This testimony summarizes the work performed to evaluate the agriculture water use efficiency for four of the five Cachuma Project Member Units in connection with the State Water Resources Control Board (SWRCB) hearings. This work consists of comparing calculated theoretical water delivery requirements for irrigated agricultural land to historical water delivery records to determine the agriculture water use efficiency.

The five Cachuma Project Member Units, hereafter referred to as Districts, consist of 1) Goleta Water District, 2) Montecito Water District, 3) Carpinteria Valley Water District, 4) Santa Ynez River Water Conservation District, Improvement District Number 1 (ID#1), and 5) City of Santa Barbara. The City of Santa Barbara was not evaluated for agriculture water use efficiency because only approximately one percent of its water demand is for agriculture. The four Districts addressed in this study are located in the central coast region of California as shown on Figure 1. The Districts receive a portion of their water supply from the Santa Ynez River basin. Water production within each District is for domestic, municipal, industrial and agricultural purposes. This testimony addresses only the water used for agricultural irrigation purposes.

The agricultural water use efficiency will be defined here as the volume of water theoretically required by the crops divided by the volume of water delivered to the irrigated field. For example, if a crop requires one acre-foot of water and two acre-feet of water is delivered, then the efficiency is 50 percent. The total volume of water theoretically required by the crops was calculated based on the net irrigation requirement (NIR) plus the leaching requirement times the irrigated acreage. The volume of water theoretically required by the crops was calculated based on climatic factors such as temperature, precipitation, wind speed, humidity, and solar radiation. Climate is an important factor in determining the crop water requirements because the hotter, dryer, windier, and sunnier it is, the more water the crop requires. The soil type is also an important factor because water from precipitation that is stored in the soil can be used by the crop to satisfy a portion of its water requirement.

The agricultural water use efficiency was established based on the following:

- Irrigated acreage
- Crops grown
- Theoretical water delivery requirements (NIR plus Leaching)
- Agriculture water delivery

The volume of water delivered to the irrigated field is measured at the irrigated field and not at the source of the water supply.

The average agricultural water use efficiency ranges from 159% to 288% for farms in the four Districts that receive only District water and is summarized in Table 1. The agricultural water use efficiency greater than 100 percent may be the result of deficit irrigation.

TABLE 1 AGRICULTURAL WATER USE EFFICIENCY[1]

District	Average[2]

Goleta	204%
Montecito	250%
Carpinteria	288%
ID #1	159%

[1] *Based on irrigated land receiving only District water.*
[2] *Efficiency greater than 100% suggests deficit irrigation;*
Average efficiency is based on the weighted average using acreage.

The agricultural watering practices within the four water Districts located in the Cachuma project service area mainly rely on drip, micro-sprinkler, and sprinkler irrigation systems. These types of irrigation systems are among the most efficient methods used for irrigation in California. By 2020, the California Department of Water Resources assumes that the on-farm efficiency in the state of California will average 73 percent, which is considerably lower than the average efficiency of the four Districts located in the Cachuma project service area.

IRRIGATED ACREAGE

The irrigated acreage used for my analysis for each of the four Districts for each year of each District's study period is described as following:

Goleta

Goleta Water District provided information on approximately 3,400 acres of agricultural lands. Of those, only a fraction is irrigated and has delivery records for the study period (2000, 2001, and 2002). In addition, many farms have private wells that provide additional un-metered water. To determine the agriculture water use efficiency, it is necessary to evaluate those lands receiving District water separate from lands receiving District and other water. Table 2 summarizes the irrigated acreage in the District for the three-year study period.

TABLE 2 GOLETA IRRIGATED ACREAGE

	2000	2001	2002
Irrigated Acreage	3,442	3,414	3,437
Irrigated Acreage with Delivery Records	3,391	3,371	3,193
Irrigated Acreage with Delivery Records Receiving only District Water	1,909	1,901	1,662

Montecito

Montecito Water District provided information on irrigated lands as of May 2003. As a result, it was assumed that there has been little irrigated land use change in the period of record (1999-2002) and the provided acreages are valid. The irrigated acreage is 531 acres based upon May 27, 2003 data.

Carpinteria

Carpinteria Valley Water District provided information on approximately 3,500 acres of agricultural lands. Of those, only a fraction is irrigated and has delivery records for the study period (1994-1998). In addition, many farms have private wells that provide additional un-metered water.

To determine the agriculture water use efficiency, it is necessary to evaluate those lands receiving only District water.

Table 3 summarizes the irrigated acreage in the District for the study period.

TABLE 3 CARPINTERIA IRRIGATED ACREAGE

	1994	1995	1996	1997	1998
Total Acreage	3,573	3,486	3,496	3,431	3,423
Irrigated Acreage Receiving only District Water[1]	485	511	516	507	506

[1] *Does not include irrigated acres in parcels with substantial acreage in covered nurseries or irrigated acres in parcels sharing a meter with parcels using non-District water.*

ID#1

ID#1 states there are 2,144 acres of agricultural lands in the District that receive District water. This total came from the APN acreage. We know that 100 percent of the APN acreage is not irrigated based on field observations and discussion with District personnel. An estimation was made to determine the percent of APN acreage that contains roads, houses, and barns, etc. that is not irrigated. Because there is no further information on this percentage, this analysis assumes that 80% of the total property acreage is irrigated farmland. This percentage is based on field observations and the percentage of total property acreage that is irrigated acreage from Goleta and Montecito Water Districts. The irrigated farm land for the Montecito and Goleta Water Districts is 61 percent and 56 percent of their total property acreage, respectively, for the irrigated acreage reviewed in the study. Therefore, the irrigated acreage for ID#1 thus equals 1,715 (acreage based upon the area of the APN parcel times 80%).

CROPS GROWN

The next step in estimating the agricultural water use efficiency is to determine the crops grown in each District. It is necessary to determine the type of crops grown in order to calculate the theoretical water delivery requirement, which is a function of the crop type.

Goleta

Table 4 shows the 2000, 2001 and 2002 crop distribution for irrigated agricultural lands with water delivery records for the Goleta Water District.

TABLE 4 GOLETA CROPPING PATTERN FOR IRRIGATED ACREAGE WITH WATER DELIVERY RECORDS

	2000		2001		2002	
Crop	Irrigated Acreage	Percentage	Irrigated Acreage	Percentage	Irrigated Acreage	Percentage
Avocado	1,833.4	54.1%	1,811.4	53.7%	1,707.7	53.5%
Citrus	950.2	28.0%	970.7	28.8%	895.8	28.1%
Nurseries	244.0	7.2%	251.0	7.4%	251.5	7.9%
Vegetables	289.0	8.5%	264.1	7.8%	263.6	8.3%
Other[1]	74.6	2.2%	74.6	2.3%	74.6	2.2%
Total	3,391.2	100%	3,371.8	100%	3,193.4	100%

[1] *Other includes cherimoyas, berries, pasture, fruit trees, oats, olives, persimmons, figs, and nuts.*

Because avocados, citrus, nurseries and vegetables make up approximately 98% of the irrigated lands, this analysis will be limited to these crops.

Table 5 shows the crop distribution for lands that receive only metered District water. These lands will be the primary focus of my analysis but the lands that receive District and other water will be investigated separately.

TABLE 5 GOLETA CROPPING PATTERN FOR IRRIGATED ACREAGE WITH DELIVERY RECORDS RECEIVING ONLY DISTRICT WATER

	2000		2001		2002	
Crop	Irrigated Acreage	Percentage of Total[1]	Irrigated Acreage	Percentage of Total[1]	Irrigated Acreage	Percentage of Total[1]
Avocados	940.6	27.7%	920.6	27.3%	784.4	24.6%
Citrus	596.0	17.6%	625.8	18.6%	524.0	16.4%
Nurseries	203.2	6.0%	210.2	6.2%	210.2	6.6%
Vegetables	169.0	5.0%	144.1	4.3%	143.6	4.5%
Total	1,908.8	56.3%	1,900.7	56.4%	1,662.2	52.1%

[1] *Percentage of irrigated acreage shown in*

Table 4.

Montecito

Table 6 shows the distribution of crops grown in the Montecito Water District.

TABLE 6 MONTECITO CROPPING PATTERN

	Acreage[1]	Percentage
Avocados	330.8	62.3%
Citrus	155.1	29.2%
Other[2]	45.3	8.5%
Total	531.2	100.0%

[1] Based on May 27, 2003 data.
[2] Other consists of stone fruit, potted plants, berries, and flowers

Avocados and citrus make up 91% of the crops grown (486 acres) in the Montecito Water District and will be the basis for the calculation of the agriculture water use efficiency.

Carpinteria

Carpinteria Valley Water District provided the cropping pattern shown in Table 7 for 1996 through 1998.

TABLE 7 CARPINTERIA CROPPING PATTERN FOR ALL IRRIGATED ACREAGE[1]

	1996		1997		1998	
Crop	Irrigated Acreage	Percentage of Total	Irrigated Acreage	Percentage of Total	Irrigated Acreage	Percentage of Total
Avocado	1,859	53%	1,854	54%	1,834	54%
Lemons	254	7%	217	7%	214	6%
Other Fruit Trees	242	7%	247	7%	260	8%
Nurseries	640	18%	571	17%	538	16%
Covered Nurseries	398	12%	422	12%	429	12%
Other[2]	103	3%	120	3%	148	4%
Total	3,496	100%	3,431	100%	3,423	100%

[1] Data for 1994 and 1995 not available.
[2] Other consists of pasture and truck crops.

Twelve percent of the irrigated lands consist of covered nurseries. Because climate conditions in covered nurseries cannot be represented with data from outdoor climate stations and because covered nursery conditions vary substantially depending on operating practices, theoretical water delivery requirements were not calculated for lands in covered nurseries. Table 8 shows the cropping pattern for Carpinteria irrigated acreage without substantial covered nursery acreage receiving District water only. Avocados, lemons, and nurseries make up between 76 and 78% of the total irrigated lands in the District. These crops as well as cherimoya and pasture are the focus of this study.

TABLE 8 CARPINTERIA CROPPING PATTERN FOR LANDS WITH INSIGNIFICANT COVERED NURSERIES THAT RECEIVE ONLY DISTRICT WATER

	1994		1995		1996	
Crop	Irrigated Acreage	Percentage of Total	Irrigated Acreage	Percentage of Total	Irrigated Acreage	Percentage of Total
Avocados	297	61%	289	57%	283	55%
Citrus	23	5%	21	4%	21	4%
Nurseries	103	21%	138	27%	148	29%
Cherimoyas	25	5%	26	5%	27	5%
Pasture	37	8%	37	7%	37	7%
Total	485	100%	511	100%	516	100%

	1997		1998	
Crop	Irrigated Acreage	Percentage of Total	Irrigated Acreage	Percentage of Total
Avocados	282	56%	289	57%
Citrus	20	4%	20	4%
Nurseries	148	29%	138	27%
Cherimoyas	28	5%	30	6%
Pasture	29	6%	29	6%
Total	507	100%	506	100%

ID#1

Table 9 shows the distribution of crops grown in ID#1.

TABLE 9 ID#1 CROPPING PATTERN

	Acreage[1]	Percentage
Vineyard	671.7	39.2%
Truck Crops [2]	419.9	24.5%
Pasture	202.5	11.8%
Alfalfa	114.7	6.7%
Other [3]	306.5	17.8%
Total	1,715.3	100.0%

[1] Based on 2003 data, acreage is based on APN parcel acreage times 80%
[2] Truck crops consist of peppers, tomatillos, squash, snow peas, and corn.
[3] Other includes trees, oat hay, and fallow

Vineyards, truck crops, pasture, and alfalfa represent 82% of the crops grown (1,409 acres) and will be the basis for the calculation of the agriculture water use efficiency.

THEORETICAL WATER DELIVERY REQUIREMENTS

The theoretical water delivery requirement is equal to the volume of irrigation water beneficially used by the irrigated crop. The volume of irrigation water used beneficially by the crop refers to the minimum amount of irrigation water required to obtain maximum yield plus any additional water necessary for leaching potentially harmful salts from the crop root zone. This quantity is often called the net irrigation requirement (NIR) plus the leaching requirement.

Reference Crop Evapotranspiration

Evapotranspiration (ET) is the process by which water is evaporated from the soil and transpired by growing plants. The amount of water needed by a plant is primarily dependent on temperature, wind, humidity and solar radiation. Various methods exist for estimating reference evapotranspiration (ET_o). A modified version of the Penman equation was deemed the most accurate and was used for estimating crop evapotranspiration.

The California Irrigation Management Information System (CIMIS), developed by the University of California at Davis and the California Department of Water Resources, has maintained a network of climate measuring stations throughout the state since 1982. These stations measure all the climatic variables needed for determining reference evapotranspiration using the modified Penman equation.

Table 10 shows the reference evapotranspiration stations used for each District's lands.

TABLE 10 REFERENCE EVAPOTRANSPIRATION AND PRECIPITATION STATIONS

	ETo Data Source		Precipitation Data Source	
District	**Station Name**	**Station Operator**	**Station Name**	**Station Operator**
Carpinteria	Santa Barbara	CIMIS	Carpinteria Fire Station	Santa Barbara County Flood Control District
Goleta	Goleta Foothills and Santa Barbara	CIMIS	Goleta Foothills	CIMIS
ID#1	Santa Ynez	CIMIS	Santa Ynez	CIMIS
Montecito	Santa Barbara	CIMIS	Montecito	U.S. Forest Service

Table 11 shows annual ET_o for the four Districts using the Santa Barbara, Goleta Foothills and Santa Ynez CIMIS stations.

TABLE 11 ANNUAL REFERENCE EVAPOTRANSPIRATION (ET_O) ON DISTRICT LANDS (INCHES PER YEAR)

Year	Goleta	Montecito	Carpinteria	ID#1
1994	[1]	[1]	42.1	[1]
1995	[1]	[1]	43.1	[1]
1996	[1]	[1]	47.0	[1]
1997	[1]	[1]	47.5	[1]
1998	[1]	[1]	46.1	44.8
1999	[1]	48.3	[1]	48.1
2000	47.1	44.9	[1]	47.2
2001	41.8	39.6	[1]	48.9
2002	44.4	42.1	[1]	52.2

[1] *Reference evapotranspiration not calculated for the years that water delivery records were not provided by the Districts*.

Crop Evapotranspiration

The crop evapotranspiration for each crop in each District is shown in Table 12 through

Table 15 and was calculated using the following equation:

$$ET_c = K_c * ET_o$$

Where:
ET_c = Crop evapotranspiration
K_c = Crop coefficient
ET_o = Reference evapotranspiration.

TABLE 12 GOLETA ET_C
(INCHES PER YEAR)

Year	Avocados	Citrus	Nurseries[1]	Vegetables[2]
2000	30.2	24.5	23.6	18.7
2001	26.8	21.7	20.9	16.8
2002	28.4	23.1	22.2	17.3

[1] *Outside ornamental nurseries without climate-controlled greenhouses*

[2] *Vegetables include double-cropped broccoli and lettuce*

TABLE 13 MONTECITO ET_C
(INCHES PER YEAR)

Year	Avocados	Citrus
1999	30.9	25.1
2000	28.7	23.4
2001	25.3	20.6
2002	27.0	21.9

TABLE 14 CARPINTERIA ET_C
(INCHES PER YEAR)

Year	Avocados	Citrus	Nurseries[1]	Cherimoya	Pasture
1994	26.9	21.9	21.0	18.5	31.6
1995	27.6	22.4	21.6	19.0	32.4
1996	30.1	24.4	23.5	20.4	35.2
1997	30.4	24.7	23.7	20.5	35.6
1998	29.5	24.0	23.1	20.2	34.6

[1] *Outside ornamental nurseries without climate-controlled greenhouses*

TABLE 15 ID#1 ET_C
(INCHES PER YEAR)

Year	Alfalfa	Pasture	Truck Crops [1]	Vineyard
1998	35.5	33.6	24.4	21.1
1999	37.3	36.1	25.3	22.1
2000	37.2	35.4	24.9	22.1
2001	39.4	36.7	25.8	23.5
2002	41.5	39.2	28.9	24.8

[1] *Truck crops based on double-cropped peppers and snow peas*

Net Irrigation Requirement

The net irrigation requirement (NIR) is the amount of water still needed by the crop after considering the contribution of effective precipitation to the crop's ET_c requirement. NIR is calculated by subtracting effective precipitation from the crop's ET_c requirement as shown in the equation below:

$$NIR = ET_c - P_E$$

Where:
NIR = Net irrigation requirement in inches
ET_c = Crop evapotranspiration in inches
Pe = Effective precipitation in inches

The NIR was determined for each crop grown in each District using appropriate reference evapotranspiration, crop coefficients and effective precipitation and is shown in Table 16 through Table 19.

TABLE 16 GOLETA NIR
(INCHES PER YEAR)

Year	Avocados	Citrus	Nurseries	Vegetables
2000	22.6	17.1	17.5	12.9
2001	14.9	10.5	12.2	7.0
2002	23.7	18.3	17.4	12.5

TABLE 17 MONTECITO NIR
(INCHES PER YEAR)

Year	Avocados	Citrus
1999	25.5	19.8
2000	18.2	12.5
2001	14.7	9.9
2002	22.1	17.1

TABLE 18 CARPINTERIA NIR
(INCHES PER YEAR)

Year	Avocados	Citrus	Nurseries	Cherimoya	Pasture
1994	21.0	16.1	15.2	12.8	23.0
1995	18.6	12.9	14.5	8.5	20.5
1996	21.7	16.2	15.6	12.4	23.1
1997	23.8	18.3	18.6	14.2	26.9
1998	18.6	12.2	13.6	7.5	19.3

TABLE 19 ID#1 NIR
(INCHES PER YEAR)

Year	Alfalfa	Pasture	Truck Crops	Vineyard
1998	25.0	22.6	17.0	11.1
1999	29.5	30.2	20.1	15.1
2000	23.7	23.4	16.4	9.7
2001	18.1	15.9	14.3	7.1
2002	33.2	32.3	22.4	16.1

Leaching Requirement

To sustain high crop production, harmful soluble salts must be removed from the crop root zone by applying additional irrigation water. The amount of additional water applied is called the leaching requirement. The leaching requirements are estimated based on the District's water quality and crops grown.

Table 20 shows the resulting leaching fraction for a drip irrigation system for each District for the various crops.

TABLE 20 LEACHING FRACTION FOR DRIP IRRIGATION

Crop	Goleta	Montecito	Carpinteria	ID#1
Alfalfa	NA[1]	NA	NA	0.03
Avocado	0.07	0.06	0.07	NA
Cherimoyas	NA	NA	0.06	NA
Citrus	0.05	0.05	0.06	NA
Nurseries	0.03	NA	0.03	NA
Pasture	NA	NA	0.03	0.03
Truck Crops	NA	NA	NA	0.05
Vegetables	0.02	NA	NA	NA
Vineyard	NA	NA	NA	0.04

[1] *NA means that this crop is not grown in this District*

Table 21 shows the resulting leaching fraction for a sprinkler irrigation system for each District and for the various crops.

TABLE 21 LEACHING FRACTION FOR SPRINKLER IRRIGATION

Crop	Goleta	Montecito	Carpinteria	ID#1
Alfalfa	NA[1]	NA	NA	0.10
Avocado	0.15	0.13	0.16	NA
Cherimoyas	NA	NA	0.11	NA
Citrus	0.11	0.10	0.12	NA
Nurseries	0.09	NA	0.10	NA
Pasture	NA	NA	0.10	0.10
Truck Crops	NA	NA	NA	0.14
Vegetables	0.10	NA	NA	NA
Vineyard	NA	NA	NA	0.14

[1] NA means that this crop is not grown in this District

On-Farm Water Requirement

The on-farm water requirement is defined as the amount of water required for growing crops that occur within the boundaries of private property. The on-farm water requirement does not include any water lost during conveyance of the water from the source of supply that is outside the property boundaries.

The on-farm water requirement is calculated as the sum of the NIR and the LR and is shown on Table 22.

TABLE 22 ON-FARM WATER REQUIREMENTS (ACRE-FEET)

Year	Goleta	Montecito	Carpinteria	ID#1
1994	---	---	942	---
1995	---	---	889	---
1996	---	---	1,016	---
1997	---	---	1,104	---
1998	---	---	872	2,028
1999	---	1,083	---	2,543
2000	3,585	778	---	1,937
2001	2,423	634	---	1,545
2002	3,190	938	---	2,771
Average	3,066	858	965	2,164

The unit on-farm water requirements are shown on Table 23.

TABLE 23 UNIT ON-FARM WATER REQUIREMENTS
(ACRE-FEET PER ACRE)

Year	Goleta	Montecito	Carpinteria	ID#1
1994	---	---	1.94	---
1995	---	---	1.74	---
1996	---	---	1.97	---
1997	---	---	2.18	---
1998	---	---	1.72	1.44
1999	---	2.23	---	1.80
2000	1.88	1.60	---	1.37
2001	1.27	1.30	---	1.10
2002	1.92	1.93	---	1.97
Average	1.69	1.76	1.91	1.54

AGRICULTURE WATER DELIVERY

Table 24 presents a summary of the agriculture water delivery information provided by each District.

TABLE 24 AGRICULTURE WATER DELIVERY
(ACRE-FEET)

Year	Goleta	Montecito	Carpinteria	ID#1
1994	---	---	310	---
1995	---	---	285	---
1996	---	---	320	---
1997	---	---	452	---
1998	---	---	309	1,208
1999	---	419	---	1,510
2000	1,437	345	---	1,288
2001	1,267	218	---	1,374
2002	1,793	418	---	1,417
Average	1,499	350	335	1,359

Table 25 shows the unit agriculture water delivery.

TABLE 25 UNIT AGRICULTURE WATER DELIVERY (ACRE-FEET PER ACRE)

Year	Goleta	Montecito	Carpinteria	ID#1
1994	---	---	0.64	---
1995	---	---	0.56	---
1996	---	---	0.62	---
1997	---	---	0.89	---
1998	---	---	0.61	0.86
1999	---	0.86	---	1.07
2000	0.75	0.71	---	0.91
2001	0.67	0.45	---	0.98
2002	1.07	0.86	---	1.01
Average	0.83	0.72	0.66	0.97

AGRICULTURAL WATER USE EFFICIENCY

There are several performance indicators commonly used to describe agricultural water use efficiency such as application efficiency, on-farm efficiency, distribution efficiency, conveyance efficiency, and distribution uniformity. For my analysis the agricultural water use efficiency will be defined as the volume of water theoretically required by the crop divided by the volume of water delivered to the irrigated field. The volume of water delivered to the irrigated field is measured at the irrigated field and not at the source of the water supply.

The agricultural water use efficiency is calculated annually for each parcel using the following formula:

$$Efficiency = \frac{NIR + LR}{WD}$$

Where:
NIR = Net irrigation requirement in acre-feet per acre per year.
LR = Leaching requirement in acre-feet per acre per year.
WD = Volume of water delivered to the farm for agricultural purposes in acre-feet per acre per year.

A summary of the agriculture water use efficiency for each District is shown on Table 26 followed by analysis for each District.

TABLE 26 AGRICULTURE WATER USE EFFICIENCY AND AVERAGE SUMMARY

District	Average Irrigated Acreage[1]	Average Irrigated Acreage for Efficiency[2]	Average Efficiency
Goleta	3,431	1,824	204%
Montecito	531	486	250%
Carpinteria	3,481	505	288%
ID#1	2,144	1,409	159%

[1] *Average irrigated acreage for study period.*

[2] *Average irrigated acreage used for calculating the agriculture water use efficiency.*

Conclusion

The agricultural watering practices within the four water Districts located in the Cachuma project service area mainly rely on drip, micro-sprinkler, and sprinkler irrigation systems. These types of irrigation systems are among the most efficient methods used for irrigation in California. By 2020, the California Department of Water Resources assumes that the on-farm efficiency in the state of California will average 73 percent, which is considerably lower than the average efficiency of the four Districts located in the Cachuma project service area.