EXHIBIT "A"

COPY

WATER MASTER PLAN
DISCOVERY BAY

prepared for

Discovery Bay Community Services District

by

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I. Introduction

Background

Discovery Bay is an unincorporated community that receives water and sewer services provided by the recently created (1998) Discovery Bay Community Service District (DBCSD). Prior to the creation of the DBCSD, water and sewer services were provided by Contra Costa County Special District 19. In turn, District 19 contracted with Delta Diablo Sanitation District (DDSD) to operate and maintain Discovery Bay's water and wastewater systems. DDSD originally commissioned the preparation of this Master Plan, a draft of which was completed during the transition from DDSD to DBCSD as the community water system operator. Subsequently, the DBCSD assumed the responsibility for finalizing the Plan and selecting the water supply and distribution system alternative that best meets the water needs of the existing and future Discovery Bay community.

The Discovery Bay water system has incrementally grown from two water supply wells and a distribution system initially constructed in 1971, to five water supply wells and an expanded distribution system currently serving about 3,400 services in the Discovery Bay and Pacific Waterways (Albers) developments. The current water system has no water storage tanks or water treatment facilities other than disinfection.

This Master Water Plan was prepared in response to a need to begin to expand the Discovery Bay water system to ultimately accommodate an additional estimated demand of 2,495 equivalent dwelling units (EDU) in the western part of Discovery Bay on properties of Discovery Bay West (Phases 1 through 4), Byron 78, Evans, Pantages, Storrer, and Venhaus. This Master Plan also addresses the existing Discovery Bay system; the water supply system in the existing portion of Discovery Bay is designed to accommodate up to about 4,100 EDU (the projected combined buildout of the original Discovery Bay and the adjoining Pacific Waterways Albers project). The locations of the various developments that comprise Discovery Bay are illustrated in Figure 1-1.

This Master Plan includes estimates of the future water demand associated with the expansion of the Discovery Bay Community. Due to the California State Department of Health Services (DHS) position that water supply for new development will require compliance with secondary drinking water standards (the existing sources of supply have had waivers from the secondary standards for dissolved concentrations of iron and manganese), this Master Plan identifies system improvements that potentially include new wells, and treatment and storage facilities for new development. This plan also presents alternatives that represent a significant departure from the historical approach to water supply for the existing community, which has consisted of using wells (without storage) to directly meet all system demand up to and including peak hour flow and potential fire flow demands. The alternatives discussed in this plan include the use of existing wells and new storage tanks and treatment plants to provide treated water to both the existing and new developments.

A hydraulic model was developed and used to identify the need for additions and/or modifications to the water distribution system. Alternatives for water system improvements, the estimated construction costs, and the relevant design criteria and standards applicable to the water system are presented in this Master Water Plan.

Finally, this Master Water Plan was prepared in part based on three previous reports on the existing water system prepared by Luhdorff and Scalmanini, Consulting Engineers: **Water Requirements and Supplies, Discovery Bay**, January 1993; **Water Requirements and Supply, Discovery Bay West,** November 1993; and **Projected Water Requirements and Alternative Water Supplies, Albers Project**, November 1992.

Purpose

The primary purpose of this Master Water Plan is to identify the needed improvements or additions to the water system to meet existing and projected water demands. The improvements include options for continuing to provide untreated water to the existing developments at Discovery Bay (continuation of waivers from secondary drinking water standards) while providing treated water to new development, or for providing treated water to existing development while also providing treated water to new developments. Estimated capital costs for the proposed facilities are provided for budgeting purposes.

Scope

The scope of work has included the completion of the following tasks:

- Review water use/production records.
- Develop a hydraulic model of the water supply and distribution system.
- Establish design criteria for water supply, water treatment, storage, pumping, and distribution piping.
- Identify alternatives for water system modifications based upon projections of supply needs and the DHS requirement to meet secondary drinking water standards for future developments.
- Use the hydraulic model to size water system improvements.
- Define the need and timing for placing ground-water monitoring wells for collection of ground-water data (water levels and water quality) as part of evaluating the yield of the ground-water basin.
- Develop a Master Plan that, for each alternative, presents information on the water supply wells, treatment plants, storage facilities, pumps, and major distribution mains to meet existing and projected development.
- Develop a "phased" approach for the development of the water system and provide estimated capital costs for general planning purposes.

II. Water Supply Requirements

Historic Water Use

Beginning with the original design of the Discovery Bay project in the early 1970's, water requirements were generally projected on the basis of unit factors for water demand and the number of dwelling units in the project at a particular time. Until 1990, the unit factors for water demands were largely based on experience with other Central Valley communities. In 1990, the Delta Diablo Sanitation District installed meters at all the water supply wells, which subsequently allowed for analysis and interpretation of water production data to define average, maximum, and peak water use rates.

The last complete analysis of available data on water production and dwelling units indicated that, for the 1986-1991 period, total water demand increased as building increased, but the unit average daily water use remained between 0.34 and 0.40 gallons per minute per equivalent dwelling unit (gpm/EDU), as summarized in Table 2-1. A review of DHS records for 1996 and 1997 indicated that the average daily demands in those two years were 0.35 and 0.38 gpm/EDU respectively, remaining within the previously analyzed 0.34 to 0.40 gpm/EDU range. Therefore, for purposes of this Plan, it is assumed that the average unit water demand will be 0.375 gpm/EDU, which is slightly higher (more conservative) than the actual average for the eight year record (1986-1991 and 1996 and 1997).

Historically, the highest monthly water use in Discovery Bay has occurred during July and August. During those highest water usage months, the maximum daily water requirement is essentially twice the annual average daily demand. Peak hour demand was last analyzed via review of daily recorded charts from all the Discovery Bay wells (LSCE, 1993). Based on observed highest and longest (four hours) "peak hour" demands, a peaking factor of 1.8 times the maximum day demand (or 3.6 times the average day demand) is applicable for the Discovery Bay system.

Fire Flow Requirements

The original fire flow protection requirements for Discovery Bay were specified by the Byron Fire Protection District which uses the requirements of the National Fire Protection Association for the determination of fire flow rates and duration. For the original Discovery Bay development, Byron Fire Protection District determined that the commercial space (including the marina) and multi-story apartments required a fire flow of 3,000 gpm for a minimum of three hours. A fire demand of 1,500 gpm for two hours was also determined for two story, single family dwelling units with wood or tile roofs.

The Contra Costa County Fire Protection District (CCCFPD) currently specifies the required level of fire protection. In March 1998, the CCCFPD specified that Discovery Bay West (Village 1) must have a total flow of 2,000 gpm supplied by two hydrants flowing simultaneously for a duration of 120 minutes at a residual pressure of 20 psig. The fire flow demand for future commercial structures within Discovery Bay West has not been established. The fire flow demand is dependent on size, type, and material of a structure, and whether or not the structure incorporates a sprinkler system. (Uniform Fire Code, 1994). For purposes of this Master Plan, the fire flow demand for commercial space and multi-story apartments is assumed to continue to be 3,000 gpm for a minimum of three hours.

Projected Water Demands

Future Discovery Bay water demand was estimated on the assumption that the unit average water demand will remain at 0.375 gpm/EDU; it also assumes that peaking factors for maximum day and peak hour demands will remain constant (2 times average day and 3.6 times average day, respectively). Water demand projections for each proposed development in Discovery Bay are listed in Table 2-2. If the system were to expand to meet increasing demand by adding source capacity (wells), as has historically been the case, the addition of future source capacity would follow the curves illustrated in Figure 2-1 for average day, maximum day, peak hour, and fire flow requirements. However, in light of State Department of Health Services indications that no exceptions will be granted from secondary drinking water standards for new development, future system source capacity may not exactly follow the curves in Figure 2-1. As discussed in this Master Plan, there are two basic alternatives for meeting future demand: 1) develop a separate, treated water supply for future development, with the existing system unchanged (assuming that the current waiver from secondary standards is renewed); and 2) develop an enlarged, treated water system for the entire

Table 2-2

Current and Projected Development And Water Demand Discovery Bay

	Equivalent Dwelling Units (EDU)		
Development Name	Existing Development[1]	Projected Future	Full Build-out
Discovery Bay	3,700		3,700
Pacific Waterways (Albers)	400		400
Discovery Bay West			
Phase 1		300	300
Phase 2		500	500
Phase 3		600	600
Phase 4		600	600
Byron 78		85	85
Evans		19	19
Pantages		275	275
Storrer		100	100
Venhaus		16	16
Total	4,100	2,495	6,595
Estimated Water Demand	Capacity (gpm)		
Ave. Day (EDU x 0.375)	1,540	940	2,470
Max. Day (ave. day x 2)	3,080	1,880	4,940
Peak Hour (ave. day x 3.6)	5,540	3,380	8,890
Fire Demand	3,000	3,000	3,000
Max. Day + Fire Demand	6,080	4,880	7,940

[1]Assumes and includes "buildout" of both Discovery Bay and Pacific Waterways (Albers); combined, they are currently developed to about 3,400 EDU. Completion of buildout will be within the existing water distribution network, and water service to the remaining units is assumed to be the same as the balance of the existing system.

V. Water Master Plan Alternatives

The historic approach to meet increasing water demand at Discovery Bay has been to incrementally install additional wells and pumps and connect them directly to the distribution system. Two main problems associated with this approach have included low water quality, principally dissolved manganese, odor and the associated discoloration when oxidized, and hydraulic problems and inefficiencies associated with large capacity pumps operating in response to small pressure changes in the distribution system due to the lack of any system storage. In addition to these technical problems, recent regulatory interpretation of the strict applicability of secondary drinking water standards for new development leads to the need for a revised approach to meet projected future demand. This revised approach is reflected in two alternatives which comprise the water supply portion of this Master Plan: 1) develop an independent, treated water supply and distribution system for all new development (Discovery Bay West, Pantages, Storrer, Venhaus, and Byron 78), while leaving the existing Discovery Bay water supply and distribution system intact; or 2) using some of the existing Discovery Bay source capacity (i.e. wells), install treatment and storage facilities such that the entire system (existing and future development) receives treated (for iron and manganese removal) water.

Alternative 1 assumes that Discovery Bay's existing waiver from secondary drinking water standards, which expired at the end of 1998, will be renewed such that the existing system, which now has sufficient source capacity for buildout of both the existing developments on the system, will continue to serve both Discovery Bay (nominal 3,700 EDU at buildout) and Pacific Waterways (Albers) (nominal 400 EDU at buildout). Alternative 1 also assumes that all future development can only receive treated water which meets secondary drinking water standards; as a result, the water system for future development cannot be "backed up" by the existing system to meet peak demands (peak hourly demand, fire flow, etc.), and must have sufficient source capacity and/or storage to meet peak demands with treated water.

Alternative 2 assumes that the existing and new water systems will be combined, with treated water delivered to both systems. Strictly speaking, as long as there is sufficient treated water to meet all future demands, it would theoretically be possible to incrementally "phase" the conversion of the existing system to treated water. However, for a number of reasons (most notably the variations in water quality likely to occur through the existing system during "phasing", and the fact that the time frame for conversion to treated water can be completely arbitrary and is not regulatory-driven), this alternative assumes that the existing system is converted to treated water at the same time that facilities are installed to treat water for future development.

Alternative 2 is subdivided into two sub-alternatives because, with water treatment located near future development on the west side of the existing system, there is insufficient pipeline capacity to convey fire flow with treated water through the existing system. Consequently, the storage and distribution system will have to change in this alternative either: 1) by installing a new, larger arterial main between new facilities in the west and the arterial main at Discovery Bay Boulevard, or 2) by installing a storage tank and booster pumping station within the existing distribution system at a location on or near Discovery Bay Boulevard.

Both alternatives require treatment of at least some of the water supply to meet all secondary drinking water standards; in turn, proper operation of one or more treatment plants will require some storage in the distribution system to avoid short intermittent pumping and treatment cycles. The following two sections discuss water treatment and storage parameters which are subsequently incorporated in the two water system alternatives.

Water Treatment

The only method of water treatment presently utilized at Discovery Bay is disinfection of the production water using sodium hypochlorite. The chemical feed systems are located at each well and consist of a day tank (usually 55 gallons of 12.5 percent available solution), a feed pump, tubing and a mainline ejector. The chemical is introduced at a concentration of approximately 1 milligram per liter (mg/l), with desired system end point concentration of 0.2 to 0.5 mg/l.

As discussed in this Master Plan, ground water in the Discovery Bay area exceeds the secondary standard for manganese (and sometimes iron). Concentrations of manganese and iron in ground water can be summarized as follows:

	Measured Range (mg/l)	Measured Average (mg/l)	Drinking Water Secondary Standard (mg/l)
Manganese	0.08-0.20	0.14	0.05
Iron	0.07-0.44	0.18	0.30

For purposes of this master plan, it is planned that removal of iron and manganese will be accomplished by an oxidation-filtration method, with chlorine utilized to oxidize iron and manganese and possibly control odor (hydrogen sulfide). Dechlorination of the water would be performed using sodium bisulfate. The overall process would include: introduction of chlorine at the well head; water would then enter a contact chamber to enhance the oxidation of the dissolved iron and manganese by increasing detention time; the water would then be conveyed to multi-media filters for removal of precipitated iron and manganese; after filtration, the water would be conveyed to surface storage tanks. Pilot testing will be required to define design parameters for chemical oxidant additions, filtration rates and operational methodology.

The filters would be occasionally backwashed to reduce the build-up of pressure across the filters caused by plugging with iron and manganese precipitates. Backwash water from the filters would be conveyed to an on-site decant tank. After the backwash cycle is complete, the solids would be allowed to settle with the supernatant pumped back to the head of the treatment plant and reintroduced to the treatment process. The accumulated volume of sludge from the backwash cycle of an iron-manganese removal plant is generally very low. Consequently, at a present system average day flow rate and utilizing the average concentrations of dissolved iron and manganese, the initial sludge volume is projected to be 11,000 gallons containing 4 percent solids per year.
At buildout, the anticipated sludge volume will increase to 18,000 gallons (4 percent) per year. This small amount of sludge can be disposed of by pumping to the Discovery Bay sewer system.

Treated Water Storage

The existing Discovery Bay system does not contain any system storage. The proposed water treatment plants will require storage to enhance (via lengthened operating cycles) the operation of the water treatment facilities and to provide water for fire suppression and for periods of high demand.

In order to determine the storage requirements for Discovery Bay and future development, the following "components" of storage were addressed on the basis of historical and projected water use and alternative operational protocols.

- Operational Storage - Operational storage is the amount of storage required to meet short duration (usually analyzed for four hours) peak hour system demands that exceed supply (source) capacity. At full build-out of Discovery Bay and new development, this component is estimated to be approximately 850,000 gallons.

- Fire Flow Storage - This component is the amount of storage for the sole purpose of providing an adequate amount of water for fire fighting purposes. Fire flow requirements for commercial/industrial purposes at Discovery Bay and new development have been set at 3,000 gallons per minute for a three hour duration (or a total of 540,000 gallons). Storage requirements for residential units are lower: 2,000 gallons per minute for a duration of two hours (or a total of 240,000 gallons). The two volumes need not be additive. Consequently, the larger volume of 540,000 gallons is used as a design guideline for determination of the fire storage component for Discovery Bay and new development.

- Emergency Storage - This component is the amount of storage held in residence to accommodate demand requirements in the event of prolonged power outages, mainline breaks or interruptions in supply. The amount of water is normally determined by operational protocol of the water purveyor. Since generators are presently being designed for use with Wells 1B, 4A, and 5A, (and Wells 2 and 3 have emergency engines), it is envisioned that all required emergency storage would be withdrawn from the ground-water basin: therefore, no emergency storage component is included in the above-ground storage tank requirements.

- Unusable Storage - This component is the fraction of total storage that is not available due to the location of the tank overflow, and the location of inlet and outlet piping in proximity to the top and bottom of the tank. For the purpose of this Master Plan, an assumed amount of 10 percent of total tank volume is deemed to be unusable.

Alternative 1 - Independent Water Systems

In this alternative, the existing water supply system will remain unchanged; as introduced above, it has sufficient source capacity to meet the projected buildout demand of both the Discovery Bay and the Pacific Waterways (Albers) developments. However, since there is no surplus existing source capacity, sufficient new source capacity (wells) will need to be constructed, and treatment will need to be installed, to meet projected water demands of new growth outside Discovery Bay and Pacific Waterways (Albers).

Total currently projected new development includes Discovery Bay West Phases 1 through 4, Byron 78, Evans, Pantages, Storrer, and Venhaus. At build-out, these developments are projected to consist of a total of 2,495 EDUs as summarized in Table 2-2. For purposes of comparing the present-value costs of the water supply alternatives described herein, full buildout of Discovery Bay West is estimated to be completed in approximately twelve years (Year 2010). This assumes an average build-out of approximately 270 EDUs per year.

The estimated water demand of future development is summarized on Table 2-2. Based on historic unit water requirements, the maximum day demand at full build-out (2,495 EDUs) is projected to be nearly 1,900 gpm and the peak 4-hour demand is projected to be approximately 3,380 gpm. As discussed in Section 2, the Contra Costa County Fire Protection District has specified a fire flow of 2,000 gpm for a two hour duration for the first phase of Discovery Bay West; that flow rate is assumed to increase to 3,000 gpm for three hours when future commercial structures are developed.

To meet the projected water demand of all future development, sufficient source capacity will have to be developed to meet maximum day demand (assuming all higher flows such as peak hour and fire flow are met from new storage, as further discussed below). Further, it is generally accepted engineering practice that source capacity be adequate to meet demand with the largest single source assumed to be out of service. Following those criteria, two new wells, each with a nominal design capacity of 1,900 gpm, will be required to meet projected maximum day demand. In order to meet secondary drinking water standards, a water treatment plant will be installed to remove dissolved manganese (the same treatment system will also remove dissolved iron from the water supply). The treatment plant will have a design capacity equal to the maximum day flow (1,900 gpm) such that either water supply well can be treated at the plant.

Traditional operation of the existing Discovery Bay water system has been for wells to start and stop in response to instant water demand in the system; such operation results directly from the lack of any storage in the system. While that operation has caused some difficulties, it is an unacceptable practice for the operation of water treatment plants, which require some stability and duration of flow to effectively oxidize and filter dissolved metals such as iron and manganese. As a result, some surface storage will be a necessary component of an independent future water system to serve new development. Based on an analysis of peak hour and fire flow demands, a total of 1.0 million gallons of storage will be needed by full buildout of currently projected future development.

Alternative 1 is schematically illustrated in Figure 5-1. Estimated costs for the phased construction of a separate treated water supply system for all future development are summarized in Table 5-1. It is notable that essentially all the ultimate facilities would be required at the outset of future development for two primary reasons: 1) there is no permanent surplus capacity available in the existing system; hence, new source capacity (and backup) will be immediately required for the new independent system; and 2) untreated water (from the existing system) cannot be used to meet peak demands; hence, sufficient storage must be in place to accommodate peak hour and fire flow demand; this storage will also facilitate longer pumping/treatment cycles as is preferred for optimal treatment performance. Consequently, the initial treated water system would include construction of two wells and pump stations, a treatment plant, and an 0.5 MG storage tank with booster pumps. The initial facilities will be adequate through the buildout of 1,100 new EDU. Above 1,100 EDU, an additional 0.5 MG storage tank will be required to accommodate increased peak hour and commercial fire flow demand. The estimated cost to construct the initial treated water system components discussed above is $2,070,000 (Table 5-1); addition of a second 0.5 MG storage tank, after 1,100 EDU are constructed, will cost an estimated $230,000 (current dollars).

Alternative 2 - Combined Water System for Existing and Future Development

In light of the requirement that all future development receive treated water which conforms to all secondary (as well as primary) drinking water standards, an alternative emerges whereby the historical approach of incrementally adding new wells to meet growth can be replaced by treatment and storage of existing source capacity, thus precluding the need for new well and pump station construction. This alternative would be possible because, if fire flow and peak hour demand were met from storage, source capacity would only have to meet maximum day demand. Existing source capacity, even with the largest single source out of service, is more than sufficient to meet that

Table 5-1
Modified Water Master Plan Alternative 1
Independent Water System For New Developments[1]

Construction Phase	Description	Equivalent Dwelling Units			Water System Components	Unit Cost	Present Worth[2]
1	Includes two new wells, 0.5 MG storage tank, and treatment Plant	0	to	1,000	(1) Well and Pump, Controls, Piping and Treatment Plant, Booster Pumps and 0.5 MG Storage Tank at new Well site	$1,610,000	
					Subtotal:	$1,610,000	$1,610,000
2	Includes an additional 0.5 MG storage tank.	1,000	to	2,244	Additional 0.5 MG Storage Tank	$230,000	
					Subtotal:	$230,000	$185,354
					Total:	**$1,840,000**	**$1,800,000**

1 New development includes Discovery Bay West Phases 1 through 4, Byron 78, Evans, Pantages, Storrer and Venhaus (2,244 proposed EDUs).
2 Present Worth cost assuming an interest rate of 6% and an EDU development rate of 270 EDUs/Year.

demand at buildout. Consequentially, if storage of treated water were introduced, new wells would not be required to meet future growth.

Alternative 2 recognizes that treated water from two existing wells would be more than sufficient to meet all average day demand, 2,475 gpm, through the total buildout of all existing and currently projected future development (6,595 EDU). The alternative further recognizes that treated water from three existing wells can meet all maximum day demands (4,950 gpm) through total buildout. In effect, Alternative 2 conceptually "replaces" the new wells and treatment that would be required to independently serve future development and instead "constructs" treatment facilities for existing wells, plus storage, to then serve the entire existing plus future development. Since treatment of three wells will not initially be required to meet maximum day demand, Alternative 2 can be phased whereby sufficient treatment capacity is initially installed for two wells, and treatment capacity is added for a third well when maximum day demand exceeds the capacity of the first two treated wells. Since all the wells have different pumping capacities, the selection of wells for treatment will have some impact on the timing of addition of future treatment. However, as discussed below, that selection has a minimal impact on estimated construction cost.

The degree of complete development and land use commitments in Discovery Bay to date substantially limit the availability of space on which to physically place treatment and storage facilities. All the existing well sites, except Well 4A, are too small to accommodate water treatment and storage facilities (although, with some demolition of existing building at Well 1B, a treatment plant could be installed there, as further discussed herein). As a result, this alternative necessarily assumes that the primary treatment and storage facility will be at the Well 4A site, with piping to deliver untreated water from another well (Well 5A) for treatment at the Well 4A site, and with piping and/or storage located at selected locations to deliver treated water to the distribution system. Hydraulically, the existing distribution piping at the well 4A site is inadequate to accommodate fire flow from that location to the entire existing system. Consequently, a component of this alternative will need to be either: 1) the installation of a larger diameter (16 inch) interconnection between the treatment/storage/booster pumping facilities at Well 4A and the existing main line at Discovery Bay Boulevard., or 2) the construction of a storage tank and booster pumping facility near the existing main line at Discovery Bay Boulevard. Conceptually, then, the combined, fully treated water system for both existing and future development would include:

- at buildout, three water supply wells (Wells 1B, 4A and 5A) with treatment to meet secondary drinking water standards; initially, only two of the wells would be required (until total connections reach 4,500 or 4,900 EDU, depending on which two wells are initially treated).

- a water treatment facility located at the Well 4A site and sized to treat the combined flow from Wells 4A and 5A.

- a raw water transmission pipeline from Well 5A to the treatment plant at the Well 4A site.

- surface storage of treated water to meet peak hour and fire flow demands; some or all of the storage would be located at the Well 4A site; some could be located within the existing Discovery Bay distribution system; total storage of 1.5 MG would be installed by build-out.

- if surface storage is not installed within the existing system, a treated water transmission main from the Well 4A treatment plant site to the existing main pipeline at Discovery Bay Boulevard.

- a water treatment facility located at the Well 1B site and sized to treat the capacity of that well.

- two emergency standby wells (Wells 2 and 3).

Alternative 2A - Combined Water System with Remote Storage

This alternative will be implemented in two phases, and includes storage facilities at two locations. The initial phase includes the installation of treatment and storage to meet buildout of the existing developments plus new development through a total of 4,900 EDU, to be expanded at that time by the addition of treatment at one more well. Notable to this alternative is the construction of a portion of surface storage within the existing Discovery Bay distribution system, preferably at or near the commercial space about midway between Wells 2 and 3. The latter storage, with attenuant booster pumping facilities, would be to provide peak hour and fire flow of treated water to the existing system within acceptable operating and residual pressures. Alternative 2A is schematically illustrated in Figure 5-2 and is summarized in Table 5-2. The latter table includes a breakdown of facilities and estimated capital costs (current dollars) as a function of total connections to the water system. In brief summary, the components of the water system, as would be developed in chronological order, will include:

Table 5-2
Water Master Plan Alternative 2A
Combined Water System With Remote Storage

Alternative	Description	Phase	Equivalent Dwelling Units			Water System Components	Unit Cost	Present Worth[1]
2A	Includes storage tanks at well site 4A and at a central DB location. Uses Wells 4A and 5A initially, and 1B as development increases. All water is treated at all times, except under an emergency.	1	3,400	to	4,900	Treatment Plant, Booster Pumps and 0.75 MG Tank at Well 4A.	$1,320,000	
						0.75 MG Tank/Boosters at DB	$590,000	
						Well 5ATreatment Plant at 4A	$320,000	
						Pipeline (Well 5A to 4A)	$450,000	
						Subtotal:	**$2,680,000**	**$2,680,000**
		2	4,900	to	6,600	Treatment Plant at 1B	$550,000	
						Subtotal:	**550,000**	**$397,901**
						Total:	**$3,230,000**	**$3,080,000**
2A(a)	Includes storage tanks at well site 4A and at a central DB location. Uses Wells 4A and 1B initially, and 5A as development increases. All water is treated at all times, except under an emergency.	1	3,400	to	4,500	Treatment Plant, Booster Pumps and 0.75 MG Tank at Well 4A.	$1,320,000	
						0.75 MG Tank/Boosters at DB	$590,000	
						Treatment Plant at 1B	$550,000	
						Subtotal:	**$2,460,000**	**$2,460,000**
		2	4,500	to	6,600	Well 5ATreatment Plant at 4A	$320,000	
						Pipeline (Well 5A to 4A)	$450,000	
						Subtotal:	**$770,000**	**$607,285**
						Total:	**$3,230,000**	**$3,070,000**

1 Present Worth cost assuming an interest rate of 6% and an EDU development rate of 270 EDUs/Year. (Full buildout of 6600 EDUs accomplished in the Year 2010.)

- water treatment plant at Well 4A site, with design capacity of 3,700 gpm to treat both Well 4A and Well 5A.

- untreated water transmission line from Well 5A to the treatment plant at the Well 4A site.

- surface storage tanks at Well 4A site, with storage capacity of 0.75 MG.

- surface storage tank within existing water distribution system, with a storage capacity of 0.75 MG, near existing commercial development about midway between existing Wells 2 and 3.

- booster pumping facilities at both surface tank sites, with combined design capacity to meet peak hour (8,890 gpm) requirements.

- addition of a treatment plant at Well 1B when development reaches 4,900 EDU.

The selection of which wells are initially treated will affect the timing of expansion of the system. Because Well 5A has a higher capacity than Well 1B, initial connection of Well 5A will carry the system farther into future development before additional treated water is required (from Well 1B). As summarized in Table 5-2, the initial treatment of Wells 4A and 5A would provide treated water through 4,900 EDU before treatment would be required at Well 1B. Conversely, the initial treatment of Wells 4A and 1B (Alternative 2A(a) on Table 5-2) would require the addition of treatment at Well 5A after 4,500 EDU. Ultimately, as indicated in Table 5-2, the total projected cost, in current dollars, and the present value of all projected costs are very similar regardless of the selection of initially treated wells.

Alternative 2B - Combined Water System without Remote Storage

The only difference between this alternative and the previously described Alternative 2A is the location of surface storage. Recognizing both the degree of complete development and dedicated land use within the existing system, the installation of a surface storage tank and booster pumping facility within the existing Discovery Bay may be quite challenging. If it turns out that such storage cannot be located within the existing system, and thus has to be located at the Well 4A treatment and storage site, there will be a need to install a large diameter (16 inch) transmission main from the Well 4A storage and booster pump station to the existing 12 inch main line at Discovery Bay Boulevard. This transmission main will be to convey peak hour and/or fire flow of treated water to the existing system within acceptable operating and residual pressures. Alternative 2B is schematically illustrated in Figure 5-3 and is summarized in Table 5-3. The latter table includes a breakdown of facilities and estimated capital costs (current dollars) as a function of total connections to the water system. In brief summary, the components of the water system, as would be developed in chronological order, will include:

- water treatment plant at Well 4A site with design capacity of 3,700 gpm to treat both Well 4A and Well 5A.
- untreated water transmission line from Well 5A to the treatment plant at the Well 4A site.
- surface storage tanks at Well 4A site, with storage capacity of 1.5 MG.
- a 16 inch transmission pipeline from the Well 4A site to the existing 12 inch main line beneath Discovery Bay Boulevard; interconnection will be near the existing commercial development about midway between existing Wells 2 and 3.
- booster pumping facilities at the Well 4A tanks, with design capacity to meet peak hour (8,890 gpm) requirements.
- addition of treatment plant capacity at Well 1B when development reaches 4,900 EDU.

Similar to Alternative 2A, the timing of expanding the treatment capacity and storage volume will be affected by the selection of which wells are initially connected to treatment plants. Because Well 5A has a higher capacity than Well 1B, initial connection of Well 5A will carry the system further into future development before treated water is required (from Well 1B). As summarized in Table 5-3, the initial treatment of Wells 4A and 5A would provide treated water through 4,900 EDU before treatment would be required at Well 1B. Conversely, the initial treatment of Wells 4A and 1B (Alternative 2B(a) on Table 5-3) would require the addition of treatment at Well 5A after 4,500 EDU. Ultimately, as indicated on Table 5-3, the total projected cost, in current dollars, and the present value of all projected costs, are very similar regardless of the selection of initially treated wells.

EXHIBIT "B"

COPY

Executive Summary

Introduction

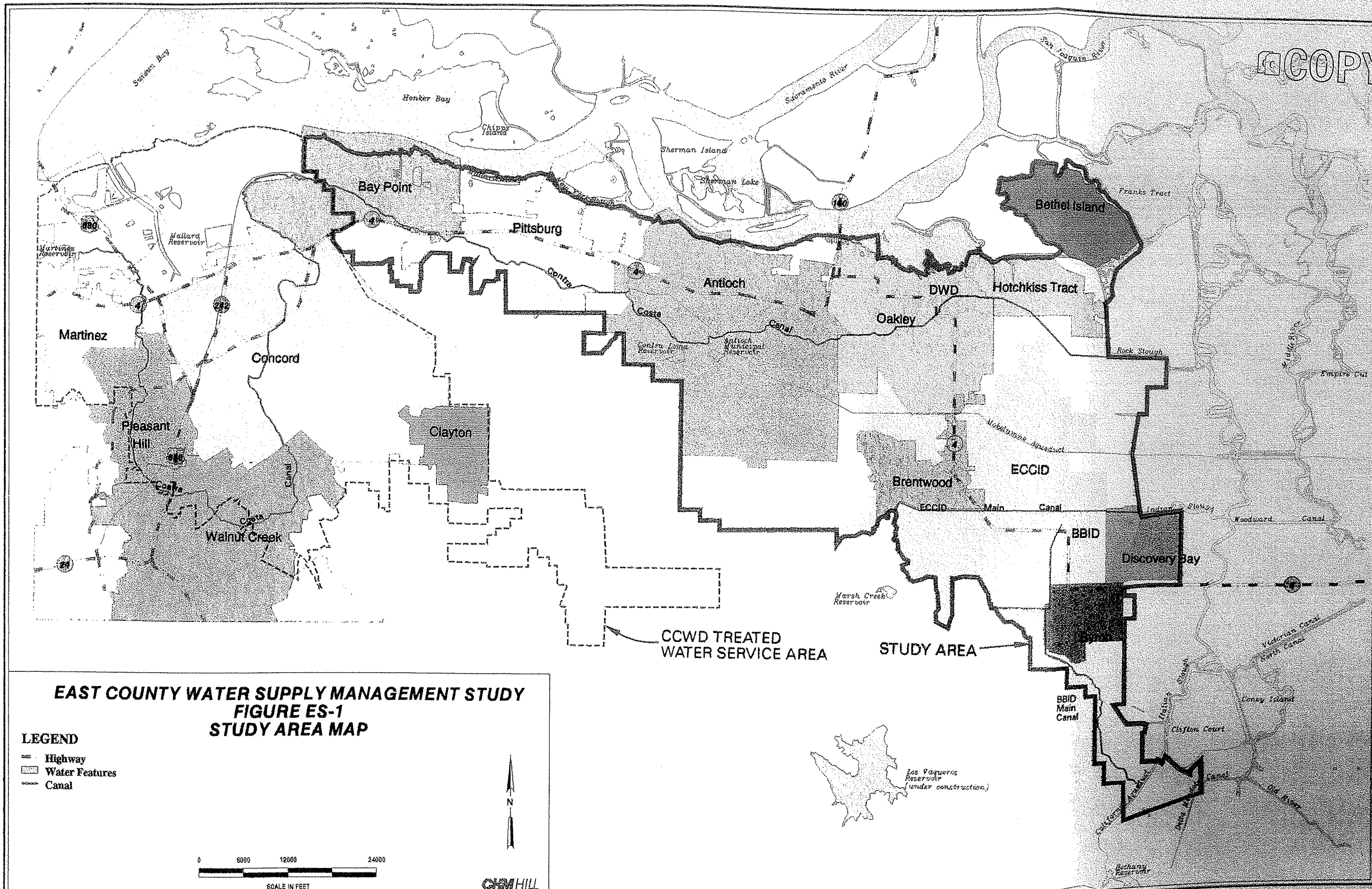
According to projections by the Association of Bay Area Governments (ABAG), Contra Costa County will grow from 800,000 residents to more than 1.1 million residents by 2010. ABAG also projects that most of the population growth will occur in the eastern communities of Antioch, Oakley, and Brentwood. Brentwood is one of the fastest growing communities in California. When population projections for Pittsburg are included, eastern Contra Costa County (East County) is expected to account for more than half of the total projected growth in Contra Costa County by the year 2010. This report focuses on the water resources and water treatment and supply infrastructure needed to respond to the increased water demands associated with the urbanization of East County and identifies potential water management strategies that can be used to meet future water needs.

This study is being conducted by the East County Water Management Association (ECWMA), a consortium of 11 water agencies in the study area (see Figure ES-1). The study activities are managed by the Joint Managers' Committee (JMC), a group of the General Managers or their designees from ECWMA. Policy-level guidance was provided by the Governing Board Representatives (GBR); the Board consists of an elected official (and alternate) from each member group.

ECWMA Member Agencies

- City of Antioch
- City of Brentwood
- Byron-Bethany Irrigation District (BBID)
- Contra Costa County Sanitation District No. 19
- Contra Costa County Water Agency
- Contra Costa Water District (CCWD)
- Delta Diablo Sanitation District (DDSD)
- Diablo Water District (DWD)
- East Contra Costa Irrigation District (ECCID)
- Ironhouse Sanitary District (ISD)
- City of Pittsburg

The East County Water Supply Management Study was divided into two phases. Phase I, completed in 1994, provided a preliminary analysis of future demand, water supplies, existing infrastructure, and general issues related to cooperative water resources management. Phase II focused on developing, evaluating, and recommending alternatives for providing cost-effective and reliable water supplies to the study area through the year 2040.



EAST COUNTY WATER SUPPLY MANAGEMENT STUDY
FIGURE ES-1
STUDY AREA MAP

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Chapter 1—Introduction

1.1 Purpose of the Project

The purpose of the East County Water Supply Management Study is to evaluate water supply management options for meeting future water needs in eastern Contra Costa County (East County). The study area, shown in Figure 1-1, consists of the cities of Antioch, Brentwood, and Pittsburg; the unincorporated communities of Bethel Island, Byron, Discovery Bay, Oakley, and Bay Point; Diablo Water District; East Contra Costa Irrigation District; Byron Bethany Irrigation District; and the rural portion of East County.

East County is subject to significant growth pressures; the municipal water need in this area is projected to more than double from 37,200 acre-feet in 1990 to about 99,670 acre-feet in year 2040 (shown to the right).

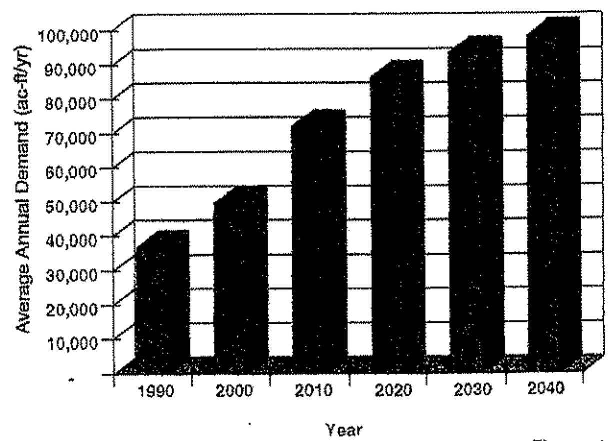

Figure 1-2
East County Urban Demands

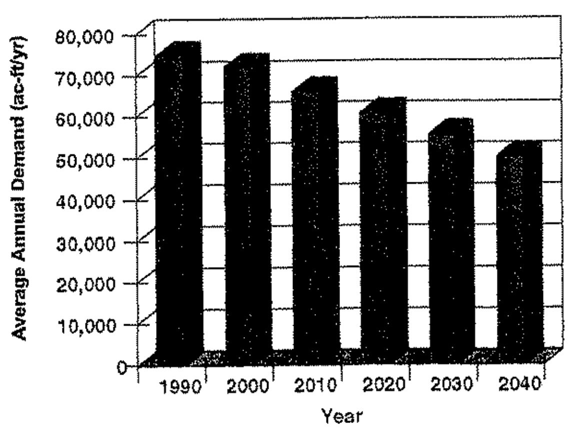

Figure 1-3
East County Agricultural Demands

In contrast, agricultural water need is projected to decrease from about 73,500 acre-feet in 1990 to about 48,600 acre-feet in 2040 (shown left), while the industrial water demand remains constant at 20,000 acre-feet. As a result, East County needs to develop water and infrastructure supply plans to meet future water needs as well as to treat and deliver water to meet municipal and industrial (M&I) demands.

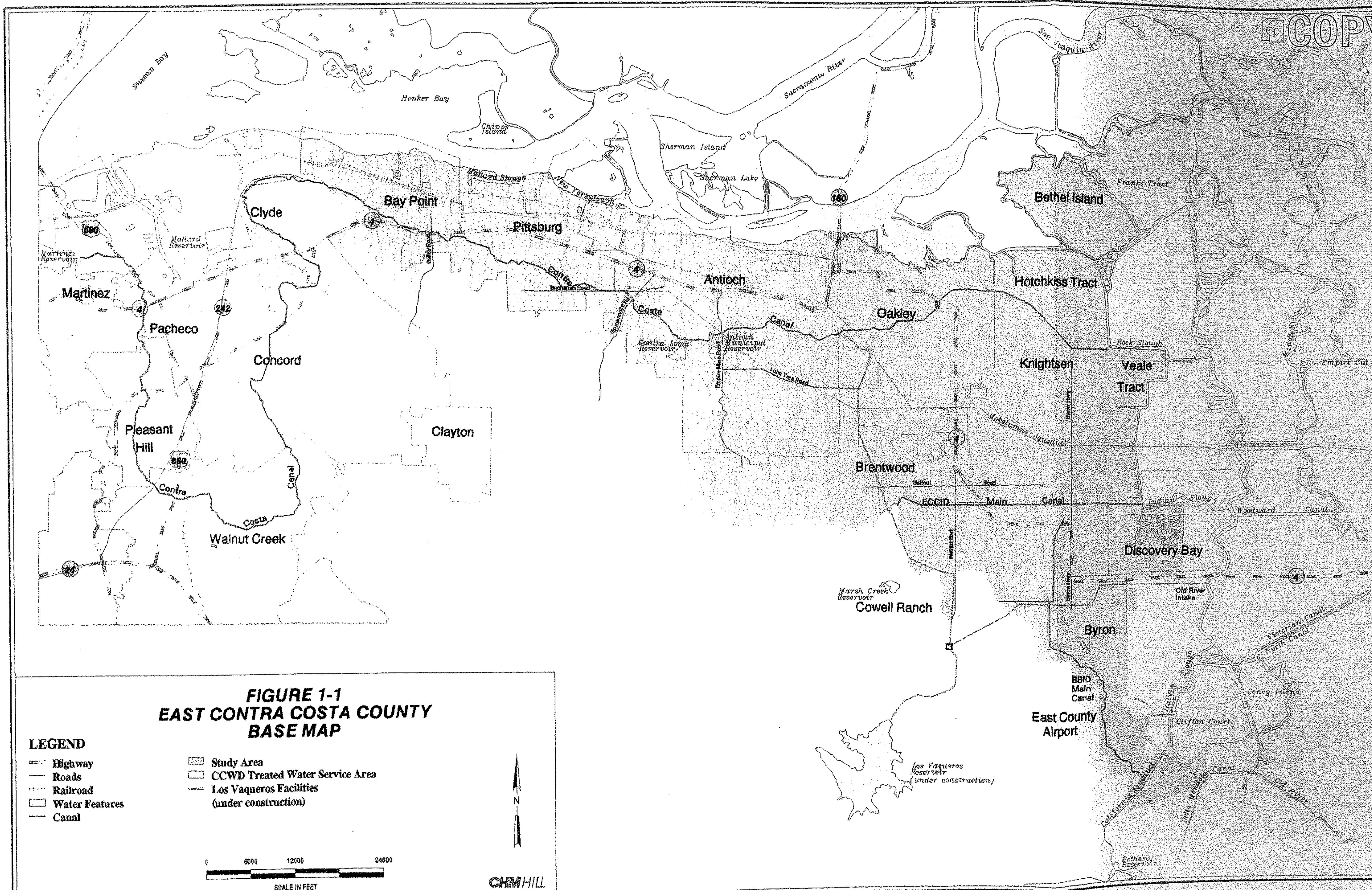

FIGURE 1-1
EAST CONTRA COSTA COUNTY BASE MAP

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EXHIBIT "C"

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

GROUND-WATER RESOURCES
HYDROLOGY • DEVELOPMENT • MANAGEMENT

COPY

MEMORANDUM

OVERVIEW OF FINAL REPORT
INVESTIGATION OF GROUND-WATER RESOURCES IN THE EAST CONTRA COSTA AREA

March 1999

An investigation was authorized by five east county public agencies in August 1998 in a joint effort to answer a set of basic questions concerning ground-water in a region of eastern Contra Costa County. The participating agencies were the Contra Costa County Water Agency, Contra Costa Sanitation District No. 19 (now Discovery Bay Community Services District), the City of Brentwood, Diablo Water District, and the East Contra Costa Irrigation District. A final report will be distributed under separate cover which contains details about the study methods, discussions about the data used in the study, exhibits, and conclusions. The purpose of this memorandum is to provide a brief overview of the investigation and cite the significant findings.

Objectives

The study area was defined as the region encompassing Brentwood and the East Contra Costa Irrigation District, Byron to the south, Oakley to the north, and Discovery Bay to the east. The scope of the investigation was posed as a set of basic questions about ground water to which answers were generally unknown on a regional scale for the study area:

1. What is the areal extent of the ground-water system in the study area? How is the aquifer system vertically divided and distributed?

2. Is the ground-water system in the study area hydraulically connected to that in Discovery Bay to the east or Oakley to the north?

3. What are the characteristics of the ground-water system in terms of quantity and quality of water?

4. How is ground water recharged? How does ground water discharge, or flow out of the area?

5. Is the ground-water system overdrafted?

6. Can more ground water be developed? How much? Where?

These questions represent the most significant issues facing water agencies throughout California with respect to managing existing resources and planning for future needs.

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Methods

The methods used in the investigation relied on existing information provided by each of the participating agencies, other information found through literature searches, and data obtained through the State Department of Water Resources and Division of Oil and Gas. The information sought for the investigation included anything related to ground water and consisted primarily of well data; i.e., driller's descriptions of aquifer materials encountered while drilling wells, ground-water levels, results of ground-water quality tests, and well yields.

Multiple tools were used to depict ground-water conditions in the study area and included:

Geologic Cross Sections - Cross sections were used to delineate and interpret the distribution and extent of aquifer materials throughout the study area. Aquifer materials were identified from drillers reports, geophysical surveys, as well as surveys conducted in oil and gas exploratory boreholes. Eight cross sections were constructed which depict and correlate the occurrence of aquifer units throughout the study area.

Water Level Hydrographs - Hydrographs depicting water levels in wells over time were used to illustrate historical conditions in the ground-water system. Distinguishing trends were noted and used to interpret climatic influences versus possible impacts of pumping activities.

Water Level Contour Maps - Water level contour maps were constructed to show the relative elevation of ground water throughout the study area as well as the flow direction. Maps were constructed representing various points in time to interpret flow patterns on a seasonal basis, changes due to extremes in climatic conditions (e.g., drought periods), and changes due to influences of urbanization.

Water Quality Maps and Graphs - Ground-water constituents were mapped and plotted in various forms to delineate and interpret distribution and trends in overall water quality.

Findings

Initial efforts to collect and organize information resulted in the development of a large data base of well drillers reports and ground-water levels which formed the basis for addressing the investigation objectives. Water quality data was the most sparse and lacking of the primary categories of information sought for the study. As a result, some firm conclusions could be drawn with respect to the occurrence and distribution of aquifer materials, as well as historical ground-water conditions, with limited conclusions regarding water quality. These conclusions can be summarized as follows:

Four ground-water regions were delineated in the study area which are distinguished by the manner in which aquifer materials were distributed and deposited. Of the two largest regions, one consists of ground water which occurs in materials deposited by streams originating from the coast range to the west. Conditions found in the greater Brentwood area would be most representative of this depositional environment. The second of the two large ground-water regions consists of materials deposited by the San Joaquin river system flowing northward through the Delta. Conditions at Discovery Bay are distinct and representative of this depositional environment. This is significant because:

- Differences in the occurence and patterns of aquifer units, as well as ground-water quality and quantity, between the western part of the study area (represented by Brentwood) and the eastern (represented by Discovery Bay as well as northward to Oakley) can be attributed to the natural history (i.e., geology) of the region.

Cross sections developed for the investigation provide coverage of the entire study area and can be used to project the occurrence of aquifer units throughout. Interpretation of the well information and cross sections indicates:

- For most of the study area, the extent of aquifer materials capable of yielding quantities of water suitable for municipal and/or agricultural purposes is to depths of 400 feet.

Water level hydrographs reflect seasonal fluctuations and, in some areas, climatic influences (such as drought periods) on ground water. In general, comparing conditions since the late 1950's to present, the data indicates:

- There is no apparent overdraft of the ground-water system suggesting that historical extraction patterns have not exceeded the safe yield of the basin.

Ground water contour maps were constructed to depict ground-water levels at various times since the late 1950's. These revealed flow patterns and direction of ground water throughout most of the study area. The maps indicate:

- There are no significant changes in movement of ground-water within the study area since the late 1950's.

Water quality data, while sparse, indicates wide variations in TDS and nitrate concentrations. Discovery Bay is notable for relatively better water quality in terms of TDS and no nitrate concentration when compared to areas directly to the west. This is likely attributable to the distinct depositional environments associated with the two areas, as cited above, as well as differences in historical land use. Nitrate problems in the greater Brentwood area are likely a result of surficial influences by agricultural practices where localized pumping or infiltration has caused introduction of nitrogen to shallow ground water, followed by movement of nitrate to deeper aquifer units. Such problems are most likely best addressed through specific well design features, such as selective well completions and deep annular well seals, to hydraulically isolate the shallow zones from the target completion intervals (i.e., water zones) in supply wells.

COPY

The significance of the findings cited above is that there are apparently limited, if any, adverse impacts to ground-water storage in the study area as a result historical use patterns. Impacts appear to be limited to the occurrence of elevated nitrate concentrations in shallow ground water which is likely a result of agriculture and, in some cases, possibly septic systems.

Data did not permit quantification of how much additional pumpage could be sustained in the basin without impacting the apparent safe yield. Any significant incremental pumpage should be monitored to determine if that safe yield is exceeded. This can be accomplished by updating key-well hydrographs and the water level contour maps to determine if downward trends in water levels or flow patterns result. The combination of geologic cross sections and historical water level data can serve various future water supply development needs. Most significantly, a systematic water quality sampling and testing program should be instituted to more fully assess ground-water quality in the region.

Recommendations

The subject investigation developed some general conclusions with respect to historical and current ground-water conditions. Public agencies involved with water resources should be concerned with any increment of ground-water extraction that results in downward trends in water levels or shifts in flow direction. The affected agencies should consider instituting a program to monitor conditions on a periodic basis. Since the basin extends across multiple boundaries of influence, it would be beneficial to share information in order to completely depict regional ground-water conditions. This program should consist of:

- Identification of key wells for water level monitoring and water quality testing.
- Updating hydrographs for key wells on a semi-annual (spring and fall) basis.
- Updating water level contour maps on a semi-annual (spring and fall) basis.
- Production of an annual report which incorporates updated hydrographs, contour maps, and water quality test results. The report should highlight any significant changes in ground-water use patterns.

In conclusion, the affected agencies are in a position to manage ground-water resources at a point where the impacts of future development can be assessed for a system which has been relatively stable over several decades. Considering the vertical extent as well as the quality of aquifer materials present in the study area, the agencies should prepare to react to any adverse changes in the historical water level and flow patterns caused by any changes in extraction patterns. This need is underscored by the fact that water quality is poor in many areas (e.g., high TDS and nitrate) and the aquifer system is limited areally and vertically (i.e., to depths of about 400 feet) as reflected in the geologic cross sections constructed for this investigation.

III. Ground-Water Conditions

Introduction

This chapter discusses ground-water conditions in terms of ground-water levels, which are a reflection of ground-water storage, and ground-water quality. Throughout the study area, the primary water-bearing units for water supply purposes exist primarily in the upper 300 to 400 feet of geologic material. From the analyses presented in the previous chapter, there is no apparent basis for subdividing the aquifer system into subunits on a regional scale due to a lack of correlation although locally there are apparent variations in aquifer characteristics, water levels, and water quality.

The most extensive collection of historical water level and quality data was provided by the East Contra Costa Irrigation District (ECCID). This data covered the area from Oakley in the north to south of Brentwood, and from west of Highway 4 east toward Discovery Bay. The period of record for the ECCID data began in 1958 and provided an excellent basis to evaluate trends in water levels over time, especially during drought periods. This data was the primary source for the generation of contour maps of equal ground-water elevation and depth-to-water, and water level hydrographs discussed below. Ground-water quality data is also predominantly from this area but is also very limited in scope so that only a few general conclusions could be drawn with respect to questions concerning this topic.

Ground-Water Level Hydrographs

Representative water level elevation hydrographs of wells monitored by ECCID were constructed and evaluated to assess historical trends. A hydrograph, which is a plot of water level versus time, reflects ground-water storage over time. The factors which affect ground-water levels and storage include seasonal and climatic changes, use patterns (e.g., municipal and agricultural pumping), and artificial and natural recharge. A long-term or permanent decline in ground-water elevation is generally interpreted as an overdraft condition where extraction of ground water exceeds the recharge components. Short-term water level declines may result from climatic conditions such as drought. In this case, overdraft would not exist if water levels recover after the drought period. In areas where ground water is extracted for various purposes, seasonal fluctuations can often be correlated to recharge during the winter period (water level rise) and pumping through spring and summer (water levels fall). The hydrographs analyzed for this study and a well location map are included under Exhibits at the end of this report.

Ground-water level data obtained from ECCID spanned from the late 1950's and served as an excellent basis for interpreting ground-water storage over time for a significant portion of the study area. The data indicates that water levels in the east county area have remained fairly stable with no evidence of long term or dramatic declines. Minor shifts in water levels have occurred in two areas of the east county region. Wells located north of Lone Tree Way in Brentwood in the Marginal Delta Dune area have exhibited an upward to relatively flat trend in water levels. The upward trend is exhibited by an increase of approximately two to five feet over the last 25 to 35 years.

Wells located in the Alluvial Plain area south of the Marginal Delta Dune area have generally exhibited either stable or slightly declining trends in water levels. The wells which have shown a slightly decreasing trend have had a decline of two to five feet in the last 25 to 35 years, almost a mirror image of the upward trend in the Marginal Delta Dune area. The amount of decline is not considered significant in terms of impacts to either ground-water quantity or quality in the affected area.

Climatic and seasonal water level changes are most noticeable in wells located in the western portion of ECCID's well network. These wells commonly have seasonal or climatic water level changes of five to twenty feet. Wells located in other areas of ECCID do not have pronounced seasonal or climatic water level changes. These wells may be affected by proximity to the Delta whereas the wells located in the western portion of ECCID are likely influenced more by boundary effects caused by proximity to the edge of the ground-water system, i.e., the Coast Range foothills.

Long-term water level data were not found for other east County areas. This problem could be addressed by extending the monitoring conducted by ECCID to the other regions including south of Brentwood in the Byron area, the Oakley area, the Discovery Bay area, and east beyond the county line. However, considering that the most significant historical ground-water extraction activities have been focused in the greater Brentwood area, it is expected that the outlying areas would not show a significant deviation from the stability reflected in the ECCID data. In Discovery Bay, long-term monitoring of water levels of the confined unit tapped by its municipal wells would be of key importance with regard to ground-water conditions in that area.

Ground-Water Level Contour Maps

Regional water level contours were constructed for spring and fall of 1958, 1975, and 1991, and spring or fall of 1977, 1986, and 1996. The 1991 contour maps were augmented with data from Diablo Water District and Discovery Bay. The contour maps were used to assess historical changes in ground-water flow directions since 1958 during time periods which experienced wide variations in precipitation, e.g., during "wet" years (mid 1980's) and "dry" years (mid 1970's, late 1980's). The plots were also used to determine areas which have experienced increases in ground-water pumpage and which have little or no recorded water level data.

All the ground-water elevation contour plots show ground-water flow directions from west to east in the southern portion of the study area (Brentwood to Discovery Bay) and from southwest to northeast in the central and northern portions of the area (from Brentwood toward Holland Tract). Immediately south and southwest of Brentwood near ECCID's Main Canal, there appears to be a flattening of ground-water elevations, possibly resulting from ground-water pumping in the vicinity (an effort should be made in the future to verify the measuring point elevations in this area as the apparent flattening of contours could be a data quality problem). This is most noticeable from 1975 through 1991, when more water level data is available in this area, and does not appear to be developing into a ground-water depression, even during drought periods (1977 and 1991). There is a lack of data south of Brentwood in 1996 and prior to 1975 to evaluate whether the flattening of ground-water levels persists before or after that time period. This area does not appear to have a dramatic affect on water levels either in the Discovery Bay area or in the Brentwood area.

The hydraulic gradient is approximately 15 feet per mile in the southern portion of the basin to 20 feet per mile in the northern portion of the basin. The hydraulic gradients have not changed significantly since 1958 with the exception of the flattening of the gradient in the area south of Brentwood since 1975.

Depth-to-Water Contour Maps

Depth-to-water contour maps were prepared for the same time periods as the water level elevation contours discussed above. These maps, included in the Exhibits section along with the ground-water elevation maps, can be used to assess how depth-to-water in a particular area has changed over time; they can also, for example, serve as a useful reference when assessing available drawdown for well development purposes. Unfortunately, there is a lack of historical water level data west of Highway 4, in the Oakley area, south of Brentwood to Byron, and in the Dutch Slough, Rock Slough, and Indian Slough areas; this lack of data limits the scope of depth-to-water mapping in the overall study area.

The depth-to-water maps show that ground water occurs at shallower depths from west to east. These maps are consistent with the hydrographs and elevation contour maps in that they indicate no significant changes over time nor any apparent significant impacts by historical extraction within the area for which data is available.

Ground-Water Levels in Newer Brentwood Municipal Wells - Although there is no extensive data on water levels in municipal wells operated by the City of Brentwood, it is known that static levels in the City's two main well fields (Wells 6, 7, and 8 near Marsh Creek and Wells 11, 12, and 13 to the south) are deeper than the shallower levels reflected in the broad ECCID data base. Static water level readings from Brentwood's wells indicate that the water level difference may be 20 to 40 feet in magnitude and is most likely caused by the municipal pumping. The City's pumping, however, has not impacted the larger regional system as reflected in the well hydrographs or water elevation contours discussed previously. At least locally, the City should be concerned with how the water level difference between the deeper completion zones of its newer municipal wells and the shallow zones might cause degradation of water quality by inducing downward movement of water quality constituents of local concern (e.g., nitrate). As development of the deepest portion of the aquifer occurs, it would be advisable to monitor the municipal wells separately to determine if a distinction of the aquifer system into shallow and deep units is appropriate.

Ground-Water Quality

Ground-water quality data was reviewed to assess trends and characteristics of ground water throughout the study area. Data was limited in quantity and distribution, with most concentrated in the greater Brentwood area and within the East Contra Costa Irrigation District. Water quality data is presented in a series of graphs for wells located on the study Base Map under Exhibits at the end of this report.

Ground-water quality data posted on maps include concentrations of total dissolved solids (TDS), chloride, and nitrate. As discussed below, because of the limited amount of data, the most significant finding concerning water quality variations throughout the study area is the notably better water quality in Discovery Bay as compared to other areas where data is available.

A series of graphs was also used to assess water quality characteristics for this investigation. These graphs were constructed by plotting various water quality constituents versus the depth of the well intake structure; that is, the top of the well perforations or screen. Most notably, there is a strong correlation between nitrate concentration and the depth of the intake structure, which is consistent with the generally understood concept that nitrate degradation occurs as a result of surficial influences. Other constituents also showed a relationship that suggests that water quality improves with depth as discussed below.

Total Dissolved Solids - Data on total dissolved solids in ground water in the study area varies widely, although it is characteristically high, up to 1,000 mg/l, in many areas (see TDS map). Discovery Bay is notable for significantly lower TDS in ground water with all measured values between 500 and 600 mg/l. As discussed further below, this information lends support to the theory that the ground-water system in that area may be hydraulically distinct from the depositional areas to the west and perhaps the north. This hydraulic distinction is not apparent from the ground-water elevation maps discussed previously because of a lack of data around Discovery Bay.

Other constituents of ground-water quality, including electrical conductivity, were plotted as a function of the depth of the well intake structure. Each of these indicates a slight trend of better water quality with depth. Considering a very strong relationship with nitrate, which is usually derived from surficial sources, it may be possible that there is some degradation in ground-water quality (besides nitrate) that is a result of the same influences. However, the preponderance of the data suggests that water quality is naturally high in TDS (up to 1,000 mg/l) and other constituents such as chloride, and that local degradation may have occurred possibly due to man-made influences.

Nitrate - Nitrate in ground water is widely distributed in the study area, with some values exceeding the maximum contaminant level (MCL) set by EPA for drinking water (45 mg/l as nitrate). The eastern portion of the study area is notable as having significantly lower values; the wells in Discovery Bay have no detectable nitrate present. While the occurrence of nitrate in ground water in this area has generally been attributed to agricultural influences, its occurrence is clearly limited to the upper sequences of aquifer materials as reflected in the plot of nitrate concentration versus depth of well intake structures. For the available data, nitrate concentrations decline appreciably for wells completed below 200 feet; i.e., for wells where the top of the perforations are 200 feet or more below the surface. This suggests that, in many cases, nitrate contamination may be mitigable through well design, for example, by incorporation of wells seals to 200 feet and limitation of well screens to depths below 200 feet.

Aquifer Confinement

The representative hydrographs and contour maps analyzed for this investigation are included at the back of the report under Exhibits. The wells monitored by ECCID are widely distributed throughout the region and are representative of the main aquifer system which occurs in the upper 300 to 400 feet below ground surface. The water level data reflects primarily conditions in the western portion of the study area, with most of that falling within the Alluvial Plain depositional region but extending into the Marginal Delta Dune region around Oakley. Considering the depositional region as well as the consistencies in data from well to well, the aquifer system appears to act locally confined. That is, there appears to be hydraulic continuity from the shallow aquifer materials to the deeper ones as reflected by the similarities in water levels from all wells.

The hypothesis of local confinement is supported by the apparent discontinuous nature of aquifer materials as reflected in the cross sections discussed in the previous chapter. Under this model, some local confinement would be expected as a result of the presence of clay beds and would affect the drawdown characteristics of wells, for example. However, these beds are not areally extensive and hydraulic equilibrium would likely be reached between shallow and deep zones when wells are inactive (e.g., in the winter). In the Brentwood area, this is consistent with the experience that well sealing can successfully mitigate nitrate degradation by preventing locally induce downward migration of shallow ground water as a result of deeper pumping.

In contrast to the apparent conditions in the Alluvial Plain, municipal wells in Discovery Bay produce from a zone which appears to be confined by an extensive layer of clay material (see Cross Sections 1 and C). The confinement of the main aquifer in the Discovery Bay area is indicated also by the difference in head between the deep zone and a shallow brackish zone which has caused some problems in operation of the municipal well facilities. These problems have been shown to be effectively mitigated by sealing the well through the brackish zone to achieve complete hydraulic isolation of both the deeper aquifer and the well structures from the brackish aquifer.

The apparent confinement of the main aquifer at Discovery Bay appears to be representative of the Fluvial Plain region. The same may not be true immediately north into the Delta Islands where the cross section interpretation seems to make confinement more difficult to correlate and there is no water level data for added support.

Recharge Sources

The study area consists of an aquifer system having a mix of depositional patterns as discussed in Chapter II. From the depositional models, it is not unlikely that there are different sources of recharge of the various aquifer materials which are sources of water supply. From water level data, it is clear that ground water is moving from the Coast Range foothills toward the east through the Alluvial Plain and Marginal Delta Dune regions. As discussed above, there is no clear extensive confinement of aquifer materials in these areas. In contrast, ground water developed in municipal supply wells in Discovery Bay appears to be confined and, when water quality information is considered, it is likely that there is different recharge source as well. One possibility is that the Fluvial Plain region, where Discovery Bay is located, is recharged from the south in a manner that is consistent with the depositional model discussed previously. Again, it should be noted that this is not reflected on the ground-water elevation contour maps primarily because of lack of data around Discovery Bay.

Recharge of the Delta Islands may be a combination of fluvial influences from the south but also the hydraulics of the Delta system. The lack of pronounced seasonal and climatic influences on water levels as cited previously underscores the likely significance of the Delta system with regard to recharge. The latter is especially true considering the lack of the correlatable confinement that is a characteristic of the Fluvial Plain. No other conclusions regarding recharge could be made except for those cited above mainly because of the lack of water level information outside of the ECCID area. It should be noted that in some areas, particularly to the north in the Delta Islands and Marginal Delta Dune regions, significant increases in pumpage may have the potential to induce recharge from poor quality, or brackish, water as a result of proximity to Bay and Delta influences. The inability to assess recharge in parts of the study area underscores the need to develop a broader range of water level monitoring outside the boundaries of ECCID. In Discovery Bay particularly, where ground water is relied on for municipal water supply purposes, it would be desirable to investigate ground-water conditions in more detail to the north, south, and east to delineate flow direction and potential recharge influences.

Basin Yield

Historical conditions as reflected in the hydrographs and contour maps discussed above suggest that, for much of the Alluvial Plain and Marginal Delta Dune regions, where most of the historical data is available, extraction activities have not exceeded the sustainable yield of the ground-water system. Here, sustainable yield, sometimes called "safe" yield, refers to that level at which extraction has not adversely impacted ground-water conditions, e.g. levels, storage, quality, etc. As cited above, stability in ground-water levels and storage reflected in the well hydrographs and the ground-water contour maps.

Although it may be stated that the sustainable yield in much of the east County area has not been adversely impacted as reflected by the ground-water level data, less certainty exists at Discovery Bay and other areas, including Brentwood (deeper zones), because of the lack of data and/or short period of record. It is unlikely, however, that sustainable yield, as defined above, has been exceeded because of the general lack of ground-water development throughout much of these other areas. Furthermore, areas in the vicinity of the river and Delta systems have a large source of potential recharge which could offset potential adverse impacts due to increased extraction.

Sustainable yield also refers to that level at which ground-water extraction does not degrade water quality. On this matter, less is apparent based on available water quality data in the study area. It is likely that pumping on a local level in the Brentwood area, for example, induces some degradation by nitrate. However, it is also likely that some of these local influences are caused by, and can therefore be mitigated through, well design practices. On a regional scale, significant increases in pumpage could cause migration of poor quality water in some areas, particularly the Alluvial Plain region, which could degrade water quality (e.g., nitrate, TDS). In the Delta areas, increased extraction may not affect quantity, but may induce movement of shallow brackish water that would be a hazard to fresh ground-water sources. Again, these considerations further point to the need for expanded monitoring in parts of the study area to better understand local conditions beyond where historical data is concentrated.

IV. Conclusions

Data Quantity and Quality

Initial efforts to collect and organize information resulted in the development of a large data base of well driller's reports and ground-water levels which formed the basis for addressing the investigation objectives. Ground-water quality data was the most sparse and lacking of the primary categories of information sought for the study. As a result, some firm conclusions could be drawn with respect to the occurrence and distribution of aquifer materials, as well as historical ground-water conditions, but with limited conclusions regarding ground-water quality.

Well data in the form of driller's reports permitted construction of geologic cross sections covering the entire study area. These tools can serve various future water supply development needs including targeting depths for exploratory test holes prior to new well construction. Since there was a limited quantity of electrical logs available, which provide precise delineation of lithologies, the cross sections should be reassessed when new logs become available (from new wells).

The data did not permit quantification of how much additional pumpage might be sustained in the basin without impacting the sustainable yield. As a result, it is recommended below that any significant incremental pumpage be monitored to determine if sustainable yield is exceeded. This can be accomplished by identifying key representative wells for the purposes of tracking water levels in the form of updated hydrographs and water level contour maps. These tools will permit detection of adverse or downward trends in water levels or flow patterns; they will also allow identification of appropriate local or other corrective measures (e.g., relocation or redistribution of pumpage, augmentation of recharge, etc.).

Because of the lack of water quality data, a systematic ground-water quality sampling and testing program is also recommended to more fully assess ground-water quality in the region and to serve as a basis for future ground-water management activities.

Hydrogeologic Regions

Four ground-water regions were delineated in the study area which are distinguished by the manner in which aquifer materials were distributed and deposited. These include the Alluvial Plain, Fluvial Plain, Delta Islands, and the Marginal Delta Dune. For reference, the aquifer system underlying the City of Brentwood is representative of the Alluvial Plain region; the aquifer system in Discovery Bay is representative of the Fluvial Plain; Bethel Island is central to the Delta Islands regions; and Oakley is within the Marginal Delta Dunes. The western extent of the entire hydrogeologic system is at the Coast Range foothills which represent the most distinct hydrogeologic boundary in the study area.

For most of the study area, the extent of aquifer materials capable of yielding quantities of water suitable for municipal and/or agricultural purposes is to depths of 400 feet. Each region has characteristic quantities of aquifer materials (i.e., net sand thickness) that are related to depositional patterns.

The depositional models are useful for a number of purposes. For example, differences in the occurence and patterns of aquifer units, as well as ground-water quality and quantity, between the western part of the study area (represented by Brentwood) and the eastern (represented by Discovery Bay as well as the other regions) can be attributed to the natural history (i.e., geology) of the region. The distinctions between the Alluvial Plain and the Fluvial Plain likely include different recharge sources which explains some significant differences in water quality between Brentwood and Discovery Bay, for example.

Ground-Water Conditions

Water level hydrographs reflect seasonal fluctuations and, in some areas, climatic influences (such as drought periods) on ground water. In general, comparing conditions since the late 1950's to present, the data indicates that there is no apparent overdraft of the ground-water system, suggesting that historical extraction patterns have not exceeded the sustainable yield of the system. However, there may be localized pumping influences around Brentwood that should be investigated further. In that area, newer municipal wells which tap deeper aquifer units (below 300 feet) have apparent lower static water levels than measured in the surrounding ECCID data base.

Ground water contour maps, constructed to depict ground-water levels at various times since the late 1950's, reveal patterns and directions of ground-water flow throughout a large portion of the study area from the western edge toward Discovery Bay. The maps indicate that there have been no significant changes in movement of ground water within the study area since the late 1950's. Furthermore, there have apparently been limited, if any, adverse impacts to ground-water storage in the study area as a result historical use patterns. Impacts appear to be limited to the occurrence of elevated nitrate concentrations in shallow ground water which is likely a result of agriculture and, in some cases, possibly septic systems.

Ground-Water Quality

Ground-water quality data, while sparse, indicates wide variations in TDS and nitrate concentrations. Discovery Bay is notable for relatively better water quality in terms of lower TDS and no detectable nitrate concentrations when compared to areas directly to the west. This is likely attributable to the distinct depositional environments associated with the two areas, as cited previously, as well as differences in historical land use. Nitrate problems in the greater Brentwood area are likely a result of surficial influences by agricultural practices where localized infiltration has caused introduction of nitrogen to shallow ground water. Such problems are most likely best addressed through specific well design features, such as selective well completions and deep annular well seals, to hydraulically isolate the shallow zones from the target completion intervals (i.e., water zones) in supply wells.

In the northern hydrogeologic regions, shallow, poor quality water (i.e., brackish) may exist as a result of influence by the Bay in the Delta over geologic time. The extend of this problem can be identified through exploration tools such as electrical logs and may be mitigated through well design. The known shallow brackish zone at Discovery Bay is considered anomalous in that the fluvial depositional model does not suggest a source of the poor quality water.

Ground-Water Exploration and Development Potential

Based on the geologic evaluation and cross sections, some general conclusions may be drawn regarding future ground-water exploration and development in the study area. In general, exploration should be confined to depths above about 400 feet except within a mile or two of the Coast Range Foothills where depths of exploration would be even shallower. Most alluvium sand and gravels beds occur above about 350 feet depth. Some thin sand or sandstone beds may be found below 400 feet.

In the Fluvial Plain region, wells of relatively high yields (up to 2,200 gpm capacity) have been constructed above 400 feet in the Discovery Bay area. However, shallow and possibly deeper brackish water problems have been found which must be avoided. The better water quality (in terms of lower TDS) developed in the municipal wells in Discovery Bay, as compared to the other regions, is likely due to the existence of a separate recharge source to the south. This source is likely related to the depositional pattern of the river system.

Development of wells in the Fluvial Plain region, with characteristics similar to the Discovery Bay municipal wells, may be possible particularly north of that community. However, this area does not have a population base to warrant such development at present. It is expected that exploration below 400 feet will not encounter suitable aquifers for water supply purposes.

In the eastern Delta Islands, wells of moderate yield appear to have been constructed. From the drillers' reports, depths of 400 feet appear to be the bottom of exploration potential. Brackish or saline water quality problems, especially in shallow aquifers above 200 feet, may be found as discussed previously.

In the Marginal Delta Dunes area, limited exploration has occurred to 400 feet. Potentially moderate yielding wells may be possible, but exploration is needed to evaluate deeper aquifer potential. Potential shallow aquifer problems of brackish water may be present and should be evaluated as part of any exploration effort in that area.

In the Alluvial Plain area, local areas of thick alluvial sand and gravel above 350 feet represent the best potential for development of ground-water sources. Two areas have been identified, one to the north near City of Brentwood Wells 6, 7, and 8, and an area to the south near City Well 13. In the southern area, additional exploration to the northeast may allow mapping of the sand beds of the channel sequence. Exploration between the north and south area is recommended to evaluate the possibility of correlation between the two areas, which may reveal a greater distribution of aquifer units suitable for ground-water extraction.

Some development of deeper aquifers below 300 feet has occurred, but has resulted in low well yields (less than 400 gpm capacity) due to poor aquifer characteristics, although good water quality was encountered (Brentwood Well 13). In general, it is suspected that high yielding wells (1,000 gpm capacity or more) suitable for municipal or irrigation needs will only be found in the alluvium to about 300 to 350 feet in depth. Shallow water quality has been found to be degraded by the presence of nitrate in the upper 100 to 200 feet of the alluvium zone and must be considered in well development programs. Exploration to the east, outside of the trends of the stream channel sand zones, is not likely to be encouraging based on the results of this subsurface investigation.

The area west of Oakley towards Antioch is poorly defined, but is suspected to be a poor ground-water supply region due to lack of alluvium deposits and possible brackish water quality problems. The Byron area shows very low exploration potential due to limited sand beds present and its apparent marginal relationship to the greater Alluvial Plain region in which Brentwood is central as well as representative.

Recommendations

The east County water entities are in a position to manage ground-water resources at a point in time that impacts of future development can readily be assessed for a system which has been relatively stable over several decades. Considering the vertical extent as well as the quality of aquifer materials present in the study area, the entities should prepare to react to any adverse changes in the historical water level and flow patterns caused by changes in extraction patterns. This need is underscored by the fact that water quality is poor in many areas (e.g., high TDS and nitrate) and the aquifer system is limited areally and vertically (i.e., to depths of about 400 feet) as reflected in the geologic cross sections constructed for this investigation.

The east County entities should be concerned with any increment of ground-water extraction that results in downward trends in water levels or shifts in flow direction. The affected entities should consider instituting a program to monitor conditions on a periodic basis. Since the basin extends across multiple boundaries of influence, it would be beneficial to share information in order to completely depict regional ground-water conditions. This program should consist of:

- identification of key wells for water level monitoring and water quality testing.
- updating hydrographs for key wells on a semi-annual (spring and fall) basis.
- updating water level contour maps on a semi-annual (spring and fall) basis.
- production of an annual report which incorporates updated hydrographs, contour maps, and water quality test results; the report should highlight any significant changes in ground-water use patterns.

Such a program is conducted in many major ground-water basins in the State. The various maps and hydrographs created for this investigation can serve as initial products of an ongoing monitoring program. These products can be easily interpreted for ground-water management purposes including protection of water quality and limiting of extraction to the sustainable yield of the basin. They would also be useful with efforts to increase sustainable yield, correspondingly increasing pumpage, by management actions such as augmenting recharge and treatment of high TDS and/or nitrate-contaminated water.