American shad (I) +
Acanthogobius flavimanus
yellowfin goby (I) +
Cottus asper
prickly sculpin (N) +
Leptocottus armatus
Pacific staghorn sculpin (N) +
Oncorhynchus tshawytscha
chinook salmon (N) +

Oncorhynchus mykiss
steelhead (N) +
Gambusia affinis
mosquitofish (I) +
Gasterosteus aculeatus
threespine stickleback (N) +
Entosphenus tridentata
Pacific lamprey (N) +
Lampetra ayresi
river lamprey (N)
Mugil cephalus
striped mullet +
Hypomesus transpacificus
Delta smelt (N) + 2/
Spirinchus thaleichthys
longfin smelt (N) +
Platichthys stellatus
starry flounder (N) +
Acipenser transmontanus
white sturgeon (N)
Acipenser medirostris
green sturgeon (N)

* I = introduced; N = native; + indicates species collected in DFG's 1980-1983 electrofishing survey
1/ State species of special concern 2/ State candidate species

An intense commercial sturgeon fishery existed in the 1800s, but was closed in 1901 after the catch plummeted. The fishery reopened in 1910, was closed in 1917, and in 1954 reopened for recreational purposes only (SWRCB,430,453). Angling is popular in the Sacramento River up to Colusa, in the Delta (SWRCB,405,35-36), and in the bays. Sturgeon are taken in San Francisco Bay where they congregate to feed during the herring runs (SWRCB,430,454). Party boats reportedly harvested 2,400 sturgeon in 1967. There is no information on the recent magnitude of the fishery.

Adult steelhead migrate upstream from the ocean during the spring through fall. Spawning occurs from December through April in tributaries above the Delta. Like salmon, steelhead return home to their natal stream; unlike salmon, not all adults die after spawning. Steelhead are known to have spawned up to four or more times (SWRCB,405,60; SWRCB,450,5-7). There are several seasonal runs of steelhead migrating through the Delta (SWRCB,405,59-60; SWRCB,450,5-6). The size of the recreational fishery for steelhead adults and juveniles is unknown.

o Species of Concern

The Sacramento splittail, Pogonichthys macrolepidotus, is one of two species of special concern because its distribution is restricted to the Bay-Delta Estuary and it has recently declined in abundance (USFWS,35,1). The other, the Delta smelt, Hypomesus transpacificus, once abundant in Suisun Marsh and the Delta, has undergone a precipitous decline since the early 1970s (USFWS,35,20). Both fish have been recommended as candidate species by the USFWS to be studied to determine whether they should be added to the federal Endangered and Threatened list (USFWS,35,11)[1].

The splittail is a category 2 candidate and the Delta smelt is a category 1 candidate. (A category 1 species is one for which the USFWS has substantial information to support a proposal for listing as endangered or threatened. A category 2 species is one for which information available indicates that a proposal for listing is possibly appropriate but that the data available are not conclusive.)

A petition was submitted June 9, 1989 to the Fish and Game Commission to list the Delta smelt as an endangered species under the California Endangered Species Act. On August 29, 1989, the Commission accepted the petition and for one year the Delta smelt was a candidate species. During this time DFG staff reviewed the pertinent data and recommended that the species be listed as threatened. The Fish and Game Commission on August 31, 1990 decided that there was insufficient evidence to list the species at all and that further studies on the species should be conducted. The Delta smelt remains a species of Special Concern.

1/ Listing refers to a process established under state and federal Endangered Species Act by which Native species are identified. Those listed are determined to be in immediate jeopardy of extinction ("endangered") or to be present in such small numbers throughout their range that they may become endangered if their present environment worsens (rare plant or threatened species) (California Fish and Game Code Sections, 7, and 2068; 16 USC Section 1531 et seq.)

2/ Section 670.1, Title 14, CCR and Sections 2072 and 2072 and 2072.3 of the Fish and Game Code.

The USFWS was petitioned by the California-Nevada Chapter of the American Fisheries Society on June 26, 1990 to list the Delta smelt as an endangered species under the federal Endangered Species Act. A USFWS administrative finding on the petition request stated that substantial information was presented such that listing may be warranted. This initiates a one year review period, from the date of receipt of the petition (6/29/90), in which the USFWS will gather information on which to make a determination on whether to list the Delta smelt. Until this determination is made, its status remains a category 1 candidate species.

The information on resident freshwater species and other anadromous fish presented in the Phase I hearing was mostly descriptive. No quantitative data were presented on the relationship between population abundance, distribution and salinity regimes.

Subsequent investigations have revealed that the Delta smelt inhabit the open surface water of the Delta and Suisun Bay and live about one year. The adult Delta smelt spawn in freshwater between the months of December and April (Moyle, 1976) and most apparently die after spawning. The buoyant larvae are washed downstream until they reach the entrapment zone, where the currents keep them suspended and circulating with the zooplankton, which is their food. During the larval stage, from approximately April through June, the smelt are not yet of sufficient size to be efficient swimmers and effectively pursue their prey. Therefore, a high density of prey items in suitable habitat offers an advantageous environment for rearing (Moyle, pers. comm., 10/89). The smelt grow rapidly and within six to nine months reach adult length. In the next three months the smelt become sexually mature and move up into the freshwater to spawn. All sizes are found primarily in the main channels of the Delta and Suisun Marsh, and the open water of Suisun Bay (Moyle, 1989). Delta smelt, most of the year, are found in water of less than 2 ppt TDS (2.9 mmhos/cm EC) and occasionally are found in water up to 10 to 12 ppt TDS (14.6 to 17.5 mmhos/cm EC) (Moyle, 1989). Spawning occurs in freshwater when the water temperatures are between 7 and 15°C (44.6 to 59°F) (Wang, 1986).

4.0.5.2 Bay Habitat

Suisun, San Pablo, San Francisco and south San Francisco (South) bays are considered here. Since, for this Plan, Suisun Bay is considered to be part of the Bay, it is included here for purposes of discussion.

Fishery Habitat Protection (Entrapment Zone)

As in the freshwater portions of the Estuary, phytoplankton and zooplankton form important parts of the food chain in the more saline portions of the Estuary. Many fish rely upon the presence of copepods and cladocerans, e.g., Neomysis, Corophium, and Lagunogammarus. These zooplankton in turn feed upon detritus and upon phytoplankton, the primary producers. Maximum phytoplankton production for this Estuary appears to occur when outgoing freshwater and incoming ocean water mix at approximately the upstream end of Suisun Bay (USBR,111,28; USBR,112,53-70). The area just downstream of this location, known as the entrapment zone, is a concentration site for certain diatoms, detritus, Neomysis and other zooplankton (USBR,111,27).

The Suisun Bay normally receives enough annual fluctuation in salinity that neither marine nor freshwater filter-feeding benthic organisms could establish themselves and survive indefinitely (Nichols, 1985). However, the recently introduced benthic clam, Potamocorbula, appears to be much more euryhaline (tolerant of wide ranges in salinity), and so has been able to survive throughout the Bay. It has even penetrated upstream in the Delta as far as Rio Vista (Jan Thompson, USGS, personal communication, 1/90).

In addition to the Suisun Bay entrapment zone, a proposal was made to develop a second entrapment zone in San Pablo Bay. This second entrapment zone (or at least an area with stratified flow with a strong horizontal salinity gradient) is proposed to provide additional phytoplankton production (CCCWA/EDF,3,23).

Finally, regarding phytoplankton, a proposal was made to enhance their production in South Bay (CCCWA/EDF,4). Research has shown that the clam Macoma balthica tended to show growth rate increases consistent with microalgae availability, including phytoplankton (T,LI,181:20-182:15).

Benthic Invertebrates

"The 'benthos' is the community of invertebrate animals (worms, clams, shrimp, etc.) living on the bottom of aquatic environments. These animals consume organic matter that grows on, or settles to the bottom and in turn become food for fish and other consumers including humans" (TIBCEN,23,65). Benthic invertebrates in the Estuary tolerate a range of salinities; some prefer different flows and salinities at different life stages (DFG,59,14). There are species requiring only freshwater, species requiring a combination of salt and freshwater, and those surviving only in saltwater. For example, some species prefer fresher water during early life stages and as juveniles are found in the upper reaches of the estuary, whereas adults prefer higher salinities and occupy the Bay (DFG,59,22). Adult shrimp occupy bottom areas in their preferred habitat, while shrimp larvae are found in less saline surface layers. These behavioral differences, combined with the effects of the two-layered flow in the Bay, result in different distributional patterns of young and old shrimp (USBR,110,15). For example, Crangon spp. shrimp breed in the Bay, produce planktonic larvae which may be carried into the ocean near shore by surface water, drop down as benthic post-larvae and re-enter the estuary carried by gravitational circulation (DFG,59,23).

The following benthic organisms found in the Estuary are part of the food chain which supports popular sport or commercial fisheries and wintering waterfowl:

o mollusks, including clams (Macoma balthica, Mya arenaria, Tapes japonica, Gemma gemma, Corbicula spp.), mussels (Ischadium demissum, Mytilus edulis), oysters (Ostrea lurida), and snails (Nassarius obsoletus);

- arthropods, including amphipods (Corophium spp., Grandidierella japonica, Ampelisca milleri, Lagunogammarus spp.), shrimp (Crangon spp.), and crabs (Cancer spp.); and

- worms (Limnodrilus spp., Boccardia ligerica, Streblospio benedicti) (Markmann, 1986).

There is a pronounced "faunal break" west of Suisun Bay, where freshwater and brackish water species give way to salt-tolerant species found in San Pablo Bay (DFG,59,12).

Fishery Resources

In reporting that "sport fishing is the most popular recreational activity in the San Francisco Bay and Delta area," DFG estimated that 4.4 million recreation-days were used in this activity, with a much larger, as yet undeveloped, potential demand (DFG,59,10). Striped bass, Chinook salmon, and halibut are the most popular species caught in the Bay; other sport species include brown rockfish, surf perch, lingcod, jacksmelt, topsmelt, white croaker, shark, ray and skate.

The commercial harvest of finfish in the Bay has been limited by legislation (T,LII,19:3-20), with only herring and anchovy being taken commercially today (DFG,59,11). The herring fishery is primarily for roe which is exported to Japan. Anchovy are harvested primarily for bait. DFG estimated the commercial harvest of herring roe and shrimp from San Francisco Bay landings to have a value of $11.6 million per year (H. Chadwick, pers. comm., 12/28/87).

DFG collected 122 fish species and about 1,642,000 individual fish, including larvae, during a six-year study from January 1980 through December 1985 (DFG,59). Most species were so rare they were not analyzed further. Near bottom (demersal) habitats supported a more abundant, diverse fish community than open water (pelagic) or nearshore areas (DFG,59,6). Table A4-10 identifies the predominant species caught in each of these areas.

Many of the species which are prey for other fish or birds are permanent residents of the Bay, including gobies, topsmelt, and Pacific staghorn sculpin. The Bay also provides nursery and rearing habitat for species which are harvested commercially and recreationally (see Table A4-11). For example, the English sole and starry flounder spawn offshore but their eggs or young are carried by gravitational circulation into the Bay where they mature. Adults of other commercially important species such as Pacific herring and northern anchovy actively move into and spawn in the Bay where their young also mature (DFG,59,10).

4.0.5.3 Marine Habitat

The beneficial uses of the marine habitat include the propagation and sustenance of fish, shellfish, marine mammals, waterfowl and vegetation such as kelp.

TABLE A4-10

Most common Bay fish collected from demersal, pelagic and nearshore areas by DFG, 1980-1986
(From: DFG, 59,6)

SHORE HABITAT	PELAGIC HABITAT	DEMERSAL HABITAT
Atherinops affinis topsmelt	Engraulis mordax Northern anchovy	Spirinchus thaleichthys longfin smelt
Clupea harengus pallasi Pacific herring	Spirinchus thaleichthys longfin smelt	Engraulis mordax Northern anchovy
Engraulis mordax Northern anchovy	Clupea harengus pallasi Pacific herring	Morone saxatilis striped bass
Atherinopsis californiensis jacksmelt	Morone saxatilis striped bass	Cymatogaster aggregata shiner perch
Morone saxatilis striped bass		Parophrys vetulus English sole
Leptocottus armatus Pacific staghorn sculpin		Genyonemus lineatus white croaker
Menidia beryllina tidewater silverside		Leptocottus armatus Pacific staghorn sculpin
Clevelandia ios arrow goby		Lepidogobius lepidus Bay goby
Cymatogaster aggregata shiner perch		Citharichthys stigmaeus speckled sanddab
Micrometrus minimus dwarf perch		Acanthogobius flavimanus yellowfin goby
Acanthogobius flavimanus yellowfin goby		Platichthys stellatus starry flounder
		Clupea harengus pallasi Pacific herring

TABLE A4-11 Life history and descriptive information for the most abundant species of fish collected. (DFG,59)

Species	Species origin	Species type	Life history: Spawning time	Life history: Spawning location	Life history: Nursery area	Center of population	Importance of species	Preferred habitat	Use of Bay	Life stage major food source: Adult	Life stage major food source: Juvenile
Pacific herring	N	M	Fall - Winter	Bay	SSFB - SPB	Ocean	Commercial Forage	Pelagic	Spawning Nursery	P	P
Longfin smelt	N	E	Winter	Rivers	SPB	SPB	Forage	Pelagic	Nursery Residence	P	P
Pac. staghorn sculpin	N	E	Winter	Bay	Bay	CSFB - SPB	Forage	Demersal	Residence	F,B	B
Starry flounder	N	E	Winter	Ocean	SB- Delta	Ocean - Bay	Commercial Recreation	Demersal	Nursery Residence	B	B
Speckled sanddab	N	M	All Year	Ocean	Ocean - CSFB	Ocean	Forage	Demersal	Nursery	B	B
English sole	N	M	Winter	Ocean	Ocean - Bay	Ocean	Commercial	Demersal	Nursery	B	B
California tonguefish	N	M	Summer - Fall	Ocean	Ocean - CSFB	Ocean	Forage	Demersal	Nursery	B	B
Yellowfin goby	I	E	Winter	Bay	SB - Delta	SPB - SB	Forage Commercial	Demersal	Residence	B	B
Arrow goby	N	M	Spring - Summer	Bay	SSFB - SPB	SSFB - SPB	Forage	Demersal	Residence	B	B
Bay goby	N	M	Summer - Fall	Bay	SSFB - SPB	CSFB	Forage	Demersal	Residence	B	B
Topsmelt	N	M	Summer	Bay	SSFB - CSFB	SSFB	Forage	Littoral/ Pelagic	Residence	B	B
Jacksmelt	N	M	Spring - Summer	Bay - Ocean	SSFB - CSFB	Ocean	Recreation Forage	Pelagic	Spawning Nursery	F	P
Northern anchovy	N	M	Spring - Summer	Ocean	Ocean	Ocean	Commercial Forage	Pelagic	Spawning Nursery	P	P

N = native, I = introduced, E = estuarine, M = marine, SSFB = South San Francisco Bay, CSFB = Central San Francisco Bay, SPB = San Pablo Bay, SB = Suisun Bay, P = plankton, B = benthos, F = fish

The protection of marine habitat in many cases will be accomplished by measures to protect wildlife habitat. Some marine habitats may require special protection. Water quality requirements for some individual marine species are not well known (RWQCB 2, 1986).

4.0.6 Wetlands Habitat

Wetlands are those areas that are inundated or saturated by surface or groundwater that under normal circumstances support a prevalence of vegetation adapted for life in saturated soils. Wetlands include marshes, swamps, and riparian areas. Wildlife habitat is the most significant actual and potential beneficial use of wetlands (RWQCB 2, 1986).

4.0.6.1 Delta

The Delta area totals about 738,000 acres, including about 515,000 acres in agriculture; about 50,000 surface acres of meandering channels; 7,000 acres of shrub-brush and woodland riparian habitat; 7,000 acres of freshwater marsh and about 32,000 acres of urban habitat (DFG,6,1). Freshwater marsh and riparian habitat support the greatest diversity of plant and animal species (DFG,6,4). The Delta currently supports from 450,000 to 600,000 migratory waterfowl during the winter, with thousands of shorebirds and wading birds making use of the shallows of seasonally flooded fields (DFG,6,6).

Over 230 species of birds and 43 species of mammals occur in the Delta (DFG,6,1). There are also 15 reptile species and eight amphibian species reported or thought to occur in the Delta (Delta Wildlife Habitat Protection and Restoration Plan, DFG & USFWS,1986).

Migratory waterfowl in particular use spilled and unharvested corn and other grain crops, especially when Delta islands are allowed to be ponded or flooded for leaching purposes (DFG,6,4). Sandhill cranes now depend on wet or flooded pasture and cultivated grains (DFG,6,4&7). The peregrine falcons depend upon waterfowl for a major part of their diet (USFWS,17,2).

4.0.6.2 Rare, Threatened and Endangered Species

In the Delta many of the following animals are so uncommon they have been identified on official lists of rare, threatened or endangered species by wildlife agencies. Seven bird species are listed by either the state or federal government as threatened or endangered. Two more bird species are candidates for federal listing (DFG,6,3; USFWS,19, 20,21). The giant garter snake is a state-listed threatened species as well as a candidate for federal listing as either threatened or endangered (DFG,6,3; USFWS,22). Two mammals, the riparian brush rabbit and the riparian woodrat, are candidates for federal listing as threatened or endangered; three invertebrates also are federally listed as threatened or endangered and thirteen plants are listed by federal and/or state agencies as rare, threatened or endangered (DFG,6,3).

In Suisun Marsh, several sensitive[1/] plant species have been identified (CNPS,3). These are the soft bird's-beak (Cordylanthus mollis mollis), Mason's lilaeopsis (also known as the mud squill, Lilaeopsis masonii), Delta tule pea (Lathyrus jepsonii jepsonii), and Suisun aster (Aster chilensis var. lentus). The soft bird's-beak and Mason's lilaeopsis are listed by the state as "rare" and by the federal government as "candidate" species. The Delta tule pea, the Suisun slough thistle (Cirsium hydrophilum var. hydrophilum) and the Suisun aster are also federal candidate species. CNPS has testified that the California hibiscus (Hibiscus californicus) is a sensitive species even though it is not state or federally listed.

There are also several animal species in the Marsh that have been designated by the USFWS or the DFG as threatened or endangered. These are the salt marsh harvest mouse (Reithrodontomys raviventris), the California clapper rail (Rallus longirostris obsoletus), the California black rail (Laterallus jamaicensis coturniculus), and the winter-run Chinook salmon (Oncorhynchus tschawytscha). The salt marsh harvest mouse and the California clapper rail are listed as "endangered" by both the State of California and the federal government. The California black rail is listed as "threatened" by the State of California and is a federal candidate species. The winter-run Chinook salmon is listed as "threatened" by the federal government and "endangered" by the state (USFWS,17; T,XXIX,112:24-112:15; T,XXX,5:4-11; List of State and Federal Endangered and Threatened Animals in California, DFG, Revised April 1989; Notice of Findings of Sacramento River Winter-Run King Salmon, California Fish and Game Commission, May 22, 1989).

The USFWS is reviewing a petition to list the Suisun song sparrow (Melospiza melodia maxillaris) as endangered or threatened (USFWS, pers. comm., 10/89). The salt marsh common yellow throat (a bird) (Geothylpis trichas sinuosa) and the Suisun ornate shrew (Sorex ornatus sinuosus) are federal candidate species (memo from DFG to SWRCB, June 13, 1989).

The endangered salt marsh harvest mouse and the California clapper rail are also found in the tidal marshes around San Pablo Bay (USFWS,17,1; USFWS,18; USFWS,19; DFG,7,7; T,XXX,5:12-15). Both species are dependent upon dense cover composed of pickleweed and allied plant species; adjacent, higher elevation escape cover for refuge from high water is needed (DFG,7,7; DFG,7,11-12). Any expanded areas of cordgrass and pickleweed which may occur if soil salinities increase, however, will not necessarily be useful to these endangered species because the areas with adequate escape cover are limited. The black rail, a state-listed threatened species and a federal candidate species, is also found in the San Pablo Bay marshes (DFG,7,7,12; USFWS,16,4; USFWS,21). The Delta tule pea, Mason's lilaeopsis, and the soft bird's-beak are also found in the marshes of north San Pablo Bay (DFG,7,13; T,XXIX,144:25-145:1).

1/ As used in this chapter, "sensitive plants" includes state-listed "rare" and federal "candidate" species.

In San Francisco Bay, a variety of species of wildlife listed as threatened or endangered by state or federal wildlife agencies depend on Bay habitats for all or part of the year. Salt marsh harvest mice, California clapper rail, black rail, California brown pelican, and California least tern are listed (DFG,7,13). In Bay marshes, both soft bird's-beak and Mason's lilaeopsis occur near the upper reaches of the Bay.

4.0.6.3 Suisun Marsh

Suisun Marsh, with an area of 116,000 acres, including about 88,000 acres below the five-foot contour, is the largest contiguous brackish water marsh in the United States (T,XXIX,12;DFG,5,1). The major habitat types are managed marshes that are subject to controlled inundation and drainage (generally for the enhancement of waterfowl habitat) and tidal marshes that are influenced by the water regime in the channels. There are also substantial areas of habitat consisting mostly of annual grasses and weedy growth, cropland and open ground. Between 54,000 acres (T,XXX,110:AA4-5) and 57,000 acres (DFG,5,3) are marshland, of which approximately 10,000 acres are tidal marsh (T,XXX,49:21,110:5). Estimates differ, depending on the definitions used and the areas examined, as to what proportion of the marsh acreage is managed and what is tidally influenced. By all estimates, most (80 to 90 percent) of the marshland is managed for plant species considered beneficial to wintering waterfowl (DFG,5,6).

The principal waterfowl using Suisun Marsh in winter are pintail, mallard, shoveler, widgeon and green-winged teal. Mallard, gadwall, and cinnamon teal breed here. The plants which are preferred food items for wintering waterfowl are alkali bulrush, brass buttons, and fat-hen (DFG,5,9). During the remainder of the year, invertebrates are important food for pre-nesting females and broods of ducklings (DFG,5,13).

4.0.6.4 Other Tidal Marshes

San Francisco Bay's tidal marshes, ranging from fresh to salt water habitats, include 53 square miles of tidal marsh, 15 square miles of diked marsh and 55 square miles of diked ponds (DFG,7,1). Large areas of tidal wetland occur on the northeast shore of San Pablo Bay, specifically Tubbs Island, Napa and Petaluma Marsh. Diked marshes, ponds and mudflats are extensive in the South Bay (DFG,7,1).

Bay area wetlands and aquatic habitats support over half of the Pacific flyway's wintering population of such waterfowl as canvasback ducks and are very important for scaup, scoters and redhead ducks. Aquatic habitat and aquatic invertebrates are important in their contribution to the food supply of higher forms of Bay wildlife. One of the most important food items for canvasback ducks is the clam *Macoma balthica*; two other mollusks, *Mya arenaria* and *Musculus senhousia*, are also extensively eaten. These mollusks are also food for clapper rails, as are a variety of other invertebrates (DFG,7,9).

Although many Bay tidal marshes are relatively isolated from the Delta outflow of low salinity water, the nearby Bay waters are affected by stratification, gravitational circulation, and flushing induced by outflow. To the degree that mollusk and fish species and aquatic habitat productivity changes in the Bay, the value of the adjacent marshes and beaches for sensitive wildlife, such as rails, terns, and pelicans, may change (DFG,7,10-12).

4.0.7 Estuary Recreation Beneficial Use

The waters of the Estuary are used for water contact recreation, including swimming, boating, fishing, hunting, water skiing, and houseboating. The waters are also used for competitive events, marine parades and emerging activities, such as boardsailing and jetskiing (EBRPD,1-33). There are also a variety of water-oriented, non-contact activities such as sightseeing, bird watching and beachcombing, all of which depend on the esthetic or visual quality of the Estuary's waters to some degree (EBRPD,1-33).

4.0.7.1 Sacramento-San Joaquin Delta and Tributaries

Evidence was provided which projected user days and economic values for freshwater recreation in the Delta as compared to similar types of recreation at storage and export reservoirs and facilities (SWC,65,24). Freshwater-oriented recreation in the Delta was estimated to be 8.3 million user days in 1977-78, although this number includes some activities which do not depend entirely on the Delta's waters. Brackish water, ocean and estuary activities were not included in the total (SWC,66,5). Testimony and evidence were also provided which indicated that recreation visits to Estuary shoreline park facilities have been growing rapidly compared to the projections used by SWC, i.e., 122 percent in two years compared to 0.8 percent/year (T,LV,160:17-161:1; EBRPD,24,T1). Millions of user days and daily values of $20 or more per user for water use are calculated for each recreational user of Estuary water (BISF,38,T4). An extrapolation of old studies of Delta recreation has generated estimates in the range of 13 million recreation-days annually (PICYA,2,51). Testimony by SWC suggested that these estimates were high and should be reduced to 6.95 million. No current information based on recreation use studies during this decade is available (T,LV,137:13-16).

4.0.7.2 Suisun Marsh and Carquinez Strait Area

Some evidence was submitted on the recreational use of the Suisun Marsh or Carquinez Strait area of the Bay-Delta Estuary. BAAC submitted evidence inferring that bird watching goes on in the Suisun Marsh (BAAC,20;26;27). From evidence submitted by EBRPD, estimated recreation at its Contra Costa shoreline facilities (Antioch and Martinez shoreline) increased greatly between 1981 and 1987, growing from 84,000 visitors to 287,000 visitors, or about 340 percent in six years (EBRPD,34,T1). Although there is little evidence linking the number of visitors in this reach to water quality, both BAAC and EBRPD expressed concern that visitors to these recreational areas would experience losses of the value they place on wildlife and fish resources, which might be harmed if flow decreased and salinity increased (T,XXX,45:12-23; T,LV,184:15-25,185:1-2).

The recreational use of EBRPD units with water quality problems Point Isabel and San Leandro Bay, increased from 71,000 users in 1981 to 487,000 users in 1987, an increase of over 680 percent (EBRPD,34,T1). This occurred despite serious heavy metal contamination at these beaches. In comparison, the use of the nearby, unpolluted Hayward and Miller-Knox shorelines has grown from 21,000 users in 1981 to 196,000 in 1987, an increase of 930 percent. There was no specific information on the features which prompt users to attend the various park units, nor on the method by which use estimates were made. Moreover, it is noteworthy that users did not avoid contaminated sites, and it does not seem reasonable to suppose that a moderate change (of one or two parts per thousand) in salinity would substantially change future recreational use. This might not be true if the change were such as to convert a freshwater beach to saltwater; however, no data are in the record on this subject.

4.0.7.3 San Francisco Bay Basin

The Basin Plan for Region 2, the San Francisco Bay Basin, identifies most of the same forms of recreation as the Delta. Recreational uses are also identified for the Pacific Ocean and the San Francisco Bay system and all other surface waters (RWQCB 2, 1986). Water-oriented recreation in the San Francisco Bay area was estimated to total over 127 million user-days (BISF,38,T3).

4.0.8 Other Beneficial Uses

4.0.8.1 Navigation

Navigation in the Estuary includes commercial, naval, and recreational activities. There are seven major ports in the Estuary (San Francisco, Oakland, Alameda, Redwood City, Richmond, Stockton, and Sacramento), serving more than 5,000 ships annually (NOAA, 1986,8); there are also numerous oil transfer terminals located between Richmond and Suisun Bay. In 1984, imports at the Estuary's seven major ports were worth $10,419,000, while exports were worth $6,295,000 (NOAA, 1986). Six million tons of cargo have been transported annually in the Stockton and Sacramento deep-water ship channels (DWR, 1987). In 1985 there were 143,646 recreational boats registered in the nine counties surrounding San Francisco Bay (NOAA, 1986), and about 82,000 pleasure boats were registered in the Delta area (DWR, 1987). These Delta area boaters are served by more than 8,500 berths, 119 docks and 27 launching facilities (DWR, 1987).

4.0.8.2 Dilution of Pollutants

Freshwater flows to dilute pollutants in the Estuary and upstream was a subject of considerable testimony during Phase I. Under both the Porter-Cologne Act (Section 13050(f)) and EPA Regulations (40 CFR131.10(a)), neither waste disposal or transport nor waste assimilation can be designated as beneficial uses. This does not, however, preclude the State Board from addressing any action(s) which may have curtailed the natural assimilative capacity of the Estuary.

4.0.9 Uses of Water Exported From the Bay-Delta Estuary

The following sections address water use in the areas of export, that is, the areas defined for purposes of this Plan as being outside the legal boundary of, and receiving water diverted from, the Bay-Delta Estuary.

4.0.9.1 Municipal and Industrial Uses

Most of California's population lives in semi-arid areas where population and industrial expansion have exceeded the ability of many communities to meet their water needs with local sources. Local as well as distant communities have seen the Estuary's waters as a means to meet their needs.

Municipal and Industrial (M&I) water exports to local areas outside the Estuary began in 1929 when EBMUD initiated the first export of Delta supplies by diverting Mokelumne River water through its Mokelumne Aqueduct to Alameda and Contra Costa counties. In 1934 San Francisco began diverting water from the Tuolumne River through the Hetch-Hetchy Project for use in San Francisco, San Mateo, and Alameda counties. In 1940 the Contra Costa Canal (CCC), the first unit of the CVP, was completed and began supplying water to the Antioch-Pittsburg area. The City of Vallejo began importing Delta surface water from Cache Slough in 1953. USBR began diverting Putah Creek water via the Putah South Canal to Fairfield and Benicia in 1957. In 1965 the South Bay Aqueduct of the SWP began exporting an interim supply of Delta water from the Delta-Mendota Canal (DMC) to Alameda and Santa Clara counties. The North Bay Aqueduct Phase II facilities of the SWP divert Delta waters from Barker Slough tributary to Lindsey and Cache sloughs, and connect to the Phase I facilities just west of Cordelia to deliver water to Solano and Napa counties (DWR,207,1-7).

The first exports to distant municipalities began in 1968 when the federal CVP began exporting water to Coalinga, Huron and Avenal through the DMC and San Luis Canal (DWR,204,1). In 1971 the SWP's California Aqueduct began exporting water to southern California through the Edmondston Pumping Plant over the Tehachapi Mountains (DWR,207,1-7).

CVP M&I deliveries in 1986 were estimated 381,204 AF with a projected delivery in the year 2010 of 936,072 AF (Table A4-12) (USBR, 1987). In 1985, SWP M&I deliveries were approximately 1,008,000 AF (Table A4-13) (DWR,461,1). No estimate of SWP projected deliveries to southern California for M&I use was presented. Table A4-14 lists state and federal water transfer facilities and the areas each serve.

Population and economic projections indicate growing M&I water demands. The Department of Finance has estimated that the state population will increase from 27,000,000 people in 1986 to 36,280,000 people in 2010 (DOF, 1987). Of this, the population of the six most populated counties in southern California--Ventura, Los Angeles, Orange, Riverside, San Bernardino, and San Diego--are expected to increase from a 1986 level of 15,290,000 people to 20,220,000 in 2010 (SWC,6,7). The expected additional M&I demand for Bay-Delta water supply is a result both of the loss or degradation of alternative water supplies and of increases in population (SWC,4,6).

TABLE A4-12
MUNICIPAL AND INDUSTRIAL WATER CONTRACTS
CENTRAL VALLEY PROJECT
(acre-feet)

Sacramento Valley and American River Service Areas			
Contracting Entity	Contract Maximum a/	1986 Deliveries b/	Projected 2010
Bella Vista WD d/	7,000	2,060	7,000
City of Folsom d/	22,000	15,042	22,000
City of Redding d/	21,000	10,424	21,000
City/Redding(Buckeye)	6,140	2,320	6,140
City/Redding(Buckeye)	40	40	0
City of Roseville	32,000	11,591	32,000
City/Sacramento(AmRv) d/	326,000	71,331	227,500
City/Sacramento(SacRv) d/	above	18,896	above
Clear Creek CSD	10,300	1,346	6,400
County of Colusa	40	40	40
Diamond International	510	0	510
Diamond International d/	425	425	425
East Bay MUD	150,000	0	20,000
East Yolo CSD	9,290	0	8,860
El Dorado ID	2,875	3,006	2,875
El Dorado ID	7,500	1,540	7,500
Elk Creek CSD d/	100	96	100
Folsom Prison d/	4,000	1,432	4,000
Foresthill PUD	2,500	1,084	2,500
G. W. Williams	130	0	130
Keswick SD	500	140	300
Lake CA (Rio Alto)	200	200	200
Louisiana Pacific	25	26	25
Mather AFB (Temporary)	350	271	350
Mountain Gate	350	457	350
Napa Co. FCWCD	7,500	3,167	1,500 e/
Parks & Recreation d/	5,000	15	15
Placer Co. Water Ag. d/	150,000	4,921	75,000
Riverview Golf Club d/	280	280	280
San Juan Suburban WD	5,600	7,840	5,600
San Juan Suburban WD d/	33,000	23,100	33,000
Shasta County WA	5,000	162	2,800
Shasta CSD	1,000	602	1,000
Shasta Dam PUD	3,227	1,573	3,227
So. Cal. Water Co. d/	10,000	1,612	10,000
Sacramento MUD	7,500	3,167	1,500
Summit City PUD	1,170	300	1,170
U.S. Forest Service	10	10	10
TOTAL SACRAMENTO AND AMERICAN RIVER*	832,562	188,516	505,307

San Joaquin Valley Service Areas			
Contracting Entity	Contract Maximum a/	1986 Deliveries b/	Projected 2010
Arvin Edison WSD	500	0	500
Arvin Edison (Cross Val.)	500	0	500
Broadview WD	20	23	20
City of Avenal	3,500	1,257	3,500
City of Coalinga	10,000	6,000	10,000
City of Fresno	60,000	45,000	60,000
City of Huron	3,000	828	3,000
City of Lindsay	2,500	2,021	2,500
City of Orange Cove	1,400	422	1,400
City of Tracy	10,000	5,734	10,000
Contra Costa WD	195,000	124,386	195,000
County of Madera	200	30	200
County of Tulare	1,345	1	1,345
Fresno County WW#18	150	59	150
Musco Olive Prod. (temp)	- -	0	- -
Pacheco WD	80	12	80
Panoche WD (DMC)	37	18	37
Panoche WD (SLC)	63	23	63
San Benito WD	8,250	0	6,680
Santa Clara WD	128,700	0	117,200
San Luis WD (DMC)	140	109	140
San Luis WD (SLC)	440	387	440
State of California	10	10	10
Stockton-East WD	10,000	0	8,000
Tracy Golf Club-CA (temp)	- -	451	- -
Westlands WD	10,000	5,917	10,000
TOTAL SAN JOAQUIN*	445,835	192,688	430,765
TOTAL SACRAMENTO AND SAN JOAQUIN*	1,278,397	381,204	936,072

* Note: Original USBR sum differs from total column summation.

a/ Quantity is a contract maximum or is projected M&I use within a combination M&I/agricultural water service contract.
b/ Deliveries may include water transferred from other contrators or purchased under provisions of the contract and may therefore be higher than contract maximum.
c/ Includes Solano FCWCD and Napa Co. FCWCD of Solano Project
d/ Contract includes water rights; no payment is made to the United States for water rights water.
e/ Present use includes City of Napa which will cease when North Bay Aqueduct completed.

Source: USBR, Factsheet: "Exhibits and Testimony before SWRCB, Bay-Delta Hearing, 1987", 1987

TABLE A4-13

SWP WATER DELIVERIES FOR AGRICULTURE, MUNICIPAL AND INDUSTRIAL USES, RECREATION USE AT SWP FACILITIES AND HYDROELECTRIC ENERGY, 1962 to 1985.

	Water Delivered (Acre-Feet)								
	Entitlement Water			Other Deliveries					
Year	Municipal & Industrial Use	Agricultural Use	Total	Municipal & Industrial Use	Agricultural Use	Other Water a/	Total Delivery	Recreation Supported (Recreation Days) /b	Hydroelectric Energy Generated (megawatt-hours) c/
1962						18,289	18,289	30,000	
1963						22,456	22,456	105,000	
1964						32,507	32,507	331,600	
1965						44,105	44,105	449,800	
1966						67,928	67,928	482,700	
1967	5,747	5,791	11,538	0	0	53,605	65,143	455,200	
1968	46,472	125,237	171,709	10,000	111,534	14,777	308,020	931,300	628,000
1969	34,434	158,586	193,020	0	72,397	18,829	284,246	1,554,800	2,614,000
1970	47,996	185,997	233,993	0	133,024	38,080	405,097	1,804,800	2,679,000
1971	85,286	272,054	357,340	2,400	293,619	44,127	697,486	2,085,900	3,302,000
1972	181,066	430,735	611,801	22,205	401,759	73,127	1,108,892	1,971,200	1,922,000
1973	293,824	400,564	694,388	3,161	293,255	43,666	1,034,470	2,502,000	3,298,000
1974	418,521	455,556	874,077	4,753	412,923	48,342	1,340,095	4,073,600	4,672,000
1975	641,621	582,369	1,223,990	21,043	601,859	67,170	1,914,062	4,189,300	3,159,000
1976	818,588	554,414	1,373,002	32,488	547,622	116,962	2,070,074	4,239,600	2,131,000
1977	280,919	293,236	574,155	0	0	390,176	964,331	3,951,900	958,000
1978	742,385	710,314	1,452,699	3,566	13,348	122,916	1,592,529	5,773,700	2,882,000
1979	690,659	969,237	1,659,896	66,081	582,308	189,396	2,497,681	5,298,700	2,485,000
1980	730,545	799,204	1,529,749	19,722	384,835	48,590	1,982,896	5,701,900	2,988,000
1981	1,057,273	852,289	1,909,562	12,000	896,428	283,849	3,101,839	6,017,800	3,358,000
1982	928,721 e/	821,303	1,750,024	0	215,873	155,820 e/	2,121,717	6,187,700	5,097,000
1983	483,499	701,370	1,184,869	0	13,019	188,596	1,386,484	5,838,200	5,419,000
1984	723,468 f/	865,043	1,588,511	3,663	259,254	387,505 f/	2,238,933	6,273,100	3,368,000
1985	998,138	1,002,915	2,001,053	9,638	292,372	414,566	2,717,629	6,639,800	3,227,000
Total d/	9,209,162	10,186,214	19,395,376	210,720	5,525,429	2,885,384	28,016,909	76,889,600	54,187,000

a/ Includes preconsolidation repayment water, emergency relief water, regulated delivery of local supply, non-SWP water delivered to Napa County FC&WDC through SWP facilities conveyance of CVP water (including Decision 1485 water), recreation water, and demonstration ground water fill withdrawal.
b/ A recreation day is the visit of one person to a recreation area for any part of one day.
c/ Includes SWP share of generation from Hyatt-Thermalito, San Luis, Devil Canyon, Warne, and Castaic Powerplants.
d/ In addition, SWP dams have prevented millions of dollars worth of flood damage.
e/ Revised and corrected from, Bulletin 132-85 to reflect 557 acre-feet of 1978 exchange water (MWDSC Basin) changed from other water to municipal and industrial use entitlement water.
f/ Revised and corrected from, Bulletin 132-85 to reflect 126 acre-feet of 1982 exchange water (MWDSC Basin) changed from other water to municipal and industrial use entitlement water.

(DWR,461)

TABLE A4-14

DELTA DRINKING WATER DIVERSIONS
AND AREAS SERVED
(From SWC, 76, 6)

DIVERSION POINT (Transfer Facility)	**Area Served**
State Facilities	
Barker Slough[1/] (North Bay Aqueduct)	Solano-Napa County Fairfield Vacaville Vallejo Benicia Napa American Canyon
Clifton Court (South Bay Aqueduct)	Livermore Valley Alameda CWD Santa Clara Valley WD
(California Aqueduct)	Avenal[2/] Coalinga[2/] Kern County WA Antelope Valley MWDSC San Diego CWA Crestline-Lake Arrowhead San Bernardino Valley Palm Springs Indio
Federal Facilities	
Rock Slough (Contra Costa Canal)	Concord Oakley Pittsburg Antioch Martinez Pleasant Hill Walnut Creek
Old River (Delta-Mendota Canal)	Tracy Huron Dos Palos

1/ Cache Slough is used as an alternative diversion point for this transfer.

2/ CVP contractor served from joint-use facilities of the California Aqueduct.

In the future the SWP and the CVP plan to expand deliveries to new areas and to areas experiencing increased need. SWP is studying a Coastal Branch which will supply water to Santa Barbara and San Luis Obispo counties, and an East Branch enlargement which will increase deliveries to the eastern part of the Metropolitan Water District's service area, and to San Bernardino County and the Antelope Valley. CVP is studying an extended San Felipe Branch which will supply water to Monterey and Santa Cruz counties, as well as an American River Aqueduct which will increase deliveries to EBMUD's service area in the Bay Area. SWP is also planning additional transfer and storage facilities at these locations that will increase its water distribution capabilities: the Kern Water Bank, Los Banos Grandes Reservoir, the South Delta, the North Delta Facilities, and additional pumps at the Delta Pumping Plant (DWR,707,42-53).

4.0.9.2 Agriculture

There were about 9.5 million acres of irrigated agricultural land in California in 1980. The Central Valley (not including the Delta) contained approximately 6.9 million acres of this total (DWR, 401,29; DWR,304).

The CVP and SWP export water from the Estuary to support many farming and ranching operations (RWQCB 5, 1975). The main area of agricultural use of export waters is the San Joaquin Valley; three of its counties, Fresno, Kern, and Tulare, ranked first, second, and third in the nation in gross cash receipts from annual farm marketing in 1982 (CVAWU,41). The CVP exports water primarily for agricultural use to the San Joaquin Valley, with smaller amounts exported to other areas (see Table A4-15).

By 1970 the entitlement of agricultural contractors (including exchange contractors1/) to CVP export waters totaled over two million AF/yr (CVPWA,10-1). With the addition of the Cross Valley Canal Unit and expansion of the San Luis Unit, the 1980 total was almost 2.5 million AF/yr (CVPWA,10-1).

TABLE A4-15

CVP EXPORT AREAS

Export Area	**CVP Unit**
San Joaquin Basin	Delta Mendota Canal San Luis Mendota Pool
Tulare Lake Basin	San Luis Cross Valley Canal
Contra Costa County	Contra Costa Canal
Santa Clara & San Benito Counties	San Felipe Unit

1/ Exchange contractors formerly diverted from the San Joaquin River, but exchanged their diversion rights for a contract that granted more consistent water supplies from the DMC. The maximum contractual entitlement of these users is 0.84 million AF/yr (USBR,1987).

During the 1985 Water Year, the various units of the CVP exported a total of about 2.79 million AF of water to serve 1.22 million acres (Table A4-16).

TABLE A4-16

AGRICULTURAL WATER EXPORTS AND SERVICE AREAS
BY CVP UNIT FOR THE 1985 WATER YEAR

CVP Unit	Water Exported (AF)	Area Served (ac)
Delta Mendota Canal (including exchange contractors)	1,050,000 (CVPWA,11;USBR, 1984;USBR,1985)	356,000 (T,XXVI,186:6-8,11-17)
San Luis	1,545,000 (CVPWA,11)	698,000 (T,XXVI,186a:24)
Mendota Pool	94,000 (CVPWA,11)	42,000 (T,XXVI,187:14)
Cross Valley Canal	102,000 (Schafer, 1988)	125,000 (CVPWA,11(b)-3)
Contra Costa Canal	895 (T,XXVI,185:16-21)	
TOTAL	2,792,000	1,221,000

The recently completed San Felipe Unit began deliveries in mid-1987, two contracts for which have been executed totalling 68,600 AF/yr (T,XXVI,194:2-8). The projected water use by the existing CVP contractors is not expected to differ substantially from the 1985 Water Year level (T,XXVI,208:6-8). However, additional CVP supplies are needed to help solve ground water overdraft if present uses are maintained (T,XXVI,209:6-13).

SWP exports water for agricultural use via the California Aqueduct to Oak Flat WD in the San Joaquin Basin, to the Tulare Lake Basin and to southern California, and via the South Bay Aqueduct to Santa Clara and Alameda counties. The volume of SWP deliveries to the 13 southern California contractors for agricultural use was not identified in the hearing record. The annual SWP exports for agricultural use (excluding southern California) increased from about 237,000 AF in 1968 to about 1.3 million AF in 1985 (DWR,461). The future demand for exported SWP water for agriculture should not change substantially from this 1985 amount (DWR,707,11). However, additional SWP supplies are needed to help solve ground water overdraft (SWC,412,5).

The main change in agricultural production in the San Joaquin Valley since 1955 has been the increased acreage devoted to the production of vegetables, fruits and nuts (CVAWU,26). The acreage of vegetables increased from about 250,000 acres in 1955 to almost 400,000 in 1985. The acreage devoted to the production of fruits and nuts increased from about 550,000 acres in 1955 to about 1,300,000 acres in 1985 (CVAWU,26). The acreages of field crops and seeds in the San Joaquin Valley have remained relatively stable since 1955. Overall, the acreage devoted to these four major commodity groups (vegetables, fruits and nuts, field crops, and seeds) in the San Joaquin Valley has increased about 25 percent from 1955 to 1985, from about 3.7 million acres to about 4.6 million acres (CVAWU,26).

In 1985, the CVP units listed in Table A4-16 delivered over 2.7 million AF of water to over 1.2 million acres in the export areas of the San Joaquin Valley to produce crops with a gross value of about $1.2 billion (CVPWA,12&13; EDF,11,G-148) (Table A4-17). These numbers do not include the contribution from the Friant-Kern Canal, Madera Canal, or Millerton Lake units of the CVP. These units are considered to be in the upstream areas of the San Joaquin Valley, not the export area.

In 1985, the SWP delivered over 1.3 million AF of water to about 445,000 acres of the San Joaquin Valley to produce crops with a gross value of about $431 million (DWR,489h) (Table A4-18). These numbers do not include the agricultural uses of water in southern California.

TABLE A4-17

MAJOR CROPS GROWN IN THE CVP EXPORT AREA
BY ACREAGE AND APPROXIMATE GROSS CASH VALUE
(from DWR, 489 h)

Crop	**Acreage[1/] (thousands of acres)**	**Gross Cash Value[2/] (millions of dollars)**
Cotton	446	357
Alfalfa	104	66
Wheat	87	22
Tomatoes	84	125
Melons	51	128
Barley	42	6
Other	407	529
TOTAL	1,221	1,200

1/ CVPWA,12; EDF,11,G-148

2/ CVPWA, 12&13; EDF,11,G-148. Values of an average crop ($/acre from CVPWA 12&13) are multiplied by crop acreages for the exchange contractor area (from EDF,11,G-148) to get appropriate cash value.

TABLE A4-18

MAJOR CROPS GROWN IN THE SAN JOAQUIN VALLEY PORTION
OF THE SWP EXPORT AREA
BY ACREAGE AND GROSS CASH VALUE
(From DWR,489 h)

Crop	**Acreage (thousands of acres)**	**Gross Cash Value (millions of dollars)**
Cotton	210	154
Alfalfa	40	27
Almonds	35	26
Wheat	30	9
Pistachios	18	28
Wine grapes	18	13
Table Grapes	6	28
Oranges	4	19
Carrots	5	18
Other	79	109
TOTAL	445	431

Since water usage and acreage for livestock, poultry, and dairy production were not separately identified in the hearing record by CVP or SWP export areas, an accurate account of the effect of export water on the market values of these products cannot be given. In addition, because these areas often use supplemental water supplies from ground water and local sources, only a part of the value of agricultural production in the export area can be directly attributed to project exports. An indirect indication, however, can be made from the fact that the market value of livestock, poultry and dairy products for the entire San Joaquin Valley in 1982 was over half the value of all crops (CVAWU,28):

	1950	**1969**	**1982**
Crops	$455 million	$933 million	$4,039 million
Livestock, Poultry Dairy	$199 million	$751 million	$2,053 million

4.0.9.3 Fishery Habitat

Export fishery habitat consists primarily of the reservoirs and conveyance channels used for movement and storage of Bay-Delta water south of the Delta. In all cases this habitat may be classified as warm water fishery habitat. The major facilities discussed here and in Section 4.0.9.5 (Export Recreation) are:

- San Joaquin Valley and San Francisco Bay Area

Delta-Mendota Canal, San Luis Canal, Edmund G. Brown California Aqueduct, Lake Del Valle, Bethany Reservoir, San Luis Reservoir (and O'Neill Forebay), and Los Banos Grandes Reservoir.

- Southern California

West Branch California Aqueduct (Pyramid Lake, Castaic Lake), East Branch California Aqueduct (Silverwood Lake, Lake Perris) (SWC,65,6).

Recreational access at all SWP facilities is shown in Figure A4-7 (SWC,65,6). Expansion of this habitat will not occur unless additional facilities are built (e.g., Los Banos Grandes Reservoir) (DWR,707).

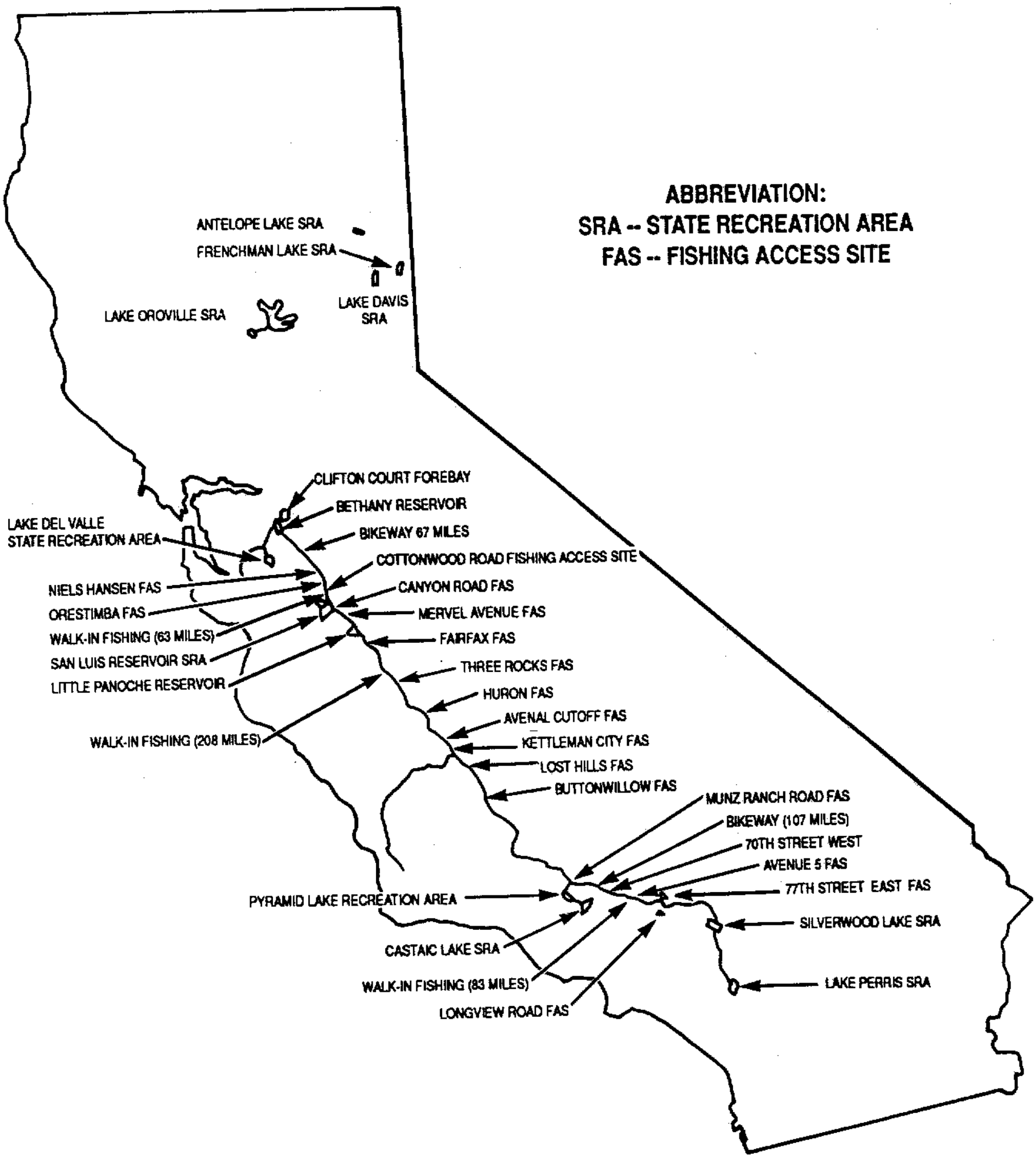
Some of the eggs and larvae of some fish entrained into the export pumps survive and develop in the aqueducts and some of the reservoirs such as Bethany Reservoir and San Luis Reservoir (and O'Neill Forebay) (SWC,65,45). The hearing record is unclear whether these populations are self-sustaining or are maintained by additional entrainment. In other reservoirs, the majority of fish are planted for recreational fishing (SWC,65,47) (see Section 4.0.9.5). (It was inferred from SWC,65,47 that DFG plants the fish in these reservoirs, but no direct evidence was presented.) No information was presented on which species are planted, or what percent of total statewide fish planting is dedicated to SWP facilities.

The aqueducts tend to provide a relatively stable habitat for fish because the export water quality is determined by municipal and industrial standards, and because water depth in the aqueducts does not change. In some reservoirs, such as San Luis, the habitat may change significantly due to either seasonal variation in temperature or drawdown to meet water demands. The San Luis Reservoir recreational storage objective for Labor Day is 6,900 acres of surface area, or approximately half the surface area of the full reservoir (DWR,708,14). This converts to an 83 percent reduction in storage and, therefore, a significant reduction in fishery habitat. Other reservoirs, especially the terminal SWP reservoirs in southern California, are operated to retain more stable water levels because of the level of recreational activity on them (T,XXXIX,122:2-9) and the potential need as an emergency water supply in the event of an aqueduct outage. DWR presented the specific operating criteria for their facilities (DWR,708).

4.0.9.4 Export Wetland Use

Water exported from the Sacramento-San Joaquin watershed provides some marsh and riparian habitat wherever it is delivered. Examples of important wildlife uses may be found in a number of export areas (SWRCB,14,III-9). Water in SWP reservoirs and in wildlife areas in southern California provides aquatic habitat where there might formerly have been none or replaces wetland habitat which was damaged or destroyed by earlier urbanization or water development. Substantial waterfowl habitat is maintained with DMC water in the Grassland Water District, an area that formerly received water from San Joaquin River overflows and agricultural return flows which ceased when Friant Dam began operations (EDF,11,II-2).

FIGURE A4-7 State Water Project Recreation Developments
(From: SWC, 65,6)



SOURCE: DWR BULLETIN 132-86

4.0.9.5 Export Recreation

The aqueducts and reservoirs in the SWP[1/] facilities are used for recreation in both central and southern California. Fishing and bicycle riding are the main activities along the aqueducts, and numerous fishing access points are available along them (SWC,65,6) (see Figure A4-7). The reservoirs are used for a wide variety of water-contact and non-water contact activities, including fishing, swimming, boating, waterskiing, camping, picnicking and bird watching (SWC,65,5). About five million visitors used the SWP facilities south of the Delta in 1985, and they spent an estimated $95 million to travel to and use these sites (SWC,65,7,14). More than one million game fish were stocked in 1985 (SWC,65,7) to support recreational fishing activity in the four southern California SWP reservoirs. No evidence was presented on alternative sites for freshwater recreation in southern California.

1/ Discussion is limited to recreational activities directly related to export facilities of the SWP. No information was provided on recreation at CVP export facilities other than those used jointly by the CVP and SWP, which are included in the SWP descriptions. These facilities are listed in Section 4.0.9.3 (Export Fishery Habitat).

APPENDIX 4

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APPENDIX 5.0
ADVOCATED LEVELS OF PROTECTION

The objectives advocated by various parties for the protection of beneficial uses of Bay-Delta waters are discussed below.

5.0.1 Municipal and Industrial

5.0.1.1 Salinity and Sodium

Advocated Levels of Protection

The following organizations have recommended that the D-1485 objectives be retained in total or in part to protect M&I use (DWR,280; T,LIX,189:1-7; T,VI,125:4-15). Modifications to D-1485 M&I standards were recommended by DWR, USBR, SWC, MID/TID, CVPWA and CCWD. DWR and USBR are unified in their recommended modifications; SWC's recommended modifications are similar to those made by DWR and USBR. The parties' recommendations, presented in Table 5-5, are:

o DWR and USBR

Eliminate the 250 mg/l maximum mean daily chloride quality standard at Cache Slough. The City of Vallejo will divert water from the newly finished North Bay Aqueduct; the Cache Slough diversion point will only be used as a secondary M&I supply source (DWR,280).

Add a quality objective at the North Bay Aqueduct intake at Barker Slough. The recommended objective would be set at a maximum mean daily chloride level of 250 mg/l for all water year types. Barker Slough is an M&I diversion point for Napa, Vallejo, and Sonoma counties (DWR,280).

o DWR, USBR, SWC, MID/TID, and CVPWA

Eliminate the 150 mg/l chloride quality standard at both the Antioch Water Works Intake on the San Joaquin River and the Contra Costa Canal Intake at Rock Slough. This standard is set to protect industrial uses in the Antioch-Pittsburg area. The recommendation to eliminate this standard is based on the evidence indicating that diversion of water for industry of this quality at Antioch is not reasonable when considering the Delta outflow required to maintain it (DWR,280; T,LIX,149:12-20; WQCP-MID/TID-7, 13; WQCP-CVPWA-205,2).

Add quality objectives at Old River near Rock Slough and Cache Slough near Junction Point. The recommended objectives would be set at a maximum mean daily chloride level of 250 mg/l for all water year types. These objectives will help in determining an "allocation of responsibility" for meeting the standard at the Contra Costa Canal Intake, the North Bay Aqueduct Intake, and the City of Vallejo Intake (DWR,280; T,VI,97:8-19; T,LIX,213:8-214:8; WQCP-DWR-14,7).

- CCWD

  A goal of providing the "best achievable" water quality for drinking water supplies should be promoted (WQCP-CCWD-20,8).

  Retain the 150 mg/l chloride objective for protection of M&I use, including disinfection by-product concerns, as specified in the Delta Plan (WQCP-CCWD-20,1).

  Add a 50mg/chloride objective for the protection of M&I use for portions of all years, except during prolonged droughts (WQCP-CCWD-20,1).

  Add a quality objective at the site of the future intake to the Kellogg/Los Vaqueros Reservoir. The location of the intake has not yet been determined. The recommended objective would be set at a maximum chloride level of 50 mg/l for the months of April through June (T,VII,57:1319; T,VII,118:16-120,9).

Fibreboard Louisiana-Pacific Corporation (Fiberboard), a witness for CCWD, presented the only testimony that supported the need for process water containing not more than 150 ppm chloride for the production of linerboard (T,IX,75:23-81:23). To keep the chlorinity in their linerboard (used in corregated boxes) at levels which will not corrode canned goods, this process water is kept below 150 mg/l chloride (T,IX,75:23-81:23). When the chlorinity in the San Joaquin River supply is higher than 150 mg/l, a partial supply of water is purchased from CCWD; when the chlorinity level reaches 250 mg/l, the entire supply is taken from the Contra Costa Canal (T,IX,77:23-78:6).

5.0.1.2 Trihalomethanes (THMs) and other Disinfection By-Products (DBPs)

<u>Advocated Levels of Protection</u>

Parties who presented testimony and exhibits on the issue of THMs included CCWD, DWR, EBMUD, SWC, the Palmdale Water District, and the cities of San Francisco, Tracy, Avenal, Coalinga and Huron.

The following alternatives were discussed by the parties cited during and after the Phase I hearings.

- SWC, CCWD, and California Urban Water Agencies

  Several alternatives for source control of THMs were put forth.

- Discharge Delta island agricultural drains downstream of the Delta to eliminate the contribution of THM precursor materials from the Delta islands (T,XLVI,141:11-142:10).

- Take Municipal and Industrial water supplies from tributary streams above the Delta (T,XLVI,136:7-13; Brown and Caldwell, 1989, 4-35).

- Treat the Delta island agricultural drainage before discharge into the surrounding channels (Brown and Caldwell, 1989, 4-35).

Chlorine is currently the disinfectant of choice for most municipalities (T,VI,129:5-16). In order to meet the anticipated EPA treated drinking water quality standards for THMs and DBPs, municipalities may be required to modify present treatment plants, construct major new facilities, and apply new technology to achieve more stringent levels of treatment (T,XLVI,121:22-122:16). Two possible revised treatment scenarios were discussed:

- Disinfect with ozone followed by chloramination to maintain a disinfectant residual in the distribution systems used to distribute domestic water. However, ozonation of water with high levels of bromide or TOC can still produce DBPs of health concern concentration levels; or

- Use granular activated carbon (GAC) adsorption to remove dissolved organics followed by disinfection with chlorine. However, data were presented which indicate that GAC absorption for removing THM precursors from Delta water may be "extraordinarily high". Furthermore, it was stated that GAC would require frequent regeneration and that California air quality standards may not allow siting of GAC regeneration furnaces in the state (T,46,138:5-142:10;WQCP-SWC,601,12-18).

o Metropolitan Water District of Southern California (MWD)

  MWD discussed the possibility of the State Board developing a water quality objective for THM precursors in Delta water that is to be used for domestic purpose (T,XLVI,142:3-5), thus shifting the burden of treatment for THMs from the domestic water supplier to the source of the THM precursors.

o Delta Municipal and Industrial Water Quality Workgroup

  The Delta M&I Workgroup submitted several statements on THMs in its October 1989 draft report to the Board although there were dissenting opinions voiced by members representing organizations in the workgroup.

  Bromide and chloride are correlated in Delta waters; thus, a chloride objective can be set for the purpose of maintaining sufficiently low levels of bromide to ensure that treated domestic water supplies do not contain excessive levels of brominated THMs or other brominated DBPs.

  Future EPA MCLs for treated domestic water supplies may be more stringent, and will be difficult to meet unless bromide levels in raw water supplies from the Delta are less than 0.15 mg/l (corresponding to chloride levels below 50 mg/l).

Total organic carbon (TOC) in water supplies contributes to production of THMs as well as that of other DBPs in water treatment plants. A reduction in Delta water TOC levels will aid in meeting expected drinking water MCLs for THMs and DBPs.

Agricultural drains, Delta channels and tributary streams are sources of the TOC and THMFP levels in raw domestic water supplies taken from the Delta. THMFP levels in Delta agricultural drain waters often exceed the THMFP levels in adjacent channels by factors of ten or more.

Data collected at the water treatment plants of several of the members of the Workgroup show definite relationships between raw water bromide levels and treated water levels for several DBPs. On the basis of those relationships and the bromide to chloride correlation observed in Delta water, the Workgroup recommended that a 50 mg/l chloride water quality objective, when feasible, be set for Delta Municipal and Industrial water supply intakes for the purpose of maintaining bromide levels below 0.15 mg/l.

The Workgroup recognizes that meeting a 50 mg/l chloride water quality objective throughout the Delta at all times is not feasible under all water supply conditions with the physical distribution and storage facilities presently available to the major water suppliers (e.g., DWR and USBR) or the water purveyors (e.g., CCWD, MWD, EBMUD). Because of their ability to store high quality water for subsequent blending with waters of lesser quality, various proposed facilities, such as the Buckhorn, Los Vaqueros and Los Banos Grandes offstream storage reservoirs, may help reduce the period of time the recommended 50 mg/l chloride water quality objective would need to be met in the Delta. However, not all M and I users of Delta water have access to offstream storage facilities to receive such benefits. Other facilities and solutions should be studied and evaluated to help determine a strategy for meeting the recommended 50 mg/l chloride objective.

Several parties to the Workgroup recommended that, in the short term, salinity levels be provided at the Delta water supply intakes which are less than or equal to those achieved under current water quality objectives.

- California Department of Water Resources

  During Phase I of the Bay-Delta proceedings, DWR recommended that the construction of Delta facilities should be considered as potential means to improve project (SWP and CVP) operational flexibility and export water quality. The facilities recommended for consideration were North and South Delta channel improvements, enlargement of Clifton Court Forebay, relocation of the Contra Costa Canal Intake, and additional pumping capacity at the Harvey O. Banks Pumping Plan.

  DWR did not concur with the Delta M&I Workgroup statements, based on the following four points:

- EPA's Strawman Rule for THM standards is very preliminary, and it is premature to use this "rule" as the basis for making Delta water supply decisions of great importance to California.

- DWR disagrees with the recommendation to set a chloride objective for the purpose of maintaining sufficiently low levels of bromide. The reason for this is that chloride is added to surface waters by activities such as the use of fertilizers. Chloride is also leached from soils and is contributed by shallow ground water. There is no reason to believe that these sources of chlorides also add bromides in the classic seawater ratio of .003 BR:Cl. Therefore, the chloride vs. bromide relationship may vary significantly at different locations in the Delta.

  Significant data are only now being collected to prove or disprove this relationship. Also, new technology now makes direct bromide measurements practical; therefore, bromides should be specifically addressed in the salinity plan.

- Meeting a 50 mg/l chloride objective at M&I stations with the present configuration of the Delta would reduce critical period water supplies by over 1 million acre-feet per year.

- DWR recommends against setting a total organic carbon objective because their data indicate that TOC and THM formation potential often do not correlate well.

5.0.2 Agriculture

Advocated Levels of Protection

o Central Delta Water Agency (CDWA)

Water Quality Objectives:

The agricultural water quality objectives for the Delta should be set at a minimum water quality of 0.45 mmhos/cm EC year round except for "relaxations" in the drier months of drier years. The objective should not require a "leaching regimen" more rigorous than "winter flooding" or "fall subirrigation" more frequently than once in three years (CDWA,Brief,26-27).

Monitoring Locations:

The CDWA requests that monitoring stations be established at Old River near Holland Tract or Rancho Del Rio and on Turner Cut near McDonald Island Bridge, in addition to those previously established by the Delta Plan at Emmaton, Jersey Point, San Andreas Landing and Terminous (CDWA,Brief,27).

- o Central Valley Project Water Association (CVPWA)

  Water Quality Objectives:

  The Delta Corn Study provides adequate data from which to establish salinity objectives for Delta agriculture. (WQCP-CVPWA-205,3).

  Objectives should be established at 1.5 mmhos/cm EC for the April 1 through August 15 period at Emmaton and Jersey Point. This objective should be adjusted to 2.78 mmhos/cm EC at Emmaton, and 2.20 mmhos/cm at Jersey Point in critical water years. No objectives need be established for the areas of the Delta covered by contracts with the Department of Water Resources. DWR currently meets the Delta Plan standards in contracts with ECCID and NDWA (CVPWA,Brief,49; WQCP-CVPWA-205,14).

- o Contra Costa Water Agency (CCWA)

  Water Quality Objectives:

  To achieve a 100 percent yield of corn, CCWA recommends that the EC water quality standard necessary be set at 0.45 mmhos/cm for organic soils in the Delta (CCWA,Brief,17).

- o Contra Costa Water District (CCWD)

  Water Quality Objectives:

  Agricultural discharges in the Delta should be monitored and regulated. (WQCP-CCWD-20,1).

- o Delta Tributaries Agency Committee (DTAC)

  Water Quality Objectives:

  DTAC recommends that the Delta Plan agricultural standard for the Central Delta be relaxed and that it range from 1.5 to 2.5 deciSiemens/meter in all but critical years (one deciSiemen/meter is equal to one mmho/cm EC). No objectives were suggested for critical years (DTAC,Brief,6).

  Leaching Objectives:

  Water quality standards should be carefully established "to provide fall leaching water at the levels needed to leach a necessary minimum amount of salt from the crop root zone of Delta soils, but such leaching standard should be related to the quantity of water available for such leaching" (DTAC,Brief,6-7).

Southern Delta Objectives:

DTAC recommends that the Board impose a short timetable for completion of the negotiations between SDWA, DWR, and USBR. Pending completion of such an agreement, the Board should require elimination of reverse flows in the San Joaquin River which are attributable to export pumping, and require continuance of Delta Plan standards (DTAC,Brief,6-7).

- Department of Water Resources (DWR)

Water Quality Objectives:

"Water quality objectives for the western and central Delta should be based upon the results and information derived from the Corn Study" (DWR,Brief,28). No specific numerical water quality criteria were recommended.

Monitoring Locations:

DWR recommends that specific Delta agricultural objectives for the irrigation season should be adopted for the following locations: (1) Sacramento River at Emmaton; (2) San Joaquin River at Jersey Point; (3) Mokelumne River at Terminous; (4) San Joaquin River at San Andreas Landing; and (5) Cache Slough near Junction Point (DWR,Brief,30-31). Furthermore, the water quality objective at Emmaton should be eliminated when overland water supply facilities are developed for Sherman Island (DWR,Brief,32). The objective would be moved to the intake of the overland facilities.

Southern Delta Objectives:

Negotiations should be completed among the DWR, USBR, SDWA to provide permanent solutions to the problems of local water level, water quality and circulation in the southern Delta (DWR,Brief,32).

- North Delta Water Agency (NDWA) and East Contra Costa Irrigation District (ECCID)

Water Quality Objectives:

NDWA and ECCID recommend that no change be made in Delta agricultural water objectives which would impair the contractual rights and obligations embodied in the contracts among NDWA, ECCID, and DWR (NDWA,Brief,2). These standards are outlined in summaries of testimony for ECCID and NDWA.

o South Delta Water Agency (SDWA)

SDWA advocated two sets of recommendations. The first are recommendations with no southern Delta facilities (SDWA,115,1-2). The second are recommendations with southern Delta facilities (SDWA,116,1-2).

Water Quality Objectives (Without Facilities):

SDWA recommends that water quality at any monitoring point should not exceed an average of 400 mg/l TDS for the period March 1 through September 30 and must not exceed 400 mg/l TDS on a seven-day running average between March 1 through June 30 and 500 mg/l TDS seven-day running average between July 1 and October 31. A TDS of 550 mg/l would be the maximum permissible seven-day running average between November 1 and February 28 (T,XV,31:15-31:23).

SDWA also recommended that the minimum monthly flow at Vernalis be adequate to maintain the above water quality.

Monitoring Locations (Without Facilities):

SDWA proposes monitoring for water quality in the San Joaquin River near Vernalis, Mossdale, the bifurcation of Middle River and Old River, Middle River at Howard Road Bridge, San Joaquin River at, or near, the former location of Brandt Bridge, Old River at Tracy Boulevard, and Old River at Westside Irrigation District intake (SDWA,115,1).

Water Quality Objectives (With Facilities):

"Water quality required at the inflow points would be specified as a function of net daily inflow rate and of channel depletion by months for the channel reaches receiving water from each inflow point. The values would be initially determined by mathematical modeling of the system to give water quality equivalent to the no barrier standards. The required net daily inflow rates at each inflow point would be in accordance with a monthly schedule sufficient to maintain the required unidirectional net daily flow in each channel reach" (SDWA,116,2).

Monitoring Locations (With Facilities):

"Water quality would be monitored at Vernalis, on the downstream (intake) side of each barrier, at the former location of Brandt Bridge on the San Joaquin River north of Old River, and at Tracy Boulevard on Grant Line Canal. Flow would be measured at Vernalis and through each barrier" (SDWA,116,1-2).

o State Water Contractors (SWC)

Western and Interior Delta:

The State Water Contractors believe that the Corn Study provides adequate data, and the State Board should use the Corn Study as a basis for setting new salinity objectives in the western and interior

Delta. Western Delta agriculture can be protected at full yield with a 1.5 mmhos/cm EC applied water objective, in combination with winter leaching operations and rainfall to maintain the soil salinity below the corn salt tolerance level prior to planting. In critical hydrological years, the applied water objective should be relaxed to 2.78 mmhos/cm EC at Emmaton and 2.20 mmhos/cm EC at Jersey Point for the growing season. New objectives should be based on a 28-day running average to coincide with the lunar cycle.

With regard to the protection of Delta agriculture in the interior Delta, the existing D-1485 agriculture salinity objective of 0.45 mmhos/cm EC at San Andreas Landing and Terminous should be maintained, at least until completion of the leaching studies discussed below. The 14-day running average in D-1485 should be changed to a 28-day running average.

Additional leaching studies initiated in the DWR-sponsored Western/Interior Delta Agriculture Workgroup are needed. The new leaching studies are appropriately focusing on the cost and effectiveness of existing leaching practices that growers have described in the workshop sessions. A winter leaching objective is not needed for reasonable protection of Delta agriculture.

Monitoring Locations:

The measuring station at Emmaton in the Sacramento River should be relocated to Three Mile Slough upon completion of overland water supply facilities to serve Sherman Island (SWC,Brief,I-43).

Southern Delta:

"The 1978 Delta Plan southern Delta salinity objectives should <u>not</u> be implemented."

Better water quality for the interior stations within the southern Delta will probably be obtained by implementing the agreement (between SDWA, the Bureau, and DWR) that will provide a permanent solution to the southern Delta's water level and quality problems. Therefore, the State Board can be assured the three-party agreement will provide the water quality protection needed within the southern Delta.

- Bureau of Reclamation with support from the U.S. Department of Interior

Western and Interior Delta:

The results of the Corn Study, presented in Phase I of these hearings, supports an objective of 1.5 mmhos/cm EC. (WQCP-USBR-126,1).

Southern Delta:

The USBR presented testimony on the leaching requirements for beans, fruit and nuts, vineyards, corn and alfalfa, the five most salt-sensitive crops grown in the Delta uplands (USBR,10A&10B; USBR,14A&14B). From these leaching requirements, average irrigation season water quality objectives of 800 mg/l TDS in a normal water year and 600 mg/l TDS in a dry one were developed for Delta agriculture (T,XV,139:15-139:21). USBR did not formalize these requirements into recommendations (T,XV,140:3-140:9).

5.0.3 Fish and Wildlife Beneficial Uses

5.0.3.1 Fishery Habitat Protection (Entrapment Zone) in the Bay-Delta Estuary

Advocated Levels of Protection:

o CCWA/EDF

CCWA/EDF recommend that the entrapment zone be maintained in upper Suisun Bay for maximum phytoplankton abundance. The recommended objective is a 28-day tidally-averaged mean bottom salinity at Chipps Island of 2 ppt TDS or less from April through September, except in a one-in-twenty dry year. This objective would result in a maximum habitat area occurring (CCWA/EDF,1).

They also suggest that a flow objective be set for the period from April through June to position a second entrapment zone in San Pablo Bay. This objective would apply in all years except those when the unimpaired Delta outflow for the prior October through March period is less than the 30-percentile dry year, as determined by the average October-through-March unimpaired Delta outflow (CCWA/EDF,3).

CCWA/EDF concluded that grazing by benthic organisms can have a significant inhibiting effect on the standing crop depending upon the relative rates of removal versus the rates of production (T,XLVI,29:8-10). In order to limit the intrusion of marine benthic organisms into Suisun Bay, CCWA/EDF recommend that the tidally-averaged bottom salinity at Martinez should be less than 5 ppt over at least a 28-day period between October and April (CCWA/EDF,2). The standard would not apply in the event of a one-in-20 dry year as determined by unimpaired Delta outflow (CCWA/EDF,2).

5.0.3.2 Chinook Salmon

Advocated Levels of Protection

Most of the parties presenting testimony on Chinook salmon agreed that specific causes of salmon mortality upstream and in the Delta should be addressed to improve survival rates of juvenile fish. The major differences dealt with: (1) when, where, and what actions should be taken; and (2) which factors were the most influential on adult and/or young salmon survival and production. Only the fishery agencies and environmental groups presented proposed levels of protection that differed significantly from current State Board objectives.

The primary factors identified by the USFWS, DFG and others that improve smolt survival in the Delta are: (1) higher spring flows, (2) water temperatures below the stressful range of about 66° to 68°F, (3) minimizing the adverse impacts of water diversion that transport Sacramento Basin fish through the Delta Cross Channel and Georgiana Slough, (4) minimizing reverse flows that transport San Joaquin Basin fish away from their normal migration routes to CVP and SWP export pumps, and (5) minimizing diversions into upper Old River in the San Joaquin River Delta (T,XXXVI,156:21-23; USFWS,31,62).

Following the September 1987 testimony on Chinook salmon, a five-agency working group was formed to begin discussions on how to deal with problems identified at that time. Membership includes staff from the USFWS, DFG, NMFS, USBR, DWR, and consultants from these agencies (T,XLIII,78:12-23). Other groups such as the SWC and DTAC have participated in the discussion and planning process. A document summarizing the general goals listed possible actions to achieve these goals (DFG,65).

The goal set forth by the five-agency working group is to "...analyze actions which will improve the survival rates of juvenile salmon migrating downstream through the Sacramento or San Joaquin Rivers and the Delta" (DFG,65,2). The group plans to evaluate the cost and effectiveness of various actions proposed to increase salmon survival (DFG,65,2). These actions included evaluation of ways to increase or modify: current Delta flows, physical structures and/or operational changes to enhance survival and food supplies and to decrease diversion losses, and water temperatures (DFG,65,4-5).

The positions of the various parties on water quality and related issues with regard to Chinook salmon in Phase I of the hearings are summarized below.

o SWC (SWC,201,22-27; T,LIX,170:7-173:13)

SWC recommended current striped bass flow standards be maintained as the salmon flow objectives until adequate data are available to determine whether changes are required.

SWC also recommended that the State Board adopt a salmon-management program including: short-term measures to increase the number of salmon spawning in the streams and rivers of the Central Valley; a comprehensive program of research, monitoring and full scale testing to provide the basis for developing a long-term program to achieve the goals.

o DWR (T,XLIII,219:2-221:8)

Having presented data on the impacts of elevated temperatures on smolt survival, DWR did not propose any modifications in operation or flows in the Delta to minimize the impacts. DWR recommended that the existing striped bass standards should be the salmon standards.

- USBR (T,LXI,120:24-131:6)

  USBR recommended: An increase in natural salmon production; development of a system-wide management plan that addresses conditions in all salmon habitats; structural solutions, such as screens, to improve Delta survival instead of flow increases since structural solutions would minimize impacts on other beneficial uses; continuation of interagency studies and refine monitoring to determine effectiveness of new programs; operational flexibility to respond to recommendations of the five-agency salmon group, and no change in existing standards until the recommendation of the five-agency salmon group can be evaluated.

- DTAC, TID/MID (DTAC,Brief,9-14)

  DTAC and TID/MID recommended that the smolt survival index not be used as a standard. Field studies using wild salmon should be carried out to address the effects of temperature on salmon survival and DFG, USFWS and NMFS should examine the effects of fishery management policies on salmon escapement.

- USFWS (USFWS,31,31d-j and 47)

  USFWS recommended: The protection of Sacramento Basin fall-run smolts from April 1 through June 30 and San Joaquin Basin smolts from April 1 through June 15; the elimination of reverse flows during smolt emigration; the prevention of delays to adult migrants; and maintenance of unobstructed migration routes. Survival goals could be achieved by a combination of flow, operational and physical modifications. USFWS also recommended that the dissolved oxygen levels be maintained above 5 mg/l between Stockton and Turner Cut in the San Joaquin River in the fall months. No other participants made specific recommendations in regard to dissolved oxygen levels in either the San Joaquin or Sacramento rivers.

  The USFWS recommended that salmon not be diverted from the Sacramento River at Walnut Grove, from the San Joaquin River at its junction with Upper Old River, and that water temperature be decreased to protect Delta salmon if it can be accomplished with a net benefit to fish.

- NMFS (T,LXI,22:24-28:4)

  NMFS recommended that: In the Sacramento River system, Delta smolt survival for all four races should be that which occurred under 1940 levels of water development; the Plan should contain a blend of physical and operational management measures as well as some increment of flow increase to improve smolt survival; and interim standards should be established for the San Joaquin River System to improve salmon production.

- o DFG (T,XLIII,76:24-80:24; DFG,64 and 30)

  DFG recommended that: survival of each race in the Delta should be based on 1940 historical levels; survival rate for Sacramento Basin fall-run salmon should be based on the USFWS flow to survival relationship in Exhibit 31; flow reversal should be eliminated by 1995 in the San Joaquin River and in Old and Middle rivers; survival levels in the San Joaquin River should also be based on historical levels (but these still need to be defined); and physical and operational measures should be considered to achieve protection.

- o BISF (BISF,Brief,85-86 and 93-98)

  BISF recommended that there should be objectives for wet, median, and dry year spring flows at levels greater than D-1485; and that outflows could be reduced in dry years provided compensating flows are available in other years. BISF also supported other measures proposed by USFWS.

5.0.3.3 Striped Bass

Advocated Levels of Protection

The issue of what to do about the decline in striped bass dominated much of the exhibits and testimony in Phase I and the Water Quality Phase, and the debate continues. Two main positions have evolved out of the debate. The first position is that there is still not enough known about the cause(s) for the decline of striped bass or that causes other than water quality problems are responsible for the decline; therefore, the current objectives should remain in effect. In particular, greatly enhanced springtime flows, as advocated by DFG, USFWS and other participants in Phase I, should not be instituted at this time, but other interim measures, such as increased hatchery production, should be implemented (SWC,203,4-5).

The second position is that, for whatever reasons, the striped bass are in serious decline and something substantial needs to be done now, even if we do not know all the answers. In particular, the current objectives are not providing adequate protection and should be modified to provide increased springtime Delta outflow and greater curtailments of spring and early summer exports for protection of young bass (USFWS,47,5; DFG,64,6; WQCP-USFWS-5).

The recommendations proposed by the participants fall into three major categories: flow and diversions, salinity and temperature, and "other". This third category includes operational changes, monitoring, physical facilities, special studies, changes in fishing regulations, control of pollution sources, and other non-water quality, non-flow recommendations. The only recommendations discussed here are those relating to development of salinity and temperature objectives.

- Salinity

  For striped bass, the major issue relating to salinity was the establishment and maintenance of a suitable spawning area in the lower San Joaquin River. Current D-1485 objectives establish a spawning area between Antioch and Prisoners Point. DFG data show that striped bass do not migrate upstream into the eastern Delta past locations where the EC is greater than 0.55 mmhos/cm (DFG,25,44-46). In addition, the majority of striped bass apparently prefer to spawn in water of less than 0.3 mmhos/cm EC. DFG has testified that the formation of a salinity barrier in the mainstem San Joaquin River above Venice Island tends to restrict spawning runs and spawning activity in that area (T,XLI,68:1-69:10). DFG also testified that historically striped bass did spawn above the Delta in the San Joaquin River system, but this activity has diminished due to reduced flows and degraded water quality (T,XLII,56:5-19).

  No participant other than DFG discussed the spawning zone salinity issue in Phase I (except indirectly by recommending continuation of the current D-1485 objectives). Those participants who wanted to make changes in these objectives recommended increases in Delta outflow or reductions in allowable export levels, rather than salinity changes. The spawning zone issue received considerably more discussion in the February 1990 Workshop and the August 1990 hearing. The water development community generally opposed any significant changes in the present objectives at this time, while DFG and USFWS agree that expansion of the habitat would be desirable. Salinity protection discussions are found in Section 5.6.2 and in Appendix 5.4.5.

- Temperature

  No participant advocated any temperature protection objectives for adult bass migration or spawning, or for young bass survival. A review of two DWR exhibits and other relevant information on temperature effects on striped bass is presented in Appendix 5.4.6.

5.0.3.4 American Shad

Advocated Levels of Protection

TIBCEN and USFWS recommended flows for protection of American shad; USFWS also recommended certain operational modifications to provide additional protection. BISF made no specific recommendations for American shad, but did recommend flows for the entrapment zone to provide adequate food. USBR recommended more comprehensive management of the system for protection of American shad and other resources (USDI,Brief,24). All other participants either made no recommendation or indicated that current objectives, or new objectives advocated for the protection of striped bass, would also provide adequate protection for shad. None of the proposed objectives were for salinity or temperature, except as related to the current D-1485 objectives for protection of striped bass spawning habitat.

5.0.3.5 Delta Smelt

Advocated Levels of Protection

No specific recommendations for water quality objectives for the Delta smelt were discussed during Phase I.

Since conclusion of the Phase I hearings, a petition has been filed with the California Fish and Game Commission requesting that Delta smelt be added to the list of endangered species under the California Endangered Species Act (See Appendix 4.0.5.1). The Delta smelt was a candidate species for the state endangered species list for one year. DFG reviewed the petition and pertinent data and recommended that the species be listed as threatened. The Fish and Game Commission at the August 31, 1990 meeting decided that there was insufficient evidence to list the species. Consequently, the Delta smelt presently has no legal status under the California Endangered Species Act. Under the federal Endangered Species Act (Federal Register, Volume 154, No. 4) the Delta smelt is listed as a category 1 species. USFWS was petitioned in June, 1990 to list the Delta smelt as a federal endangered species. (See Appendix 4.0.5.1). A number of possible factors in the Delta could be contributing to the population decline. However, the petition recommended that the "... best and probably only way of preventing it (Delta smelt) from becoming extinct is to maintain high enough freshwater outflow through the Delta to keep the entrapment zone in Suisun Bay during March, April, May and June for most years. The entrapment zone should not be upstream from Suisun Bay for more than two years in a row" (Moyle and Herbold, 1989).

5.0.4 Suisun Bay Wildlife Habitat Beneficial Use

5.0.4.1 Suisun Marsh

Advocated Levels of Protection

o DWR, USBR, DFG, SRCD--Suisun Marsh Preservation Agreement (SMPA)

  At the Phase I hearing addressing wildlife, DWR provided testimony and exhibits describing the measures taken by DWR, USBR, DFG and SRCD (called the Four Parties) to meet the Delta Plan requirements (DWR,503; 504; 506A; 506B; 507A; 507B; 508A; 508B; 509; 510; 511; 512; 513; 514; 517 A-B; 518; 519; 520 & 521). The measures included the Plan of Protection for the Suisun Marsh, Suisun Marsh Preservation Agreement, Mitigation Agreement, and Monitoring Agreement. (See Table A5.0-1 and Figure A5.0-1 for the water quality control stations and "standards", respectively, in the SMPA.)

o BCDC

  BCDC proposed that the Board revoke its decision of December 5, 1985, which amended the standards compliance schedule in D-1485 and changed monitoring locations (BCDC,5,31; T,XXIX,238:22-25). The BCDC testimony also proposed an additional standard to protect tidal marshes adjacent to Suisun Bay (BCDC,5,T4; T,XXIX,239:25-240:2). It is BCDC's position that the Board's 1985 amendments to D-1485 reduced

Table A5.0-1

SUISUN MARSH PRESERVATION AGREEMENT WATER QUALITY CONTROL STATIONS

Sacramento River at Collinsville	C-2 RSACO81	
Montezuma Slough at National Steel, 3 mi south of Miens Landing	S-64 SLMZU25	effective Oct 1,1988
Montezuma Slough near Beldon Landing (0.35 mi east of Grizzly Island Bridge)	S-49 SLMZU11	

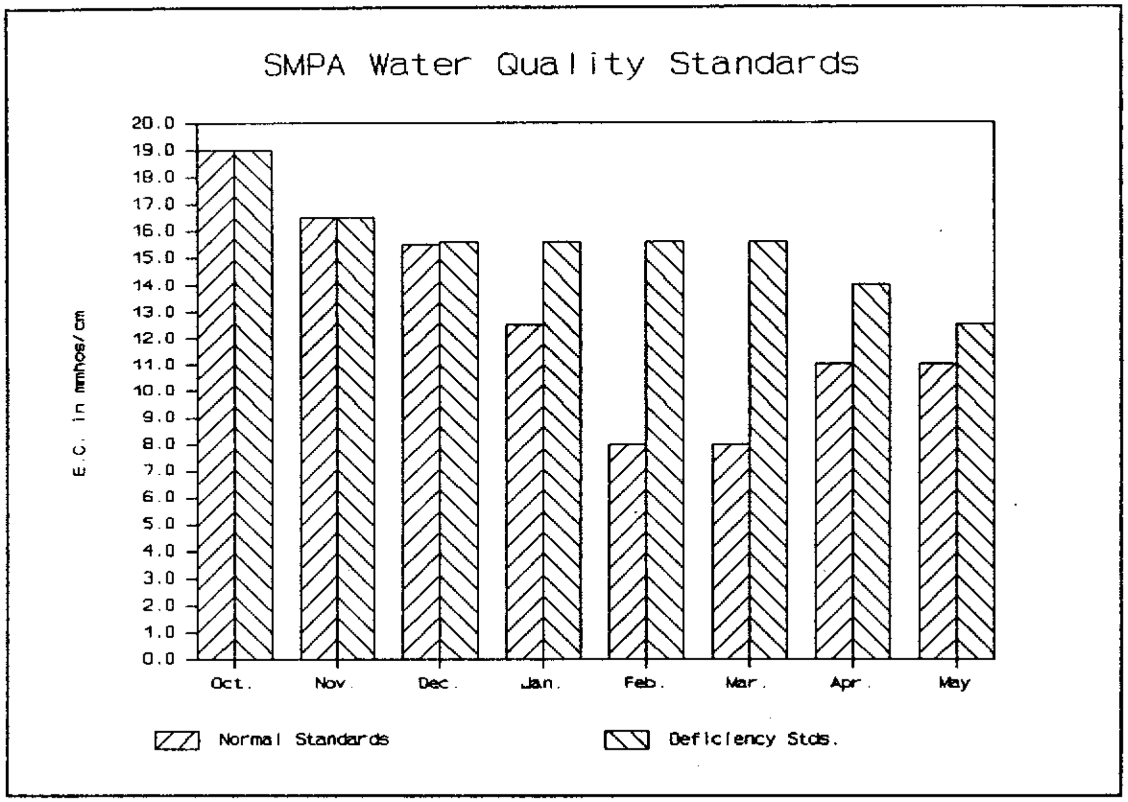
Chadbourne Slough at Chadbourne Road	S-21 SLBCN01	
and		
Cordelia Slough 500 ft west of S.P.R.R. crossing at Cygnus	S-33 SLCRD04	effective Nov 1,1992
or		or
Chadbourne Slough at Chadbourne Road	S-21 SLBCN01	effective Nov 1,1994
and		
Cordelia Slough at Cordelia-Goodyear Ditch	S-97 SLCRD06	

Goodyear Slough at Morrow Island Clubhouse	S-35 SLGYR03	effective Nov 1,1992
or		or
Goodyear Slough, 1.3 mi south of Morrow Island Ditch	S-75(old) SLGYR04	effective Nov 1,1995

Suisun Slough, 300 ft South of Volanti Slough	S-42 SLSUS12	effective Nov 1,1998
Water Supply Intake locations for Waterfowl Manangement Areas on Van Sickle Isl. and Chipps Isl.	No Locations specified	

revised Sep 5, 1990

Figure A5.0-1



Month	SMPA-Normal Standards (Mean Monthly High Tide, E.C. in mmhos/cm)	SMPA-Deficiency[1] Standards (Mean Monthly High Tide, E.C. in mmhos/cm)
Oct.	19.0	19.0
Nov.	16.5	16.5
Dec.	15.6	15.6
Jan.	12.5	15.6
Feb.	8.0	15.6
Mar.	8.0	15.6
Apr.	11.0	14.0
May	11.0	12.5

1 SMPA Article 1(f): "Deficiency Period" shall mean (1) a Critical Year following a Dry or Critical Year; or (2) a Dry Year following a year in which the Four Basin Index was less than 11.35; or (3) the second consecutive Dry Year following a Critical Year.

SMPA Article 1(r): "Wet Year", "Above Normal Year", "Below Normal Year" and "Subnormal Snowmelt Year" are as defined in Footnote 2 of Table II of D-1485 as adopted by the SWRCB in August 1978. "Critical Year" and "Dry Year" are also as defined in Footnote 2 of Table II of D-1485 except that runoff for the remainder of the water year shall be assumed to be equal to the lower value of the 80 percent probability range, as shown in the most recent issue of Bulletin 120, "Water Conditions in California".

protection for unmanaged tidal marshes and delayed the implementation of measures to protect water quality and beneficial uses in the managed wetlands of the Suisun Marsh (BCDC,5,5). BCDC contends that approximately 40 percent of the 10,000 acres of unmanaged tidal brackish marshes around Suisun Bay which were originally protected by the Delta Plan are not protected under present conditions (BCDC,5,12; BAAC,4; USFWS,17;18;19;20).

o BAAC

BAAC recommended a flow and salinity standard which provides greater protection for brackish water tidal marshes than does the Delta Plan (T,XXX,52:6-22). In addition, they recommended that salinity objectives for water quality in tidal marshes (levels not specified) be set for summer rather than ending in May (T,XXX,54:10-21). The position of BAAC was that the brackish water marshes have already been degraded and they would like to see them improved and restored more toward their natural condition, which would require more stringent salinity standards (T,XXX,94:20-95:2). The BAAC testimony did not explicitly state what those freshwater flows or what salinity standards should be to adequately approach natural conditions.

5.0.4.2 Wildlife Habitat in Other Tidal Marshes

Advocated Levels of Protection

o DFG

The DFG testified that they do not expect reductions in Delta outflow to change the vegetative character of the tidal marshes in the central or southern portions of San Francisco Bay. Those tidal marshes are already fairly saline and support mostly pickleweed or cordgrass. They testified that the marshes around the periphery of San Pablo Bay, which contain some rare plants, could be subject to some harmful impacts if there were significant reductions in outflow. (DFG did not indicate whether peak or annual outflow reductions are under consideration.) They also stated that the marshes around Suisun Bay, including those on the southern shore from about Martinez to Pittsburgh would likely change from the existing emergent brackish water vegetative pattern to one more characteristic of saline marshes. The degree of change would depend upon the magnitude of the change in Delta outflow (T,XXIX,146:17-148:3). DFG did not propose any water quality objectives to address this possible change in vegetative character.

o BCDC and EDF

BCDC and EDF proposed salinity objectives to protect the brackish water tidal marshes around Suisun Bay (BCDC,5,T4; EDF,19,A). They proposed that the monthly average of the daily high-high tide electrical conductivity be no more than 15 mmhos/cm during February and March, 18 mmhos/cm during April, and 20 mmhos/cm during May. BCDC proposed that these salinity objectives be met at the following locations: Martinez, the mouth of Suisun Slough at Grizzly Bay, Port Chicago, and Chipps Island. The salinity objectives for February and March would apply at all stations during all water year types except for the 1-in-10 dry year; the objectives for April and May would apply in all water year types (BCDC,5,T4).

- BAAC

BAAC maintains that the brackish water marshes have already been degraded and they would like to see them improved and restored more toward their natural condition, which would require more stringent salinity standards than the present objectives (T,XXX,94:20-95:2). BAAC did not indicate how the brackish marshes fared during historical dry periods such as 1928 to 1934.

BAAC recommended that flow and salinity objectives be set to provide greater protection for brackish water tidal marshes than does the Delta Plan (T,XXX,52:6-22). In addition, they recommended that the salinity objectives for water quality in tidal marshes (the levels are not specified) be set for summer rather than ending in May (T,XXX,54:10-21). The BAAC testimony did not explicitly state what freshwater flows or what salinity standards should be to adequately approach natural conditions.

5.0.5 Benthos

Advocated Levels of Protection

The benthic grazing hypothesis was proposed to explain the low phytoplankton and zooplankton populations during the 1976-1977 drought (CCWA/EDF,7,385). In Suisun Bay, the benthic salt-tolerant, filter-feeding population (especially *Mya arenaria*, which increased ten-fold compared to non-drought conditions) apparently become sufficiently abundant to be capable of filtering the equivalent of the entire volume of Suisun Bay in a day.

With this amount of feeding, it is hypothesized that benthic filter-feeders consumed virtually all phytoplankton and nutrient material in the water column. The pelagic (open-water) food web, which is based on phytoplankton, was therefore replaced by the benthic food web (CCWA/EDF,7,386). CCWA/EDF is concerned this phenomenon would occur more frequently in the future with additional water development and exports. To address these concerns, CCWA/EDF proposed a 28-day tidally-averaged, bottom salinity of 5 ppt at Chipps Island in upper Suisun Bay to repel salt-tolerant benthic organisms from the entrapment zone area in Suisun Bay (T,LIV,316:16-317:3). This objective would apply from October through April in all years, except the one-in-twenty dry year (T,LIV,258:20-259:1; EDF,Brief,7). No comparable objective was proposed for San Pablo Bay (T,LIV,259:13-14). No participant proposed specific temperature or salinity objectives for the protection of the benthos.

5.0.6 Other Beneficial Uses

Other beneficial uses of the Estuary include navigation and contact and noncontact water recreation. Uses that are part of noncontact water recreation also include esthetic appreciation and educational and scientific study (RWQCB5, 1975, 5B, I-2-2).

5.0.6.1 Navigation

Advocated Levels of Protection

Commercial Navigation -- no advocate for commercial navigation presented any testimony during Phase I of the proceedings.

Recreational Navigation -- PICYA recommended that there be improvements at the Delta Cross Channel for boat passage, protection of existing unleveed Delta islands, and maintenance of through navigation (PICYA,4), but these are not related to salinity or temperature objectives.

5.0.6.2 Estuary Recreation Beneficial Use

Advocated Levels of Protection

- EBRPD

  EBRPD submitted testimony and exhibits which showed that there has been rapid growth (122 percent increase in two years) in water-oriented recreation within their jurisdiction (EBRPD,34,1).

  EBRPD and PICYA emphasized their common interest in having abundant supplies of uncontaminated fish to provide boaters and fishers with an opportunity to experience successful fishing (PICYA,1,3; EBRPD,34,3).

- SWC

  No explicit objectives were proposed by SWC for the protection of recreational uses in the Estuary. SWC argued instead that increased diversions would have no effect on recreational fishing in the Bay-Delta, and would be to the state's economic advantage because of higher recreational values in Southern California (SWC,66,12).

- BISF

  BISF submitted exhibits and testimony regarding recreational uses of the San Francisco Bay area (BISF,38,T2; T,XXX,174:29), and identified the values of a variety of water-oriented recreational activities from the California State Parks and Recreation Department's PARIS model (BISF,38,T3).

5.0.6.3 Export Recreation and Export Fishery Habitat

Advocated Levels of Protection

No participant proposed any salinity or temperature objectives for export recreation or export fishery habitat distinct from the levels provided by the protection of municipal and industrial uses.

5.0.6.4 Export Agriculture

Advocated Levels of Protection

No specific water quality objectives were advocated for export agriculture during Phase 1 of the proceedings. Tolerances, in terms of EC, to salinities of several crops grown in export areas was presented by DWR (DWR,327). The crops addressed will theoretically experience reduced yields if the irrigation water exceeds these salinity tolerances.

APPENDIX 5.1
TRIHALOMETHANES (THMs)

5.1.1 Types of THMs

Four different types of THMs, compounds consisting of a carbon atom combined with one hydrogen atom and three halogen atoms (usually, chlorine or bromine), are commonly created in drinking water when it is disinfected (T,VI,38:5-8). Combinations of the halogens can exist in all four possible permutations: chloroform, (containing three chloride ions), bromodichloromethane (one bromide and two chloride ions), dibromochloromethane (two bromide and one chloride ions), and bromoform (three bromide ions) (T,VI,45:11-17).

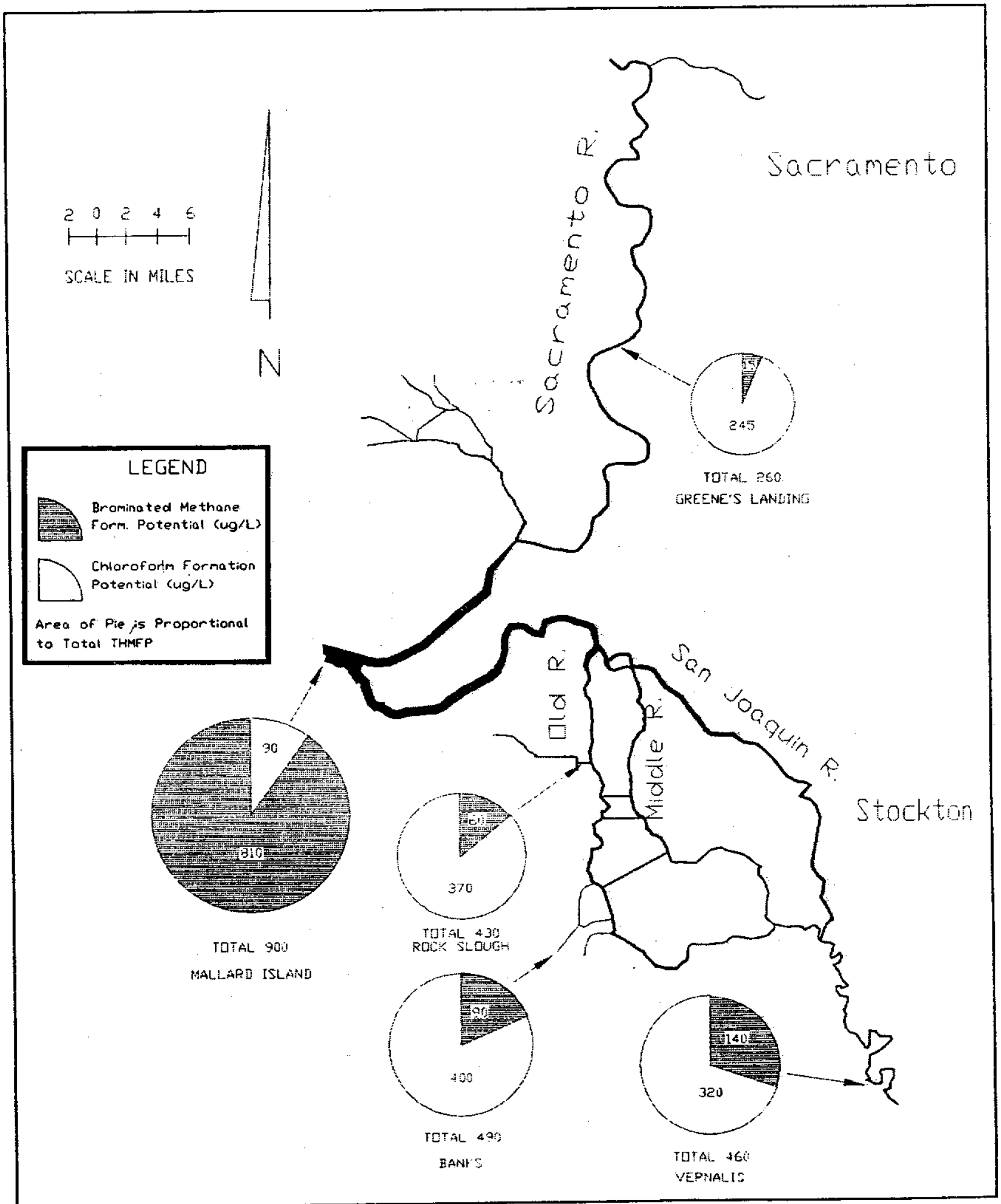
5.1.2 Trihalomethane Formation Potential (THMFP)

In order to evaluate alternative water supplies, suppliers of domestic water have developed analytical techniques to determine the potential of a water supply to produce THMs within the utility's water distribution system. The analytical techniques measure the trihalomethane formation potential (THMFP) of the water. The techniques for determining the THMFP of a water sample have not been standardized, nor can the THMFP of a raw water supply correlate directly to THM concentrations of the water in a distribution system after water treatment. However, lower THMFP levels in source water do indicate lower THM concentrations after water treatment.

Based upon data from the Interagency Delta Health Aspects Monitoring Program (IDHAMP), the THMFP of water increases as it travels across the Delta (DWR,225). The 50 percent probability of occurrence values for THMFPs in Cache Slough, Rock Slough, Delta-Mendota Canal, Clifton Court, and H.O. Banks Pumping Plant are 740, 430, 440, 450, and 480 ug/l, respectively. The levels in the Sacramento River at Greens Landing and the San Joaquin River near Vernalis (the principle Delta source of fresh water) are 250 and 450 ug/l, respectively. Using these values, the THMFP of water moving across the Delta increased by approximately 170 ug/l (SWC,204,11-15). Although a significant correlation has not been developed between the THMFP of a source water and the THM concentration of the treated water delivered to a domestic user, the THMFP levels present in Delta waters are nonetheless a significant water treatment issue to users of Delta water (T,XLVI,122:17-142:10).

Figures A5.1-1, A5.1-2 and A5.1-3 show the THM formation potential (THMFP) in the Delta for a 5-year median, 1983-1987 (Figure A5.1-1); under low flow conditions, October 1985 (Figure A5.1-2); and under high flow conditions, March 1986 (Figure A5.1-3). Five key water quality stations located in the Delta are shown in these figures. Each station is represented by a pie chart that is divided into two portions. The shaded portion shows the fraction of the total that contains brominated THMFPs; the unshaded portion shows the fraction that contains only chloroform. The Mallard Island station in Figures A5.1-1 and A5.1-2 indicates that seawater is the primary source of bromide ions.

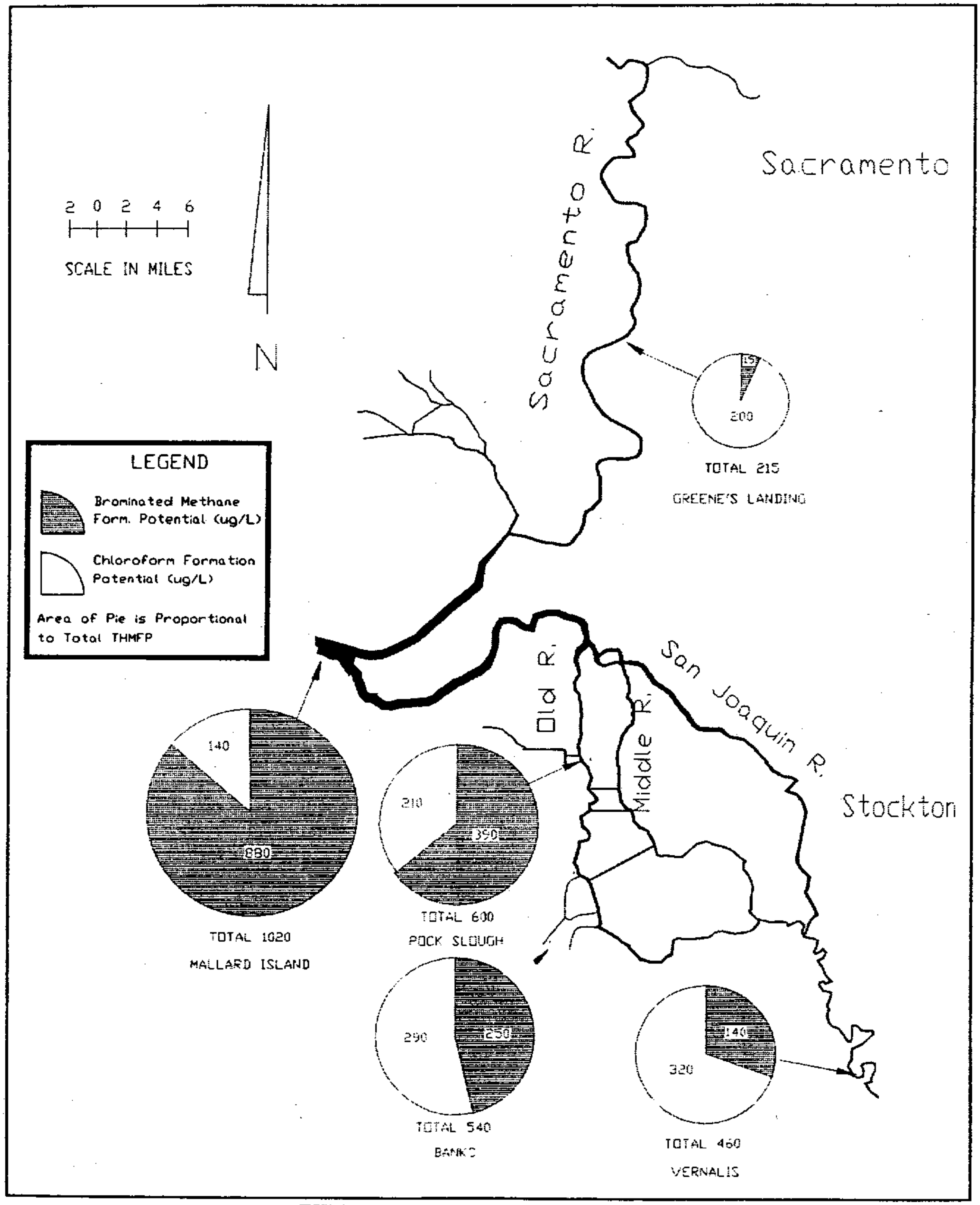
Figure A5.1-1



THM FORMATION POTENTIAL IN THE DELTA, 5-YEAR MEDIAN, 1983-1987

(From DWR: The Delta as a source of drinking water)

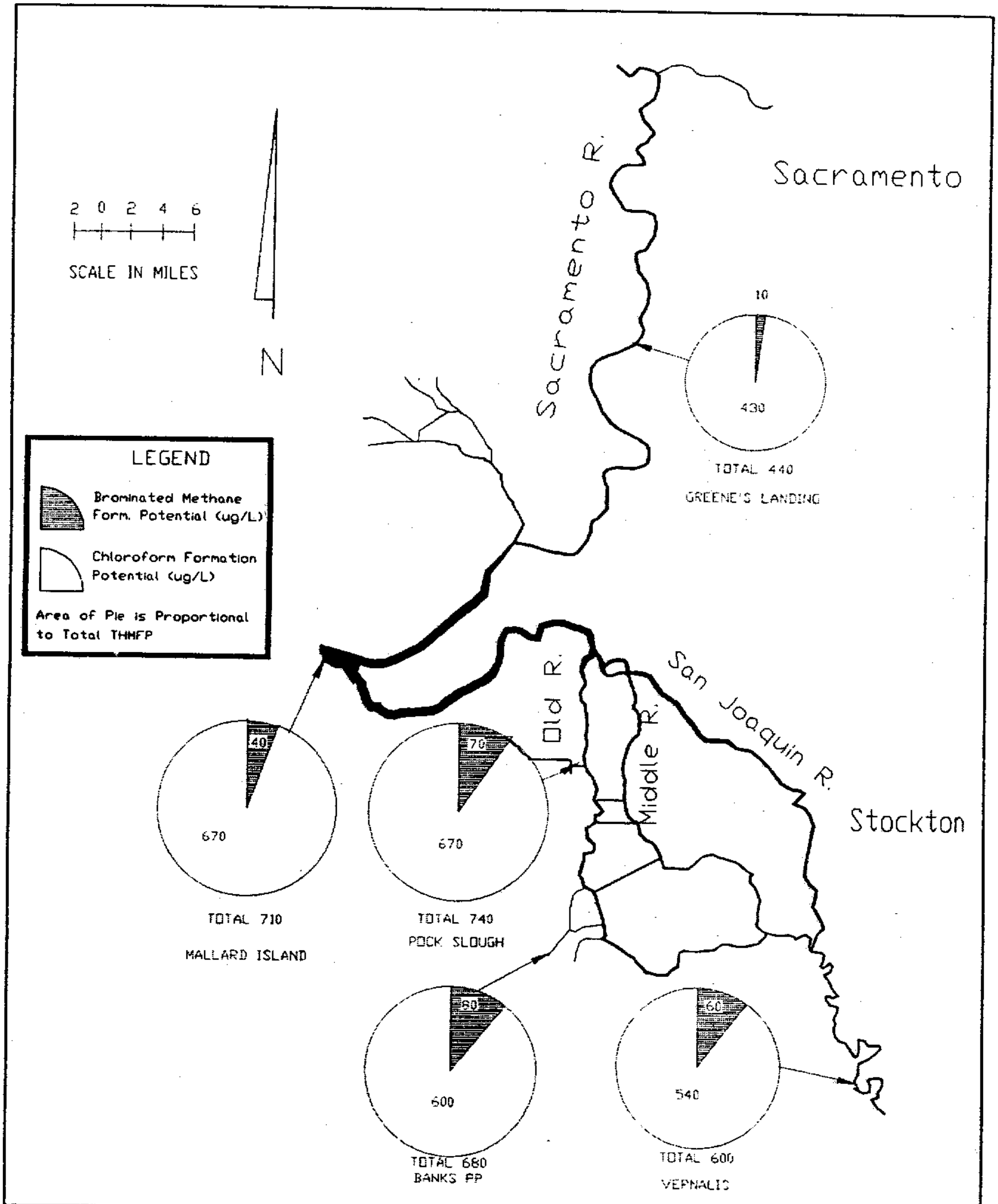
Figure A5.1-2



THM FORMATION POTENTIAL IN THE DELTA UNDER LOW FLOW CONDITIONS , OCTOBER 1985

(From DWR: The Delta as a source of drinking water)

Figure A5.1-3



THM FORMATION POTENTIAL IN THE DELTA UNDER HIGH FLOW CONDITIONS, MARCH 1986

(From DWR: The Delta as a source of drinking water)

Figure A5.1-2 shows that the brominated THMFPs measured during October 1985, increased to three times the median value at Harvey O. Banks Pumping Plant and six times the median value at Rock Slough, as a result of seawater intruding into the Delta during low flow conditions. However, the brominated THMFP values in the Sacramento and San Joaquin rivers remained near median values. In contrast, Figure A5.1-3 (THMFP under high flow conditions) shows that the brominated THMFP at the export pumps is reflected by the influences of both seawater and the San Joaquin River (IDHAMP - Summary of Monitoring Results, 1983 to 1987).

Of the total median brominated THMFP concentrations from the Sacramento and San Joaquin rivers only, the San Joaquin concentrations are nine times greater than those in the Sacramento River. The sources of bromides in the San Joaquin River are not known. Possible sources are connate water, from marine sediments found in the San Joaquin drainage, and bromide-containing Delta water used in San Joaquin agriculture (IDHAMP - Summary of Monitoring Results, 1983 to 1987).

5.1.3 Bromide Ions

Bromide ions are present in seawater, typically at concentrations about 0.003 times the concentration of chloride ions. Measurements by agencies using Delta water for raw drinking water show a relationship of this same type. MWD developed the following linear regression, equation relating bromide and chloride ions for SWP water delivered to their service area:

$$Br^- = 0.00289\,(Cl^-) + 0.00671$$

Where;

Br^- = The bromide ion concentration, in mg/l, and
Cl^- = The chloride ion concentration, in mg/l

The correlation coefficient for the above equation is definitely significant ($r = 0.955$) (Krasner, 1989, p. 3). An apparent second, though less significant, source of bromide ions is connate ground water which enters the San Joaquin River upstream of Vernalis (Jung, 1989, p. 6). Some connate waters with relatively high bromide levels exist beneath at least two Delta islands (i.e., Bouldin Island and Empire Tract) and may contribute bromide ions to the agricultural discharges from those islands (Winkler, 1989; DWR,225,22).

The difficulties with bromine arise for two reasons: one is due to its molecular weight, the other is due to the chemistry of bromine. The atomic weight of bromine is approximately twice that of chlorine, so the substitution of bromine for chlorine in a molecule increases the molecular weight. Drinking water standards are set on a weight basis. Thus, the existing EPA 100 ug/l THM water quality standard that is met when no bromine is present may not be met if a significant amount of bromine is substituted for chlorine (without changing anything else) (Delta M&I Workgroup, 1989, p. 4.). Chemical reactions involving bromine in water treatment systems which do not use free chlorine can result in the production of disinfection by-products (DBPs) other than THMs. For example, ozone reacts with bromine to form bromate and hypobromous acid, which in turn reacts with dissolved organics to form bromoform (Daniel, 1989).

5.1.4 Human Health Effects

Although EPA is currently evaluating the cancer risk of THMs as a class of chemicals, each brominated THM has already been classified as a probable or possible human carcinogen by the EPA (Delta M&I Workgroup Report, Appendix A, M. McGuire and S. Krasner, MWD). Also, it is currently believed that brominated THMs pose a greater hazard to human health than the totally chlorinated THM (chloroform) (Delta M&I Workgroup Report, 1989, p.5).

5.1.5 Water Treatment Problems

All conventional treatment processes, including chlorination, chloramination and ozonation, result in the production of brominated THMs and other brominated DBPs when bromide ions are present (Delta M&I Workgroup, p.3). When both organic matter and bromide ions exist in water, THM concentrations increase more rapidly during or after chlorination compared to water without bromide ions (T. Aizawa et al., "Effect of Bromide Ions on Trihalomethane Formation in Water" - <u>Aqua</u>, Vol. 38, pp. 165-175, 1989). Some of the conclusions drawn by Aizawa include:

1. <u>When water containing bromide ions is chlorinated, brominated THMs are formed preferentially</u>. The major factors in the formation of brominated THMs are bromide ion concentration, pH and water temperature. The pH affects the dissociation of chlorine in water and determines its oxidized ratio with bromide.

2. In the reaction of THM formation, chloroform concentration was reduced in proportion to bromide ion concentration. However, the concentration of total THM increases with the augmentation of bromide ions with the same amount of chlorine dosage. <u>The increase in total THM concentration is up to two times higher than in the absence of bromide ions.</u>

3. Even when residual chlorine is not present, the THM intermediates, once formed, are hydrolyzed depending on the pH and water temperature. The stability of the chlorinated intermediate and the brominated intermediate are different. The intermediates which contain greater amounts of bromide show a greater extent and a faster rate of hydrolysis.

These findings parallel those reported by participants of the Delta M&I workgroup after they analyzed the relationships among chloride, bromide, total THM concentrations. For example, data from the Metropolitan Water District's Mills and Jensen Water Treatment Plants for 1985 to 1989 (Tables A5.1-1 and A5.1-2) indicate that both the bromide level and concentration of brominated THMs increased as water supply chloride levels increased. The total THM concentration

TABLE A5.1-1
Mills Plant THM Results*

		Plant Influent			Plant Effluent				
TTHMs µg/L	Date	Temp. °C	EC µmho/cm	Cl^- mg/L	Br^- mg/L	$CHCl_3$ µg/L	$CHCl_2Br$ µg/L	$CHClBr_2$ µg/L	CHB µg/
	5/7/85			35					
63	5/16/85##	17	357			30	21	11	1
90	5/8/86	15	493			25	32	28	5
	5/13/86			68					
	4/28/87			50	0.17				
78	5/7/87	18	472			29	29	18	2
	5/10/87			59					
	4/11/88			98					
99	4/28/88	16			0.28	8	25	50	16
	5/3/88			105					
79	5/9/89	20	454	75	0.23	19	29	26	5

*Treatment plant: pre-chlorination/post-ammoniation.

##Free chlorine only.

Reference: Delta M & I Workgroup Report, Appendix A

TABLE A5.1-2
Jensen Plant THM Results*

TTHMs µg/L	Date	Plant Influent: Temp. °C	EC µmho/cm	Cl^- mg/L	Br^- mg/L	Plant Effluent: $CHCl_3$ µg/L	$CHCl_2Br$ µg/L	$CHClBr_2$ µg/L	CHBr µg/I
46	8/15/85	18	447			20	16	9	1
	8/85 CMP			35					
48	11/14/85	18	451			15	17	14	2
	11/85 CMP			45					
64	11/6/86	18	522			12	21	25	6
	11/86 CMP			69					
	11/2/87				0.13				
63	11/12/87	18	486			17	21	21	4
	11/87 CMP			58					
78	11/3/88	20	651	100	0.28	7	18	35	18
	5/9/89			131	0.39				
	6/89 CMP			123					
	7/89 CMP			125					
103	7/18/89##	16				4	18	43	38

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*Treatment plant: pre-chlorination/post-ammoniation.

##Free chlorine only.

CMP = monthly composite sample.

Reference: Delta M & I Workgroup Report, Appendix A

increased to approximately 100 ug/l; this forced MWD to change its disinfectant from chlorine to chloramines. As chloride concentrations increase in Delta water, the accompanying increases in bromide concentrations result in higher total THM formation upon disinfection (Delta M&I Workgroup - S.Krasner). Data presented by researchers (Krasner, McGuire et al., AWWA Journal, August 1989; also Delta M&I Workgroup Report, Appendix A, Krasner, MWD) indicate that elevated levels of bromide result in THM concentrations that are close to, or in excess of, current standards.

Theoretically, the Delta water THM problem could be resolved through removing either the bromide ions or total organic carbon (TOC) from the water prior to treatment or the THMs after treatment. However, there are no conventional treatment methods that will efficiently and economically remove THM precursors, TOC, bromide ions or THMs. Conventional treatment methods include chlorination, chloramination and ozonation; these can be used in various combinations to limit the formation of THMs. In the process of disinfection, however, these technologies will cause the formation of other DBPs (Delta M&I Workgroup Report, p.3).

While mentioned above under conventional treatment, ozonation/post-chloramination is considered to be an advanced water treatment technology by some members of the water treatment community and of the Delta M&I Workgroup. Other non-conventional or advanced water treatment technologies include ultra-filtration, reverse osmosis, granular activated carbon (GAC), and PEROXONE. These technologies are discussed below:

- Ozonation/post-chloramination is considered to be the treatment of choice at many water treatment plants. This treatment method will result in reduced THM concentrations in delivered water, particularly if bromide ions are not present in the source water. However, the use of ozone will result in the formation of other DBPs which are currently under regulatory consideration. The Delta M&I Workgroup concluded that ozonated water containing high bromide levels will result in the production of brominated THMs. Based on information submitted in the Workgroup report, it appears that ozonation/post-chloramination may be a viable water treatment technology if a revised EPA objective (standard) for THMs is around 50 ug/l.

  Information recently obtained by the State Board (pers. comm. with P. Daniel and P. Meyerhofer of Camp, Dresser, and McKee, Inc.) suggests that water treatment using ozonation/chlorination with the addition of a trace amount of ammonia upstream of the ozone contactor may result in very low THM levels, less than 3 ug/l. Other DBPs produced are similarly low. Water spiked to a 2.0 mg/l bromide level corresponds to approximately a 690 mg/l chloride level when back calculated using the bromide/chloride ion concentration relationship. However, inaccuracies are magnified when using the relationship at levels being discussed.

Uncertainties exist using the ozonation/chlorination/ammoniation water treatment method. The work completed to date is very preliminary and thus far no conclusions can be drawn. Additional uncertainties include:

- Bromamine, a DBP may form as a result of ammonia reacting chemically with bromide. The extent of this reaction and resultant odor threshold of the bromamine are unknown at this time.

- Ammonia may act as a source of nitrogen for bacterial growth, resulting in high regrowth. Further investigation is needed.

MWD's estimated capital costs for conversion to ozone treatment is $300 million. Estimated total annual cost for conversion to ozone (amortized capital costs and operations and maintenance costs) are approximately $67.5 million. (Delta M&I Workgroup Report, Appendix A, S. Krasner, MWD.) Table A5.1-3 shows the costs for adding ozone treatment to existing water treatment plants.

o Theoretically, it may be possible to remove the bromide ion and TOC prior to disinfection by ultra-filtration. However, according to the Delta M&I Workgroup Report, "...ultra-filtration has not been used in full-scale at any major United States plant and is too new a technology to be relied upon to meet the needs of the next five to ten years" (S. Krasner, Delta M&I Workgroup Report, p.9).

o Reverse osmosis could theoretically eliminate the THM and DBP problems even with the current TOC and bromide levels found in Delta source waters. However, the associated costs would be very high. MWD claims it would cost about $0.5 billion to convert 150,000 AF of Delta quality water to quality similar to that of the Mokelumne River and approximately $3 billion for MWD's total supply (pers. comm., D. Clemmer, MWD). This estimate does not include the associated costs for brine disposal which absorbs about 10 to 15 percent of the delivered water supply (pers. comm., J. Gaston).

o Granulated Activated Carbon (GAC), according to the Delta M&I Workgroup Report, will not remove inorganic ions such as chlorides or bromides; however, simulated distribution testing indicates that it will remove organic THM precursors (TOC) to levels that would produce 5 to 10 ug/l THMs. (The simulated distribution system test was developed by MWD to mirror actual treatment conditions that would be found in a water treatment plant). A study completed by MWD which focused on the reduction of THMs and other DBPs to very low levels, concluded that GAC is an expensive way to control THMs. The siting of GAC regeneration furnaces in southern California would present a problem due to the atmospheric emissions of toxic by-products. MWD has estimated that the approximate costs for conversion of its treatment facilities to GAC technology would be $1.3 billion in capital costs and $421 million in yearly total

TABLE A5.1-3
Cost for existing surface water treatment plants to add ozone treatment

AGENCY	PLANT NAME	DESIGN FLOW MGD	CAPITAL COST $Million	AMORITIZED CAPITAL $Mil/yr.	O & M COST $Mil/yr.	TOTAL COST $Mil/yr.
Alameda CFCWOD, Zone 7	Patterson Pass	14	$4.2	$0.42	$0.41	$0.84
Alameda CFCWOD, Zone 7	Del Valle	18	$4.9	$0.50	$0.47	$0.97
Alameda CWD		10	$3.3	$0.34	$0.30	$0.64
American Canyon WD		2	$1.1	$0.12	$0.17	$0.28
Antelope Val/East Kern	Eastside	3	$1.5	$0.15	$0.19	$0.35
Antelope Val/East Kern	Rosamond	14	$4.2	$0.42	$0.41	$0.84
Antelope Val/East Kern	Quartz Hill	28	$6.6	$0.67	$0.61	$1.28
Antioch		16	$4.5	$0.46	$0.44	$0.91
Avenal		2	$1.1	$0.12	$0.17	$0.28
Benicia, City of		10	$3.3	$0.34	$0.30	$0.64
Castaic Lake Water Agen.	Earl E. Schmidt	12	$3.8	$0.38	$0.39	$0.77
Coalinga		12	$3.8	$0.38	$0.39	$0.77
Contra Costa WD	Bollman	90	$14.4	$1.47	$1.66	$3.13
Crestline-Lake Arrow.	Crestline-Lk.Arrow	5	$2.1	$0.21	$0.22	$0.43
Fairfield	Waterman	22	$5.6	$0.57	$0.53	$1.10
Fairfield	Fairfield	30	$6.9	$0.70	$0.64	$1.34
Huron		2	$1.1	$0.12	$0.17	$0.28
Kern Co WA, ID #4		28	$6.6	$0.67	$0.61	$1.28
Martinez, City of		12	$3.8	$0.38	$0.39	$0.77
Metropolitan WD SoCal	Mills	236	$27.5	$2.80	$3.60	$6.39
Metropolitan WD SoCal	Skinner	554	$48.5	$4.94	$8.02	$12.96
Metropolitan WD SoCal	Jensen	870	$65.6	$6.68	$13.55	$20.24
Metropolitan WD SoCal	Weymouth	500	$45.3	$4.62	$7.74	$12.36
Metropolitan WD SoCal	Diemer	710	$57.3	$5.84	$9.68	$15.52
Napa	Hennessey	20	$5.3	$0.54	$0.50	$1.04
Naval AS-Lemoore		8	$2.9	$0.29	$0.28	$0.57
Oakley		6	$2.4	$0.24	$2.49	$2.73
Palmdale		12	$3.8	$0.38	$0.39	$0.77
Pittsburg		12	$3.8	$0.38	$0.39	$0.77
Santa Clara VWD	Penitencia	40	$8.4	$0.85	$0.83	$1.68
Santa Clara VWD	Rinconada	75	$12.8	$1.30	$1.24	$2.54
Santa Clara VWD	Santa Teresa	100	$15.5	$1.58	$1.94	$3.51
Tracy		12	$3.8	$0.38	$0.39	$0.77
Vallejo		5	$2.1	$0.21	$0.22	$0.43
Vallejo		30	$6.9	$0.70	$0.64	$1.34
	T O T A L S :	3520	$394	$40.18	$60.35	$100.53

AMORTIZED COST AT 8% AND 20 YEARS

Reference: Delta M & I workgroup report, Appendix A

costs (amortized capital costs plus operations and maintenance costs). This is based on meeting a revised total THM maximum contaminant level (MCL) of 25 ug/l (Delta M&I Workgroup Report, Appendix A, S. Krasner, MWD).

The SWC have also estimated costs for meeting GAC technology. They estimate $2 billion in capital costs and $344 million in operations and maintenance costs per year for a total annual cost of $549 million (Table A5.1-4). This would yield an aggregate cost of $140/AF (T,XLVI,138:5-10). It was not made clear what THM MCL level this technology could meet.

- PEROXONE is the combination of ozone and hydrogen peroxide. Delta M&I Workgroup participants believe that this technology shows promise for disinfection, oxidation of taste and odor compounds, and control of DBPs. Costs associated with this technology are lower than the others previously discussed. MWD has estimated that the approximate costs for conversion to PEROXONE would be $200 million. The effectiveness and reliability of PEROXONE have yet to be demonstrated at full scale. The Delta M&I Workgroup Report (Appendix A, S. Krasner, MWD) states that unresolved questions remain concerning how large-scale hydraulic mixing systems will affect the reactions between hydrogen peroxide and ozone, and whether disinfection efficiencies demonstrated in pilot-scale studies can be confirmed at full-scale. MWD is proceeding with plans to test PEROXONE at a 5.5 mgd demonstration treatment plant, the results of which should be available in 1992 (Delta M&I Workgroup Report, p.9).

5.1.6 Regulatory Problems

DBPs were not recognized as potential human health hazards present in treated drinking water in the 1978 Delta Plan and subsequent triennial reviews. Information on the subject was not available at that time. Currently, limited information is available. In summary, this information is limited to the general facts that DBPs are formed as a result of disinfecting drinking water; that DBPs are suspected human health hazards; and that DBPs will likely be regulated by EPA in the near future, around 1994. DBPs are being addressed here in recognition of the fact that, while much uncertainty exists regarding their formation and health effects, the minimization of DBPs should be considered in the search for any long-term solution regarding Delta drinking water quality.

Every chemical disinfectant currently being used produces DBPs (Delta M&I Workgroup Report, Appendix A; S. Krasner, MWD). The EPA is currently considering the establishment of MCLs for certain DBPs and for disinfectants used to treat drinking water supplies. MCLs for disinfectants and for DBPs are scheduled to be proposed in late 1991 and finalized in fall 1992, barring development of new information that would require reevaluation and additional time for public comment. Under this time schedule, compliance by water districts would be required in 1994 (Delta M&I Workgroup Report, Appendix A; S. Clark, EPA).

TABLE A5.1-4
Cost for existing surface water treatment plants to add GAC

AGENCY	PLANT NAME	DESIGN FLOW MGD	CAPITAL COST $Million	AMORITIZED CAPITAL $Mil/yr.	O & M COST $Mil/yr.	TOTAL COST $Mil/yr.
Alameda CFCWOD, Zone 7	Patterson Pass	14	$16	$1.6	$1.5	$3.1
Alameda CFCWOD, Zone 7	Del Valle	18	$19	$1.9	$1.9	$3.8
Alameda CWD		10	$13	$1.3	$1.1	$2.4
American Canyon WD		2	$6	$0.6	$0.3	$0.9
Antelope Val/East Kern	Eastside	3	$7	$0.7	$0.4	$1.1
Antelope Val/East Kern	Rosamond	14	$16	$1.6	$1.5	$3.1
Antelope Val/East Kern	Quartz Hill	28	$25	$2.5	$2.9	$5.4
Antioch		16	$17	$1.7	$1.7	$3.4
Avenal		2	$6	$0.6	$0.3	$0.9
Benicia, City of		10	$13	$1.3	$1.1	$2.4
Castaic Lake Water Agen.	Earl E. Schmidt	12	$14	$1.4	$1.3	$2.7
Coalinga		12	$14	$1.4	$1.3	$2.7
Contra Costa WD	Bollman	90	$61	$6.2	$9.1	$15.3
Crestline-Lake Arrow.	Crestline-Lk.Arrow	5	$9	$0.9	$0.6	$1.5
Fairfield	Waterman	22	$21	$2.1	$2.3	$4.4
Fairfield	Fairfield	30	$26	$2.6	$3.1	$5.7
Huron		2	$6	$0.6	$0.3	$0.9
Kern Co WA, ID #4		28	$25	$2.5	$2.9	$5.4
Martinez, City of		12	$14	$1.4	$1.3	$2.7
Metropolitan WD SoCal	Mills	236	$139	$14.1	$23.9	$38.0
Metropolitan WD SoCal	Skinner	554	$282	$28.7	$51.9	$80.6
Metropolitan WD SoCal	Jensen	870	$394	$40.1	$83.5	$123.6
Metropolitan WD SoCal	Weymouth	500	$264	$26.9	$47.4	$74.3
Metropolitan WD SoCal	Diemer	710	$346	$35.2	$69.7	$104.9
Napa	Hennessey	20	$20	$2.0	$2.1	$4.1
Naval AS-Lemoore		8	$11	$1.1	$0.9	$2.0
Oakley		6	$10	$1.0	$0.7	$1.7
Palmdale		12	$14	$1.4	$1.3	$2.7
Pittsburg		12	$14	$1.4	$1.3	$2.7
Santa Clara VWD	Penitencia	40	$32	$3.3	$4.1	$7.4
Santa Clara VWD	Rinconada	75	$52	$5.3	$7.6	$12.9
Santa Clara VWD	Santa Teresa	100	$66	$6.7	$10.0	$16.7
Tracy		12	$14	$1.4	$1.3	$2.7
Vallejo		5	$9	$0.9	$0.6	$1.5
Vallejo		30	$26	$2.6	$3.1	$5.7
	T O T A L S :	3520	$2,021	$205.0	$344.3	$549.3

AMORTIZATION AT 8% AND 20 YEARS

Reference: Delta M & I workgroup report, Appendix A

Table A5.1-5 lists some of the disinfectants and DBPs considered for MCLs and maximum contaminant level goal (MCLGs) by EPA. If a contaminant is a known or possible human carcinogen, then the MCLG is set at zero. A balance of the health risk of DBPs with the health risks of microbial disease is established by EPA when considering establishment of MCLs. The following narrative is derived from Appendix A of the Delta M&I Workgroup Report, as presented by J. Orme, EPA.

According to EPA, classes of DBPs rather than the individual compounds themselves will probably be regulated in much the same way as THMs. MCLs will likely continue to be considered on a mass per volume basis.

Much uncertainty exists concerning the hazards to human health posed by these disinfectants. For example, chlorine has been used as a disinfectant for nearly eighty years without undergoing rigorous toxicological testing to determine its effects on human health from ingestion. Studies indicate that chlorine can affect kidneys and thyroid hormone levels of laboratory animals. A weak correlation has also been established between consumption of chlorinated surface water and bladder cancer in humans. Chlorine dioxide affects red blood cells and appears to have developmental and neurotoxic effects. Chloramines affect the organ weights of rats and mice. Additional risk assessment studies for these disinfectants are underway.

TABLE A5.1-5
SOME DISINFECTANTS AND DISINFECTION
BY-PRODUCTS CONSIDERED FOR DEVELOPMENT OF MCLGs AND MCLs

Disinfectants

Chlorine
Chlorine Dioxide
Chloramine
(Ozone is not being considered because no residual is left upon which to base an MCL)

Disinfection By-Products

Trihalomethanes: Chloroform
Bromoform
Bromodichloromethane
Dibromochloromethane
Chlorinated Acetic Acids/Brominated Acetic Acids
Chlorinated Alcohols
Chlorinated Aldehydes
Chlorinated Ketones
Chlorite and Chlorate
Haloacetonitriles
Chlorophenols
Chloropicrin
Cyanogen Chloride
Iodide, Iodate
Bromide, Bromate
MX

Reference: M&I Workgroup Report, Appendix A

Brominated THMs have been classified as a probable or possible human carcinogen by EPA. Chloroform is still suspected to be a carcinogen. Chlorinated acetic acids have been found to occur in concentrations equal to THMs. Animal studies suggest that certain species of the chlorinated acetic acids are potent neurotoxins and may also be carcinogenic. Based on animal studies, haloacetonitriles are believed to be carcinogenic. Health hazards associated with chloropicrin are currently under study. Although health effect information on cyanogen chloride is limited, it was used as a nerve gas agent in World War I. MX is known as a highly unstable potent mutagen. Studies on this chemical continue.

The formation of DBPs is dependent upon several variables: bromide concentration, oxidant concentration, contact time, the presence of dissolved organics, temperature, and pH. In short, every method of water treatment has advantages and disadvantages. In a recent DBP survey of 35 utilities conducted for the California Department of Health Services by the EPA, it was found that THMs measured by weight, were the largest class of DBPs found. The next significant class found were the haloacetic acids, followed by the aldehydes. Of the 35 utilities in the study, only three employed ozone, yet almost all had detectable levels of formaldehyde and acetaldehyde. (Aldehydes were initially discovered as by-products of ozonation; however, they also appear to be caused by chlorination) (AWWA Journal, August 1989).

Ozonation/chloramination is frequently mentioned by many water treatment plant managers as the alternative treatment of choice for reduction of THMs. Ozone alone should not produce chloroform or other chlorinated DBPs. However, if bromide ions are present in the source water, ozonation will cause the formation of hypobromous acid, which will react with organic precursor material to form brominated forms of THMs. In addition, chloramination tends to increase the formation of cyanogen chloride at the same time it decreases the formation of THMs (Delta M&I Workgroup Report, Appendix A; M. McGuire and S. Krasner, MWD).

APPENDIX 5.2
ANALYSIS OF CORN YIELD TO VARIATIONS IN APPLIED WATER AND LEACH WATER SALINITY

To ensure a reasonable level of protection for western and interior Delta agriculture information is needed in the following three areas:

1. The impacts of irrigation and leaching water quality on crop yield,

2. The economics of implementing various leaching practices, and

3. The practicality of implementing and the effectiveness of various leaching practices.

The Corn Study developed information on the impacts of irrigation and leaching water quality on corn yield, only limited information on the practicality of implementing and the effectiveness of specialized leaching practices, and no information on the practicality, effectiveness, and economics.

Although insufficient information is available to set a water quality objective, it is important to discuss the progress made in the first area, impacts of irrigation and leaching water quality on corn yield.

- Salinity Requirements for Corn

  Salinity requirements to maximize the yield of corn grown on organic subirrigated soils are based on the testimony and exhibits from Phase I and the results of a modified DWR DELCORN model (modified DELCORN). This body of information indicates that corn yield is affected by both short-term water quality and long-term, average water quality. Evidence indicates that in order to maintain maximum corn yield, in the short-term, the maximum 14-day running average of daily average salinities of applied water should be no more than 1.5 mmhos/cm EC from April 1 through July 31. After July 31 salinity levels may rise to a level of up to 6.0 mmhos/cm EC without affecting yield (SWRCB,24,1). Proper corn yield also requires long-term average irrigation water quality maintain soil salinity at a level requiring a particular frequency of pond leaching[1/]. The frequency of pond leaching is determined by considering the practicality and the economic effects of the farming practices needed to maintain maximum corn yield.

1/ Pond leaching is that practice which is performed by constructing berms around an area and flooding the area. Following an extended period of flooding, the field is drained to prepare for cropping. Drainage ditches and drainage pumps are assumed to be in operation throughout the leaching period (DWR,334,2). Pond leaching occurs in the months of December through February when the previous irrigation seasons's average saturated soil extract salinity (ECe) exceeds 2.1 mmhos/cm EC.

To help determine this long-term average water quality objective, the modified DELCORN model was used to identify possible alternative levels of irrigation and leaching objectives needed to protect western and interior Delta agriculture. DWR's DELCORN model's algorithm uses Hoffman's equations, which were presented as SWRCB evidence in Phase I of the Hearing (SWCRB,23-30). These equations describe the relationships between seasonally applied water quality, soil salinity, and yield. DWR's DELCORN model applies a 57-year hydrology to these equations at a number of locations in the western and interior Delta to simulate a history of soil salinities and subsequent yields. The DWR DELCORN model has gained general acceptance, with some reservations. The model is believed to overestimate the frequency that leaching is required. A comparative impact analysis is therefore considered more reliable than a predictive study.

- Description of Comparative Impact Analysis

The modified DELCORN model was used to develop pond leaching frequency curves for the comparative impact analysis. Each curve identifies a set of combinations of irrigation and pond leach water quality needed to maximize corn yield, given a particular hydrologic condition.

Inspection of these curves illustrates the importance to agriculture of a factor generally overlooked, that is, "umbrella protection". Western and interior Delta agricultural water quality is not only determined by agricultural water quality objectives, but much of the time by the incidental effect of unregulated flow releases and objectives protecting other beneficial uses. These incidental benefits are given the term "umbrella protection". Most of the time umbrella protection controls agricultural water quality in the western and interior Delta. The following analysis determines that the factor controlling the quality of water that agriculture receives will not be the long-term average water quality objective, but either the umbrella protection or the 1.5 mmhos/cm EC maximum irrigation water quality objective over the irrigation season.

- Comparative Impact Analysis of Irrigation and Leaching Water

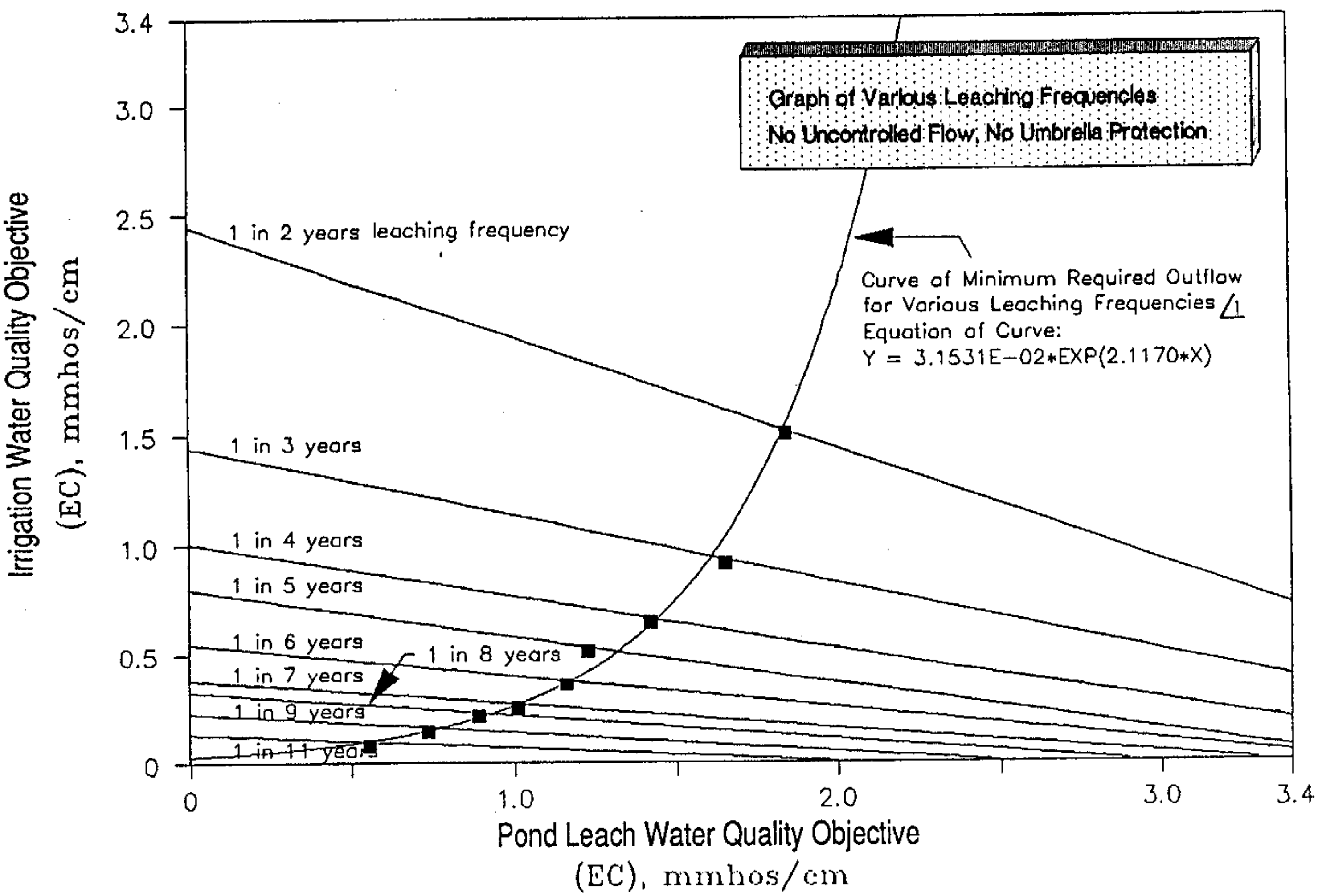
Figure A5.2-1 shows the estimated pond leaching frequencies that are required if there is no umbrella protection. A wide range of combinations of irrigation and pond leach water quality can be used to attain a particular leaching frequency. For a given leaching frequency the optimal EC concentration to obtain the objectives with the minimum Delta outflow is shown by the intersection of the appropriate leaching frequency curve and the minimum required outflow curve (see Figure A5.2-1). Figure A5.2-2 shows the estimated pond leaching frequencies that are required if uncontrolled reservoir releases and Delta Plan level umbrella protection are available. Figure A5.2-3 shows present level of development or base condition impacts for a 57-year hydrology.

The curves shown in Figures A5.2-1 and A5.2-2 and information from Figure A5.2-3 are used in a comparative analysis to determine the relative effects between the current or base condition and various other levels of protection, based on frequency of leaching. In this comparative analysis, a base condition and two alternative conditions are chosen. These alternative conditions are then compared to the base condition to arrive at an incremental effect.

FIGURE A5.2-1

IRRIGATION VS. POND LEACH WATER QUALITY AT EMMATON FOR MAXIMUM YIELD

DATA GENERATED USING DWR'S DELCORN MODEL

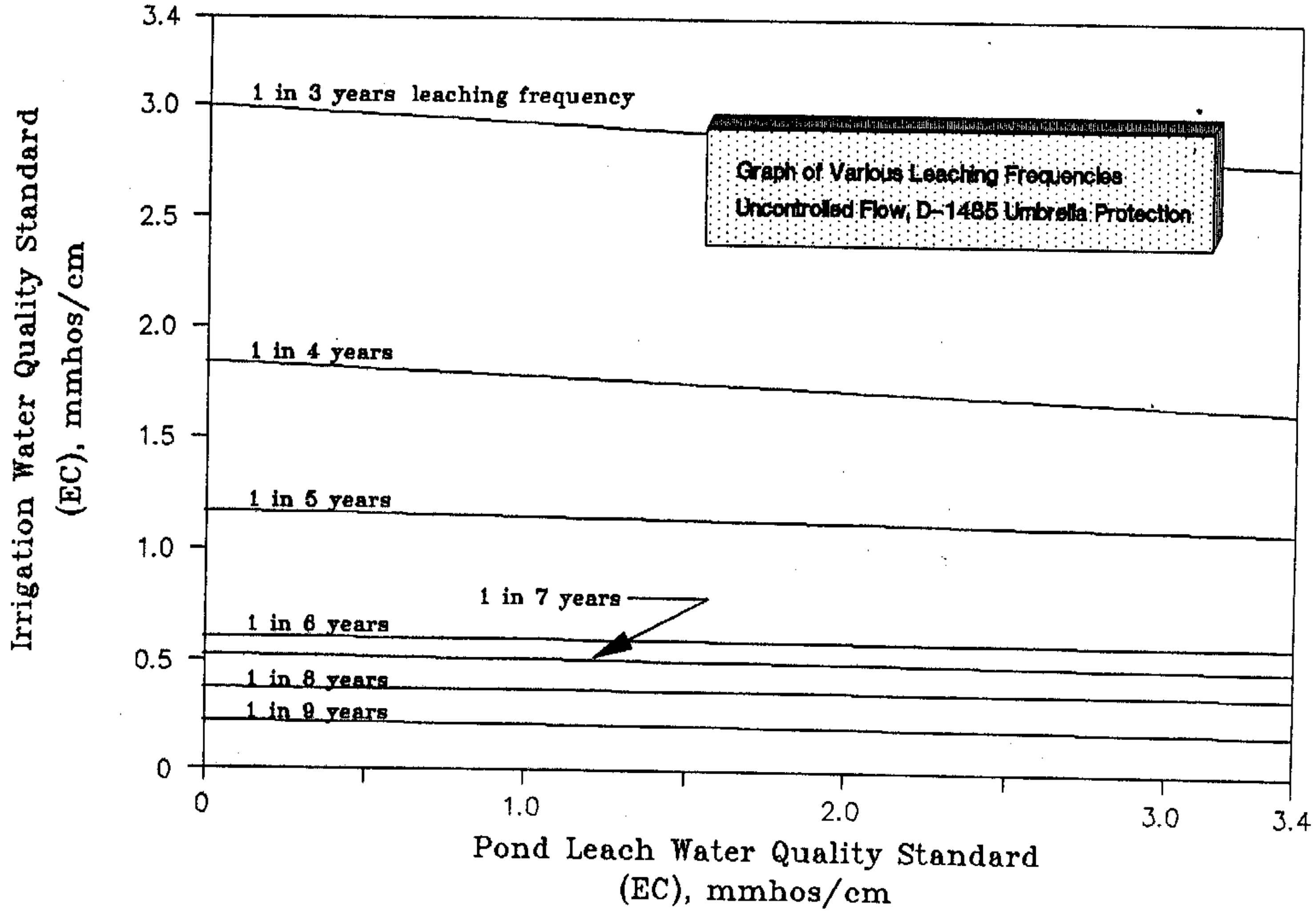


△1 For a given leaching frequency the optimal concentrations (EC) to obtain the objectives with minimum flow is shown by the intersection of the flow curve and the appropriate frequency curve.

FIGURE A5.2-2

IRRIGATION VS. POND LEACH WATER QUALITY AT EMMATON FOR MAXIMUM YIELD

DATA GENERATED USING DWR'S DELCORN MODEL

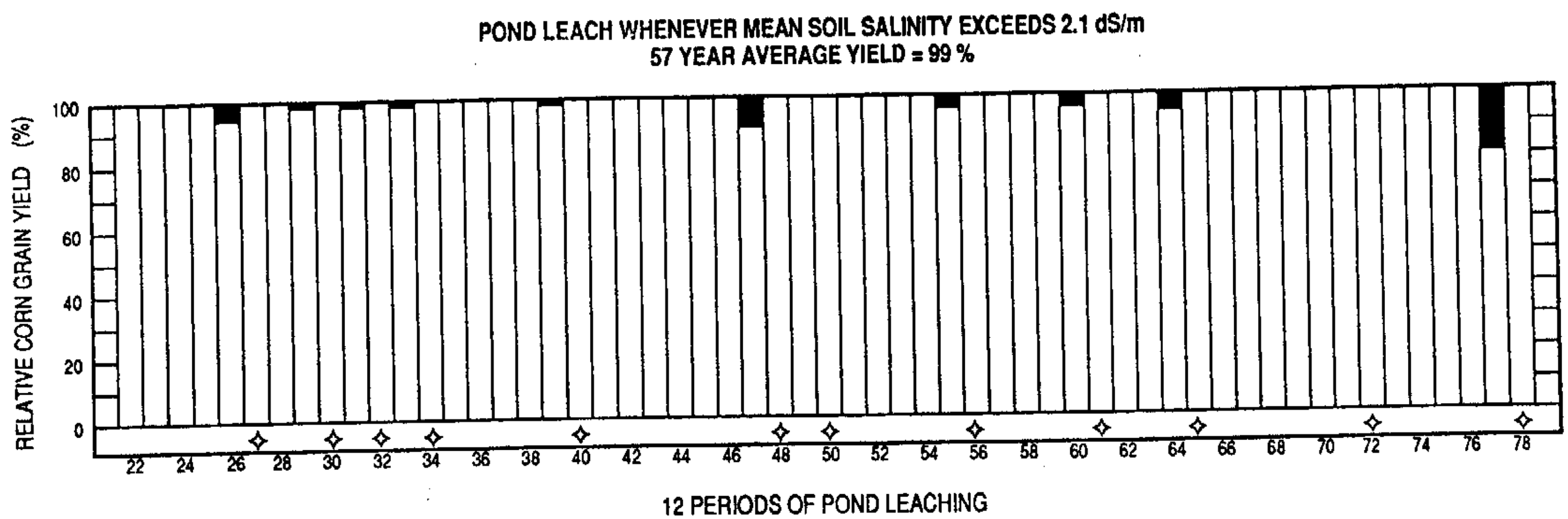


PRELIMINARY
SUBJECT TO REVISION

FIGURE A5.2-3 Variation in Corn Yield With Different Leaching Practices at Emmaton

Assuming 1990 Level of Development Hydrology
Meeting D1485 Standards (Study A)

(Corrected Pond Leaching Equation Incorporated)



LEGEND:
✧ = Pond Leaching Performed

From DWR Subworkgroup Handout

CHA0043R1

The current objectives, including umbrella protection, were chosen as the base condition for this comparative analysis. DWR provided this information from a model simulation (see Figure A5.2-3). The results indicate that, under this base condition, pond leaching would be required 12 times during this 57-year period, approximately once every five years.

The first alternative level of protection studied was that level of salinity, assuming Delta Plan umbrella protection, for which the frequency of leaching was the same as for the base condition; once in five years. This level of salinity can be determined by looking at the plot of curves in Figure A5.2-2. From these curves it can be seen that a short-term maximum irrigation salinity objective of approximately 1.2 mmhos/cm EC and virtually any level of leach water quality will achieve a pond leaching frequency of once in five years. In comparison, this frequency is the same one that was achieved under the base or current condition. This comparative analysis indicates that setting a short-term maximum irrigation water quality objective of 1.2 mmhos/cm EC and no leach water quality objective will provide the same protection to western and interior Delta agriculture as the base condition, that is, the present level.

The second alternative level of protection studied assumed Delta Plan umbrella protection, and a salinity level for irrigation of 1.5 mmhos/cm EC, the indicated short-term maximum allowable salinity for irrigation water quality. Figure A5.2-2 indicates the effect would be to increase the pond leaching frequency to approximately once in four years. At this level of salinity, approximately one to two more periods of pond leaching would be required during the historical 57-year period as compared to the one in five year leaching frequency condition, or base condition.

This second comparative analysis, evaluating the incremental difference between the second alternative's short-term objective at a threshold level of 1.5 mmhos/cm EC and the base condition, indicates that the controlling factor will not be the average water quality objective, but will be either the umbrella protection or the maximum short-term irrigation water quality objective.

APPENDIX 5.3
CHINOOK SALMON

Numerous and complex field and laboratory studies have been conducted to determine how temperatures affect Chinook salmon. The survival results of field studies, when compared to temperature data, differ from the literature on temperature tolerance experiments. The field studies indicate a roughly linear relationship between smolt survival and temperature, whereas, the lethal temperature tests indicate curvilinear and threshold relationships (WQCP-USFWS-0,3; WQCP MID/TID-1; WQCP-SWC-605). The laboratory studies control the conditions to which the fish are subjected and the responses of the fish are generally attributable to those conditions. In the field studies, the fish subjected to high water temperatures may die either directly due to the temperatures or indirectly due to becoming more susceptible to the hazards of predation, entrainment, etc., because of the temperatures. The following testimony and evidence describe the influence of temperatures and other conditions on Chinook salmon.

- Chinook salmon are a cold water species and water temperatures below 60°F are required for spawning and the survival and growth of eggs and fry (USFWS,29,4; USFWS,31,4;T,XXXV,43:68). The virulence of many diseases affecting Chinook salmon is reduced when temperatures are below 60°F (USFWS,29,23). Juvenile emigrants (smolts) can tolerate water temperatures somewhat higher than 60°F but above about 65°F a variety of stress effects occur (DWR,562,3; DWR,563,1-3; USFWS,31,4 and 42; DFG,15,23-27). Water temperatures above 18°C (64.4°F) are usually considered undesirable for Chinook juveniles (USFWS,31,38). At temperatures of about 68°F or more, smolts are highly stressed (DFG,15,25-26); 76°F is lethal (USFWS,31,42).

- Sublethal or stressful temperatures can cause increased susceptibility to disease, predation and entrainment (Letter from DFG to SWRCB dated August 9, 1989).

- Laboratory studies have shown that a salmon smolt's tolerance of elevated temperatures is improved when food supply is optimal (DWR,563,1-3). DWR's consultants testified that DFG's records indicate that the abundance of Neomysis, one of the primary foods of emigrating salmon (T,XXXVII,207:23-25), has decreased significantly in the last 20 years (T,XXXVII,207:25-208:1) and that upstream and estuarine food supplies may be poor. Taken together, these conditions could aggravate the effects of higher temperatures during emigration (T,XXXVII,207:3-9).

- Acclimatization increases the short-term temperature stress tolerance. Survival in elevated temperatures will depend upon the temperature to which the fish are acclimatized and factors contributing to the response of the fish may include ration or nutrition, salinity and size (DFG,15,23).

- Survival in both the Sacramento and San Joaquin basins may be reduced when spring water temperatures are above the stressful range of 66 to 70°F (T,XXXVI,159:17-20; DWR,562,60; T,XXXVI,150:24-151:11; DFG,15,26-27).

- Available information indicates that temperatures are not optimal in the San Joaquin and Sacramento rivers, especially during smolt outmigration in May and June (USFWS,31,144). The USFWS found smolt survival in the Delta decreases as water temperatures increase between the City of Sacramento and Suisun Bay (USFWS,31,42).

- Upstream factors identified as contributing to the decline in natural salmon production include loss of habitat from construction and operation of dams and diversion (T,XXXV,25:20-23; DFG,15,8; T,XXXV,33:7-37:12). Stressful (sublethal) to lethal water temperatures, reduced or fluctuating flows, and harmful concentration of toxins are also factors (USFWS,29; DWR,561).

High water temperatures are associated with increased smolt mortality; however, other conditions in the Delta, such as flow, direction of flow, food availability and migration paths, may also influence their survival (USFWS,31,254,138) (USFWS, 1988). The results of the USFWS smolt survival studies indicate that variable rates of mortality occur between 60 and 75°F depending upon the location where the smolts were released (USFWS, 1988).

Chinook salmon smolts were marked and released at the various sites and recaptured at Chipps Island. Variables that may have also influenced survival include the temperature differences between the hatchery truck, the temperature at the release site, and the duration of exposure to the elevated temperatures. The survival index is useful as a reflection of trends and general magnitude of change in survival as conditions change.

The following table is a summary of predicted smolt survival indices in the Sacramento River Delta during the spring under various export levels, percent of flow diverted through the Delta Cross Channel and under various water temperatures (Predicted Appendix Table 5.3-1).

Fall-run Chinook salmon:

Fall-run Chinook salmon are affected by temperatures in the fall during the upstream migration and in the spring during the outmigration. When inflows are high, fall-run Chinook fry rear in the upper Estuary from approximately January to March. Fall-run smolts emigrate from approximately April through June, and the adults migrate upstream from August through November. The temperature impact in the Delta on the fall-run smolts occurs during the late spring, May and June, when water temperatures are warming (T,XXXVII,226:15-20).

Appendix Table 5.3-1
Survival Indices for Chinook Salmon Smolts Migrating through the Sacramento River Delta Under Varied Water Temperatures, Percent Diverted at Walnut Grove and CVP/SWP Export Rates (WQCP-USFWS-0).

Export Rate 2,000 cfs	Temperature (°F)					
	60	62	64	66	68	70
Percent Diverted						
0	0.64	0.51	0.4	0.3	0.22	0.15
30	0.57	0.46	0.36	0.27	0.2	0.14
70	0.47	0.39	0.3	0.23	0.18	0.12

Export Rate 6,000 cfs	Temperature (°F)					
	60	62	64	66	68	70
Percent Diverted						
0	0.64	0.51	0.4	0.3	0.22	0.15
30	0.52	0.41	0.32	0.24	0.17	0.11
70	0.36	0.28	0.21	0.16	0.11	0.07

Export Rate 10,000 cfs	Temperature (°F)					
	60	62	64	66	68	70
Percent Diverted						
0	0.64	0.51	0.4	0.3	0.22	0.15
30	0.47	0.37	0.28	0.21	0.15	0.1
70	0.25	0.18	0.13	0.09	0.07	0.04

The various life stages of the Chinook salmon occurring in the lower reaches of the Sacramento River during the high temperature months are:

	May	June	July	August	September	October
Fall-run	smolts	smolts	--	adults	adults	adults
Late Fall-run	smolts	smolts	--	--	smolts	smolts/ adults
Winter-run	adults	adults	--	--	(fry)1/	(fry)
Spring-run	adults	adults	--	--	--	

(Letter to SWRCB from DFG, August 9, 1989; USFWS,29,5,Figure 2).

Also, see Figure A4-4 on page 4.0-14 of this Appendix.

1/ *"Young winter-run salmon potentially could enter the estuary as early as September following early storms".*

APPENDIX 5.4
STRIPED BASS

5.4.1 Methods to Assess the Population Levels of Striped Bass

Adults:

1. Petersen Estimate--Mark and recapture method; 1969 to present; sampled at specific stations in Delta and Sacramento River; creel census (see below) contributes data from San Francisco Bay and ocean areas; statistical analysis of number of fish recaptured which were marked previously.

2. Catch Per Unit Effort (CPUE) Index--Index of population based on number of fish caught per standardized unit of time; same locations as for Petersen estimate; 1969 to present except 1977, 1978, and 1981; possibly more reliable than Petersen estimate (DFG,25,Appendix 1).

3. Tag Returns--1958 to present, except 1962-1964 and 1967-1968; analysis of tags returned by fisherman; provides basis for comparison of fishing vs. "natural" mortality.

4. Party Boat Census--Monthly reports submitted by party boat operators, required since 1938, plus direct sampling by creel census since 1970's; provide information on numbers of fish caught, number of angler-days, per cent of total catch by party boats, length and age composition, and related information.

5. Creel Census--Surveys of shorelines, minor piers, and private and party boats; begun 1969, continued most years since, with increased effort in recent years with Striped Bass Stamp Fund support; locations surveyed, particularly ports, vary depending on catch success; provides data on catch rates, fish sizes, proportion of population which is tagged (part of Petersen Estimate process), and other information.

Eggs, Larvae and Juveniles:

1. Petersen Fecundity Estimate--Annual since 1977; combines Petersen population estimate with fecundity (egg number) data from Striped Bass Health Monitoring Program, with certain correction factors (age and number of fish spawning), to estimate total number of eggs produced.

2. CPUE Fecundity Index--Uses same procedure as above except that uses catch per unit effort (CPUE) index value for number of spawning females rather than Petersen estimate.

3. Egg and Larva Survey--Area sampled is variable but standardized in recent years to Suisun Bay, central and western Delta, and Sacramento River to Colusa; 1966-1973, 1975, 1977, 1984-1986, 1988-1990; intensive sampling at 75 stations in spring to monitor number, growth, movement and mortality of larvae up to about 14 mm in length; Sacramento River stations also monitor egg abundance and movement (but these stations not sampled in 1988 to 1990).

4. Tow Net Survey--1959 to present, except 1966; Delta and Suisun Bay; biweekly sampling at 30 to 40 stations in summer until average length of young bass exceeds 38 mm length; provides index of abundance (actual Striped Bass Index, or SBI) and distributional information.

5. Midwater Trawl--Throughout Bay-Delta Estuary up to Rio Vista and Clifton Court Forebay; 1967 to present except 1974 and 1979; typically monthly tows between September and December at a variable number of stations; gives measure of young-of-the-year abundance; more variable than SBI, but correlates well with it.

Related Surveys:

1. Salvage Records--Provides numbers of fish salvaged from Skinner Fish Protective Facility in SWP Clifton Court Forebay, and from Tracy Fish Facility at CVP Tracy Pumps intake channel; Skinner reports annual from about 1970 to present, Tracy records back to 1950's; provide general estimates of population trends and densities based on numbers salvaged over time.

2. Striped Bass Health Monitoring Program--1978 to present, not all years; 1984 to 1988 under consistent format; analysis of tissues of 40 prespawning adult female fish from Rio Vista and Antioch; provides samples for fecundity data; program undergoing extensive review at the present time.

3. Other--Various other special purpose studies which provide special information on striped bass (Export Curtailment Study, gut content analysis, summer die-off monitoring, etc.).

5.4.2 Striped Bass Index (SBI)

The striped bass populations in the Estuary have declined substantially in recent years, in terms of numbers of both adult and young bass. The D-1485 objectives have not maintained the SBI at the "without project" predicted index level of 79, the expected level of protection under these objectives; nor have they stopped the decline which had begun to become evident even before the objectives were established. Based on a mathematical relationship (predicted SBI) developed by DFG, the actual SBI under the D-1485 objectives for the period 1979-1985 should have averaged about 69 (corrected from DFG,25,134-136 after consultation with DFG staff). In fact, during those years the actual SBI averaged 22.4, about one-third of the predicted SBI (corrected from DFG,25,136). For the period 1979-1990, during which the D-1485 objectives have been in effect, the predicted SBI average is 60.95, while the actual SBI average is 19.1; or 31.3% of the predicted value (Table A5.4-1).

The actual SBI is a value obtained after extensive field sampling and measuring of young striped bass each summer. This value is a measure of the relative abundance of young striped bass in the Estuary when the average length of the young-of-the-year population is 38 mm (1.5 inches). It is called an index because it is a relative value and is not directly translatable into an absolute value of the number of young bass in the Estuary. However, it is a legitimate and relatively sensitive measure of

TABLE A5.4-1
ACTUAL AND PREDICTED STRIPED BASS INDEX VALUES

YEAR	YEAR TYPE (1)	ACTUAL INDEX: DATE SET	ACTUAL INDEX: DELTA INDEX	ACTUAL INDEX: SUISUN INDEX	ACTUAL INDEX: TOTAL INDEX	ACTUAL INDEX: DELTA % OF TOTAL	PREDICTED INDEX: DELTA INDEX (2)	PREDICTED INDEX: SUISUN INDEX (2)	PREDICTED INDEX: TOTAL INDEX (2)	PREDICTED INDEX: ACTUAL % OF PRED.
1956	W	-	-	-	-	-	47.1	53.6	100.6	-
1957	BN	-	-	-	-	-	44.1	39.4	83.6	-
1958	W	-	-	-	-	-	42.3	56.2	98.5	-
1959	D	JULY 12	30.7	3.0	33.7	91.1	35.2	-7.9	27.3	123.4
1960	BN/SS	JULY 17	32.0	13.6	45.6	70.2	41.3	8.9	50.2	90.8
1961	D	JULY 21	25.2	6.4	31.6	79.7	37.9	3.2	41.1	77.0
1962	BN	JULY 26	46.8	32.1	78.9	59.3	42.5	32.0	74.5	105.9
1963	W	AUG 03	38.2	43.5	81.7	46.8	37.8	45.7	83.5	97.8
1964	D	AUG 02	54.7	20.7	75.4	72.5	39.2	19.9	59.1	127.5
1965	W	JULY 31	49.4	67.8	117.2	42.2	40.1	43.6	83.7	140.0
1966	BN/SS	NOT DETERMINED					36.3	6.2	42.5	-
1967	W	AUG 12	35.1	73.6	108.7	32.3	33.8	57.3	91.1	119.3
1968	BN/SS	JULY 19	39.6	17.7	57.3	69.1	26.3	15.4	41.8	137.2
1969	W	AUG 09	33.6	40.2	73.8	45.5	34.5	55.9	90.4	81.6
1970	W/SS	JULY 18	36.6	41.9	78.5	46.6	34.7	28.7	63.4	123.8
1971	W	AUG 11	24.6	45.0	69.6	35.3	30.8	50.1	81.0	86.0
1972	BN/SS	JULY 25	13.4	21.1	34.5	38.8	10.8	22.4	33.2	103.9
1973	W	JULY 15	15.6	47.1	62.7	24.9	21.9	29.5	51.3	122.2
1974	W	JULY 22	17.4	63.4	80.8	21.5	15.1	46.8	61.9	130.6
1975	AN	JULY 30	23.4	42.1	65.5	35.7	30.8	50.4	81.2	80.7
1976	C	JULY 16	21.1	14.8	35.9	58.8	24.3	19.2	43.5	82.5
1977	C	JULY 24	8.3	0.7	9.0	92.2	37.1	7.0	44.1	20.4
1978	W	JULY 23	16.5	13.1	29.6	55.7	29.6	32.0	61.6	48.1
1979	D	JULY 19	5.4	11.5	16.9	32.0	25.3	36.9	62.2	27.2
1980	W	JULY 15	2.8	11.2	14.0	20.0	31.5	46.6	78.2	17.9
1981	D	JULY 02	15.4	13.7	29.1	52.9	34.4	24.7	59.0	49.3
1982	W	JULY 30	9.5	39.2	48.7	19.5	25.4	53.8	79.2	61.5
1983	W	AUG 05	1.2	14.2	15.4	7.8	17.3	57.1	74.4	20.7
1984	W/SS	JULY 13	6.3	20.0	26.3	24.0	26.8	40.1	66.9	39.3
1985	D	JULY 16	2.2	4.1	6.3	34.9	21.8	25.4	47.2	13.4
1986	W/SS	JULY 09	23.8	41.1	64.9	36.7	29.5	38.0	67.5	96.2
1987	C	JUNE 22	7.3	5.3	12.6	57.9	22.9	15.4	38.3	32.9
1988	C	JULY 24	3.9	0.7	4.6	84.8	17.2	12.8	30.0	15.3
1989	(3) BN	JULY 11	3.1	2.0	5.1	60.8	26.1	31.4	57.5	8.9
1990	C	JULY 18	2.8	1.5	4.3	65.1	(4) 36.6	24.7	61.3	7.0

NOTES:
1 = D-1485 YEAR TYPE (W = WET; AN = ABOVE NORMAL; BN = BELOW NORMAL; D = DRY; C = CRITICAL; SS = SUBNORMAL SNOWMELT)
2 = PREDICTED INDEX BASED ON REGRESSION OF ACTUAL ABUNDANCE, OUTFLOWS AND DIVERSIONS FOR THE YEARS 1959 TO 1976, EXCEPT 1966 (ACTUAL SBI NOT DETERMINED) AND 1972 (ANDRUS ISLAND FLOODING)
3 = DRY YEAR TYPE FOR FISH AND WILDLIFE OBJECTIVES; VALUES CORRECTED FROM THOSE PRESENTED IN EXHIBIT WQCP-DFG-2 (PERS. COMM., LEE MILLER, DFG, 09/06/90)
4 = 1990 PREDICTED INDEX VALUES BASED ON PRELIMINARY FLOW DATA

the change in abundance between years. The actual SBI tends to underestimate the young bass abundance in very high outflow years because many of the fish are carried downstream beyond the DFG sampling stations. The influence of high flow in recent years, especially in 1983 and perhaps to some extent in 1982, may have induced a small portion of the total decline in the actual SBI observed in the last decade. The large declines measured in dry years would not be so affected, however. Changing the station locations might provide a better measure in wet years, but would complicate calculation of index values and comparison between years. (The actual SBI has been measured every year since 1959, except 1966.)

The actual SBI is the sum of two separate indices: the Suisun Bay index and the Delta index (Table A5.4-1; Figure A5.4-1). The proportion of young bass in the Delta and in Suisun Bay depends on flow; in years with higher outflow, a higher proportion of young bass are usually found in Suisun Bay (Don Stevens, DFG, pers. comm., 1989). This general pattern existed through the 1960's. Analysis of the actual SBI data indicates a substantial shift in the distribution and abundance patterns of young striped bass in recent years. In the early 1970s the actual SBI declined, in large part because the Delta index began to contribute a much smaller proportion of the total index regardless of flow conditions (Figure A5.4-2). After the 1976-77 drought, the Delta index contributed a high proportion of the total index only in very dry years when very few young bass were able to be moved into Suisun Bay, and total numbers of young bass were at record low levels.

There has been considerable confusion in the testimony in Phase I concerning whether the SBI in D-1485 has "worked" or "failed". The reason is that the D-1485 objectives were based on a <u>predicted</u> SBI, a mathematical formula based on the relationship of the historical record of young bass abundance (actual SBI) to spring Delta outflow and exports. This formula provided a prediction of what the SBI ought to be each year, given certain flow and export conditions; it was used to develop the export and outflow requirements in D-1485. The discrepancy between the predicted and the actual SBI is the reason that some participants stated that "the SBI has failed". However, the <u>actual</u> SBI has not failed, even if it may somewhat underestimate the abundance of young fish in very wet years. It continues to provide a comparative measure of young bass abundance among years.

Various reasons have been proposed for the failure of the predicted SBI. For example, the State Water Contractors suggest that the reason for the failure is that the underlying assumptions are still correct, but "that factors in addition to flow are contributing to the problems experienced by striped bass" (WQCP-SWC-608,51). However, a strong argument can be made that the predicted SBI model has been used outside the range of flows and diversion rates from which it was derived. The original relationship among outflows, diversions and the predicted SBI was based on data developed during the period 1959-1970. During this period, exports in the spring months were primarily by the CVP Tracy pumps, and several major upstream storage projects (Oroville and New Melones reservoirs) had not been completed or had not yet had a significant effect on the Delta. As shown in Table A5.4-2 and Figure A5.4-3 total Delta exports were

FIGURE A5.4— 1 STRIPED BASS INDEX

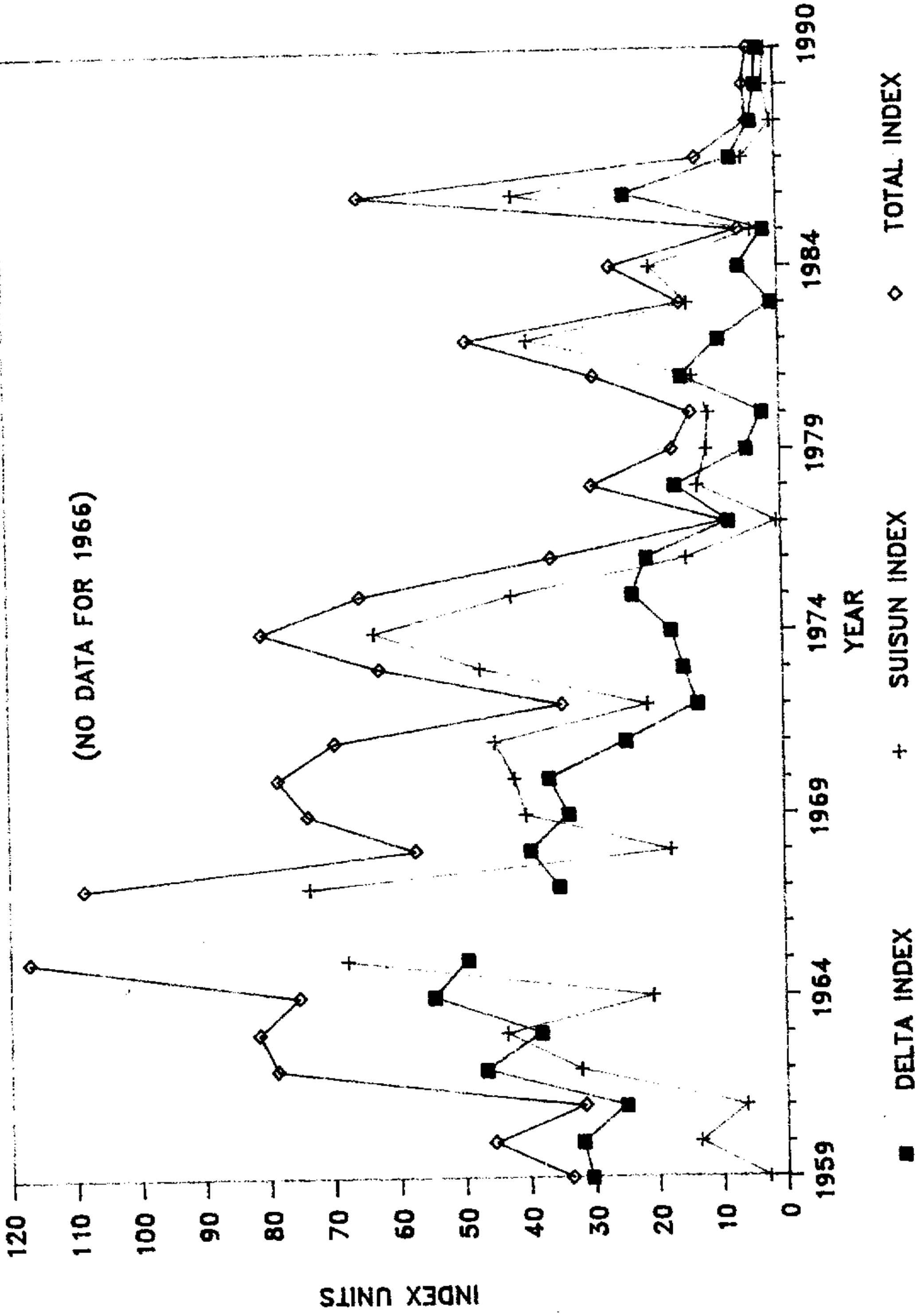
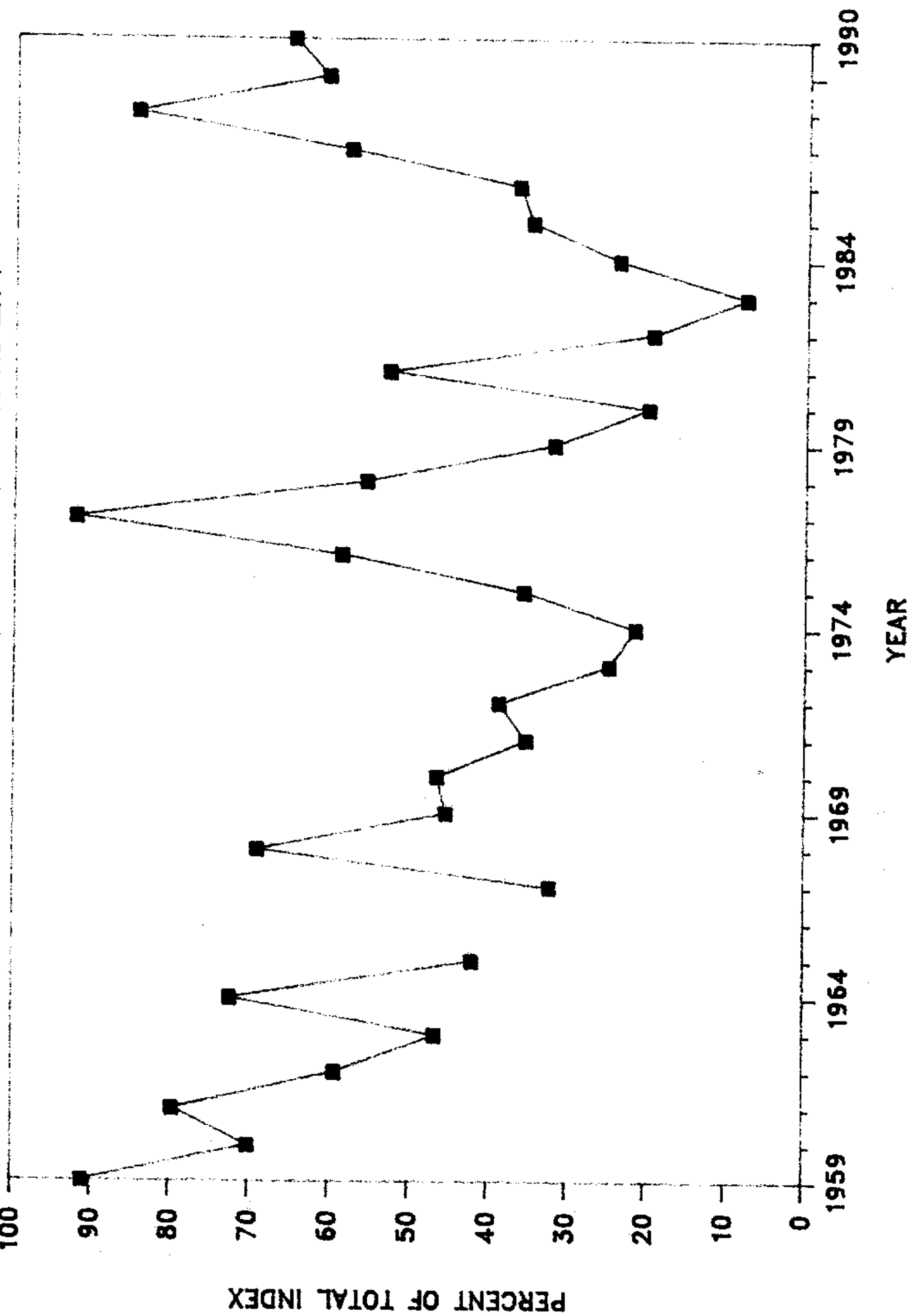


FIGURE A5.4-2
DELTA STRIPED BASS INDEX



relatively constant at about 3,500 cfs during the April through July period. However, during the 1971 through 1976 period, when the decline in the Delta portion of the SBI began to become apparent, total exports for the April through July period increased to an average of nearly 5,900 cfs. Part of this increase was due to a series of experiments to test the effects of increased pumping on striped bass survival (Don Stevens, DFG, pers. comm., 1/90). The data developed during the 1959 through 1976 period were used to develop both the predicted SBI and the 1978 D-1485 objectives. During the fifteen years of data between 1959 and 1976 (no sampling in 1966, and 1972 data were not used because of the Andrus Island flooding), average exports in the April through July period exceeded 6,000 cfs only twice (1973 and 1974), or thirteen percent of the years. On the other hand, during the twelve years that the D-1485 objectives have been in effect, average April through July exports have exceeded 6,000 cfs in seven years, or 58 percent of the years. The average April through July exports during the years under D-1485 objectives were 6452 cfs, or about 50 percent higher than the period 1959 through 1976.

DFG offers substantial additional evidence that the influence of spring outflow and export rates on young striped bass abundance may be substantially greater than previously believed, and that the high export rate experiments in the early 1970's may have helped to trigger the low abundance values seen in the late 1970's and 1980's (WQCP-DFG-3,26).

5.4.3 Possible Reasons for the Striped Bass Decline

Many reasons have been proposed to explain the decline in striped bass abundance. In 1982, the Striped Bass Working Group, composed of Interagency staff and outside consultants, examined the available data and proposed four major hypotheses for the decline. These were:

- o inadequate food supply for the young bass,
- o direct entrainment losses in diversions and changes in Delta hydrology due to diversions and exports,
- o toxic substances, and
- o lack of sufficient striped bass eggs.

These four hypotheses served as the basis for the exhibits and testimony of DFG (DFG,25) and SWC (SWC,203) in Phase I. Since then, considerable additional discussion and data analysis have resulted in an expanded and refined list of possible causative factors. This list is discussed in a new DFG report (Department of Fish and Game, 1989). The more recent 1990 DFG draft report (WQCP-DFG-3) specifically addresses the decline of the bass . The major points of the Management Plan and the 1990 report are similar and summarized below. While all the causes listed in the DFG Plan are summarized below, it is likely that only a few factors are the probable causes for the majority of the recent decline: reduced inflow and outflow; diversions; pollutants; and introduction of exotic organisms, especially as related to food-chain disruptions.

TABLE A5.4-2. TOTAL DELTA EXPORTS, CFS; SWP, CVP, AND CCC
(Diversions to Byron-Bethany Irrigation District, North Bay Aqueduct, and City of Vallejo not included)

YEAR	APRIL	MAY	JUNE	JULY	TOTAL	A-M-J-J AVG	M-J-J AVG
1953	1422	2110	2312	2904	8748	2187	2442
1954	2052	1371	3000	3292	9715	2429	2554
1955	2283	2447	3194	3205	11129	2782	2949
1956	704	423	1179	3248	5554	1389	1617
1957	2353	2186	3277	3591	11407	2852	3018
1958	152	599	772	2931	4454	1114	1434
1959	2757	2661	3564	4005	12987	3247	3410
1960	2605	2688	3825	4095	13213	3303	3536
1961	2900	2837	3992	4656	14385	3596	3828
1962	2761	2963	3799	4229	13752	3438	3664
1963	1231	2774	3543	4198	11746	2937	3505
1964	3065	3261	3795	4619	14740	3685	3892
1965	1204	3193	3694	4361	12452	3113	3749
1966	3108	3381	4075	4597	15161	3790	4018
1967	1207	1921	2162	2697	7987	1997	2260
1968	5380	5611	4708	5168	20867	5217	5162
*1969	3212	3270	2494	3382	12358	3090	3049
1970	4653	4012	4997	5227	18889	4722	4745
1971	4431	4549	5768	6509	21257	5314	5609
*1972	6356	6495	5350	5074	23275	5819	5640
1973	3352	6501	7355	7693	24901	6225	7183
1974	4203	7130	9130	10691	31154	7789	8984
1975	6304	5583	4520	5184	21591	5398	5096
1976	5037	5488	4152	4109	18786	4697	4583
**1977	1295	2987	739	845	5866	1467	1524
1978	3271	3058	7621	8088	22038	5510	6256
1979	5882	6245	6341	9339	27807	6952	7308
1980	5343	4630	5961	6869	22803	5701	5820
1981	8090	4478	4032	7046	23646	5912	5185
1982	9603	5994	3935	4032	23564	5891	4654
1983	3814	3293	5010	5207	17324	4331	4503
1984	7685	5929	6165	9457	29236	7309	7184
1985	7342	6215	6530	9465	29552	7388	7403
*1986	4696	6260	6177	8607	25740	6435	7015
1987	7021	5313	5184	8953	26471	6618	6483
1988	8577	6164	6007	8247	28995	7249	6806
1989	10435	6198	5240	9539	31412	7853	6992
***1990	9743	3487	3591	6335	23156	5789	4471
AVERAGE	4356	4045	4400	5571	18372	4593	4672

AVERAGES	APRIL-JULY	MAY-JULY
1953-1967	2791	3058
1968-1990	5768	5724
1979-1990	6452	6152
1953-1990	4593	4672
1959-1970	3511	3735
1959-1976	4299	4551
1971-1976	5874	6182

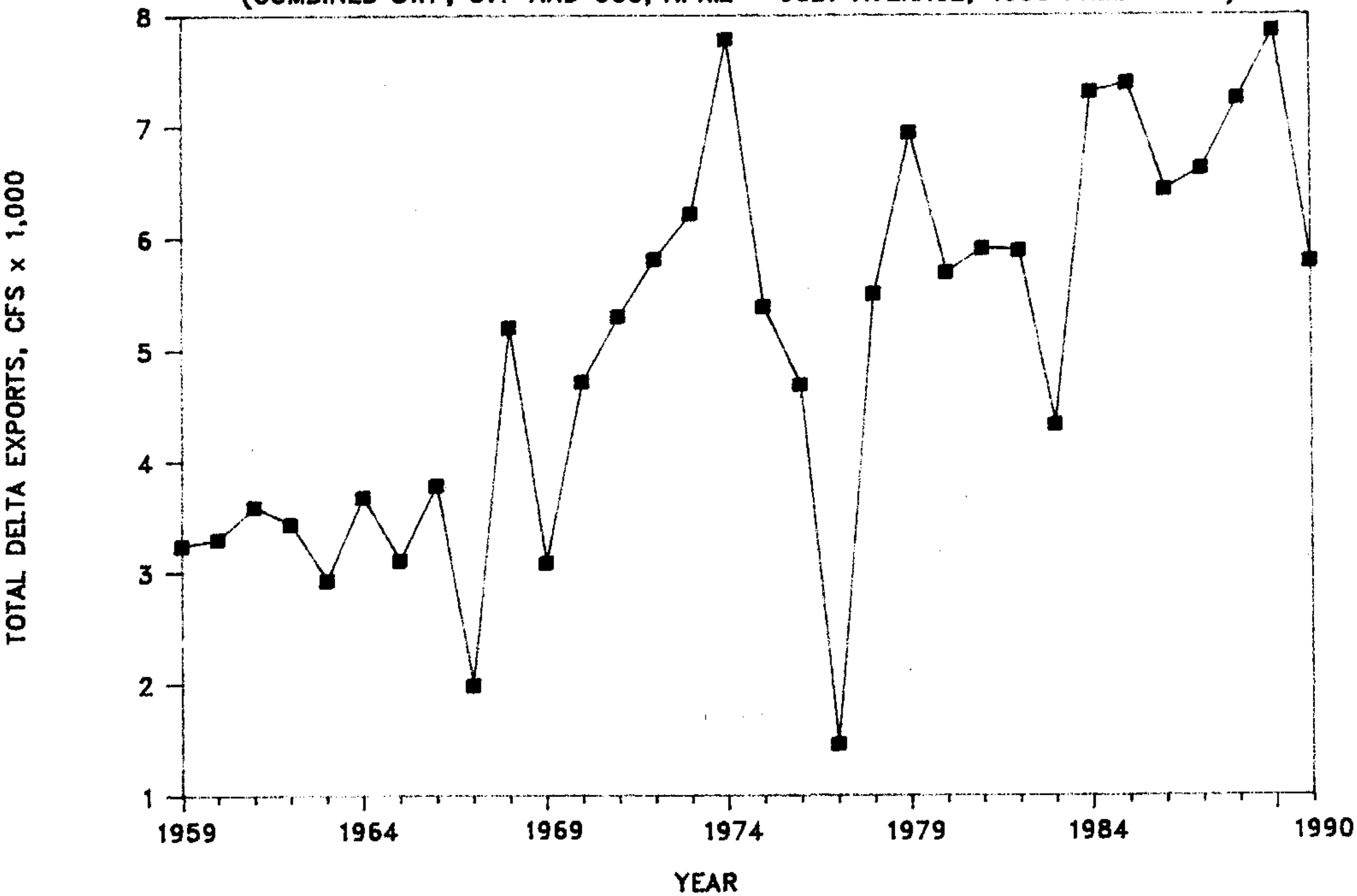
* = Values different from DAYFLOW; effects of island flooding and dewatering not included

** = SWP and CVP impose deficiencies in deliveries

*** = SWP and CVP impose deficiencies in deliveries; California Aqueduct unavailable May 1 to mid-July for repairs; preliminary values, from CVP Operations Office, 09/05/90

FIGURE A5.4–3. TOTAL DELTA EXPORTS

(COMBINED SWP, CVP AND CCC; APRIL – JULY AVERAGE; 1990 PRELIMINARY)



1. Delta and Upstream Water Diversions

Seven separate water diversion operations in and above the Delta impact striped bass. These impacts include: direct entrainment of eggs and young, losses during salvage from fish screens, increased predation at screens and at release points for salvaged fish, disruption of migration routes, translocation of Sacramento River eggs and young into the central Delta, and disruption of young bass food supplies (plankton).

The major sources of water diversions in and above the Delta are:

- The SWP Delta pumps, rated at 6,300 cfs, with construction underway to expand capacity to 10,300 cfs in the early 1990's;
- the CVP Tracy pumps, rated at 4,600 cfs;
- the Contra Costa Canal pumps, with a diversion capacity of 350 cfs;
- the North Bay Aqueduct pumps, rated at 175 cfs;
- the Pittsburg and Contra Costa PG&E power plants, with a combined intake capacity of about 4,600 cfs;
- approximately 1,600 to 1,800 unscreened agricultural diversions and subsurface seepage in the Delta, which may divert up to 4,500 cfs in July; and
- an undetermined number of agricultural, municipal and industrial diversions above the Delta on the Sacramento and San Joaquin rivers and their tributaries.

2. Reduced Delta Outflows

Extensive water development and conservation projects, combined with water exports, have changed the pattern of Delta outflows, especially by outflow reductions during the spring and early summer months critical to spawning and young bass survival. Striped bass are affected in several ways: spawning habitat is reduced, the time required to move young to nursery areas is increased, the nursery habitat is restricted, food (plankton) production is reduced, and the effects of exports on translocation and reverse flows is enhanced. Combined with armoring (riprapping) of upstream and Delta levees, upstream development may result in increased water clarity in the Delta, which may also cause increased predation on striped bass eggs and young.

3. Low San Joaquin River Flows

Low river flows combined with high dissolved solids levels, caused primarily by agricultural return flows, produce a salinity barrier in the Stockton area, which inhibits upstream migration by adults and reduces spawning habitat. Reduced San Joaquin River flow also exacerbates the effects of export operations and reduced Delta outflows by enhancing cross-Delta flows and reverse flows in western, central and southern Delta channels.

4. Water Pollution

Toxic organic chemicals (petrochemicals and pesticides) and toxic trace elements (mercury, selenium, copper, cadmium, zinc, etc.) may have acute or chronic effects on adults, eggs and young of striped bass, or on their food chain. Pollutant-caused stress or other physiological dysfunction may also reduce resistance to diseases, parasites, predators and adverse environmental conditions.

5. Navigation Structures, Dredging and Spoil Disposal

Activities related to channel maintenance are primarily water quality issues, due to resuspension of toxic materials. However, related effects -- such as excessive turbidity; abrasion of fish gills and other body parts; disruption of food chains; disturbance of migration, spawning and feeding; and loss of habitat -- may also result from navigation maintenance activities.

6. Filling of Estuary Tidelands

Filling of open water areas reduces bass and bass-food habitats and reduces the tidal prism in the Estuary. Reducing the tidal prism reduces the pollutant flushing capability of the Estuary, which may result in water quality problems for the bass or its food chain.

7. Illegal Take and Poaching

The striped bass population is affected to an unknown degree by the illegal taking of bass by means of catching more than legal limits, taking undersize fish, and using nets.

8. Diseases and Parasites

Diseases and parasites stress, debilitate or kill both young and adult striped bass. The incidence and severity of these problems are affected by toxic substances, food availability and other factors. The Striped Bass Health Monitoring Program has not demonstrated any distinct patterns of decreases in health or increases in parasitism in Bay-Delta Estuary fish since monitoring began in 1978.

9. Annual Die-off of Adult Bass

Almost every year there is a summer die-off of adult bass in the Carquinez Strait area. The cause is unknown, but may be related to liver dysfunction, possibly caused by toxic organic pollutants.

10. Commercial Bay Shrimp Fishery

The distributions of juvenile bass and market-size bay shrimp overlap considerably in various parts of the Estuary. Young bass are killed during shrimp netting operations. Regulations have been changed to reduce this incidental kill, but further information is required to determine the extent of the problem.

11. Exotic (Introduced) Aquatic Organisms

Various species of fish and invertebrates have been introduced into the Estuary from other areas. Some of these introductions, such as striped bass and American shad, were planned; the resources were managed to develop and maintain these fisheries. Other introductions were not planned. These unauthorized introductions of exotic species, primarily through the dumping of ballast water from foreign shipping, have had harmful effects on striped bass and their food supply. For example, the yellowfin goby, Acanthogobius flavimanus, feeds voraciously on invertebrates and small fish, and so may compete with striped bass for food; it may also prey on small bass. Introduced oriental zooplankton species have experienced explosive population growth in the upper portions of the Estuary in the last decade, and preliminary tests suggest that at least one species is less suitable as a food source for striped bass than the native copepod, Eurytemora affinis. The rapid establishment of the introduced clam, Potamocorbula amurensis, with its high water-filtering rates, may be having significant impacts on phytoplankton and zooplankton abundance in the striped bass nursery areas in Suisun Bay. Once established, it is virtually impossible to eradicate aquatic animal species from as open and complex an environment as the Estuary.

12. Overfishing1/

Overfishing is not viewed at present by DFG as a cause of the decline because anglers harvest only 15 to 25 percent of the adult population annually. This is viewed as being "well within safe limits for a typical striped bass population" (DFG, 1989,p.31). The more restrictive fishing regulations enacted in 1982 should have reduced the catch somewhat, but since there is no control on the number of striped bass anglers or the number of individual fishing days, the effect is not known.

13. Genetic or Other Unknown Factor 1/

Because of the decline of several distinct populations of striped bass across the country in a short span of time, there has been some thought that a common factor, such as a genetic link, might be involved. In addition, the Bay-Delta population originated from a very small stock, with presumably limited genetic diversity. Therefore, this population could be less resilient in the changing environment of the Estuary than would be the case with a larger gene pool.

1/ Not included as factors by DFG (DFG, 1989).

5.4.4 Export Area Striped Bass Fishery

In evaluating the decline of striped bass, it should also be noted that the measurements of the decline apply to the Estuary only. Substantial numbers of eggs and larvae are exported from the Estuary by the CVP and SWP systems. These provide the basis for a sustained striped bass fishery throughout the San Joaquin Valley and even in the SWP terminal reservoirs in southern California. Unfortunately, there are few data available on the size or condition of these populations, or how these populations have been affected by changes in the Estuary. DFG testified (T,LXVIII,III,63:15-22) that those fish in the export facilities do not support the estuarine fishery, nor are they part of it, except that nearly all of those fish originated in the Estuary. The development of this fishery in the export facilities is a by-product of the CVP and SWP systems, but should not be viewed as partial mitigation for the impacts of the export systems on the Estuary striped bass population. As the Estuary population declines, these export area populations may also be expected to decline, as they are probably not self-sustaining by means of successful spawning in the aqueducts or reservoirs.

5.4.5 Discussion of Issues Associated with Striped Bass Spawning in the San Joaquin River

In the August 1990 Workshop, the SWC presented an analysis of several issues related to striped bass spawning. Dr. Charles Hanson made a series of points about the validity and applicability of the data presented in previous sessions and in the June 1990 Revised Draft Plan. These points reflect the concerns of other participants which were presented at both the February and August Workshops. These points may be summarized as follows:

(1) management of stream temperature for salmon protection could affect striped bass spawning (T,LXXV,VII,85:7-86:3);

(2) most spawning data support the contention of DFG researchers that bass prefer to spawn in fresh water (less than 200 mg/l TDS (=0.35 mmhos/cm EC)), but two years (1968 and 1972) show that spawning occurred in higher salinity waters (WQCP-SWC-623B);

(3) the spawning area in the Delta appears to be fairly constant regardless of apparent EC (WQCP-SWC-623C);

(4) no consistent pattern of egg survival and salinity could be determined; once the eggs are hardened, there is no apparent relationship between survival and incubation salinity;

(5) there were no consistent differences in egg survival between the Sacramento and San Joaquin rivers, and no consistent relationship between egg survival and San Joaquin River flow, or Delta outflow;

(6) expanding the spawning area upstream of Prisoners Point on the San Joaquin River may expose eggs and young to additional entrainment from the SWP and CVP pumps (T,LXXV,VII,106:11-18).

Based on their analysis, the SWC concluded that striped bass reproductive success in the San Joaquin River and the Delta is not a water quality problem in the range of salinities found in the present spawning area (T,LXXV,VII,107:22-108:5).

The analysis provided by the SWC makes several interesting and important points; these points require some additional discussion, however. Each point listed above will be considered in turn.

(1) Concerns about temperature control for salmon detrimentally affecting striped bass are probably unfounded. The temperatures proposed for salmon protection (66-68°F), are well above those associated with the onset of striped bass spawning (59-61°F). Turner (1976) noted that in the years 1963, 1964 and 1965, almost 90 percent of spawning occurred in water temperatures between 63°F and 68°F.

(2) The two years (1968 and 1972) in which significant spawning occurred in water more saline than 200 mg/l TDS (=0.35 mmhos/cm EC) were years in which salinity intruded into the spawning area, as Turner noted (1976, p. 112). He further noted (1976, p. 118) that "striped bass universally spawn in essentially freshwater, although in a number of estuaries they do spawn immediately upstream of the limits of ocean salinity intrusion, as they do in the lower San Joaquin River". If they cannot move farther upstream due to the Prisoners Point salinity barrier, then substantial spawning will occur in somewhat more saline water, as seen in 1968 and 1972. Possible effects of this are discussed below in relation to egg hardening (No. 4).

(3) While the spawning area in the Delta does appear to be fairly constant, based on examination of WQCP-SWC-623C, what is not indicated on the exhibit is that in at least five of the seven years indicated (1968-1972), no sampling was conducted above Prisoners Point. Even if the bass did spawn farther upstream, the data would not reflect it. In addition, the use of Delta outflow as a surrogate for EC may not be appropriate, since most Delta outflow is from the Sacramento River. Higher outflow does not necessarily mean low EC in the upper San Joaquin River.

There are related issues concerning this discussion of spawning area. First, as noted, if water quality above Prisoners Point is such that the fish cannot move upstream, then of course they will spawn in whatever habitat is available to them. Second, the smaller channels with faster currents in the upper river would tend to move eggs relatively quickly downstream into the wider channels of the lower river, where slower currents and tidal action would tend to concentrate the eggs, thus suggesting that a higher percentage of spawning might be occurring there than would actually be the case.

Third, the lack of tag returns from adult striped bass from the San Joaquin River above Prisoners Point is also used as evidence that the fish are not using this area. If the water quality prohibits upstream migration, then fish will, in fact, not be caught there. Tag returns also indicate where fish are being caught, not where all the fish are. If the fishing for bass is known to be good in a particulate area, then the tag returns will reflect that increased fishing pressure. Tag returns are not an unbiased sampling tool. DFG testified that fishing used to be much better for striped bass in the San Joaquin River system than it is at present (T,XLII,55:16-56:19).

Finally, as discussed by Mr. Chadwick (DFG) and Dr. Hanson (SWC) (T,LXXV,VII,111:3-14), regular exposure to higher salinity water in a spawning area could cause striped bass to desert that area or use it less. It is possible that striped bass have largely abandoned the upper San Joaquin River as a spawning area.

(4) The point about high egg survival even in saline water once the eggs are hardened is important. The key is that the eggs were first hardened in fresh water. While the data suggest that EC's normally found in the Delta are comparable to the laboratory experimental salinity range, EC intrusion during deficiency period relaxations could result in less effective hardening of the eggs. This may result in lower survival as water temperatures increase (see Appendix 5.4.6). Additional work in this area may be warranted.

(5) The SWC analysis showed no consistent differences in egg survival between the Sacramento and San Joaquin rivers (WQCP-SWC-623H). This conclusion was based on DFG data (DFG, 1988, T21). However, this same report (Table 16) showed that the average percent of live eggs collected over six years (1972, 1975, 1977, 1984, 1985, 1986) in the Sacramento River was 58.5 percent, while in the San Joaquin River it was 41.5 percent, or 29 percent less than the Sacramento River. Taken together, the data indicate that egg survival, once development has begun, is not consistently different, but that the number of eggs laid which are viable is substantially lower in the San Joaquin River. This suggests that the present spawning habitat or other conditions in the San Joaquin River may result in lower spawning success.

Exhibit WQCP-SWC-623K shows no relationship between percent of live eggs and either April Vernalis flow or April Delta outflow. It should be noted that no more than 30 percent of total spawning occurred during April in any of the six years included (see Water Quality Control Plan, Table 5-2, p. 5-31).

(6) The concern about increased entrainment of eggs and young due to SWP and CVP facilities should spawning habitat be expanded to Vernalis has been raised by various parties. It is argued that the present condition, while far from ideal, at least may provide some protection against the influence of the pumps for some of the Delta population. No evidence was presented to support this position.

A few final comments are appropriate. As noted, the DFG data used in these analyses are taken at various locations, with different kinds of gear, and for different purposes. Therefore, these data must be cautiously interpreted. Experimental data are limited, and definitive field tests are difficult to complete successfully. Additional data are required on the actual effects of salinity (and other factors) on spawning and survival of eggs and young. For example, the variations in survival which appear to occur in the 0.3-0.8 mmhos/cm EC range are crucial to our understanding of what striped bass in the San Joaquin River really need.

5.4.6 Effects of Temperature on Striped Bass Adults, Eggs and Young

The effects of temperature on adult striped bass appear to primarily involve the range of temperatures at which spawning occurs. High water temperatures may occasionally appear to inhibit spawning, but a review of historical spawning patterns indicates that spawning is more often delayed by low temperatures. Since spawning correlates with increasing temperatures, it appears that most spawning is completed before the upper end of the suitable temperature range occurs.

DWR presented a review of the migration patterns of adult striped bass as related to temperature, especially the "thermal niche" hypothesis, which suggests that striped bass migrate in response to selection for a specific temperature range (DWR,608). No pattern of temperature selection was noted for adult bass in the Estuary. However, the first-year tag return data used in the analysis did demonstrate a changing pattern of bass migration, with a smaller proportion of the population migrating down into the lower Estuary and the ocean than in earlier years. DFG also reviewed the data and, while not concluding that there was no relationship, did not recommend any specific temperature objectives (DFG,25,24-26).

DWR exhibit 607 discusses the possible effects of high water temperature on survival of eggs and young of striped bass in the Delta and in the Sacramento River (DWR,607). The report indicates that optimal temperature ranges for eggs and young are 16° to 20°C (62°-68°F), and that reduced survival occurs below 14°C (57°F) and above 23°C (73.4°F). The report concludes that low temperatures are not a problem in the spawning areas, since adults spawn at temperatures above 15°C (59°F), and the water in the Delta tends to remain warm throughout the spawning period. Likewise, the temperature range in the Delta stays below the upper limit during the spawning and early development period. The report indicates that, in some years, there may be some losses due to high water temperatures in the Sacramento River, especially of eggs and young larvae of late spawning fish. DWR's analysis of the recent spawning pattern suggests that these losses represent only a few percent of the total Sacramento River spawn, and are not significant. No recommendations for temperature controls on the Sacramento River for protection of striped bass were proposed by DWR or any other participant. However, the report noted that potential effects of high temperatures on older larvae (beyond the yolk-sac stage) were not examined, and that Suisun Bay and Delta temperatures exceeded 23°C (73.4°F) by early July in 1981, 1984 and 1985.

The major impact that temperature may have on developing eggs and larvae is the rate of development. Albrecht (1964) noted that the rate of yolk absorption at 75°F was twice as fast as at 62-64°F. Thus, presence of food in the water column may be more critical at warmer temperatures, and lack of food may lead to higher rates of starvation, which is one of the suggested major causes for the decline in the SBI. Turner and Farley (1971) found that a combination of higher temperatures (72°F) and higher salinity (1,000 mg/l TDS) resulted in no egg survival. However, "hardening" of the eggs (formation of a vitelline membrane around the egg after fertilization) in fresh water rather than in saline water resulted in much higher survival when the eggs were subsequently exposed to higher water temperatures and more saline conditions. Given that water temperatures have exceeded the upper limits of the survival range (23°C; 73.4°F) in early June in several recent years (DWR,607,15), the maintenance of low salinity in the Delta spawning area in low flow years may be critical to the survival of more eggs.

APPENDIX 5.5
THREATENED, ENDANGERED AND CANDIDATE SPECIES

5.5.1 Animals

The salt marsh harvest mouse, the Suisun ornate shrew, and the California clapper rail are found primarily in the more saline areas of Suisun Marsh where pickleweed is common. The DFG testified that they do not expect these species to be adversely affected by an increase in channel water salinity in the marsh (T,XXIX,168:13-16).

The California black rail is found in saltwater, brackish, and freshwater marshes. Direct loss of habitat by conversion of marshes to other land uses is thought to be the primary reason for its decline (DFG, 1988 Annual Report on the Status of California's State Listed Threatened and Endangered Plants and Animals, p.28). No information was presented to indicate how the black rail may respond directly to changes in the salinity regime. The black rail requires high tide refuges with considerable vegetative cover to hide from predators when its usual feeding areas are inundated. These refuges are not common in the Suisun Bay marshes. Unless it occurred immediately adjacent to these refuge areas, expansion of the more salt-tolerant vegetation would not result in significant increases in available habitat (T,XXX,41:4-19). DFG indicated that they do not expect changes in the vegetation patterns in the bird's range to significantly affect the black rail (DFG,7,12).

The salt marsh yellow throat is a subspecies of the common yellow throat. BAAC testified that there would be negative impacts on this bird from increased salinity in the Suisun Bay marshes. However, BAAC also stated that there is a question as to which subspecies is found in Suisun Marsh (T,XXX,39:12-28).

The Suisun song sparrow is typically found in brackish tidal marshes. DFG estimates that less than 10 percent of the historically available habitat still exists, and that is in disconnected fragments and narrow strips. Increases in salinity would further reduce the available habitat (DFG, 1988 Annual Report, pp. 40-41).

Adult winter-run Chinook salmon migrate upstream through Suisun Bay and Marsh between November and April. Young smolts from the subsequent spawning are found in Suisun Bay from about November to late April. An analysis of the water quality needed for salmon is found in Section 5.5.2 of the Plan.

Delta smelt are found primarily in the fresher water of the Delta and Marsh. An analysis of the water quality objectives needed for the smelt is found in Section 5.8.2 of the Plan.

The monitoring requirements in the 1978 Delta Plan for the Suisun Marsh do not specifically address rare, threatened, or endangered species, although by inference the plan of protection (Marsh Plan) required in D-1485 term 7(a) is intended to ensure protection of all Marsh wildlife. There are a number of federal candidate species being studied for possible listing. While federal candidate species receive no special legal protection, they must be considered during analysis of this Plan because they may be proposed for listing at any time and would then gain protection under the federal Endangered Species Act (T,XXX,7:4-13,8:24-9:3). (Note: A state "candidate" species is, like a federal "proposed" species, being actually under full review for listing and is protected under the California Endangered Species Act.) If federal candidate species are listed, the possible effects of the water quality objectives on those species must be analyzed. If the effects are adverse, either the water quality objectives must be changed or mitigation measures must be devised to eliminate the adverse effects. Part of the triennial review of the water quality control plan will be to review the effects on threatened and endangered species to determine if the water quality objectives are providing adequate protection. This review would be the most likely forum for any necessary revisions of the objectives.

5.5.2 Plants

Suitable pore water salinity ranges from zero to minus five megapascals (MPa) (comparable to a range of zero to four parts per thousand (ppt) salinity, or zero to 6.25 mmhos/cm EC) for the five sensitive plants species. The California hibiscus and Delta tule pea, which are freshwater plants, can tolerate zero to minus two megapascals and Mason's lilaeopsis and Suisun aster, which tolerate somewhat brackish conditions can tolerate minus two to minus three MPa in Suisun Marsh (comparable to four to six ppt salinity, or 6.25 to 9.36 mmhos/cm EC) (T,XXX,76:5-23). On the other hand, soft bird's-beak, which grows in saline areas, could tolerate minus four to minus five MPa (comparable to 8 to 10 ppt salinity, or 12.5 to 15.6 mmhos/cm EC). These are maximum pore water potentials and should not be reached until after the March to July growing season (T,XXX,79:12-14).

DFG developed a method for producing desired soil salinities in the managed wetlands based on surface water quality and timing of applied water (DFG,5,T3). Though we recognize that the ratios of surface water salinity to pore water salinity may be different for unmanaged wetlands, until special studies are completed the use of the DFG method is warranted.

Increased salinity in tidally influenced channels would cause increased physiological stress on plants, resulting in decreased reproduction and productivity, eventually leading to changes in the plant and dependent animal community (CNPS,4,5-8). Water quality objectives allowing higher salinity levels than at present would likely increase plant stress, decrease photosynthetic productivity of marsh plants, kill salt-sensitive plant species, retard growth of new plants, and reduce plant species diversity (CNPS,4,10; T,XXX,68:20-70:20). The Mason's lilaeopsis, the California hibiscus, the Delta tule pea, and the Suisun aster would be adversely affected by changes in flow or salinity in the Suisun Marsh area (CNPS,3; T,XXX,66:11-67:13). The soft bird's-beak is a salt marsh plant and would not be stressed unduly if salinity increased; the other species would be less likely to survive, would have reduced growth or seed production, or would become less numerous (T,XXX,70:19-23). The CNPS testified that in recent years freshwater flow to the Suisun Marsh has been insufficient to prevent reductions in productivity even during normal years (T,XXX,79:15-20).

Once a population of a rare species is eliminated, it is very unlikely to be re-established because of the scarcity of seed sources (T,XXX,81:22-24). Thus, although common species, such as alkali bulrush, may be adequately protected or able to recover from a period of exposure to higher salinities during a critical or dry water year, sensitive species would be at risk. A salinity objective would need to be set at a level which permits the sensitive species to sustain normal survival, productivity, and germination.

APPENDIX 5.6
SUISUN MARSH PRESERVATION AGREEMENT -- TECHNICAL ANALYSIS

In 1928 a report was prepared describing the salt water problem in the San Francisco Bay and Sacramento-San Joaquin Delta (Means, 1928). By this date the combined effects of upstream diversions for irrigation during the summer had significantly increased the salinity of the water in Suisun Bay, which was ordinarily a fresh water body (Means, 1928, p. 10). Between 1902 and 1920 the area irrigated in the Central Valley increased manyfold (Means, 1928, p. 11). By 1928 constructed reservoir capacity in the "Golden Gate watershed" totaled approximately 4,000,000 acre-feet, with another 5,400,000 acre-feet of capacity being considered (Means, 1928, pp. 12-13). Nearly all of these reservoirs were used for irrigation within the watershed and for power generation. There was little out-of-basin transport.

It is obvious from the brief historical summary above that the initial increase in salinity of Suisun Bay occurred prior to the construction of the CVP and the SWP; in fact, salinity control in the Delta was one of the justifications for the CVP.

Export water from the Delta watershed to other parts of California commenced in the late 1950's, e.g., D-935, D-990. A series of hearings held by the State Board in the 1960's and 1970's to establish operating conditions for the CVP and the SWP led to the preparation of the 1978 Delta Plan and Water Right Decision 1485.

The permanent standards for wildlife protection in the 1978 Delta Plan, were also included in D-1485 (adopted August 1978).

The State Board determined that immediate compliance with the permanent standards for Suisun Marsh solely by fresh water outflow would be an unreasonable use of water. It was stated in the 1978 Delta Plan that "[t]he interim standards do not provide complete protection to Suisun Marsh. The interim standards require some modification of [state and federal] project operations to benefit the Marsh, but rely primarily on the occurrence of uncontrolled outflows to protect the Marsh until 1984" (1978 Delta Plan, p. VI-12).

The State Board expected DWR and USBR to complete the construction of facilities to protect Suisun Marsh habitat by 1984. D-1485 required water right permittees DWR and USBR, in cooperation with other agencies, to develop a plan for protection of the Suisun Marsh (Marsh Plan) by July 1, 1979. This Marsh Plan was to provide a monitoring network, construction of physical facilities, operation and management procedures for the facilities and assurances by land managers to maintain the Marsh as a brackish water wetland (SWRCB,1978,26). DWR and USBR were required to manage the Marsh to produce high quality feed and habitat for waterfowl and other wildlife and to implement the Marsh Plan for full protection of the Marsh by October 1, 1984 (SWRCB,1978,26-27). The final Plan of Protection for Suisun Marsh (Plan of Protection) (DWR,511) was completed in February 1984. When D-1485 was amended in 1985, the Board granted extensions of time and modifications to monitoring locations in the water right permits of the SWP and CVP (DWR,505); these same changes were not made in the Delta Plan. The interim standards have remained in effect until the present.

After the Plan of Protection was completed, DWR, USBR, DFG, and the Suisun Resource Conservation District (SRCD) negotiated a set of three agreements concerning the managed wetlands. One of these, the Suisun Marsh Preservation Agreement (SMPA), was designed to provide the managed wetlands of the Suisun Marsh with water quality suitable for the production of those particular marsh plants (especially alkali bulrush and fat hen) which are important food for waterfowl (T,XXIX,15:17-20,32:23-33:1,106:14-21,116:5-10). The water quality standards in the SMPA differ from the standards proposed in the 1984 Plan of Protection in using a different definition for "Dry" and "Critical" years for determining when the "Deficiency Standards" would be imposed on the Suisun Marsh. The 1984 Plan of Protection used the definitions in the 1978 Delta Plan; the SMPA modified the definition (see footnote to Figure A5.0-1), decreasing the predicted level of precipitation for the remainder of a water year and increasing the number of "Dry" and "Critical" years predicted for the Marsh. The State Board does not know the environmental effects of this difference.

The Biological Assessment prepared for the Plan of Protection and subsequently used for the SMPA was completed in 1981. The focus of the analysis was on the direct impacts of physical structures (e.g., Suisun Marsh Salinity Control Gate) on the salt marsh harvest mouse and the California clapper rail (the only species then on the threatened and endangered species lists). During the informal consultation process for this Plan, DFG pointed out that there have been changes in the situation since 1981 that indicate a new biological assessment is required. Since the 1981 biological assessment was prepared, additional species have been listed as rare, threatened or endangered in the Suisun Marsh area. There are also other species, e.g., federal candidate species, that, while they are not listed under the federal and state Endangered Species Acts, must be considered; harming them would be considered a significant effect on the environment (CEQA Guidelines, Sections 15064 and 15065). See Section 5.10 and Appendix 4.0 for a more complete discussion of these issues.

The plan of protection prepared by the Four Parties (DWR, DFG, USBR, SRCD) is not fully consistent with the 1978 Delta Plan. According to testimony, the Four Parties have signed an agreement to implement the plan of protection, including the monitoring they have developed (T,XXIX,27:7-23). The agreement binds the parties to petition the Board to find that the actions are appropriate to protect the Marsh and to substitute the proposed standards for the 1978 Delta Plan standards (DWR,506A,16-17).

The standards in the SMPA differ from the 1978 Delta Plan in several ways. One of the most significant differences is the use of a special set of definitions for water year types that applies to fish and wildlife protection beneficial uses (DWR,506B,1(r)). This set of definitions was not included in the Plan of Protection in 1984; it has not been subjected to analysis under CEQA and was not considered in the biological assessments done under CESA and ESA. The SMPA in its "Initial Standards" (DWR,506B,3(a)(ii)) uses a "minimum 14-day running average" of the Delta Outflow Index instead of the Delta Plan's "minimum daily" index in one of the Chipps Island's outflow standards (SWRCB,1978,TVI-1). Another difference is the elimination of two monitoring stations, one in Grizzly Bay at the mouth of Montezuma Slough and another at the mouth of Suisun Slough (S-36), and the relocation of some of the other stations further inland (SWRCB,1978; DWR,506B,TII and Fig.1; DWR,509,510; T,XXIX,17:24-25,49:20-50:12) as well as the rescheduling of the construction of the facilities called for in the SMPA (DWR,505,521). The use of deficiency standards is also new to the SMPA (DWR,506B,3(c); T,XXIX,18:20-22,19:25-21:1,34:16). These factors taken together could increase the salinity in the western and "fringe" areas of the legally-defined Suisun Marsh provided under the SMPA compared to the 1978 Delta Plan (T,XXIX,16:25-17:1,40:23-44:3,45:1-46:7,47:3-48:3).

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APPENDIX 6.1
ANALYSIS ASSUMPTIONS FOR WATER SUPPLY IMPACTS

This section discusses the assumptions and operations criteria used in operation studies to help analyze the effects of the various alternatives examined in this Plan. Only the major assumptions used in the operation studies are summarized.

1. The following hydrologic base represents the average monthly flow and salinity conditions in the Bay-Delta Estuary under the 1978 Delta Plan.

   o 1990 level-of-development 1922-1978 Delta flows

2. All of the Estuary's water quality objective locations were assigned to the Sacramento River system 40-30-30 hydrologic classification, except the following locations, which were assigned to the yet to be developed San Joaquin River system 40-30-30 hydrologic classification:

   o San Joaquin River near Vernalis

   o San Joaquin River at the former location of Brandt Bridge

   o Bifurcation of Old and Middle rivers

   o Old River at Tracy Road Bridge

3. The Delta flow and salinity conditions necessary to meet objectives can be achieved through controlling flow, exports, or gate operations at the Delta "control points". The Delta control points, which are illustrated in Figure A6.1-1, are as follows:

   o Chipps Island
   o San Joaquin River near Vernalis
   o Sacramento River at Sacramento
   o The Banks and Tracy Pumping Plants
   o The Delta Cross-Channel near Walnut Grove

4. The following basic equations apply for the hydrologic base:

   o The Delta outflow at Chipps Island, DO is defined as follows:

   $$DO = DI - NETCU - VALDIV - TOTEXP \qquad (1)$$

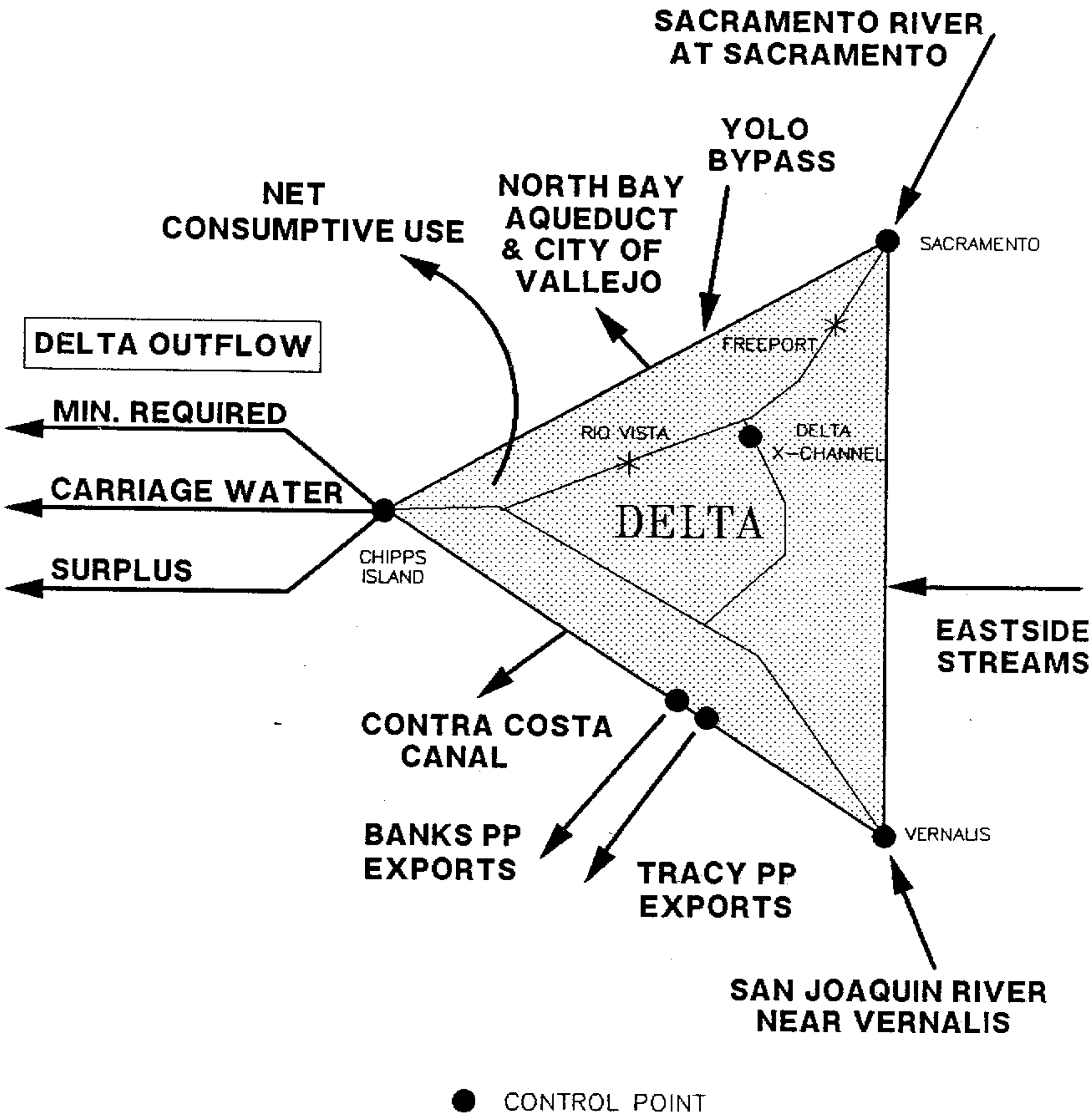
   Where: DI = Delta inflow
   NETCU = Net Delta consumptive use
   VALDIV = City of Vallejo diversions
   TOTEXP = Total CVP and SWP Delta exports

   o The Delta inflow, DI, is defined as follows:

   $$DI = SAC + YOLO + SJR + EAST \qquad (2)$$

FIGURE A6.1-1

DELTA HYDROLOGIC SCHEME USED IN THE WATER SUPPLY IMPACT ANALYSIS



Where: SAC = Sacramento River at Sacramento flow (including return flow from depletion area 21)
YOLO = Yolo Bypass flow
SJR = San Joaquin River at Vernalis flow
EAST = Eastside tributaries' flow (Mokelumne, Cosumnes, and Calaveras rivers)

- The net consumptive use, NETCU, is defined as follows:

NETCU = CU - PREC (3)

Where: CU = Delta consumptive use
PREC = Delta precipitation

- The City of Vallejo diversions, VALDIV, are the Delta diversions by the City of Vallejo.

- The total CVP and SWP Delta exports, TOTEXP, is defined as follows:

TOTEXP = BANKS + TRACY + CCC + NBA (4)

Where: BANKS = Total Banks Pumping Plant exports
TRACY = Tracy Pumping Plant exports
CCC = Contra Costs Canal exports
NBA = North Bay Aqueduct exports

- The Delta outflow, DO, can also be divided into three components:

DO = MINRQDO + CWDO + SURPDO (5)

Where: MINRQDO = Minimum required Delta outflow at Chipps Island
CWDO = Carriage water requirement at Chipps Island
SURPDO = Surplus Delta outflow at Chipps Island

5. BASIC DWRSIM ASSUMPTIONS

The No-Action Alternative was used as a base for comparison with the other alternatives.

- 1990 level hydrology and upstream area depletions and the study period for October 1921 through September 1978.

- Minimum Delta outflow requirements to meet SWRCB D-1485 standards, assuming the interim Suisun Marsh criteria.

- Carriage water requirements based on allowable export/salinity repulsion curves for Rock Slough, designed to maintain a water quality of 150 ppm or 250 ppm of chloride as per D-1485. (Actual values used in the study are 130 ppm and 225 ppm respectively, to provide an operational buffer.)

- CVP/SWP sharing of responsibility for the coordinated operation of the two projects is maintained per the Coordinated Operations Agreement, with storage withdrawals for in-basin use split 75 percent CVP/25 percent SWP and unstored flow for export split 55 percent CVP and 45 percent SWP.

- CVP Operations Criteria:

  - Trinity River minimum fish flows below Lewiston Dam are 340/220/140 TAF per year using the Shasta criteria, per the recent 1981 agreement with the USFWS.

  - Sacramento River minimum fish flows below Keswick Dam reflect the criteria specified in the USBR agreement with DFG (as modified by letter agreement of October 8, 1981). This flow ranges between 2,300 to 3,900 cfs per Shasta criteria and depends on the time of the year.

  - Sacramento River navigation flows are maintained at 4,000 cfs (April-October) or 3,000 cfs (November-March) at Wilkins Slough. Flows are modified/reduced in critical water years.

  - American River minimum fish and recreation flows are maintained per USBR operations criteria (1,500 to 2,000 cfs) as long as sufficient storage is available in Folsom Reservoir. In dry and critical years, minimum flows may be reduced to SWRCB D-893 requirements (250 to 500 cfs) in order to maintain minimum storage levels in Folsom Reservoir.

  - The San Joaquin River water quality standards at Vernalis are maintained as described below (see New Melones Operations Criteria in the Base Case Studies).

  - 1990-level CVP annual demands in TAF/Year are as follows:

Contra Costa Canal	120
DMC and Exchange	1,609
CVP San Luis Unit	1,331
Cross Valley Canal	128
San Luis Interim Deliveries	140
San Felipe Unit	104
Total CVP Delta Exports	3,432
Folsom South Canal	65
Other American River Demands	288

  - CVP agricultural deficiencies are imposed as follows: 25 percent in years 1924, 1931, 1932, 1933, and 1934; and 50 percent in 1977.

  - CVP Tracy Pumping Plant capacity is 4,600 cfs, but constraints along the Delta-Mendota Canal can limit export capacity. Pumping is also limited to 3,000 cfs in May and June in accordance with D-1485 criteria for striped bass survival.

  - Wheeling of CVP water through SWP facilities to San Luis Reservoir is permitted only when unused SWP Banks Pumping Plant capability is available. Annually, the amount of CVP water wheeled is limited to the sum of (1) what is needed to offset the CVP Tracy Pumping Plant's compliance with the D-1485 criteria; and (2) the amount needed to meet the 128 TAF/year CVP Cross Valley Canal demand.

- SWP Operations Criteria

  - Feather River fishery flows are maintained per the agreement between DWR and the DFG (August 26, 1983). In normal years these minimum flows are 1,700 cfs from October through March and 1,000 cfs from April through September, with lower minimum flows allowed in dry/critical years.

  - Sherman Island Overland facility is assumed to be in operation, satisfying the water quality requirements specified in the DWR contract with the North Delta Water Agency.

  - SWP Banks Pumping Plant average monthly capacity with existing pumps is assumed to be 6,240 cfs. Pumping is also limited to 3,000 cfs in May and June, and 4,600 cfs in July to comply with D-1485 criteria for striped bass survival. Additionally, SWP pumping is limited to 2,000 cfs in May and/or June when storage withdrawals from Lake Oroville occur (January 5, 1987 Interim Agreement between DWR and DFG).

  - 1990-level SWP annual export demands (TAF/year) are developed from the State Water Project Analysis Office's long-range projections from Bulletin 132-88, as tabulated below:

	Entitlement Request	Scheduled Surplus
North Bay Aqueduct	27	0
South Bay Aqueduct	186	2
SWP Dos Amigos demand	2,954	219
Total Demands	3,167	221
Agricultural portion	1,241	221
M&I portion	1,857	0
Recreation and losses	69	0

- Water Year Classifications

  - The 1978 Delta Plan classification was used in the no-action alternative.

  - The new (40-30-30) water year classification (including subnormal snowmelt) proposed by the Water Year Classification Subworkgroup was used in all studies, except the no-action alternative.

  - The 1978 Delta Plan classification was used in the Suisun Marsh in all studies.

- New Melones Operations Criteria in the Base Case Studies (From WQCP-DWR-4A)

The operations criteria used in modeling New Melones Reservoir for the Bay-Delta operation studies is based on the State Water Resources Control Board's Decision 1422 and two succeeding agreements as summarized below:

- In April 1973 the State Water Resources Control Board issued the "New Melones Project Water Rights Decision", D-1422. This decision requires an annual New Melones release of up to 98,000 acre-feet for the maintenance of fish and wildlife. In addition, the Decision has a provision requiring additional releases of up to 70,000 acre-feet per year to maintain 500 ppm total dissolved solids at Vernalis year-round.

- The first agreement is the October 1986 interim agreement between the South Delta Water Agency, the U.S. Bureau of Reclamation, and the California Department of Water Resources. The provisions of this agreement which are modeled are as follows:

1. Flows of the San Joaquin River at Vernalis will be maintained at not less than 500 cfs.

2. The salinity of the San Joaquin River at Vernalis will be maintained at 450 ppm TDS or better for the irrigation season (April - October) and 500 ppm TDS or better for the remainder of the year (November - March).

3. Flows of the San Joaquin River at Vernalis will be maintained at not less than the following monthly volumes (TAF/month):

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
37	31	30	30	30	30	35	44	49	69	64	45

4. The releases from New Melones required to meet the above criteria are limited to a maximum of 150,000 acre-feet per water year in addition to the releases made to maintain fish and water quality in accordance with D-1422.

- The second agreement is the June 1987 agreement between the California Department of Fish and Game and the U.S. Bureau of Reclamation which sets interim instream fish flows on the Stanislaus River below New Melones Reservoir. This agreement provides for a minimum annual Stanislaus River fish flow at 98,300 acre-feet and a maximum of 302,100 acre-feet. The actual required fish flow for any given year is based upon the available water supply for that year.

APPENDIX 6.2
D-1485

The final parameter under the Base condition is flow. Flow objectives are held constant for each alternative. These flow objectives include stream flows (Salmon Migration), Delta Outflow (Striped Bass Survival and Suisun Marsh) and diversions (Operational Constraints), some of which variable depending on year type. The water year classification system used is based on the "Four Rivers Index" for the period of 1922-1971.

In D-1485, the objectives for M&I beneficial uses were set at a maximum mean daily 250 mg/l chloride at the Contra Costa Canal Intake at Pumping Plant No. 1 with an additional maximum mean daily chloride level equal to or less than 150 mg/l a minimum of 42 to 66% of time, depending on the water year type.

The western/interior Delta agricultural objectives range from a maximum 14-day running average mean daily EC (mmhos/cm) of 0.45 on April 1 up to 2.78 EC on August 15 depending on the location and year type. This objective is based on the University of California (UC) exhibits which used estimates of the water quality needed to provided 100 percent corn yield in this region's subirrigated organic soil. The southern Delta agricultural objectives are based on the 1990 agreement between the USBR and SDWA. The base objectives, 450 TDS from April 1 to October 31 and 500 TDS from November 1 to March 31, are in effect until the ultimate conditions are phased in. The southern Delta agricultural objectives do not vary with year type. In D-1485, there were no water quality objectives for export agriculture.

The Striped Bass objective at Antioch was 1.5 mmhos/cm EC from April 15 to May 5 in all water years and ranged from 1.5/cm up to 25.2 EC in years when the projects impose deficiencies in firm supplies. At Prisoners Point for the protection of Striped Bass spawning, the average mean daily EC is not to exceed an EC of 0.55 from April 1 to May 5 in all year types.

The Suisun Marsh objectives for the protection of wildlife includes the interim objectives of a maximum running average of mean daily 12.5 mmhos/cm EC from January through May up to 15.6 mmhos/cm from October through December in dry or critical years with deficiencies plus the amended D-1485 (SMPA) interior Delta objectives of 8.0-19.0 EC depending on the month, to be phased in. At the time D-1485 was adopted no objectives were developed for the tidal marshes or rare, threatened and endangered species.

Water quality objectives for the protection of Chinook salmon were not included in D-1485. The Region 5 Basin Plan includes temperature and dissolved oxygen objectives. The Basin Plan water temperature objective specifies a 68°F water temperature objective from Hamilton City to the I-Street Bridge on the Sacramento River "when temperature increases will be detrimental to the fishery". The water temperature objectives in the Basin Plan apply to "controllable factors". The Region 5 Basin Plan specifies that dissolved oxygen concentrations shall not be reduced below: "7.0 mg/l in the Sacramento River below the I-Street Bridge and in all Delta water west of the Antioch Bridge; and 5.0 mg/l in all other Delta waters except for those bodies of water which are constructed for special purposes and from which fish have been excluded or where the fishery is not important as a beneficial use".

APPENDIX 6.3
OPERATION STUDIES

The water supply impacts are defined as the change in base flows, exports, or storage caused by the implementation of the alternative sets of water quality objectives. The base condition incorporates a present (1990) level of development operations study that uses the water quality standards of the 1978 Delta Plan and the New Melones Reservoir criteria as the controlling Delta criteria.

The alternatives were evaluated using DWR's Planning Simulation Model, DWRSIM, a generalized computer model designed to simulate the operation of the CVP and SWP project reservoirs and conveyance facilities. These operation studies are conducted on a monthly time basis and use the historical 57-year hydrologic sequence of flows from water years 1922 through 1978. In addition, these studies account for system operational objectives, physical constraints, and legal and institutional statutes or agreements. These parameters include requirements for flood control in system reservoirs, hydropower generation, pumping plant capacities and limitations, and minimum Delta operations to meet water quality objectives. A more detailed description of the DWRSIM model as well as the operations criteria used in the operation studies is presented in Appendix 6.1.

Operation studies are run with adjustments to the combined CVP-SWP system only. The local non-project reservoirs upstream of the Delta and the CVP Friant Reservoir on the San Joaquin River are pre-operated or have a "predetermined" operation throughout the simulation period. They are not operated to meet Delta objectives. Therefore, the combined CVP-SWP system acts as a surrogate to reflect the water supply impacts of the alternatives.

Since the SWP and CVP provide the major reservoir storage in the Sacramento River Basin, the DWRSIM model provides a reasonable simulation of the flow of the Sacramento River inflow to the Delta. As indicated above, all of the reservoirs in the San Joaquin River Basin, except New Melones, are "pre-operated". The results of these pre-operations are used to prepare the San Joaquin Basin input data for DWRSIM. Most, if not all, of these pre-operations were produced from 15 to 20 years ago and may not be representative of present level reservoir operations. As a result, the estimates of Delta inflow from the San Joaquin River produced by DWRSIM may not be representative of conditions and therefore, should be used only with these constraints in mind.

The operations studies utilize a complex series of assumptions, especially with respect to Central Valley hydrology and Delta flow/salinity relationships. DWR and others are conducting ongoing evaluations of the assumptions using information from the field and new analytical techniques. Revisions to assumptions underlying the operations studies are probable during the current hearing proceedings. The degree to which new assumptions may alter estimated water supply impacts or the conclusions drawn from operations studies is not known.

The water supply impacts, which are shown in the Table A6.3-1, are the changes in the following parameters:[1/2]

- o San Joaquin River Inflow
- o Sacramento River Inflow
- o Combined Total Delta Outflow plus Exports
- o Project Deliveries

Project deliveries impacts are combined changes in CVP-SWP deliveries and reservoir storage, this value is called the change and is defined as follows:

1) The total change in project deliveries, plus

2) 0.7 times the net change in storage of Sacramento basin project reservoirs during the period, plus

3) The net change in storage of San Joaquin basin reservoirs during the period, plus

4) The net change in storage of San Luis Reservoir during the period.

The storage change adjustment of 0.7 for the Sacramento Basin reservoirs is to approximate the loss to carriage water that would occur if water is released from storage for export in the Delta during balanced conditions. No carriage water correction is necessary for storage releases from the San Joaquin Basin reservoirs.

The total water supply impact of each alternative is the sum of the impacts due to the new 40-30-30 classification and the water quality objectives. The new classification is presented separately, however, to differentiate between the water supply impacts due to the classification and those due to changes in the objectives.

1 *Table 6-2 also lists "Other Flows", which is included to provide a complete Delta flow balance. In all studies, these Other Flows are assumed not to change.*

2 *The reader is cautioned that the change in average annual critical period deliveries is not a totally accurate reflection of change in "project yield" as the initial reservoir storages beginning the critical period may differ between studies.*

TABLE A6.3-1
AVERAGE ANNUAL AND APRIL-JULY WATER SUPPLY IMPACTS
OF THE ALTERNATIVE SETS OF WATER QUALITY OBJECTIVES

WATER SUPPLY PARAMETERS	BASE CONDITIONS (TAF)		CHANGE IN BASE CONDITIONS NEEDED TO MEET OBJECTIVES [1] ALTERNATIVE [2]							
			1A (A7)		1B (B7)		2 (L7)		3 (H7)	
	Yearly Avg	Apr–Jul Avg	Yearly Avg	Apr–Jul Avg	Yearly Avg	Apr–Jul Avg	Yearly Avg	Apr–Jul Avg	Yearly Avg	Apr–Jul Avg
Average (Based on 1922–78 period)										
San Joaquin River Inflow	1996	624	0	0	0	0	0	0	1	21
Sacramento River Inflow	15624	5087	0	0	-6	-16	-9	-73	-6	-37
Total Delta Exports [5]	6295	1762	0	0	4	1	50	20	-1	3
Other Flows/Diversions [6]	1652	-211	0	0	0	0	0	0	0	0
Total Delta Outflow [7]	12977	3738	0	0	-10	-17	-59	-93	-4	-19
Min Req Delta Outflow	4702	2087	0	0	-34	-31	-153	-121	-32	-27
Carriage Water	390	48	0	0	1	0	-69	-24	0	-5
Surplus Delta Outflow	7885	1604	0	0	22	13	162	52	26	13
Dry Period (May 1928–Oct 1934)										
San Joaquin River Inflow	1153	315	0	0	0	0	0	0	-6	29
Sacramento River Inflow	8890	3141	0	0	-21	-23	-47	-36	-18	-51
Total Delta Exports [5]	5290	1448	0	0	6	1	63	12	-11	-6
Other Flows/Diversions [6]	-726	-645	0	0	0	0	0	0	0	0
Total Delta Outflow [7]	4027	1363	0	0	-27	-24	-110	-48	-13	-16
Min Req Delta Outflow	3232	1309	0	0	-33	-26	-51	-78	-16	-9
Carriage Water	401	46	0	0	7	2	-172	-25	3	-7
Surplus Delta Outflow	393	9	0	0	1	0	113	56	1	0
Project Deliveries [8]	5443	N/A	0	N/A	19	N/A	77	N/A	-33	N/A
Wet										
San Joaquin River Inflow	3060	1120	0	0	0	0	0	0	0	11
Sacramento River Inflow	22960	7507	0	0	38	6	127	-10	39	-4
Total Delta Exports [5]	6693	1845	0	0	1	-1	37	10	6	4
Other Flows/Diversions [6]	5244	390	0	0	0	0	0	0	0	0
Total Delta Outflow [7]	24571	7172	0	0	37	7	90	-20	33	3
Above Normal										
San Joaquin River Inflow	2069	618	0	0	0	0	0	0	-5	14
Sacramento River Inflow	17511	5258	0	0	-84	-58	-161	-166	-86	-78
Total Delta Exports [5]	6558	1878	0	0	4	2	26	4	7	5
Other Flows/Diversions [6]	1880	-141	0	0	0	0	0	0	0	0
Total Delta Outflow [7]	14902	3857	0	0	-88	-60	-187	-170	-97	-69
Below Normal										
San Joaquin River Inflow	1680	410	0	0	0	0	0	0	6	25
Sacramento River Inflow	13274	4336	0	0	-3	-17	-29	-104	-8	-41
Total Delta Exports [5]	6468	1860	0	0	10	7	49	12	-1	8
Other Flows/Diversions [6]	120	-460	0	0	0	0	0	0	0	0
Total Delta Outflow [7]	8606	2426	0	0	-13	-24	-78	-116	-1	-24
Dry										
San Joaquin River Inflow	1201	290	0	0	0	0	0	0	-4	27
Sacramento River Inflow	10771	3757	0	0	-19	-25	-138	-185	-24	-61
Total Delta Exports [5]	6016	1705	0	0	5	0	107	66	-3	-3
Other Flows/Diversions [6]	-461	-581	0	0	0	0	0	0	0	0
Total Delta Outflow [7]	5495	1761	0	0	-24	-25	-245	-251	-25	-31
Critical										
San Joaquin River Inflow	1288	397	0	0	0	0	0	0	1	33
Sacramento River Inflow	8342	2686	0	0	-5	0	87	125	6	-18
Total Delta Exports [5]	5186	1346	0	0	1	0	17	-8	-15	-11
Other Flows/Diversions [6]	-865	-662	0	0	0	0	0	0	0	0
Total Delta Outflow [7]	3579	1075	0	0	-6	0	70	133	22	26

FOOTNOTES:

[1] Change in base conditons = Alternative minus Base; Positive values indicate an increase in flow or export.

[2] The letter/number combination in parentheses below the alternative numbers identify the corresponding DWR operation study.

[3] Alternative 1B is the base case (1A) with the new 40-30-30 water year classification.

[4] Operation studies P7, K7, and N7 use an M&I objective of 40 mg/l chlorides to provide an operational buffer.

[5] Total Delta Exports include Contra Costa Canal, North Bay Aqueduct, and Banks and Tracy Pumping Plants.

[6] Other Flows/Diversions include Net Delta Consumptive Use, City of Vallejo diversions, Yolo Bypass inflow, and East Side Streams Inflow. The Base Conditions values are negative when the Net Consumptive Use plus the City of Vallejo diversions are greater than the Yolo Bypass Inflow plus the East Side Streams Inflow.

[7] Total Delta Outflow equals the San Joaquin River Inflow + Sacramento River Inflow – Total Delta Exports + Other Flows/Diversions.

[8] Project Delivery Index is the sum of critical period deliveries change plus 70 percent of net critical period storage in the Sacramento River Basin and 100 percent of the net critical period storage change in San Joaquin River Basin and San Luis Reservoir divided by 6.5 years.

In all studies, the current "surplus" water in New Melones Reservoir is assumed to be available for Delta objectives.

TABLE A6.3-1(Cont.)
AVERAGE ANNUAL AND APRIL-JULY WATER SUPPLY IMPACTS
OF THE ALTERNATIVE SETS OF WATER QUALITY OBJECTIVES

WATER SUPPLY PARAMETERS	BASE CONDITIONS (TAF)		CHANGE IN BASE CONDITIONS NEEDED TO MEET OBJECTIVES [1] ALTERNATIVE [2]					
			4 (P7) [4]		5 (K7) [4]		6 (N7) [4]	
	Yearly Avg	Apr–Jul Avg	Yearly Avg	Apr–Jul Avg	Yearly Avg	Apr–Jul Avg	Yearly Avg	Apr–Jul Avg
Average (Based on 1922–78 period)								
San Joaquin River Inflow	1996	624	1	21	9	86	150	290
Sacramento River Inflow	15624	5087	-8	-85	-8	-127	-6	-179
Total Delta Exports [5]	6295	1762	-207	-57	-399	-123	-674	-224
Other Flows/Diversions [6]	1652	-211	0	0	0	0	0	0
Total Delta Outflow [7]	12977	3738	200	-7	400	82	818	335
Min Req Delta Outflow	4702	2087	59	-27	-35	-23	1638	348
Carriage Water	390	48	321	6	697	54	-154	-28
Surplus Delta Outflow	7885	1604	-182	13	-263	48	-667	12
Dry Period (May 1928–Oct 1934)								
San Joaquin River Inflow	1153	315	-6	29	58	91	247	273
Sacramento River Inflow	8890	3141	-19	-190	-9	-223	-4	-183
Total Delta Exports [5]	5290	1448	-364	-147	-984	-393	-1078	-321
Other Flows/Diversions [6]	-726	-645	0	0	0	0	0	0
Total Delta Outflow [7]	4027	1363	339	-14	1033	261	1321	411
Min Req Delta Outflow	3232	1309	82	-9	-16	-9	1760	444
Carriage Water	401	46	335	-5	1107	233	-211	-23
Surplus Delta Outflow	393	9	-77	0	-58	37	-229	-9
Project Deliveries [8]	5443	N/A	-366		-1075		-1339	
Wet								
San Joaquin River Inflow	3060	1120	0	11	-75	13	-69	184
Sacramento River Inflow	22960	7507	-6	-6	11	-13	-11	-37
Total Delta Exports [5]	6693	1845	-87	1	-120	2	-242	-8
Other Flows/Diversions [6]	5244	390	0	0	0	0	0	0
Total Delta Outflow [7]	24571	7172	121	4	58	-2	162	155
Above Normal								
San Joaquin River Inflow	2069	618	-5	14	-28	84	199	332
Sacramento River Inflow	17511	5258	-88	-97	-92	-111	-84	-93
Total Delta Exports [5]	6558	1878	-99	-11	-221	-47	-235	-31
Other Flows/Diversions [6]	1880	-141	0	0	0	0	0	0
Total Delta Outflow [7]	14902	3857	6	-72	101	20	350	270
Below Normal								
San Joaquin River Inflow	1680	410	6	25	73	146	285	391
Sacramento River Inflow	13274	4336	-5	1	-3	-79	32	-144
Total Delta Exports [5]	6468	1860	-226	-15	-312	-38	-672	-181
Other Flows/Diversions [6]	120	-460	0	0	0	0	0	0
Total Delta Outflow [7]	8606	2426	227	41	382	105	989	428
Dry								
San Joaquin River Inflow	1201	290	-4	27	48	115	184	261
Sacramento River Inflow	10771	3757	-26	-214	-47	-304	44	-471
Total Delta Exports [5]	6016	1705	-316	-136	-625	-219	-1442	-692
Other Flows/Diversions [6]	-461	-581	0	0	0	0	0	0
Total Delta Outflow [7]	5495	1761	286	-51	626	30	1670	482
Critical								
San Joaquin River Inflow	1288	397	1	33	62	103	307	362
Sacramento River Inflow	8342	2686	3	-209	100	-203	-61	-191
Total Delta Exports [5]	5186	1346	-396	-195	-1049	-502	-909	-249
Other Flows/Diversions [6]	-865	-662	0	0	0	0	0	0
Total Delta Outflow [7]	3579	1075	400	19	1211	402	1155	420

FOOTNOTES:

[1] Change in base conditons = Alternative minus Base; Positive values indicate an increase in flow or export.

[2] The letter/number combination in parentheses below the alternative numbers identify the corresponding DWR operation study.

[3] Alternative 1B is the base case (1A) with the new 40-30-30 water year classification.

[4] Operation studies P7, K7, and N7 use an M&I objective of 40 mg/l chlorides to provide an operational buffer.

[5] Total Delta Exports include Contra Costa Canal, North Bay Aqueduct, and Banks and Tracy Pumping Plants.

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