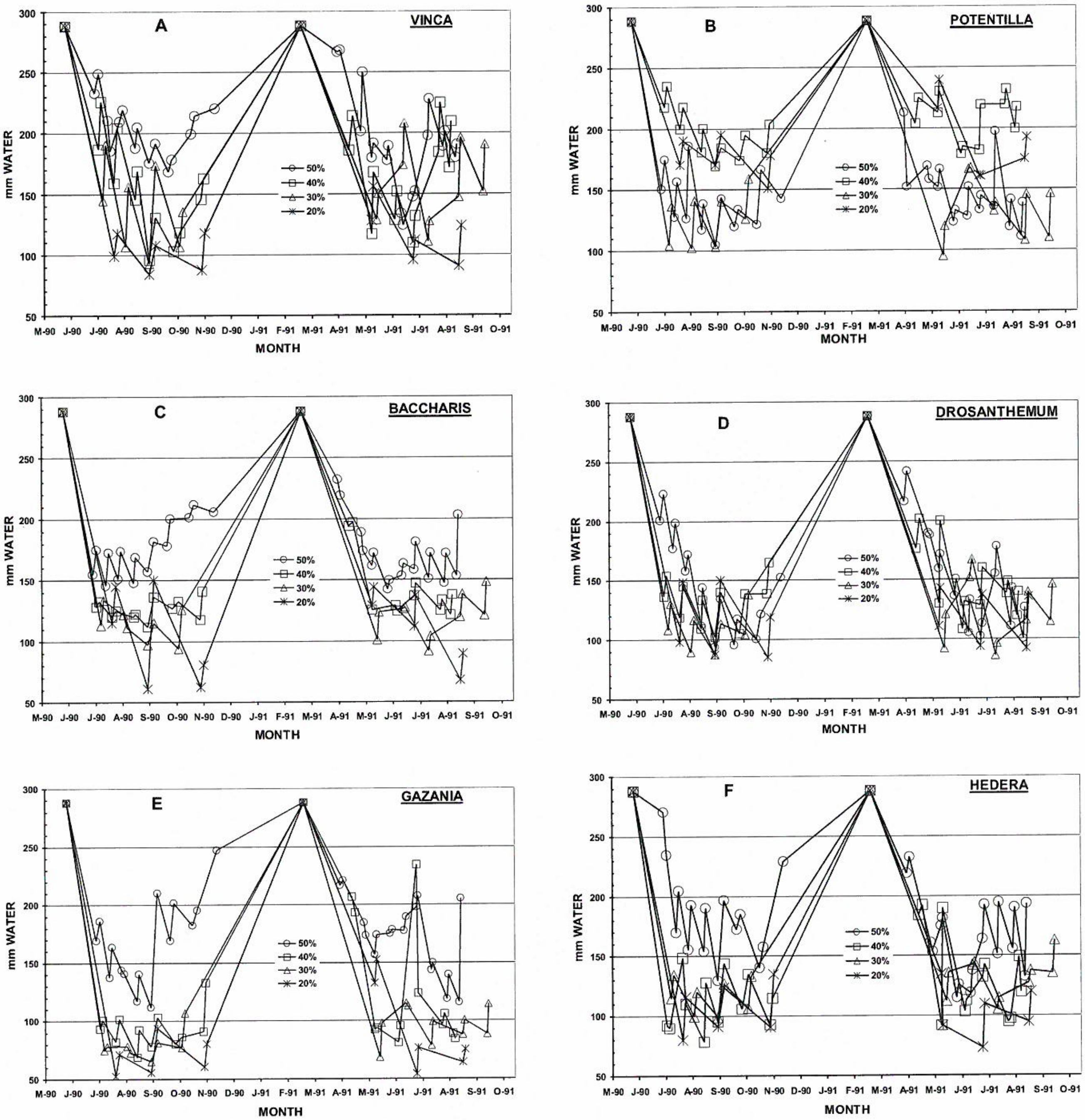

Fig. 2. Volumetric soil water content at 0–137 cm depth for six groundcover species at four irrigation levels from May 1990 through September 1991. (Field Capacity is approximately 300 mm, and Permanent Wilting is approximately 125 mm.)

mance of *Gazania* indicates that this species can be seriously injured and its recovery limited under low irrigation regimes.

The visual quality response of *Vinca* was similar for the 30%, 40%, and 50% treatments. *Vinca* visual quality remained acceptable through August although the SMC approached PWP as early as July in these treatments. However, the 20% ET_0 treatment resulted in lower SMC and significantly lower visual quality in the fall of both years. Recovery of *Vinca* in all treatments is seen in January–February 1991 and in all except the 20% ETo treatment in fall 1991. Since its visual quality recovered, except in the 20% ET_0 treatment, *Vinca* appears to adapt to low SMC if enough water is occasionally applied to move SMC above PWP. These results indicate that *Vinca* could be irrigated at 30% ET_0 since there is no consistent increase in quality with additional water.

The response of *Hedera* to irrigation treatments and soil moisture conditions was not as dramatic. The SMC of the 20%, 30%, and 40% ET_0 treatments remained in the 75–150 mm range during the summer months of 1990 and 1991. Although the SMC was higher in the 50% ET_0 treatment,

Table 1. **Seasonal reference ET, rainfall, and irrigation applied to six groundcover species at Irvine, CA, 1990–91.**

Season	Historic Ref. ET (mm)[z]	Real-time Ref. ET (mm)	Rain (mm)	Irrigation: Treatment (% of ET_0)	Irrigation: Applied (mm)	Irrigation: Number	Irrigation: Avg. schedule (days)
1990							
May through August	569	630	16	50	282	7	16
				40	224	6	19
				30	168	4	25
				20	112	3	39
September through December	325	362	21	50	163	4	23
				40	122	3	25
				30	120	3	33
				20	81	2	51
1991							
January through April	330	348	220[y]	50	78	2	40
				40	85	2	48
				30	41	1	—
				20	0	0	—
May through August	569	569	0	50	361	8	16
				40	238	5	23
				30	185	4	31
				20	103	3	45
September	120	104	25	50	81	2	19
				40	42	1	—
				30	41	1	—
				20	41	1	—

[z]Santa Ana, CA; Snyder et al. (15).
[y]March 1991 rainfall = 142 mm.

Hedera visual quality was significantly higher only in the September–October 1990 rating period. In all treatments, regardless of SMC, *Hedera*'s visual quality declined during the summer and fall but the species recovered by the next growing season. This indicates that *Hedera* acclimates well and reduced irrigation does not consistently affect its visual quality.

Drosanthemum appeared to utilize stored and applied water efficiently in all treatments, then adapted readily to low SMC and maintained very high visual quality throughout the experiment. It performed well with any irrigation regime at or below 50% ET_0, suggesting it uses water readily when it is available and tolerates or avoids drought as water becomes limiting.

On the other hand, *Baccharis* used water quickly in the early growing season and ran out of water between irrigations when irrigated below 50% ET_0. Since its visual quality was typically better at the 20% and 30% ET_0 treatments, it appears that this species is easily over-irrigated and occasional soil drying is required for it to maintain high visual quality. The performance of *Baccharis* was similar to that reported for *Myoporum parvifolium* by Feldman (7).

Overall, the results of this study show that commonly used groundcover species vary widely in their responses to severe water stress and in their climatic adaptation to southern California. We found that when SMC approached PWP, *Vinca*, *Baccharis*, *Drosanthemum*, and *Hedera* were largely unaffected or able to acclimate, but *Potentilla* and *Gazania* were seriously impaired. The specific mechanisms responsible for the varied responses of these species are areas for future research. Thus, *Baccharis*, *Drosanthemum*, and *Hedera* would be expected to have minimum irrigation needs of 20% ET_0 and *Vinca* 30% ET_0. These minimum water requirements are similar to or less than that of warm-season turfgrass (8, 11). Like warm-season turfgrasses, these groundcovers were observed to maintain deep root systems (data not shown),

Table 2. **Main effects and interaction ANOVA of four irrigation levels on visual quality ratings of six groundcover species.**

	1990 May–June	1990 July–Aug.	1990 Sept.–Oct.	1990 Nov.-Dec.	1991 Jan.–Feb.	1991 March–April	1991 May–June	1991 July–Aug.	1991 Sept.
Irrigation	NS	*	***	*	NS	NS	**	*	***
Species	***	***	***	***	***	***	***	***	***
Irrigation × Species	*	***	***	***	**	**	***	***	***

NS, *, **, *** = Nonsignificant or significant at P < 0.05, P < 0.01 or P < 0.001, respectively.

and they may have other morphological or physiological mechanisms enabling them to survive periods of drought by using stored soil moisture if a significant portion of the soil profile is occasionally rewetted during the growing season. Irrigation managers can conserve water without seriously reducing the visual quality of these groundcovers by simply extending the time between irrigation events as was done in this study and by Sach's, et al. with woody plants (14).

Substituting a groundcover for turfgrass to reduce landscape water use will be most effective when the groundcover is used to replace cool-season turfgrass, the groundcover's visual quality is acceptable compared to turfgrass, and irrigation is effectively managed. Plant materials such as *Potentilla* and *Gazania* are not good choices for water conserving landscapes of the southwestern United States since they perform poorly unless well irrigated and have little recuperative ability if injured by drought.

Results from the study also show that ET_0-based irrigation scheduling is appropriate for groundcovers. However, there is a need for future research to address the most effective way to use ET_0-based irrigation scheduling. It is unclear whether any of the species in this study would maintain higher visual quality at low irrigation amounts if irrigated more frequently to keep the soil profile from becoming too dry for too long of a period.

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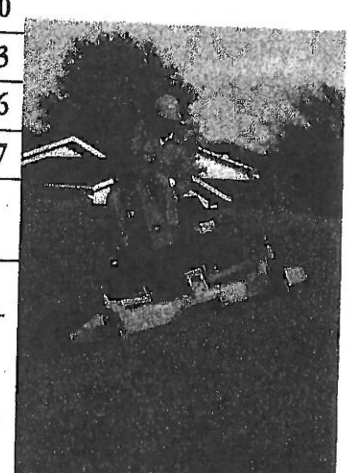
FEATURES

DEPARTMENTS

ON THE COVER



With the multitude of mowers on the market today, there is one for just about every application. Photo courtesy: John Deere.

IRRIGATION:
Study reveals certain established trees can tolerate months without any irrigation. Photo courtesy: Donald Hodel.

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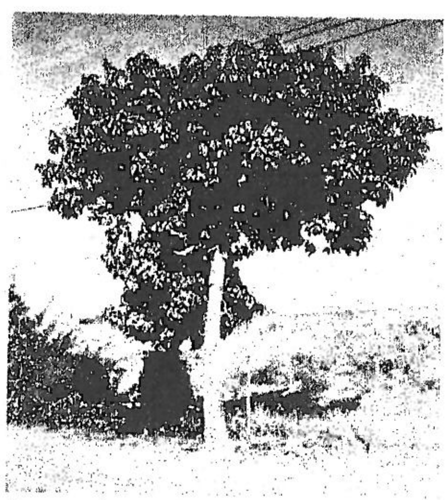
Drought Tolerance of Selected Non-Irrigated Trees

This park-like setting was once a residential neighborhood, but it was abandoned in 1976 for construction of the Century Freeway in Los Angeles. For more than eight years, only the trees remained, without water or maintenance.

By Donald R. Hodel

While scientists have studied and reported on water conservation and drought tolerance in turfgrasses, little to no technical information is available on the subject for shrubs and trees. The only published information on drought tolerance of trees and shrubs in the landscape is books and pamphlets written for homeowners (see list at end of story).

To determine the accuracy of this literature for commercial landscape use, an evaluation of several tree species common in the southern coastal areas of California was carried out in 1984. The study came about largely due to the availability of an unusual test site. . . a residential neighborhood abandoned to make room for a highway. A variety of trees had been growing in the housing tract acquired in 1976 for construction of the Century Freeway in southeastern Los Angeles County. All structures and homes in the area were destroyed, except for the trees that were located near sidewalks, roads and utility lines. But then, road construction stopped. For eight years, the trees were forgotten.



An avocado tree flourishes in the dry, park-like setting.

These well-established trees had been planted more than 25 years earlier by the former homeowners, who had maintained and irrigated them. When the homeowners left, the irrigation stopped. This grove of trees had unique scientific value to a horticulturist.

Since demolition of the homes, the area has taken on a park-like setting. In the winter and spring, the grass and weeds in the corridor are green from seasonal rains. Almost all rainfall occurs in the winter from November to April. In the summer and fall, the grass turns a light brown. The only maintenance taking place in the area is periodic mowing and trash removal by the California State Department of Transportation (Cal Trans).

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Drought Tolerance

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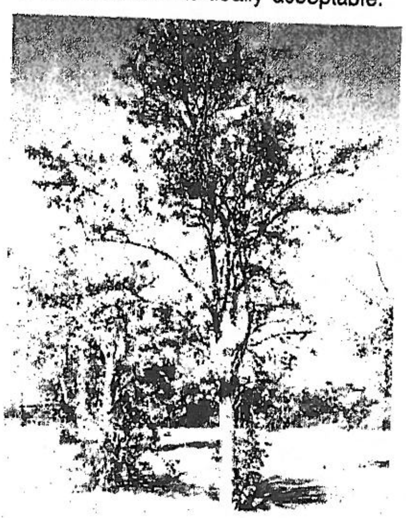
The area is characterized by warm, virtually rainless summers and relatively cool, moist winters. Records from the Los Angeles County Flood Control District indicated rainfall between 1974 and 1984 had averaged 18.1 inches per year. These figures are substantially higher than the 12-14 inch average reported for the 30 year period from 1950 to 1980. Although several of the years were exceedingly wet, the area experienced three of the warmest summers and three of the dryest winters on record.

In 1984, the trees were observed and rated for overall appearance on a scale from 1 to 5. A rating of one indicated no apparent effect from eight years without irrigation. Two indicated slight branch dieback, but acceptable. Three was given to trees with moderate branch dieback. Trees with severe dieback were given a four and those on the verge of death were given a five.

For the most part, the trees listed as drought tolerant in consumer literature showed little to no drought damage after eight years without irrigation. In general, they were slightly smaller and more compact than would be expected of irrigated trees of the same age. Damage, if any, was insignificant and the trees were esthetically acceptable.



Black locust was severely damaged without irrigation.

Included in the list of trees with little to no damage are *Araucaria bidwillii* (bunya-bunya), *Carya illinoensis* (pecan), *Citrus x paradisi* (grapefruit), *Chorisia speciosa* (floss silk tree), *Ficus elastica* (Indian rubber tree), *Ficus microcarpa var. nitida* (Indian laurel fig), *Ficus rubiginosa* rusty leaf fig), *Jacaranda mimosifolia* (jacaranda), *Liquidambar styraciflua* (American sweetgum), *Persea americana* (avocado) and *Podocarpus gracilior* (fern pine). The reduced or more compact growth of these trees resembled the effects of a growth regulator, indicating that growth retardation of some species in the landscape is possible through judicious water management.

TABLE 1—**Effect of 8 Years of Non-Irrigation on Selected Trees in the Landscape in Los Angeles County, 1985.**

Species	Common Name	Average Rating
Acacia melanoxylon	blackwood acacia	1
Acer saccharinum	silver maple	5
Acer negundo	box elder	3*
Ailanthus altissima	tree-of-heaven	2
Albizia julibrissin	silk tree	3
Alnus rhombifolia	white alder	5
Araucaria bidwillii	bunya-bunya	1
Arecastrum romanzoffianum	queen palm	3*
Brachychiton populneus	bottle tree	1
Brahea edulis	Guadalupe palm	1*
Broussnetia papyrifera	paper mulberry	4*
Callistemon citrinus	lemon bottlebrush	2
Calocedrus decurrens	incense cedar	2
Calodendrum capense	cape chestnut	4
Carya illinoensis	pecan	1*
Catalpa bignonioides	Indian bean, catalpa	2
Cedrus deodora	deodar cedar	1
Ceratonia siliqua	carob	1
Chorisia speciosa	floss silk tree	1
Cinnamomum camphora	camphor tree	1
Citrus x paradisi	grapefruit	1*
C. reticulata	tangerine	3*
C. sinensis 'Valencia'	Valencia orange	3
Cupaniopsis anacardioides	carrot wood	1
Cupressus glabra	Arizona cypress	1
C. sempervirens	Italian cypress	1
Eriobotyra deflexa	bronze loquat	1
Eucalyptus cinerea	silver dollar gum	1
E. globulus	blue gum	1
E. ficifolia	red-flowering gum	1
E. polyanthemos	red box gum	1
Ficus carica	fig	5*
F. elastica	Indian rubber tree	2
F. elastica 'Decora'	rubber plant	3*
F. microcarpa var. nitida	Indian laurel fig	1
F. macrophylla	Moreton Bay fig	3
F. rubiginosa	rustyleaf fig	1
Fraxinus uhdei	evergreen ash	3
F. velutina	Arizona ash	4
Ginkgo biloba	maidenhair tree	4
Grevillea robusta	silk oak	1
Jacaranda mimosifolia	jacaranda	1
Juglans nigra	black walnut	3*
Juniperus chinensis	Chinese juniper	1
Koelreutaria bipinnata	Chinese flame tree	1
Ligustrum lucidum	glossy privet	1
Liquidambar styraciflua	American sweet gum	2
Liriodendron tulipifera	tulip tree	5
Magnolia grandiflora	magnolia, bull bay	3
Melia azedarach	China-berry	2
Morus alba	white mulberry	1
Olea europaea	olive	1
Persea americana	avocado	1
Phoenix canariensis	Canary Island date	1
palm P. dactylifera	date palm	3
Pinus canariensis	Canary Island pine	1
P. halepensis	aleppo pine	1
P. pinea	Italian stone pine	1
P. radiata	Monterey pine	1*
Pittosporum rhombifolium	Queensland pittosporum	1
P. undulatum	Victorian box	2
Platanus x acerifolia	London plane tree	3
P. racemosa	California sycamore	1
Podocarpus macrophyllus	yew pine	4
P. gracilior	fern pine	1
Populus fremontii	western cotton wood	4
Prunus armeniaca	apricot	3
P. caroliniana	Carolina laurel cherry	5
Pyrus kawakami	evergreen pear	5
Quercus lobata	valley oak	1
Robinia pseudoacacia	black locust	5
Schinus terebinthifolius	Brazilian pepper	1
Sequoia sempervirens	coast redwood	5
Stenocarpus sinuatus	firewheel tree	3*
Syzygium paniculatum	brush cherry	3
Tristania conferta	Brisbane box	5
Ulmus americana	American elm	5
U. parvifolia	Chinese elm	2
Washingtonia filifera	California fan palm	1
W. robusta	Mexican fan palm	1
Yucca aloifolia	Spanish bayonet	1
Zelkova serrata	sawleaf zelkova	2

* Indicates less than three individuals per species rated.

A pair of Chinese flame trees have survived eight summers without irrigation.

Not all species listed in popular literature as drought tolerant exhibited acceptable damage. The following tree species were either almost dead or experienced severe branch dieback: *Ficus carica* (Common Fig), *Fraxinus velutina* (Arizona ash), *Gingko biloba* (Maidenhair tree), *Populous fremontii* (Rio Grande Cottonwood), *Prunus caroliniana* (Carolina Cherry), *Robinia pseudoacacia* (Pink Locust) and *Tristania conferta* (Brisbane box).

Many of the species that are not listed as drought tolerant exhibited damage that was marginally unacceptable (rating of 3). Perhaps with one or two well-timed irrigations during the summer these would have shown less damage and would be acceptable. It is probable that a limited number of well-timed irrigations could also result in acceptable damage to trees rated four or even five.

The trees were observed and rated for overall appearance on a scale of one to five.

It is evident from this study that most trees, once they are well- established in the landscape, can survive and be esthetically acceptable with much less water than is applied under normal circumstances. A strategy of infrequent, deep irrigations during establishment followed by management practices that emphasize a few well-timed irrigations during the summer may be sufficient.

EDITOR'S NOTE: Donald Hodel is an environmental horticulturist for the University of California Cooperative Extension, Los Angeles, CA.

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GUIDELINES FOR IRRIGATING PLANTS IN THE LANDSCAPE ACCURATELY AND ECONOMICALLY

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When irrigating plants it is best to apply only the amount of water that the plant needs for optimal growth--no more, no less. Water applied in excess of this optimal amount would be wasted and could injure the plant. Similarly, insufficient water could limit growth and/or injure the plant.

During this exercise, we will show you how to irrigate your plants accurately and economically by determining:

1. how much water your plants need,
2. when to apply this needed amount of water, and
3. how long to run your sprinkler system to apply this amount of water.

Part 1. How Much Water Do Plants Need?

Water-needs of plants vary by individual species. Generally, the amount that a plant loses through evapo-transpiration (and thus needs to be replaced) is the water-need of that species. Loss of a plant's water through evapo-transpiration is called ET. ET is usually expressed as a quantity of water in inches, centimeters, or gallons that needs to be replaced in order for the plant to maintain optimal growth.

The physiology and structure of a plant, its location in the landscape, and weather conditions are the primary factors affecting ET. For example, when growing under the same conditions, banana plants, because of their physiology and structure, use more water than cacti. Similarly, more water would have to be applied to a banana plant growing in Palm Springs than one growing in Malibu because of the hotter, drier conditions in the desert.

To assist people in irrigating plants most accurately and economically, California has developed a statewide system of computer-driven weather stations (CIMIS) that generates ET values on a daily basis. Since it would be too cumbersome, complex, and expensive to generate ET values for the thousands of different kinds of plants that could conceivably grow throughout California, each station generates only one ET value per day. This one daily value is called reference ET (ETo). Scientists, through elaborate experimentation and computation, developed ETo information using a specific type of grass maintained in a specific condition as the standard.

This grass is a pasture-type tall fescue mowed four to six inches in height and maintained in optimal condition. ETo would be the water-needs of this plant. For example, if the ETo at a particular station for one day is 0.20 inches, this means that pasture-type, tall fescue mowed four-seven inches in height would need 0.20 inches of water for that day in order to maintain optimal growth.

Irrigation rates for all other plants are pegged to ETo. Growing under the same conditions as this reference plant, all other types of plants would either need less or more water to maintain optimal growth. Most plants in the landscape like turfgrasses, groundcovers, shrubs, and trees need less water than the reference plant thus their water needs are expressed as a percentage of ETo. This percentage of ETo is often called a crop coefficient, factor, or multiplier. For example, warm-season turf like bermudagrass uses about 60% of the water that the standard reference plant needs. Thus, if we knew that ETo for a day was 0.20 inches, then bermudagrass would need 60% of this or 0.12 inches of water.

$$\begin{array}{r} 0.20 \\ \underline{\times\ 0.60} \\ 0.12 \end{array}$$

Some general water-needs of common landscape plant groups in relation to ETo on a yearly basis are below.

Yearly Water-needs of Plants as Percentage of ETo

Plant Type	% of ETo
Turfgrass	
warm-season	60
cool-season	80
Groundcovers	20-70
Shrubs	20-70
Trees	20-70

Remember that these are simply general figures or rough averages on a yearly basis; the actual values will vary by the type of grass, groundcover, shrub, or tree and the time of year. Also, note that these percentages of ETo are for optimal growth. We can maintain most plants at less than optimal but still acceptable levels of growth at lower percentages of ETo. For example, we can manage warm- and cool-season turfgrasses on 36% and 65% respectively of ETo and maintain adequate but not optimal growth.

Although we could follow these yearly guidelines and improve our irrigation efficiency, we would achieve even greater efficiency and accuracy by following monthly guidelines. Monthly guidelines for turfgrasses are listed below and are expressed as percentage of water used in relation to ETo.

Monthly Turfgrass Water-Needs as Percentage of ETo

Month	Type of Turfgrass warm-season	cool-season
Jan	55	61
Feb	54	64
Mar	76	75
Apr	72	104
May	79	95
Jun	68	88
Jul	71	94
Aug	71	86
Sep	62	74
Oct	54	75
Nov	58	69
Dec	55	60

We can see from this that in January a warm-season grass would use 55% of the amount of water that the reference crop would need while in the same month a cool-season grass would need 61% as much. Similarly, in July the same warm-season and cool-season grasses would need 71% and 94% respectively of ETo.

Putting this into the actual amount of water to apply is relatively easy. For example, if we had bermudagrass and the ET0 for a day in July was 0.30 inches, then we would have to apply 71% of this or 0.21 inches of water to maintain this grass in optimal condition.

$$\begin{array}{r} 0.30 \\ \underline{\times\ 0.71} \\ 0.21 \end{array}$$

For a cool-season turfgrass like tall fescue on the same day in July, we would have to apply 94% of ETo or 0.28 inches of water to maintain this grass in optimal condition.

$$\begin{array}{r} 0.30 \\ \underline{\times\ 0.94} \\ 0.28 \end{array}$$

Real-Time vs. Historic ETo Data

Irrigation managers who want to determine daily ET in order to schedule irrigations can choose from either:

1. real-time ETo, or
2. historic ETo.

Real-time ETo data are generated daily from each day's current weather and are made available through the CIMIS program mentioned earlier. See page 9 for information on how to access daily CIMIS ETo data by computer or phone.

Historic ETo data are 30-40 year averages of real-time ETo data. Historic ETo data by month for several sites in the Southern California are listed below.

Historic ETo (in inches)

	Los Angeles	Riverside	Irvine	San Diego
Jan	2.2	2.1	2.2	2.2
Feb	2.7	2.9	2.7	2.7
Mar	3.7	4.0	3.7	3.4
Apr	4.7	4.1	4.5	3.8
May	5.5	6.1	4.6	4.9
Jun	5.8	7.1	5.4	4.9
Jul	6.2	7.9	6.2	5.1
Aug	5.9	7.6	6.2	4.9
Sep	5.0	6.1	4.7	4.5
Oct	3.9	4.2	3.7	3.4
Nov	2.6	2.6	2.5	2.4
Dec	2.0	2.0	2.0	2.0
Yearly Total	50.2	56.7	48.3	44.2

Note: determine daily ETo by dividing the value for the month by the number of days in that month.

One can irrigate fairly accurately using historic ETo data but remember that these are averages that should serve as guidelines only since actual real-time data can vary significantly from its 30-40 year average. For example, historic ETo for a day in March in Los Angeles is 0.11 inches ($3.7 \div 30 = 0.11$). However, if a Santa Ana wind is blowing with temperatures in the 90s, the actual ETo value for the day could be double or triple its historic average. If relying on historic ETo to serve as guidelines to schedule irrigations, managers will have to make some adjustments to compensate for actual extremes of current weather.

Since ETo values (either real-time or historic) are available on a daily basis for most areas throughout California, we now know how much water to apply to specific plants to maintain them in optimal condition. The next question that must be answered is when do we apply the needed amount of water.

Part 2. How Often Do Plants Need Water?

Since we know the exact amount of water that plants need on a daily basis, we could simply apply that needed amount everyday. However, applying rather small amounts of water on a daily basis is an inefficient and unsound horticultural practice. A more

practical and effective method is to wait a period of time, usually several or more days, until the water needs of the plant have accumulated to a specified amount. Then apply that specified amount of water.

The specified amount of water depends on:

a) the type of soil and how much water it holds and

b) the effective rooting depth of the plants.

The number of days that must pass before the water needs of a particular plant accumulate to this specified amount will depend on the weather.

a) How much water does soil hold?

Different types of soil hold different amounts of water. For example, a moderately coarse-textured soil such as a sandy loam will hold about 1.25 inches of water per foot of soil. On the other hand, a fine textured soil such as clay will hold about two inches of water per foot of soil. The average available water for various types of soils is below.

Average Available Water in Inches/Foot of Different Soils

Soil Type	in./ft.
Very coarse to coarse-textured: sand	0.75
Moderately coarse-textured: sandy loams	1.25
Medium-textured: very fine sandy loams to silty clay loams	1.50
Fine and very fine-textured: silty clay to clay	2.00
Peat and mucks	2.50

b) What is the effective rooting depth of plants?

Effective rooting depths of plants vary greatly and are given below.

Plant Type	Effective Rooting Depth in Feet
Cool-season turfgrasses	
bluegrass	0.5-0.8
tall fescue	2
Warm-season turf	3-6
Trees and shrubs	1-3

The area of soil encompassed by roots and from which they can obtain water for the plant is called the soil root reservoir. The soil root reservoir of tall fescue is about two feet. If we were growing this tall fescue on a clay soil, a maximum of four inches of water is available to it.

2 inches of water/ft. of soil (clay)
x 2 feet of soil (rooting depth of tall fescue)
4 inches of water

A good, general rule-of-thumb is to irrigate when the water in the soil root reservoir has been depleted to 50% of its capacity. Thus, in our example of tall fescue on clay soil, when daily ET for cool season turfgrass accumulates to two inches, it is time to irrigate. The amount of water to apply is two inches.

4 inches (available water to tall fescue on clay soil)
x 0.50 (allowable depletion of 50%)
2 inches

Putting It All Together

What follows is an example of when to water a tall fescue on a clay soil in July given the following theoretical daily real-time ETo.

Day	ETo	factor or multiplier		Cool-season turfgrass ET
1	0.25"	x 0.94*	=	0.24"
2	0.35	x 0.94	=	0.33 0.57 accumulative
3	0.35	x 0.94	=	0.33 0.90 accumulative
4	0.40	x 0.94	=	0.38 1.28 accumulative
5	0.35	x 0.94	=	0.33 1.61 accumulative
6	0.25	x 0.94	=	0.24 1.85 accumulative
7	0.30	x 0.94	=	0.28 2.13 accumulative

By the seventh day two inches of ET have accumulated so it is time to apply two inches of water to our tall fescue. If daily ET values were even higher, we would have accumulated two inches more quickly and would have watered sooner. On the other hand, if it was during the winter, it may take several weeks to accumulate two inches of ET, especially if there is rain. Then the intervals between irrigations would be longer. No matter the interval, we only apply two inches of water to our tall fescue at each irrigation. When that irrigation occurs depends on when accumulated daily ET, whether from real-time or historic data, reaches two inches.

One might note in the above example that the daily ET for cool-season turfgrass is different from the ETo provided by the CIMIS Station each day. One will remember that this is due to the fact that cool-season turfgrass uses less water, about 94% of the reference plant, in July.

Part 3. How Long Do I Run My Sprinklers?

Now we know how much water and how often to apply it to maintain our plants in an optimal condition. Next we need to know how long to run the sprinklers at each irrigation (run time or RT) to apply the needed amount of water. This is done by performing a can test. The can test will reveal how much water in inches per hour the system is applying and how uniform is the coverage.

Can Test

Select two to five sites within your irrigation area to perform this test. Place straight-sided and flat-bottomed containers at regular (5-x-5-ft, 5-x-10-ft, or 10-x-10-ft) intervals. Soup, tuna, or cat food cans will work well. Rain gauges are nice but expensive. Use at least 40 containers. Run the sprinkler system for about 30 minutes using a stop watch to record the time. If you have sprinklers that rotate, be sure to run the system long enough so that the sprinklers make at least three revolutions.

After running the sprinklers, on a grid map of the can test site record the depth of water deposited in each container. Using an inexpensive pocket calculator, sum the 40 values and find their average depth.

Determine the average application rate (AR) of your system in inches per hour by multiplying the average of the 40 values by 60 and dividing by the number of minutes you ran the system during the test. In standard mathematical form this is:

$$AR = \frac{\text{average depth} \times 60}{\text{minutes sprinklers on}}$$

For example, if our average of the 40 values was 0.25 inches and we ran the system for 30 minutes, our average application rate would be 0.25 x 60 ÷ 30 = 0.50 inches per hour.

$$AR = \frac{0.25 \times 60}{30} = \frac{15}{30}$$

$$= 0.50 \text{ inches per hour}$$

This means that our system applies about one-half inch (0.50 inches) of water per hour over the test site.

However, this tells us nothing of how evenly the water is applied. For example, half the area could be receiving one inch of water per hour and the other half nothing! How evenly water is applied over the test area is called uniformity. Uniformity is expressed as a percentage with 100% being complete and uniform coverage over the test area.

Determine the uniformity (U) of the test site by dividing the average of the ten lowest cans by the average of the total. In standard mathematical form for our example this is:

$$U = \frac{\text{average of ten lowest cans}}{\text{average of total}}$$

In our example the average of the total is 0.25 inches and let's say that the average of the ten lowest is 0.125 inches. Put these values in the above formula and we see that the uniformity of our system is 50%.

$$U = \frac{0.125}{0.25} \times 100\%$$

$$= 0.50 \times 100\%$$

$$= 50\%$$

Sprinkler systems are rarely 100% uniform. Uniformity values of 80% or above indicate that the system is acceptable while values below this indicate that the system needs maintenance or has possible design problems. If the uniformity is below 80% (as ours is in this example), we should look at our values on the grid map of the test site and try to find the head or heads accounting for this unacceptable uniformity.

There could be several reasons for unacceptable uniformity. Old, worn, clogged, unmatched, and or damaged heads, improper pressure, and or design flaws in the irrigation systems are among possible causes of unacceptable uniformity. After adjusting the equipment or design, rerun the can test to be sure that uniformity is 80% or better. Make adjustments and repeat the test until you achieve at least 80% uniformity.

Determining Run Time (RT) for Each Irrigation

Now that we know how much water the irrigation system applies in inches per hour and the uniformity of application, it is easy to determine how many minutes to run our system at each irrigation. Let's continue with our example of a tall fescue growing on a clay soil. We know when to water by keeping track of daily ET. We water when the daily ET of tall fescue accumulates to about two inches. The question is how many minutes do we run our system to apply two inches of water.

We determined that our system applies 0.50 inches (1/2 inch) per hour. So to apply two inches of water we would run our sprinklers for four hours.

$$\frac{2 \text{ (inches to apply)}}{0.5 \text{ (rate in inches/hour, AR)}} = 4 \text{ hours}$$

However, this would only be true if our system had 100% uniformity! Since we had less than 100% uniformity, we must water a corresponding amount more than four hours. This is to ensure that even those areas receiving the least amount of water will be getting a minimum of two inches.

How much longer do we have to water to compensate for less than 100% uniformity? This is also easy to determine. Simply multiply the average application rate (AR) by the uniformity (U) and then divide this into how many inches of water that must be applied. In standard mathematical form this is:

$$\text{run time (RT)} = \frac{\text{inches of water to apply}}{\text{average application rate (AR)} \times \text{uniformity (U)}}$$

For our purposes, say we adjusted our system and improved its uniformity to 80%, then to apply two inches of water to our tall fescue at a rate of 0.50 inches per hour, we would run our system for five hours.

$$RT = \frac{2}{0.50 \text{ (AR)} \times 0.80 \text{ (U)}}$$

$$= \frac{2}{0.4}$$

$$= 5 \text{ hours}$$

I offer one final word of caution. Unless you have a very sandy soil, most sprinkler systems will apply water at a faster rate than it can be absorbed, resulting in wasteful run-off and or puddling. This will be especially true on sloping land which is a common situation in the landscape. To overcome this, one may have to cycle or pulse the irrigations off and on to avoid run-off yet still accumulate the necessary minutes of run time.

Training Classes

Irrigation managers in Los Angeles County who want training in auditing their system to determine application rate and uniformity and how to schedule irrigations using CIMIS data are urged to contact Donald R. Hodel at (213) 744-4881.

How To Access Daily CIMIS ETo Data

To learn how to access by computer daily ETo data for the CIMIS station nearest you, contact:

Holly Sheridin
Department of Water Resources
P.O. Box 942836
Sacramento, CA 94326-0001
(916) 653-9847

Also, the Three Valleys Municipal Water District in Claremont at (714) 621-5568 can verbally provide daily ETo data for its area. The Metropolitan Water District hopes to have in place this year an 800 number to access daily ETo data from any station in its service area throughout southern California.

Using Computer Programs and CIMIS

TURFIMP, a series of five comprehensive computer programs written by Rick Snyder at the University of California, Davis, is available for use with CIMIS data. The software is written for IBM compatible computers and requires about 600K of disk space. In addition to the title page and main menu, TURFIMP has programs that, among other things, analyze can test data; determine average application, uniformity, and run times; establish summary tables of daily, weekly, or monthly ETo and run times; and provide information on the costs and benefits of system improvements. TURFIMP is free of charge to those attending our irrigation audit and scheduling classes. Otherwise, it can be purchased for $10 by contacting:

Richard L. Snyder, Biometerologist
University of California
Dept. of Land, Air and Water Resources
Davis, CA 95616

SUMMARY

To irrigate accurately and efficiently, determine:

1. % of water used by your plant compared to reference plant.
2. adjusted daily ET (with real-time or historic) values for your plant.
3. 50% depletion of soil root reservoir by rooting depth and water-holding capacity of soil.
4. inches/hour of water your system applies and adjust for uniformity.
5. how long to run sprinklers to replenish 50% depletion of soil root reservoir.
6. when adjusted daily ET accumulates to 50% depletion of soil root reservoir, then irrigate.

Landscape Irrigation System Evaluation and Management

David A. Shaw and Dennis R. Pittenger

University of California Cooperative Extension

University of California Cooperative Extension
April 2009

Landscape Irrigation
System Evaluation and Management

* *

Contents

Preface

This publication presents practical information and field procedures for evaluating landscape irrigation hardware performance and determining irrigation schedules. These guidelines will enable the user to develop a superior irrigation management program that will optimize plant growth and health without wasting water. Emphasis is given to water conservation strategies that are effective during periods of restricted water use.

Green Industry personnel, at all levels of experience and training, should be able to understand and implement the information. The authors have avoided the use of technical jargon where possible. The main body of the handbook describes the overall procedures and the appendices contain formulae and other reference information.

Field evaluations and scheduling techniques require an irrigator to have a basic knowledge of water measurement calculations. The necessary calculations can be performed with either a hand-held calculator or with a computer, utilizing software or web-based irrigation management programs. While both calculators and computers will provide the same useful solutions, the computer programs offer time savings and a printed irrigation schedule useful for controller programming. Irrigation scheduling web sites and software sources are listed in Appendix F.

This publication is a working revision of *Landscape Irrigation System Evaluation and Scheduling for Southern California*, written by David A. Shaw and Paul F. Zellman. The publication supplements information presented at U.C. Cooperative Extension classroom and field demonstration sessions.

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Landscape Irrigation Management - An Overview

The goal of good irrigation management in the landscape is to supply the plant materials with the correct amount of water at the proper time. In areas where water costs are high, supplies are limited, and there is demand for high quality turf and landscapes, the irrigation manager must maintain irrigation systems for peak performance and make careful decisions on when and how much to irrigate.

Effective landscape irrigation involves the following concepts:

1. Irrigation systems should be <u>designed</u>, <u>installed</u>, and <u>maintained</u> to **distribute water as uniformly** as possible. Precise irrigation scheduling is of little value if systems have a low uniformity.

2. To assure adequate irrigation of all areas, the irrigation system should be operated long enough to **apply a depth of water equal to the water use of the landscape** plus extra to compensate for the non-uniformity of the system and leaching requirements.

3. The irrigation system should be designed, maintained, and operated to **avoid runoff.**

To address these concepts, the irrigation manager or auditor must assess the system hardware, the water requirements of the plant material, and the irrigation management. Irrigation hardware performance is defined in practical terms by the system precipitation rate and distribution uniformity. Precipitation rates are used to calculate station run times and may indicate runoff potential. Distribution uniformity values provide the irrigator with an indication of how evenly water is applied to the landscape. Landscape water use estimates are derived from reference evapotranspiration (ETo) information and crop coefficient (Kc) values.

The overall procedure to develop landscape irrigation schedules consists of the following steps:

I. Perform a **"walk-through" inspection** of each station within the irrigation system and make necessary repairs.

II. Determine the **precipitation rate** and **distribution uniformity** of irrigation systems using volumetric measurements or catch can tests.

III. Determine the **water needs** of landscape plant materials using local weather and plant water use information available from the University of California, Department of Water Resources CIMIS program, local water districts, and related agencies;

IV. Calculate station **run times** to meet the water needs of the landscape.

V. Decide the **frequency of irrigation** and if **"cycling"** is necessary.

VI. Verify the irrigation schedule with **field observations** and adjust if necessary.

For the complete Minimum Irrigation of Landscape Groundcovers, please contact Santa Ana Watershed Project Authority at onewateronewatershed@sawpa.org.

presented research will be on the use of treeshelters in producing plants in the container nursery. The results from outdoor nursery and greenhouse, solution culture experiments will be presented. Treeshelters increase the temperature, relative humidity, and carbon dioxide concentration around those plants growing in them. Photosynthetically active radiation (PAR) inside shelters is reduced 40-60% depending on treeshelter color. Plants growing in treeshelters show increases in height and in the ratio between total fresh weight and total dry weight. However, plants growing in treeshelters also show decreases in leaf, stem, and root fresh and dry weights and leaf area. The potential benefits and current challenges surrounding the use of treeshelters will be discussed.

011

MINIMUM IRRIGATION OF LANDSCAPE GROUNDCOVERS.

D.R. Pittenger*, Donald R. Hodel, David A. Shaw and D.B. Holt. Dept. of Botany and Plant Sciences, University of California, Riverside, CA 92521.

A previous field study had shown that Baccharis pilularis 'Twin Peaks', Drosanthemum hispidum, Vinca major, Gazania hybrid, Potentilla tabernaemontanii and Hedera helix 'Needlepoint', express no loss in relative aesthetic appearance when irrigated for one season at 50% of reference evapotranspiration (ET_O), but three species did not perform acceptably at 25% of ET_O. In this study these six species were grown in the field for 16 months under treatments of 50%, 40%, 30% and 20% of real-time ET_O to more closely determine their minimum irrigation needs.

Analysis of seasonal plant performance ratings indicates that for Vinca, Gazania and Potentilla there is no significant increase in relative performance when irrigated at more than 30% of ET_O. Baccharis, Drosanthemum and Hedera exhibited no significant improvement in performance when irrigated above 20% of ET_O. A general decline in aesthetic appearance and performance was observed during the study in Gazania and Potentilla at all treatments, suggesting that their long-term minimum irrigation need may be more than 50% of ET_O.

012

CARBOHYDRATE AND PROTEIN BALANCE DURING EPISODIC GROWTH IN LIGUSTRUM JAPONICUM

Jeff S. Kuehny* and Mary C. Halbrooks, Department of Horticulture, Clemson University, Clemson, SC 29634-0375.

Research defining actual changes in weight gain of roots and shoots during growth episodes of woody ornamentals is limited. The objective of this study was to develop a better understanding of the patterns of root and shoot growth, nitrogen uptake, and changes in carbohydrate and protein content of *Ligustrum japonicum*, an episodic species. Shoot elongation and lateral root formation were synchronous. The greatest increase in shoot percent of whole plant fresh weight occurred after shoot elongation however, and the greatest increase in root percent of whole plant fresh weight occurred during shoot elongation. Nitrate uptake was highest during shoot elongation and lateral root formation. Carbohydrate and protein content also varied with each episode of growth.

29 ORAL SESSION 2 (Abstr. 013–019) Vegetable Crops: Fertilizer Management

013

COVER CROP AND NITROGEN FERTILIZER RATE INFLUENCES ON YIELDS OF SEQUENTIALLY PLANTED VEGETABLES

Owusu A. Bandele*, Marion Javius, Byron Belvitt, and Oscar Udoh, Dept. of Plant and Soil Sciences, Southern University and A&M College, Baton Rouge, LA 70813

Fall-planted cover crops of hairy vetch (*Vicia villosa Roth*), Austrian winter pea (*Pisum sativum* subsp. *arvense* L. Poir), and crimson clover (*Trifolium incarnatum* L.) were each followed by spring-planted 'Sundance' summer squash [*Cucurbita pepo* var. *melopepo* (L.) Alef.] and 'Dasher' cucumber (*Cucumis sativus* L.). Squash and cucumber crops were followed by fall 'Florida Broadleaf' mustard green [*Brassica juncea* (L.) Czemiak] and 'Vates' collard (*Brassica oleracea* L. Acephala group), respectively. The same vegetable sequences were also planted without benefit of cover crop. Three nitrogen (N) rates were applied to each vegetable crop. Squash following winter pea and crimson clover produced greater yields than did squash planted without preceding cover crop. Cucumber following crimson clover produced the greatest yields. No cover crop effect was noted with mustard or collard. Elimination of N fertilizer resulted in reduced yields for all crops, but yields of crops with one-half the recommended N applied were generally comparable to those receiving the full recommended rate.

014

NITROGEN USE IN AN ASPARAGUS/LIVING MULCH CROPPING SYSTEM

Laura Paine*, Astrid Newenhouse, and Helen Harrison, Department of Horticulture, University of Wisconsin, Madison, WI 53706.

Seedlings of Syn 4-56 hybrid asparagus were planted in May, 1990 on loamy sand in the irrigated Central Sands region of Wisconsin. Treatments were unsuppressed living mulches of perennial ryegrass, Dutch white clover, a mixture of ryegrass and clover and cultivated bare ground. Ammonium nitrate was banded at rates of 90, 45, and 0 kg/ha across all treatments. Measurements of weed populations, asparagus growth, and soil and tissue nitrogen levels were made in 1990 and 1991. Soil nitrate and ammonium levels were measured in 30 cm increments to a depth of 90cm. In 1990, asparagus fern growth was greater in the bare ground controls than in any of the mulch treatment plots. In 1991, asparagus growth in the clover-based mulches was greater than that in the ryegrass mulch, although also still less than that of the bare ground control. Total accumulated nitrogen in clover-based mulch plots at the end of each season was more than twice the level of that of either the grass mulch or the cultivated plots. Percent nitrogen in asparagus tissue varied with mulch treatment; in 1991, the %N was higher in the asparagus tissue grown with clover than either that grown with the grass or on bare ground. Weed control in all mulch plots was good; in clover plots it was nearly 100%.

015

FIELD TESTS EVALUATING PRE- AND POST-PLANT NITROGEN FERTILIZER PROGRAMS FOR MUNG BEAN PRODUCTION

Mike Murray* and Carrie Young, University of California Cooperative Extension, P.O.Box 180, Colusa, CA, 95932

Field tests were conducted in commercial mung bean (Vigna radiata) fields in 1986, 1987, and 1989. The objective of these tests were to: determine optimum nitrogen fertilizer rates; evaluate preplant, postemergence or split applications of nitrogen; and develop data to utilize petiole sampling as an analytic technique to quantify plant nitrogen status.

Seed yields were significantly increased two of the three years by the addition of nitrogen fertilizers. Over three years, the addition of 40-120 pounds of nitrogen per acre resulted in an average seed yield increase of 14-37 percent, compared to an untreated control. Maximum yields were obtained with eighty pounds of nitrogen per acre. Within specific rates, there was a trend for preplant or split applications to result in the greatest yield increases.

Petiole nitrate levels did not appear to be a reliable indicator of plant nitrogen status, with wide differences between rates in different years. An average for the three-year test, six weeks after crop emergence, was 1270 ppm for the control and 2340 ppm for treatments receiving 80 pounds of nitrogen per acre.

016

DRIP/TRICKLE FERTILIZING EGGPLANTS

James W. Paterson*, Rutgers University, Rutgers Research & Development Center, RR 5, Box 232, Bridgeton, NJ 08302-9499

The effectiveness of varying rates and timing of applied primary plant nutrients as a completely soluble N-P-K fertilizer through a drip/trickle low volume irrigation system was studied during 1991 on eggplant (Solanum melongena cv. Harris Special Hibush). Before the drip irrigation tubing and black plastic mulch were laid on a coastal plain sandy loam soil, plots were treated with 0, 22, 45, and 67 kg ha^{-1} of nitrogen (N), phosphate (P_2O_5) and potash (K_2O). The higher rates of preplant fertilization did have a significant beneficial effect on total seasonal yields of quality eggplants. The preplant treatments also had an influence on mid and late season production. As the frequency of drip/trickle applied primary plant nutrients increased up to 6 seasonal applications, the total quality fruit production substantially increased. Frequency of applications also had an influence on

QUANTIFY ACCURATE IRRIGATION SCHEDULES WITH ET DATA

By Donald Hodel

When irrigating plants, it is best to apply only the amount of water than the plant needs—no more—no less. Water applied in excess of the optimal amount is wasted and could injure the plant. Similarly, insufficient water could restrict growth and/or injure the plant.

Water needs of plants vary by individual species. Generally, the amount a plant loses through evapotranspiration or ET (and thus needs to be replaced) is the water need of that species. Loss of a plant's water through evapotranspiration is called ET. ET is usually expressed as a quantity of water in inches, centimeters or gallons that needs to be replaced in order for the plant to maintain optimal growth.

The physiology and structure of a plant, its location in the landscape and weather conditions are primary factors affecting ET. For example, when growing under the same conditions, banana plants, because of their physiology and structure, use more water than cacti. Similarly, more water would have to be applied to a banana plant growing in Palm Springs than one growing in Malibu because of the hotter, drier conditions in the desert.

To assist people in irrigating plants most accurately and economically, California has developed a statewide system of computer-driven weather stations (CIMIS) that generates ET values on a daily basis. Since it would be too cumbersome, complex, and expensive to generate ET values for the thousands of different kinds of plants that could conceivably grow throughout California, each station generates only one ET value per day. This one daily value is called reference ET (ET_0). Scientists, through elaborate experimentation and computation, developed ET_0 information using a specific type of grass maintained in a specific condition as the standard.

This grass is a pasture-type tall fescue mowed 4 to 6 inches in height and maintained in optimal condition. ET_0 would be the water needs of this plant. For example, if the ET_0 at a particular station for one day is 0.20 inches, this means that pasture-type tall fescue mowed 4-7 inches in height would need 0.20 inches of water for that day in order to maintain optimal growth.

Irrigation rates for all other plants are pegged to ET_0. Growing under the same conditions as this reference plant, all other types of plants would either need less or more water to maintain optimal growth. Most plants in the landscape, like turfgrasses, groundcovers, shrubs and trees, need less water than the reference plant, thus their water needs are expressed as a percentage of ET_0. This percentage of ET_0 is often called a crop coefficient, factor or multiplier. For example warm-season turf uses about 60 percent of the water that the standard reference plant needs. Thus, if we knew that ET_0 for a day was 0.20 inches, then bermudagrass would be 60 percent of this, or 0.12 inches of water.

$$\begin{array}{r} 0.20 \\ \times\ 0.60 \\ \hline 0.12 \end{array}$$

Some general water needs of common landscape plant groups in relation to ET_0 on a yearly basis are below.

Yearly water needs of plants as percentage of ET_0

Plant type	Percent of ET_0
Turfgrass	
warm-season	60
cool-season	80
Groundcovers	20-70
Shrubs	20-70
Trees	20-70

Remember that these are general figures or rough averages on a yearly basis; the actual values will vary by the type of grass, groundcover, shrub or tree, and the time of year. Also note that these percentages of ET_0 are for optimal growth. We can maintain most plants at less than optimal but still acceptable levels of growth, at lower percentages of ET_0. For example, we can manage warm- and cool-season turfgrasses on 36 percent and 65 percent respectively of ET_0 and maintain adequate but not optimal growth.

Although we could follow these yearly guidelines and improve our irrigation efficiency, we would achieve even greater efficiency and accuracy by following monthly guidelines. Monthly guidelines for turfgrasses are listed below and are expressed as percentage of water used in relation to ET_0.

Monthly turfgrass water needs as percentage of ET_0

TYPE OF TURFGRASS

Month	warm-season	cool-season
January	55	61
February	54	64
March	76	75
April	72	104
May	79	95
June	68	88
July	71	94
August	71	86
September	62	74
October	54	75
November	58	69
December	55	60

We can see from this that in January, a warm-season grass would use 55 percent of the amount of water that the reference crop would need, while in the same month, a cool-season grass would need 61 percent as much. Similarly, in July the same warm-season and cool-season grasses would need 71 percent and 94 percent respectively of ET_0.

Putting this into the actual amount of water to apply is relatively easy. For example, if we had bermudagrass and the ET_0 for a day in July was 0.30 inches, we would have to apply 71 percent of this, or 0.21 inches of water, to maintain this grass in optimal condition.

$$\begin{array}{r} 0.30 \\ \times\ 0.71 \\ \hline 0.21 \end{array}$$

For a cool-season turfgrass, like tall fescue, on the same day in July we would have to apply 94 percent of ET_0 or 0.28 inches of water to maintain this grass in optimal condition.

$$\begin{array}{r} 0.30 \\ \times\ 0.94 \\ \hline 0.28 \end{array}$$

REAL TIME VS. HISTORICAL ET_0 DATA

Irrigation managers who want to determine daily ET in order to schedule irrigations can choose from either:

1. Real-time ET_0, or
2. Historic ET_0

Real-time ET_0 data are generated daily from each day's current weather and are made available through the CIMIS program mentioned earlier.

Historic ET_0 data are 30-40 year averages of real-time ET_0 data. One can irrigate fairly accurately using historic ET_0 data, but remember that these are averages that should serve as guidelines only, since actual real-time data can vary significantly from its 30-40 year average. For example, historic ET_0 for a day in March in Los Angeles is 0.12 inches (3.7/31=0.21). However, if a Santa Ana wind is blowing with temperatures in the 90s, the actual ET_0 value for the day could be double or triple its historic average. If relying on historic ET_0 to serve as guidelines to schedule irrigations, managers will have to make some adjustments to compensate for actual extremes of current weather.

Since ET_0 values (either real-time or historic) are available on a daily basis for most areas throughout California, we now know how much water to apply to specific plants to maintain them in optimal condition. The next question that must be answered is when do we apply the needed amount of water?

HOW OFTEN DO PLANTS NEED WATER?

Since we know the exact amount of water that plants need on a daily basis, we can simply apply that needed amount every day. However, applying rather small amounts of water on a daily basis is an inefficient and unsound horticultural practice. A more practical and effective method is to wait a period of time, usually several days until the water needs of the plant have accumulated to a specified amount. Then apply that specified amount of water.

The specified amount of water depends on:

1. The type of soil and how much water it holds
2. The effective rooting depth of the plant

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Irrigation Schedules

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The number of days that must pass before the watering needs of a particular plant accumulate to this specified amount will depend on the weather.

HOW MUCH WATER DOES SOIL HOLD?

Different types of soil hold different amounts of water. A moderately coarse-textured soil such as a sandy loam will hold about 1.25 inches of water per foot of soil. On the other hand, a fine-textured soil such as clay will hold about 2 inches of water per foot of soil. The average available water for various types of soils are listed below.

Soil Type	inches/feet
Very coarse to coarse textured: sand	0.75
Moderately coarse textured: sandy loams	1.25
Medium textured: very fine sandy loams to silty clay loams	1.50
Fine and very fine textured: silty clay to clay	2.00
Peat and mucks	2.50

What is the effective rooting depths of plants? Effective rooting depths of plants vary greatly and are given below.

Plant type	Effective rooting depth in feet
Cool-season turfgrasses	
bluegrass	0.5-0.8
tall fescue	2.0
Warm-season turf	3-6
Trees and shrubs	1-3

The area of soil encompassed by roots and from which they can attain water for the plant is called the soil-root reservoir. The soil-root reservoir of tall fescue is about 2 feet. If we were growing this tall fescue in a clay soil, a maximum of 4 inches of water is available to it.

2 inches of water/foot of soil (clay)
x 2 feet of soil (rooting depth of tall fescue)
4 inches of water

A good, general rule-of-thumb is to irrigate when the water in the soil-root reservoir has been depleted to 50 percent of its capacity. Thus, in our example of tall fescue on clay soil, when daily ET for cool-season turfgrass accumulates to 2 inches, it is time to irrigate. The amount of water to apply is 2 inches.

4 inches (avail. water to tall fescue on clay soil)
x 0.50 (allowable depletion of 50 percent)
2 inches

PUTTING IT ALL TOGETHER

What follows is an example of when to water a tall fescue on a clay soil in July given the following theoretical daily, real-time ET_0.

Day	ET_0		Factor or multiplier		Cool-season turfgrass ET
1	0.25"	x	0.94	=	0.24"
2	0.35	x	0.94	=	0.33
					0.57 accumulative
3	0.35	x	0.94	=	0.33
					0.90 accumulative
4	0.40	x	0.94	=	0.38
					1.28 accumulative
5	0.35	x	0.94	=	0.33
					1.61 accumulative
6	0.25	x	0.94	=	0.24
					1.85 accumulative
7	0.30	x	0.94	=	0.28
					2.13 accumulative

By the seventh day, 2 inches of ET have accumulated so it is time to apply 2 inches of water to our tall fescue. If daily ET values were even higher, we would have accumulated 2 inches more quickly and would have watered sooner. On the other hand, if it were during the winter, it may take several weeks to accumulate 2 inches of ET, especially if there is rain. Then the intervals between irrigations would be longer. No matter the interval, we only apply 2 inches of water to our tall fescue at each irrigation. When that irrigation occurs depends on when accumulated daily ET, whether from real-time or historic data, reaches 2 inches.

One might note in the example above, that the daily ET for cool-season turfgrass is different from the ET_0 provided by the CIMIS station each day. One will remember that this is due to the fact that cool-season turfgrass uses less water, about 94 percent of the reference plant, in July.

HOW LONG DO I RUN MY SPRINKLERS?

Now we know how much water and how often to apply it to maintain our plants in an optimal condition. Next we need to know how long to run the sprinklers at each irrigation (run time or RT) to apply the needed amount of water. This is done by performing a can test. The can test will reveal how much water in inches per hour the system is applying and how uniform the coverage is.

CAN TEST

Select two to five sites within your irrigation area to perform this test. Place straight-sided and flat-bottomed containers at regular (5 x 5 ft., 5 x 10 ft. or 10 x 10 ft.) intervals. Soup, tuna or cat-food cans will work well. Rain gauges are nice, but expensive. Use at least 40 containers. Run the sprinkler system for about 30 minutes using a stop watch to record the time. If you have sprinklers that rotate, be sure to run the system long enough so that the sprinklers make at least three revolutions.

After running the sprinklers, record the depth of water deposited in each container, on a grid map of the can-test site. Using an inexpensive pocket calculator, sum the 40 values and find their average depth.

Determine the average application rate (AR) of your system in inches per hour by multiplying the average of the 40 values by 60 and dividing by the number of minutes you ran the system during the test. In standard mathematical form this is:

$$AR = \frac{\text{Average depth} \times 60}{\text{minutes sprinklers ran}}$$

For example, if our average of the 40 values was 0.25 inches and we ran the system for 30 minutes, our average application rate would be 0.25 x 60 / 30 = 0.50 inches.

$$AR = \frac{0.25 \times 60}{30} = \frac{15}{30} = 0.50 \text{ inches per hour}$$

This means that our system applies about 1/2 inch (0.50 inches) of water per hour over the test site.

However, this tells us nothing of how evenly the water is applied. For example, half the area could be receiving 1 inch of water per hour and the other half nothing. How evenly the water is applied over the test area is called uniformity. Uniformity is expressed as a percentage, with 100 percent being complete and uniform coverage over the test area.

Determine the uniformity (U) of the test site by dividing the average of the 10 lowest cans by the average of the total. In standard mathematical form for our example this is:

$$U = \frac{\text{average of the 10 lowest cans}}{\text{average of the total}}$$

In our example, the average of the total is 0.25 inches and let's say that the average of the 10 lowest is 0.125 inches. Put these values in the above formula and we see that the uniformity of our system is 50 percent.

$$U = \frac{0.125}{0.25} \times 100 \text{ percent}$$
$$= 0.50 \times 100 \text{ percent}$$
$$= 50 \text{ percent}$$

Sprinkler systems are rarely 100 percent uniform. Uniformity values of 80 percent or above indicate that the system is acceptable, while values below this indicate that the system needs maintenance or has possible design problems. If the uniformity is below 80 percent (as ours is in this example), we should look at our values of the grid map of the test site and try to find the head or heads accounting for this unacceptable uniformity.

There could be several reasons for unacceptable uniformity. Old, worn, clogged, unmatched and/or damaged heads, improper pressure and/or design flaws in the irrigation systems are among possible causes of unacceptable uniformity. After adjusting the equipment or design, rerun the can test to be sure that uniformity is 80 percent or better. Make adjustments and repeat the test until you achieve at least 80 percent uniformity.

DETERMINING RUN TIME

Now that we know how much water the irrigation system applies in inches per hour and the uniformity of application, it is easy to determine how many minutes to run our system at each irrigation. Let's continue with our example of a tall fescue growing on a clay soil. We know when to water by keeping track of daily ET. We water when the daily ET of tall fescue accumulates to about 2 inches. The question is, how many minutes do we run our system to apply 2 inches of water?

We assume that our system applies 0.50 inches (1/2 inch) per hour. So to apply 2 inches of water we would run our sprinklers for four hours.

$$\frac{\text{2 (inches to apply)}}{\text{0.5 (rate in inches/hour, AR)}} = 4 \text{ hours}$$

However, this would only be true if our system had 100 percent uniformity. Since we had less than 100 percent uniformity, we must water a corresponding amount more than four hours. This is to ensure that even those areas receiving the least amount of water will be getting a minimum of 2 inches.

How much longer do we have to water to compensate for less than 100 percent uniformity? This is also easy to determine. Simply multiply the average

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application rate (AR) by the uniformity (U) and then divide this into how many inches of water that must be applied. In standard mathematical form this is:

$$\text{(run time) RT} = \frac{\text{inches of water to apply}}{\text{(AR)} \times \text{(U)}}$$

For our purposes, say we adjusted our system and improved its uniformity to 80 percent. To apply 2 inches of water to our tall fescue at a rate of 0.50 per hour we would run our system for five hours.

$$\text{RT} = \frac{2}{0.50\ (\text{AR} \times 0.80\ (\text{U})}$$
$$= \frac{2}{0.4}$$
$$= 5 \text{ hours}$$

A word of caution. Unless you have a very sandy soil, most sprinkler systems will apply water at a faster rate than it can be absorbed, resulting in wasteful runoff and/or puddling. This will be especially true on sloping land which is a common situation in the landscape. To overcome this, one may have to cycle or pulse the irrigations off and on to avoid runoff yet still accumulate the necessary minutes of run time.

TRAINING CLASSES

Irrigation managers in Los Angeles County who want training in auditing their system to determine application rate and uniformity, and how to schedule irrigations using CIMIS data are urged to contact Donald R. Hodel at (213) 744-4881.

HOW TO ACCESS DAILY ET_0 DATA

To learn how to access by computer daily ET_o data for the CIMIS station nearest you, contact:

Marilyn Nutt
Department of Water Resources
P.O. Box 942836
Sacramento, CA 94326-0001
(916) 445-8327

Also, the Three Valleys Municipal Water District in Claremont at (714) 621-5568 can verbally provide ET_o data for its area. The Metropolitan Water District hopes to have in place this year an 800 number to access daily ET_o data from any station in its service area throughout Southern California.

USING COMPUTER PROGRAMS AND CIMIS

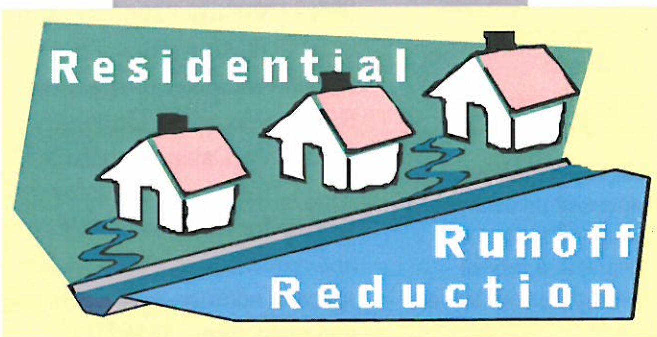
TURFIMP, a series of five comprehensive computer programs written by Rick Snyder at the University of California, Davis, is available for use with CIMIS data. The software is written for IBM compatible computers and requires about 600K of disc space.In addition to the title page and main menu, TURFIMP has programs that, among other things, analyze can test data; determine average application, uniformity and run times; establish summary tables of daily, weekly or monthly ET_o and run times; and provide information on the costs and benefits of system improvements. TURFIMP is free of charge to those attending our irrigation audit and scheduling classes. Otherwise, it can be purchased for a nominal fee by contacting Gwyn Dixon at (714) 787-5101.

SUMMARY

To irrigate accurately and efficiently, determine:

1. Percent of water used by your plant compared to the reference plant.
2. Adjusted daily ET (either real-time or historic) values for your plant.
3. Fifty percent depletion of soil-root reservoir by rooting depth and water-holding capacity of soil.
4. Inches per hour of water your system applies and adjust for uniformity.
5. How long to run sprinklers to replenish 50 percent depletion of soil-root reservoir.
6. When adjusted daily ET accumulates to 50 percent depletion of soil-root reservoir, then irrigate. ▼

Editor's note: Donald R. Hodel is an environmental horticulture advisor for the University of California cooperative extension in Los Angeles, CA.



The Residential Runoff Reduction Study

Municipal Water District of Orange County

Irvine Ranch Water District

July 2004

Executive Summary

Study Background and Rationale

In 2001, the Irvine Ranch Water District (IRWD), the Municipal Water District of Orange County (MWDOC), and the Metropolitan Water District of Southern California (MWD) completed a small-scale study of weather-based evapotranspiration (ET) irrigation controllers. This study, known as the "Westpark Study," tested the effectiveness of ET controller technology in residential applications. After 40 such controllers were installed in the Westpark neighborhood of Irvine, California, water demand and runoff in the study area were measured. The resulting average water savings for this study were 37 gallons per day, or 7 percent of total household water use and 18 percent of irrigation water use.

Based upon the findings of the Westpark Study, IRWD and MWDOC partnered on new research, the Residential Runoff Reduction (R3) Study, in which the number of sites studied was increased, a baseline area where no changes were made was included, and an "education only" area where printed educational materials were distributed was also included. This made the R3 Study one of the first studies to attempt to quantify the effectiveness of public education alone versus a technology-based plus education approach to reducing residential irrigation water usage. Figure ES-1 presents the study participants and their respective roles within the R3 Study.

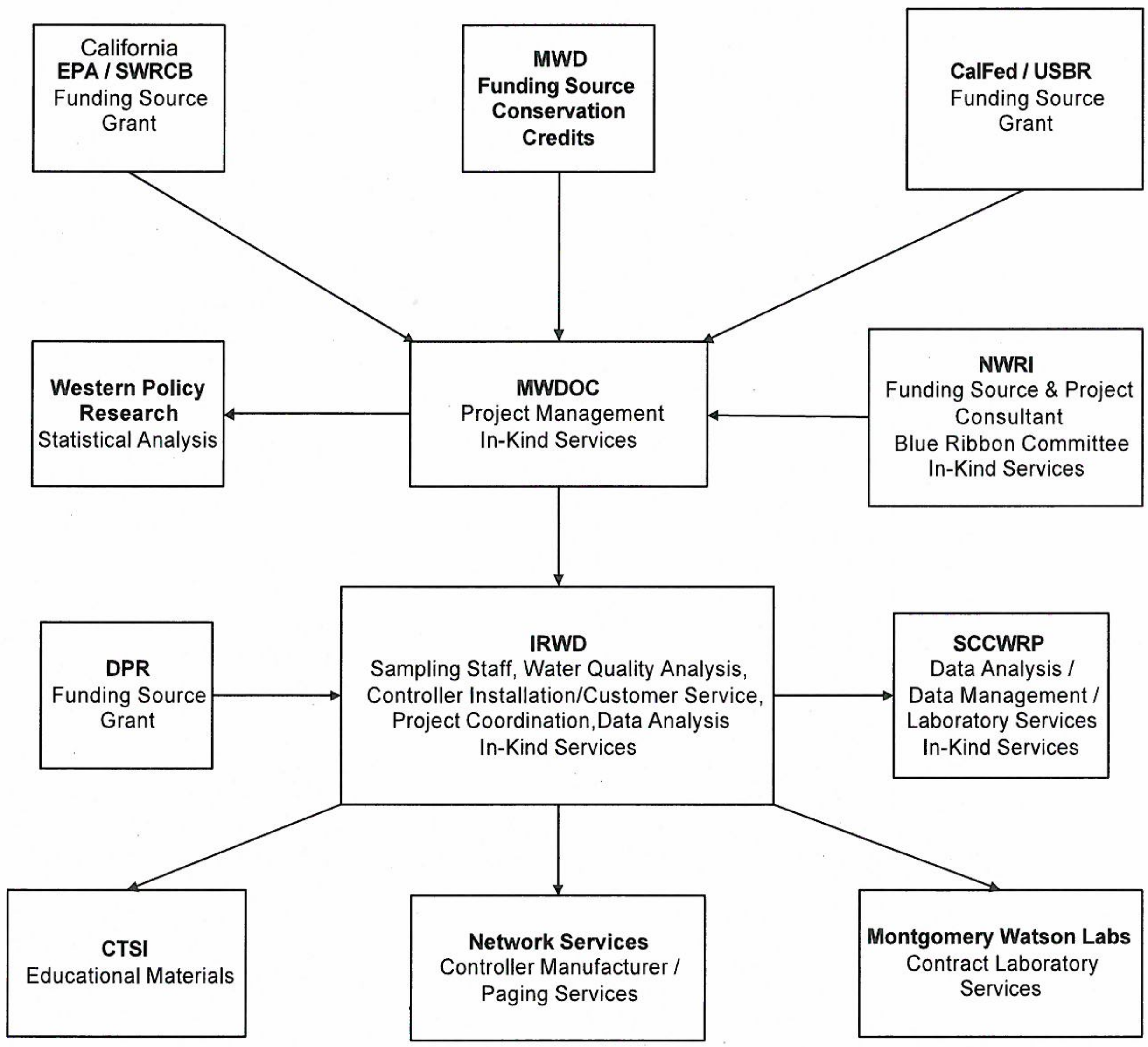
The R3 Study had four primary purposes:

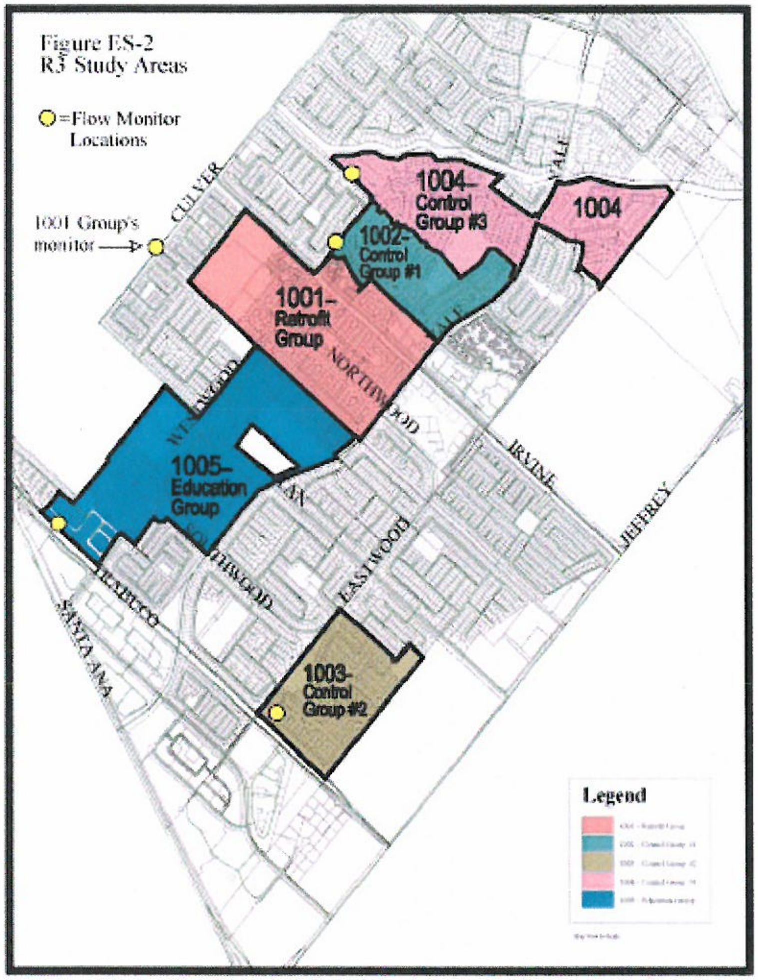
1) To test the use of weather-based irrigation technology, also known as ET controllers, to manage irrigation water for residential homes and large landscape areas;
2) To evaluate the effectiveness of a targeted education program on residential homeowners;
3) To determine the correlation between proper water application in landscape irrigation and the quantity and quality of urban dry-season runoff; and
4) To gauge the acceptance of water management via the controller technology.

Study Methodology

The R3 Study area included five similar neighborhoods (Sites 1001 through 1005) in Irvine, California, each with its own single point of discharge into the urban storm drain system. The five sites are shown on Figure ES-2. At these points of discharge from each study area, the runoff volume was monitored and water quality samples were taken. The five sites were divided into three separate areas. The first area, Site 1001 (retrofit group), used ET controller technology and public education. The second area, Site 1005 (education group), received educational materials, but did not receive controllers. The third area (control group) consisted of three separate neighborhoods (Sites 1002, 1003, and 1004), which received neither ET controllers nor educational materials.

Figure ES -1
R3 Study Participants





Evaluation Results

After the initial 18-month study period was completed, the data was compiled and evaluated for water conservation savings, dry season runoff changes, and changes in the quality of the dry season runoff water. The following summarizes the results:

a) Water Conservation Savings
Water conservation savings from the typical participant in the retrofit group were 41 gpd, or approximately 10 percent of total household water use. The bulk of the savings occurred in the summer and fall (Figure ES-3. Residential Water Savings: Technology + Education). The education group residential customers saved 26 gpd, or about 6 percent of total water use. The savings from this group were more uniform throughout the year (Figure ES-4, Residential Water Savings, Education Only). The retrofit group also included 15 dedicated landscape accounts (ranging in size from 0.14 acres to 1.92 acres), which showed average water savings of 545 gpd. The net result was eight times more water savings than with the single-family residential controller, strongly indicating that the larger the landscape, the better the savings per controller.

Figure ES -3
Residential Water Savings: Technology + Education

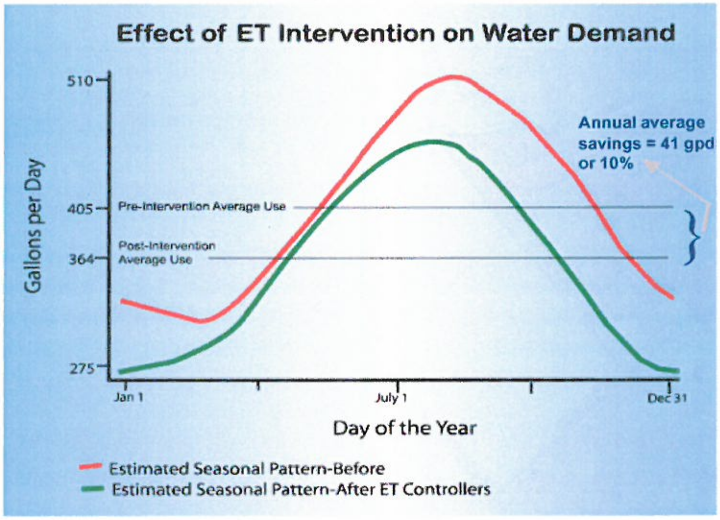


Figure ES-4
Residential Water Savings: Education Only

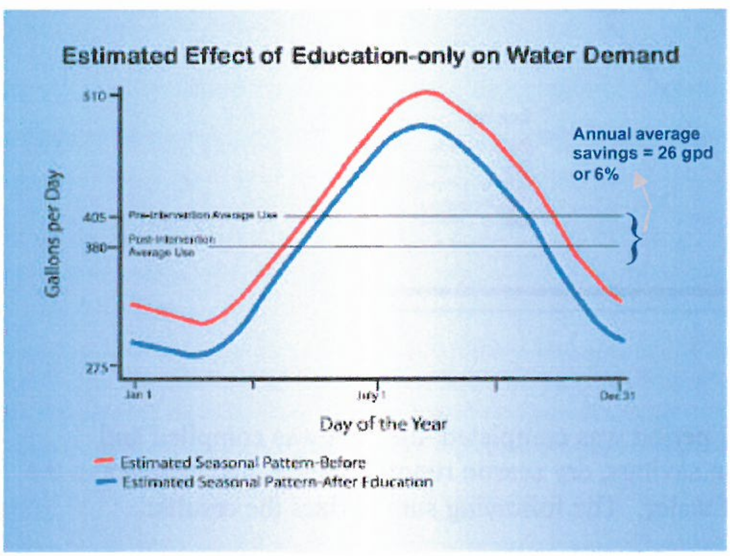


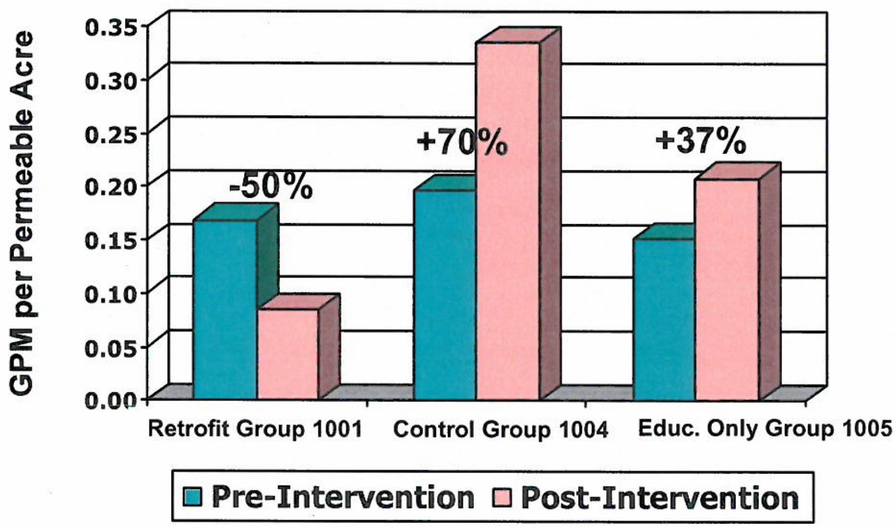
Figure ES -5
Changes in Runoff Within Each Site

b) Dry Season Runoff Changes

The retrofit group experienced a 50 percent direct reduction in water runoff (pre-intervention runoff compared to post-intervention runoff) during dry season periods. When the retrofit group is compared to the control group, the dry season runoff shows a statistical reduction of approximately 71 percent. In contrast, a comparison of direct pre-intervention and post-intervention runoff from the education group increased 37 percent, while runoff increased 70 percent within the control group. Other than the presence of an

ET controller, the primary difference between these groups is the participation of the 15 landscape accounts in the retrofit group. These accounts irrigated approximately 12 acres of landscape versus between 4 to 5 acres of total irrigated area for the 112 residential homes. Figure ES-5 presents R3 Study changes in runoff within sites.

Figure ES -5
Changes is Runoff Within Each Site



Note: It is also possible to compare post-intervention runoff *between* the study sites. These comparisons suggest a higher reduction in runoff for Site 1001 (between 64 and 71 percent) than was observed for the "within site" pre and post comparison, and a reduction in runoff of 21 percent for Site 1005. However, as described more fully in the text, these comparisons are less reliable than the "within site" pre and post comparisons shown here.

c) Changes in Runoff Water Quality

The study gathered a great deal of information on the water quality constituents present in urban runoff. In almost all cases, the data showed no changes in the concentration of these constituents in the runoff. The most significant fact to come out of the urban runoff water quality data is that the decrease in runoff volume from the retrofit group did not appear to result in an increase in the concentration of pollutants in the runoff. Thus, it is probable that a reduction in total pollutant migration could be achieved by reducing total dry season urban runoff.

d) Public Acceptance of Water Management

While there were some customer service-related issues, the retrofit group had a generally positive response to the ET controller, with 72 percent of participants indicating that they liked the controllers. The retrofit group also found that the controller irrigation either maintained or improved the appearance of the landscape. This has very positive implications. The water district customers receive a desired benefit of a healthy landscape, and the community receives several important environmental benefits from the conservation of valuable and limited water resources and the reduction in dry season urban runoff.

Findings, Conclusions, and Recommendations

The R3 Study showed that weather-based irrigation controllers, which provide proper landscape water management, resulted in water savings of 41 gpd in typical residential settings and 545 gpd for larger dedicated landscape irrigation accounts. The observed reduction in runoff from the retrofit test area was 50 percent when comparing pre-intervention and post-intervention periods and 71 percent in comparison to the control group. The education group saw reductions in water use of 28 gpd, and a reduction in runoff of 21 percent in comparison to the control group. Water quality parameters in both study areas were highly variable, and very few differences in the level of monitored constituents were detected. In terms of water savings per controller (and cost-effectiveness), the study clearly indicated that larger landscape areas (parks and street medians) should provide the initial targets for the expansion of similar programs.

For the complete Residential Runoff Reduction Study please contact Santa Ana Watershed Project Authority at onewateronewatershed@sawpa.org.

S·E·E·P

SmarTimer Edgescape Evaluation Project

FINAL REPORT

NOVEMBER 12, 2008

SUBMITTED BY

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

THE MUNICIPAL WATER DISTRICT OF ORANGE COUNTY
18700 Ward Street
P.O. Box 20895
Fountain Valley, CA 92728

GRANT AGREEMENT NO. 06-211-559-0
FOR THE STATE WATER RESOURCES CONTROL BOARD
AND
THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

A. EXECUTIVE SUMMARY

The purpose of the SmarTimer Edgescape Evaluation Project (SEEP) was to retrofit specific groups of "structural" landscape Best Management Practices (BMPs) to improve water use efficiency of landscape irrigation across a set of residential and non-residential sub-watershed assessment areas in southern Orange County, California; and to evaluate the BMPs' effectiveness in reducing water consumption, dry weather runoff and pollutant loads for constituents of concern. "Structural" landscape BMPs, for the purpose of this project, include weather-based irrigation controllers (aka "SmarTimers"), "Edgescaping" where existing irrigated lawn area along the edge of a public sidewalk, street curb, driveway and/or private walkway is replaced with lower impact landscaping and permeable ground covering, and other irrigation enhancements & adjustments to further improve water efficiency and reduce runoff by eliminating overspray onto pavements and improve distribution uniformity. A by-product of the SEEP was the ability to determine the effectiveness of residential rebate outreach programs. Costs of implementation of selected BMPs in relation to benefits realized in the storm drain system were also analyzed.

The project evaluated the effectiveness of the BMPs by implementing them in diverse sub-watersheds that each drain entirely to a single storm drain monitoring site where flow and chemical parameters were easily measurable. Twenty-three (23) sub-watershed areas, located in ten cities within four different watersheds of the San Juan Hydrologic Unit in south Orange County, were selected as assessment areas for the project. All assessment areas had been fully developed for at least fifteen years prior to initiation of the SEEP. Residential (single- and multi-family) and non-residential land uses (private and public) were represented.

Three different BMP combinations were deployed at sixteen of the twenty-three assessment areas, with pre- and post-BMP conditions evaluated in comparison to seven un-retrofitted "control" assessment areas. The three BMP-retrofit combinations included:

- Group A - SmarTimer controllers only,
- Group AB - SmarTimers plus irrigation distribution system improvements, and
- Group ABC - SmarTimers plus irrigation distribution system improvements plus turfgrass replacement.

Pre- and post-retrofit assessments for water consumption, dry-weather runoff flow, fecal indicator bacteria, nutrient loads and surface flow/seepage ratios were made for each assessment area. Field data gathering took place over twelve (12) weeks starting in May 2007 and another twelve (12) weeks starting in May 2008. In the interim between sampling periods, the BMPs were implemented in the assessment areas.

Rebate-based marketing programs, implementation standards and technical support were developed to assist participants in accomplishing consistent BMP implementation to the extent feasible. In some cases, 'smart' irrigation controllers were found to be already in place and operational over a portion of the assessment areas prior to the initiation of the SEEP. In terms of BMP implementation, the SEEP resulted in 153 new SmarTimers being successfully deployed to control a total of 2,401,399 square feet of landscaped area at 16 assessment areas. For SFRs, irrigation distribution improvements were implemented over a total of 658,301 square feet at seven (7) assessment areas, and turfgrass replacements were accomplished over 18,975 square feet at four (4) assessment areas. For NON-SFRs, irrigation distribution improvements were implemented over a total of 711,073 square feet at eight (8) assessment areas, and turfgrass replacements were accomplished over 49,963 square feet at four (4) assessment areas. The most variable implementation was at the six (6) predominately single-family residential assessment areas, where BMP-retrofit participation varied from 6.5% to 22% in terms of the number of single-family lots in the tract, representing 2.6% of their respective assessment area's overall irrigated acreage. New BMP coverage at the non-single-family assessment areas was 46.4% of overall irrigated acreage.

The PAEP for the SEEP established targets to reduce water consumption by an average of 7 to 21% at SFR sites and an average of 5 to 15% at Non-SFR sites. In order to detect changes in water consumption, water meter data for the 2002-2008 years (2002 through mid-2007 for pre-retrofit water consumption data and mid-2007 through mid-2008 for post-retrofit water consumption data) has been collected or requested to be examined for each assessment area. Not all participating water agencies were able to provide monthly consumption data. Implementation of SEEP BMPs commenced in September 2007 and was largely complete by May 2008. Thus the period of complete post-BMP installation data only occurs after May 2008. This report will present analysis of post-BMP water consumption for the brief period of post-installation available. Conclusions about the level of long term expected water savings based upon two months of post-installation history are speculative. It is highly desirable for additional follow-up analyses of water consumption once a longer history is available.

Examination of the results from the participants from the Santa Margarita Water District (SMWD) service area leads to some suggestive observations. First, the participating customers appear to have a somewhat higher level of pre-participation mean consumption than that of non-participating (control) customers. Second, mean consumption in both groups appears to fall from 2007 to 2008. Given that evapotranspiration was higher than normal in 2007 (about 7 percent higher at the California Irrigation Management Information Service (CIMIS) Irvine Station 75 in May-July 2007) and about normal in 2008, one would not be surprised to see a reduction in water consumption in 2008.

By examining SFR participants from the Moulton Niguel Water District (MNWD), these customers appear to have a somewhat lower level of pre-participation mean consumption as compared to non-participating (control) customers. And while July 2008 consumption is somewhat lower for most customers, the BMP-ABC type appears to have used more. This result should not be surprising as the new drought-tolerant plantings (contained in the "C" part of BMP-ABC) do require additional water to get established.

Dry weather flow measurements were taken continuously for twelve (12) weeks pre-retrofit from May to August 2007 and again post-retrofit in 2008 at flow gages installed at the storm drain monitoring sites for all twenty-three (23) assessment areas. Three (3) of the assessment areas produced no measurable dry weather flow, and four (4) areas had less than measurable dry weather flow under post-retrofit conditions.

Conductivity measurements were taken as twice-weekly grab samples for each of the twelve-week monitoring periods at the twenty-three assessment areas where flow was available to be measured. Conductivity was also measured continuously by sensors installed with the flow gages from July-August in pre-retrofit 2007 and for the full twelve weeks in post-retrofit 2008. The purpose of the conductivity monitoring was, to the extent feasible, to ascertain the percentage of surface irrigation runoff in the dry weather flow. This evaluation was complicated by reclaimed water used at non-residential sites within 5 of the 9 single-family residential areas, and by highly variable conditions in the geologic substrate. Pre-retrofit conductivity patterns in the nineteen (19) assessment areas where flow was available to measure showed two sites with significantly elevated conductivity, suggesting geomorphic contributory factors.

To evaluate the effectiveness of the project with respect to water quality parameters, twice-weekly grab samples for nutrients, fecal bacteria, and dissolved organic carbon were taken at the twenty-three (23) assessment areas where flow was available to be sampled during laboratory operating hours. In the Final SEEP Report, pre- and post-retrofit concentration parameter differences will be statistically analyzed to determine the following: nutrient loading variations and patterns among the A, AB and ABC areas, the relationship of dissolved organic carbon to bacteria concentrations, nutrient concentration relationships to the other parameters, and the relationship of the water quality parameters to the flow rate.

For the complete Smart Timer and Edgescape Evaluation Study, please contact Santa Ana Watershed Project Authority at onewateronewatershed@sawpa.org.

Water use in California's ornamental nurseries

Little is known about how much water container-grown plants require for maximum growth and value. This study answered some fundamental questions on the subject.

David W. Burger □ Janet S. Hartin □ Donald R. Hodel
Tim A. Lukaszewski □ Steven A. Tjosvold □ Sally A. Wagner

The cost and availability of high-quality irrigation water are important production considerations for California nursery growers. Irrigation water is expensive and now accounts for 4 to 7 percent of the total production cost of 1-gallon, ornamental plants. A great deal has been published on water use in agronomic and field crops, but little research has been conducted in California to answer fundamental questions regarding water use by container-grown, ornamental plants. It is largely unknown how much water a plant growing in a container requires for maximum growth and aesthetic value.

Stringent requirements are placed on the production of ornamental plants, because they are grown in containers with a limited soil volume and thus a limited supply of water. It is not enough to grow the plants at their maximum growth rate if the quality of that growth is reduced. Many of the marketing and pricing strategies for nursery products are closely tied to quality. The challenge is to grow the finest quality plants in the shortest period of time with a minimum use of raw materials.

In this report, we describe findings from research conducted over the past two years in Davis and other California locations. Our objectives were to determine the water-use characteristics (crop coefficients, effects of spacing) of some of the most important, container-grown ornamentals in California, to rank these container crops in terms of their water use, and to develop a system for including CIMIS (California Irrigation Management and Information System) weather data into nursery irrigation management.

Water use, as measured by weight changes of plants in containers, was determined with a digital balance attached directly to a portable microcomputer.

Water-use characteristics

Water use by container-grown plants is measured in milliliters (or cubic centimeters) of water transpired by the plant and evaporated from a container over a given period. Changes in weight of an irrigated plant can be used to determine milliliters of water used, since 1 milliliter of water essentially weighs 1 gram.

In all of the experiments conducted, we approximated the physical layout of a production nursery by spacing container plants at known densities. Once the experimental design was set, all of the plants were watered thoroughly, allowed to drain for one hour (time period to attain container capacity), and weighed. After 24 hours, the plant was weighed again. The difference between the beginning and ending weights was the water used, in cubic centimeters (cm^3) or milliliters (ml), over the 24 hours. Evapotranspiration of the container crop (ET_{crop}) can be determined from this information by using the following equation:

$$ET_{crop}\ (cm) = \frac{\text{Volume of water used } (cm^3)}{\text{Container surface area } (cm^2)}$$

The designation of surface area in the equation is slightly different from those in similar equations used for field crops. In container-grown plants, the canopy-covered, surface area and the surface area representing the water reservoir are not the same. The sole source of water for the plants is the container; the plant's canopy, however, can extend beyond the container surface area. It is therefore difficult to make direct comparisons between the ET_{crop} for container-grown plants and that for field crops. The surface area of the container (188 square centimeters for a 1-gallon container) as the "cover-crop" area has been used in all of the calculations presented here.

If the ET_0 (the reference crop evapotranspiration, which is the ET rate of healthy grass, completely covering the ground to a uniform height of 3 to 6 inches) is known for the time period when the ET_{crop} was determined, crop coefficients (K_c) can be calculated by the equation:

$$K_c = \frac{ET_{crop}}{ET_0}$$

Crop coefficients (K_c) can then be used to determine when to irrigate and how much water to apply to a particular crop.

We performed experiments at Davis during the summer of 1985 to determine evapotranspiration and crop coefficients for different container-grown ornamentals arranged in two container spacings. During these experiments, three leaf readings of three different plants spaced at 20 containers per square meter were made using a Licor autoporometer to determine transpiration rates. Three plants from each species were used to determine fresh and dry weights (to confirm that the plants were relatively similar in biomass) and to determine the total leaf area. Leaf areas were determined with a Licor leaf area meter.

During the summer of 1986, we conducted similar experiments to determine whether crop coefficients remain constant in different climates. Three frequently planted species in the California landscape, oleander *(Nerium oleander)*, bottlebrush *(Callistemon citrinus)*, and sweet mock orange *(Pittosporum tobira)*, were used.

TABLE 1. Crop coefficients (K_c) at two container spacings, 16/m² (pot-width spacing) and 36/m² (pot-to-pot spacing), of ornamental plants growing in 1-gallon containers

Species	Months in 1-gallon container	K_c 36/m²	K_c 16/m²
Heavy water users			
Pyracantha augustifolia 'Gnome'	15	4.5	5.1
Buddleia davidii 'Dubonnet'	15	4.4	4.5
Moderate water users			
Chaenomeles × Clarkiana 'Minerva'	15	2.4	3.8
Oleander, *Nerium oleander*	—	2.3	—
Spiraea vanhouttei	16	2.2	3.4
Creeping juniper *Juniperus horizontalis* 'Youngstown Compacta'	8	2.0	2.5
Forsythia intermedia 'Spring Glory'	8	2.0	3.2
Arborvitae, *Platycladus (Thuja) orientalis* 'Aureus Nana'	12	1.9	3.1
Japanese barberry, *Berberis thunbergii* 'Atropurpurea'	15	1.9	2.5
Chinese juniper, *Juniperus chinensis* 'Spearmint'	5	1.9	3.1
Savin juniper, *Juniperus sabina*, 'Buffalo'	15	1.7	3.5
Japanese privet, *Ligustrum japonicum*	11	1.7	3.1
Bottlebrush, *Callistemon citrinus*	—	1.6	—
Cotoneaster congestus 'Likiang'	16	1.5	2.6
Juniperus horizontalis 'Prince of Wales'	10	1.5	2.6
Juniperus chinensis procumbens 'Green Mound'	8	1.4	2.5
Sweet mock orange, *Pittosporum tobira*	—	—	2.4
Light water users			
Creeping manzanita, *Arctostaphylos uva-ursi*	11	1.2	1.7
Euonymus kiautschovica 'Manhattan'	15	1.2	2.8
Photinia fraseri	12	1.2	1.8
Scotch broom, *Cystisus scoparius* 'Moonlight'	12	1.1	1.8
Japanese barberry, *Mahonia repens*	11	1.1	1.7

NOTE: Values are averages of 10 to 12 plants.

Randomly selected plants from each species were sent to four California locations: Davis, Watsonville, San Bernardino, and Irvine (UC South Coast Field Station). The plants were arranged in identical experimental designs at the four locations. Thirty plants (six rows, five columns) of oleander and bottlebrush were set at a spacing of 36 containers per square meter (pot-to-pot), and 30 plants of sweet mock orange were set at a spacing of 16 containers per square meter. The outside border plants were not used in data collection. This left the inside 12 plants as the experimental units.

The plants were watered and weighed as described so that their evapotranspiration could be calculated. All of the data were sent to Davis for collating. On-line CIMIS computers were used to obtain the reference-crop evapotranspiration for each location while the experiment was in progress so that crop coefficients could be determined. Since there was no CIMIS weather station near the South Coast Field Station, we used the reference-crop data gathered there.

Results

Compared to published coefficients for other crops, those for container-grown plants are high, ranging from 1.1 to 5.1 depending on the species and the container spacing (table 1). Based on the coefficients, these plants can be grouped into heavy, moderate, and light water users. The heavy water users (pyracantha, buddleia) have coefficients greater than 4.0. Moderate water users (flowering quince, oleander, spiraea, juniper, forsythia, arborvitae, privet, bottlebrush, cotoneaster, sweet mock orange) have coefficients between 2.0 and 3.9. The light water users (manzanita, euonymus, photinia, Scotch broom, and Japanese barberry) have coefficients less than 2.0.

Container spacing has a significant effect on the K_c and ET_{crop}. This effect is to be expected, since as the container spacing increases, sunlight on the black container increases, raising the soil temperature and thus the evaporation rate. Transpiration rates of individual leaves of the test plants varied between 3 and 144 micrograms per square centimeter per second. Plants with the largest crop coefficients did not always have the largest transpiration rates (data not shown). The predictive quality of the autoporometer measurements was improved when the total leaf area of the plant was used, but the values were not accurate enough to be useful in predicting overall water use.

The crop coefficients at the four different locations remained fairly constant (table 2). Although the coefficients for oleander were variable, these values would suffice for estimations and calculations necessary for irrigation scheduling.

TABLE 2. Crop coefficients for three, ornamental species in four California locations

Species*	Crop coefficient: Davis	Watsonville	SCFS† Irvine	San Bernardino
Nerium oleander	2.3	2.1	1.8	2.1
Pittosporum tobira	2.4	2.2	2.3	2.6
Callistemon citrinus	1.6	1.8	1.7	1.7

* *Nerium* and *Callistemon* spaced at 36 containers and *Pittosporum* at 16 containers per square meter.
† SCFS = South Coast Field Station

Conclusions

The data presented here add to the growing collection of ET_{crop} and K_c data for California crops and are among the first water use data specifically for the ornamental industry. Care must be taken when using these data. Many interactive factors can alter the water use of container-grown plants. These include differences among cultivars of a given species (see the differences among the juniper species in table 1), developmental stage of the plant, nutritional status, shading, and other spacing layouts.

Crop evapotranspiration (ET_{crop}) and coefficients (K_c) are easily calculated, and a nursery manager can simply determine them for the crops being produced. Confidence in the accuracy of these coefficients will lead to the use of reference crop (ET_0) data, whether gathered from CIMIS or from pan evaporation rates calculated on-site, to predict how much water has been used and when to irrigate. For example, if the ET_0 for a given period were 2 cm and the K_c for a crop were 2.0, the equation

$$K_c \times ET_0 = ET_{crop}$$

would give an ET_{crop} of 4 cm. The nursery manager would therefore know to apply 4 cm of water on the crop.

This exercise assumes that the manager knows the application rate and distribution characteristics of the irrigation system used to apply the water. Also, plants with similar coefficients can be grouped together in the nursery and irrigated simultaneously. The importance of the diminishing supply of high-quality water and increased water costs will necessitate these kinds of improved water management techniques.

David W. Burger is Assistant Professor, Department of Environmental Horticulture, University of California, Davis; Janet S. Hartin, Donald R. Hodel, and Steven A. Tjosvold are Farm Advisors, UC Cooperative Extension, San Bernardino, Los Angeles, and Santa Cruz counties, respectively; and Tim A. Lukaszewski and Sally A. Wagner are Research Assistants, Department of Environmental Horticulture, UC Davis. *This work was conducted with the financial support of the California Association of Nurserymen. The authors thank Hines Nursery, Vacaville, and Monrovia Nursery, Azusa, California, for providing plants; and Dr. O. J. Burger for his suggestions.*

Evaluating Best Management Practices (BMPs) Effectiveness to Reduce Volumes of Runoff and Improve the Quality of Runoff from Urban Environments

Agreement Number 04-231-550-03

March 8, 2011

A research study of residential runoff in Sacramento and Orange Counties

Final Report

Evaluating Best Management Practices (BMPs) Effectiveness to Reduce Volumes of Runoff and Improve the Quality of Runoff from Urban Environments

Agreement Number 04-231-550-03

March 8, 2011

A research study in eight neighborhoods in the Counties of Sacramento and Orange

Funded by the 2003 Consolidation of Watershed Protection, Watershed Management, and Nonpoint Source Pollution Control Grants including the CALFED Drinking Water Quality Program for the amount of $2,900,350

GRANT SUMMARY

Completed Grant Summaries are made available to the public on the State Water Resources Control Board's (SWRCB) website at http://www.waterboards.ca.gov/funding/grantinfo.html

Use the tab and arrow keys to move through the form. If field is not applicable, please put N/A in field.

Date filled out: 01/31/2011

Grant Information: Please use complete phrases/sentences. Fields will expand as you type.

1. **Grant Agreement Number:** 04-231-550-3
2. **Project Title:** Evaluating Best Management Practices (BMPs) Effectiveness to Reduce Volumes of Runoff and Improve the Quality of Runoff from Urban Environments
3. **Project Purpose - Problem Being Addressed:** Residential landscape runoff
4. **Project Goals**
   a. **Short-term Goals:** To identify and measure the effectiveness of management methods that reduce runoff and/or improve the quality of the runoff from residential sources
   b. **Long-term Goals:** To reduce the pollutant loading from residential sources and improve the efficiency of water use on residential landscapes.
5. **Project Location: (lat/longs, watershed, etc.)** Eight neighborhood sites in the County of Sacramento (Dry Creek) and the Cities of Sacramento (East Drainage Canal), Folsom (Alder Creek), San Juan Capistrano (San Juan Creek), Aliso Viejo (Aliso Creek), and Laguna Niguel (Salt Creek) were used to study runoff. The City of Sacramento site is in the Lower Sacramento Watershed (108020109) and the other Sacramento sites are in the Lower American Watershed (18020111). All of the Orange County sites are in the Aliso-San Onofre Watershed (18070301). Outreach activities occurred at a Statewide level.
   a. **Physical Size of Project: (miles, acres, sq. ft., etc.)**
   Sacramento County covers about 994 square miles (2,570 km^2) and Orange County is about 948 sq mi (2,455.3 km^2).
   The total area of the eight study sites is: Sacramento 10,157,032 ft^2 (0.94 km^2) and Orange 20,742,785 (1.9 km^2).
   b. **Counties Included in the Project:** Sacramento and Orange
   c. **Legislative Districts: (Assembly and Senate)** Senate: 6,5,33,35,38 Assembly: 9,5,67,68,69,70,71,72, 73
6. **Which SWRCB program is funding this grant?** Please "X" box that applies.

☐ Prop 13 ☐ Prop 40 X Prop 50 ☐ EPA 319(h) ☐ Other

Grant Contact: Refers to Grant Project Director.

Name: Lorence R. (Loren) Oki **Job Title:** CE Specialist

Organization: University of California **Webpage Address:** none

Address: Dept.of Plant Sciences, MS 6, Davis, CA 95616-8780

Phone: (530) 754-4135	**Fax:** (530) 754-4883
E-mail: lroki@ucdavis.edu	
Grant Time Frame: Refers to the implementation period of the grant.	
From: 11/16/05	**To:** 03/31/11
Project Partner Information: Name all agencies/groups involved with project. UC Davis Dept of Plant Sciences, UC Davis Dept of Environmental Design- Landscape Architecture Program, UC Riverside Dept of Environmental Sciences, UCCE Master Gardeners of Orange and Sacramento Counties, UC IPM, UCCE Sacramento County, UCCE Orange County, USDA Center for Urban Forest Research, UC Davis California Center for Urban Horticulture, UC Davis John Muir Institute of the Environment, Institute of Ecological Health, Pacific Land Institute, Andy Bale-consultant, County of Sacramento, County of Orange Watersheds Program, Cities of Sacramento, Folsom, Elk Grove, San Juan Capistrano, Aliso Viejo, and Laguna Niguel, Irvine Ranch Water District, Moulton Niguel Water District, California Department of Pesticide Regulation, UC ANR South Coast Research & Extension Center, Laguna Creek Watershed Council, Ewing Irrigation, Hunter Industries, Bushman, Tierra Verde Industries, Ecolandscape California, Tree of Life Nursery, Clark & Green Associates, Altman Specialty Plants, Roger's Gardens, and Goodwin International.	
Nutrient and Sediment Load Reduction Projection: (If applicable) NA	

Please provide a hard copy to your Grant Manager and an electronic copy to your Program Analyst for SWRCB website posting. All applicable fields are mandatory. Incomplete forms will be returned.

Executive Summary

By utilizing information that existed prior to this project, including GIS information and pollutant data from urban environments, this project develops new information from controlled BMP studies, dry season and early storm event surface runoff data, and extends those findings through outreach activities. These activities are integrated to achieve the overall objective of reducing pollutants in surface runoff resulting in safe, reliable, and affordable drinking water; the main goal of the CALFED Drinking Water Quality Program. Overall, the project contributes to improvements in the water quality of the California Bay-Delta and other waters of the State for all beneficial uses.

This project selected 8 neighborhood study sites, 4 in Sacramento County and 4 in Orange County. These sites consisted of about 150 to 460 homes that were similar in age and parcel size. Most importantly, these sites consisted only of single family residences and did not include any other land-use type. The runoff from these neighborhoods converged to storm drain outfalls that were easily accessible such that water samples could be collected directly from the outfall pipe before the runoff flowed into a stream, detention basin, or pond.

Samples were collected beginning in July 2006 in Sacramento and October 2006 in Orange County for an extended period. Initially samples were collected weekly during the 2nd through 4th quarters of the year. Samples during the 1st quarters were collected as frequently as biweekly. Although the project was temporarily suspended in December 2008, sample collection continued through May 2009. Sample collection resumed in July 2010 once the project was restarted and concluded in December of that year.

Sample collection frequency.

Year	Q1	Q2	Q3	Q4
2006			Weekly[1]	Weekly
2007	Biweekly	Weekly	Weekly	Weekly
2008	Biweekly	Biweekly	Biweekly	Weekly
2009	Monthly	Monthly[2]	None	None
2010	None	None	Monthly	Monthly

[1]Collection began in Sacramento County in July 2006 and in Orange County in October 2006.
[2]Sampling was interrupted after May 2009 and resumed in July 2010. Samples were collected from up to 5 early storms of each season.

Runoff water samples were sent to laboratories to be analyzed for the following constituents:

Pesticides

- organophosphates (diazinon and chlorpyrifos),
- pyrethroids (including esfenvalerate, bifenthrin, permethrin, cyfluthrin, fenpropathrin, lambda-cyhalothrin, deltamethrin, and cypermethrin),
- fipronil, a relatively newer phenylpyrazole compound

Nutrients

- nitrates (NO_3^-), total Kjeldahl-nitrogen (TKN), phosphates (PO_4^{3-}), total phosphorus (P)

Drinking water quality constituents of concern

- total organic carbon (TOC) and dissolved organic carbon (DOC),
- bromide and chloride,
- total dissolved solids (TDS), total suspended solids (TSS), and turbidity

Biologicals

- bacterial indictors: including *E. coli,* Total Coliforms, and *Enterococcus*,
- parasite indicator: *Clostridium perfringens*,
- viral indicators: male-specific and somatic coliphages,
- pathogens: *Giardia* and *Cryptosporidium* (Sacramento County only)

Monitoring equipment was installed at each of the sites to measure and record at 2 minute intervals pH, electrical conductivity, temperature, depth, and velocity of the water in the outfall pipes. The depth and velocity data was used to calculate the flow volume. A rain gauge, solar panel, and remote communications equipment was also installed at each monitoring site. The high frequency of water sampling and flow data collection over an extended period has provided a large, high resolution data set of urban runoff from residential development that has not been available previously.

Pesticides were found in nearly every sample collected and, at times, at concentrations of concern. Nutrients were also found at high detection frequencies but usually at low levels. Biological indicators were found in every sample, but actual pathogens were found infrequently in northern California samples. In general, concentrations were higher in samples from southern compared to northern California. Baseline runoff flows also tended to be greater in southern compared to northern California.

The data was used to assess pollutant load models currently in use and proposed new ones. The information for Sacramento County is reported and discussed in a M.S. degree thesis. That thesis reported that since currently used dry season loading models are based on storm season data, they under-estimate loading of nitrate, for example, by as much as 50%. This thesis also projects that, if the homes in the study neighborhoods represented all of the single family homes in Sacramento County, non-storm runoff was 4.7 times greater from Sacramento County residences during the period of May 2007 to May 2008 than the runoff generated from storm sources. Those analyses were repeated for both reference neighborhoods in Sacramento and Orange Counties.

An objective of this project was to assess effectiveness of different outreach methods. A survey was conducted in each county to evaluate the landscape management methods and awareness of the homeowners in the study neighborhoods. A question was included asking about interest in participating in a project to improve water quality. Respondents who replied positively to this were visited by project cooperators and UC Master Gardeners who conducted and provided a landscape assessment of the respondent's home.

In Orange County, those homeowners were provided the contact information of the Master Gardeners who assisted in the assessment and were able to contact them to seek advice in changing the management of their landscapes to reduce water use and improving runoff water quality. In return, those homeowners were asked if the project could present a workshop at the residence to demonstrate landscape management methods that could be utilized. Only the neighbors in the immediate vicinity were invited to attend. These "cul-de-sac" events were highly effective and attendance increased with each subsequent event.

In contrast in Sacramento County, outreach events were larger in scale and all of the homeowners within a study area were invited to attend a "neighborhood" event. The attendance at these events was constantly low. It was hoped that the "cul-de-sac" types of events could be presented in Sacramento County and the larger neighborhood scale ones provided in Orange County. It was thought that the attendance in the Orange County events would be greater than that in Sacramento since homeowners in that county were aware of the services that could be provided by the Master Gardeners. It was also thought that the smaller events in Sacramento County might have the same increases in events that had occurred in the Orange County events.

These outreach events were presented in only 2 of the study neighborhoods in each county and served as "test" areas, whereas the areas not receiving outreach served as "controls." It was hoped that the surveys would reflect increases in water quality awareness and consequently changes (improvements) in landscape management that would be verified by monitoring data from the runoff sampling program. Unfortunately, the project funding was suspended in December of 2008 after only one year of outreach activities. The suspension lasted until July 2010 and there was only 6 months available to conclude data collection, so the outreach "experiment" was not continued although outreach activities did resume.

Part of these activities would have provided information on the costs of water quality improvement as a result of outreach. A partial study was completed and reported in the 2008 Q3 report, but it was not possible to complete this aspect of the project due to the extended suspension in project funding.

Information regarding the effectiveness of management methods was, in part, obtained from landscape demonstrations constructed at the UC Agricultural and Natural Resources South Coast Research and Extension Center in Irvine, CA. These demonstrations were initially funded by a Pesticide Reduction, Identification of Source, and Mitigation (PRISM) program grant. This project provided additional funding to expand the research and outreach components of the demonstrations.

Outreach activities included the development of information and numerous printed materials. These include a set of "Quick-Tip" cards (a UC IPM materials program) on water quality issues, posters, handouts, and a booklet designed for use by the general public describing results of the study, recommendations, and "how-to" instructions. Information on the project was posted as a section of the UCD California Center for Urban Horticulture website (ccuh.ucdavis.edu) and includes project background, outreach materials, and links to information on landscape water conservation. The Orange County Master Gardeners regularly developed and distributed newsletters which were initially mailed to residents in the study neighborhoods. This was replaced by an online newsletter available at http://groups.ucanr.org/garden4h2o/.

Additional training on sustainable landscape water management methods was developed for the Master Gardeners participating in this project. This curriculum provided the basis for a Statewide Master Gardener Train-the-Trainer Program on Advanced Sustainable Landscape Management. The curriculum was also provided to the Regional Water Authority's Blue Thumb Program along with information gained from the outreach methods study.

Outreach activities also included an assessment of promotion of practices to improve water quality. This assessment was conducted through a series of interviews of stakeholders across the State and the contents of the "Successes and Failures" report are included in this Final Report. Preliminary results from this assessment were used in the development of outreach materials and activities from this project.

SWRCB program staff had recommended that this project form collaborations with other existing or proposed projects sponsored by the Arden Creek Watershed Group and Laguna Creek Watershed Council. Although this was determined to not be feasible with the Arden Creek Group due to potential interference with our outreach experiment, one was established with the Laguna Creek group. A UC Davis graduate student in Education developed an education program for residents and students in the Elk Grove Unified School District to reduce runoff volumes and pollution impacts to Laguna Creek.

This project also provided several outreach events for audiences other than in our study neighborhoods. The larger events included the Water-Wise Symposium held on the UC Davis campus, the UCCE Demonstration Landscape Open House and Vendor Fair at the UC South Coast Research and Extension Center in Irvine (which included a news report and interview at http://www.youtube.com/IrvineRanchWD#p/a/u/0/PZBJzZVlSQ4), the Willows EcoGarden Opening Celebration at the Willows Shopping Center in Concord, for example. Co-sponsors were sought and requested to participate in all events and included the Irvine Ranch Water District, The Regional Water Authority, Cagwin & Dorward, Ewing Irrigation, City of Folsom, County of Sacramento, and many others.

Both PIs and other group cooperators have provided numerous presentations of various aspects of the project to groups including: American Chemical Society (including a news release and press conference on the project at http://www.ustream.tv/recorded/2010681), Society of Environmental Toxicology and Chemistry, Washington (D.C) Area Council of Governments, U.S. Environmental Protection Agency Pesticide Regulatory Education Program, American Society of Horticultural Science, San Diego Water Authority, Regional Water Authority, University of Arizona, University of Washington, California State Water Resources Control Board, USDA Cooperative State Research, Education, and Extension Service, North Coast Stormwater Coalition and the Redwood Community Action Agency, and UC Division of Agricultural and Natural Resources.

This project has provided us with data that supports alternative landscape management practices that we can recommend to California residents to reduce water quality problems. We have provided the California Department of Pesticide Regulation with preliminary data of pesticide detections in the runoff. This has led to funding from that department to project PIs to continue monitoring for 2 more years as part of an urban runoff pesticide detection program.

We will continue to extend the information developed in this program to residents and other stakeholders throughout California through our publications, presentations, web sites, Master Gardener programs, and other outreach and educational activities.

This project facilitated the collaboration of many groups and individuals across a broad range of expertise. Darren and I would like to thank everyone that participated and contributed to this project including the many others that are not included in the following list.

RESEARCH TEAM

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If you would like receive the complete "Evaluating Best Management Reduce Volumes of Runoff from Urban Environments" report please contact Santa Ana Watershed Project Authority at onewateronewatershed@sawpa.org.

Project N: Vulcan Pit Flood Control and Aquifer Recharge Project (City of Fontana)

Summary of Physical Benefits:

The proposed Project will provide the following physical benefits:

a. **Flooding Protection**
b. **Enhance Water Supply**
c. **Air Quality Improvement through Green House Gas Emissions Reduction**
d. **Water Quality Improvement**

Description of Physical Benefits:

The expected Project physical benefits are more specifically describe in the following section. Refer to Table 9 for quantified project benefit details.

I. Flooding Protection

Historically, flooding has been experienced in areas south and southwest of the proposed basin site during various storm events. The flooded area is generally bounded by Cherry Avenue on the west, West Fontana Channel and SCRRA Commuter Rail Corridor on the north, Cypress Avenue on the east, and Randall Avenue and Valley Boulevard on the south. Flooding in this area is well documented on FEMA flood mapping and various correspondences to the City from SCRRA. Proposed storm drain improvements will convey approximately 3,800 cfs of runoff from the 2,467 acre tributary area. The 1,150 acre flood inundation area has been determined using existing topography, existing hydrology, FEMA flood mapping, street cross sections, and City maintenance records, as shown on Attachment 7-1. The referenced exhibit highlights areas along and immediately along and south of the West Fontana Channel alignment experience flood inundation up to 1.5 feet. The Project will provide 100 year flood protection to this inundation area. Areas which flood protection is enhanced includes industrial, single family and multi-family residential developments, public facilities, and major and minor streets. See Table 7 for flood protection provided during various storm events. Additionally, there are no uncertainties related to the project benefits and the Project will not create any adverse effects.

II. Enhance Water Supply

The City of Fontana is served by the Fontana Water Company (FWC). FWC relies on costly import water as a supplemental water supply in an effort to reduce groundwater overdraft. In recent years, import water supplied 5% to 10% of demand. The City's Project will create new water supplies through stormwater capture and recharge and recycled water recharge. Recharged recycled water and stormwater will increase groundwater supplies and reduce groundwater overdraft in the Chino Basin. For Fontana, FWC purchases import State Water Project water through Inland Empire Utilities Agency at $743 per acre-foot.

The Project intends to construct the necessary improvements to enhance regional groundwater recharge. Annual storm runoff for the Project's 2,467 acre tributary area is estimating using the historic annual rainfall of 16 inches and applying a loss rate of 43% to account for evapotranspiration, based on Chino Basin Watermaster's 2010 Recharge Master Plan, see attached table. Approximately 1,800 acre-feet of storm water is expected to reach the Basin annually, portions of which will be recharged reducing the region's dependence on import water. Additionally, an equal amount (1,800 acre-feet) of recycled water will be recharged annually. Without the project, no new yield will be captured and recharged with projected amounts as presented above. Beneficiaries are all water producers from Chino Basin that include an estimated 2.2 million people. Annual Project physical benefits for the life of the Project are highlighted in Table 9.

III. Air Quality Improvements through Green House Gas Emissions Reduction

The Project provides for reduction in greenhouse gas emissions through development of local water supplies that eliminates the need for imported water to be delivered from the Bay-Delta of the same quantity. The Project conserves local water reducing dependence on imported water in the amount of approximately 3,600 acre-feet per year. By avoiding delivery through the state's system, a significant reduction in greenhouse gas emissions is attained. According to the California Air Resource Control Board, the energy required to deliver State Water Project water to Southern California is 3,519 kW/hrs per acre-foot. Using the recommended conversion unit amount of 0.0004 kWh to tons of CO2, green house gas emissions reduction of approximately 5,400 tons CO_2 per year for the project will be achieved. Three different sources and conversion factors were used to ensure accuracy, as shown on the attached table. Annual Project physical benefits for the life of the Project are highlighted in Table 9.

IV. Water Quality Improvement

The Project will reduce urban runoff discharge pollutants including sediment, nutrients, trash, metals, bacteria and virus, oil and grease, organics, and pesticides. Impervious surfaces associated with development increase the rate and volume of stormwater runoff that may increase downstream erosion potential and associated potential water quality impairment. Urban runoff flows to the Santa Ana River which is on the Santa Ana Regional Water Quality Control Board 303(d) List of Water Quality Limited Segments. Pollutants that settle on the impervious pavements and rooftops are washed untreated into nearby stream channels, increasing pollution in receiving water bodies. The Project will reduce approximately 1,900 acre-feet per year of stormwater runoff and subsequent pollutant discharge through the use of the Vulcan basin to infiltrate the runoff into the groundwater aquifer.

Infiltration basins use the natural filtration to remove pollutants in stormwater runoff. Filtration provides for high pollutant removal efficiency.

Table 9 - Annual Project Physical Benefit

Project: Vulcan Pit Flood Control and Aquifer Recharge Project

Type of Benefit: Flood Damage Reduction

Measure of Benefit (units): Multiple, See Below

Additional Information about Benefit: For the 1 in 100 year event

(a) Measure of Benefit Claimed	(b) Without Project	(c) With Project	(f) Change Resulting from Project (b)-(c)
100-year Flood Inudation Area (Acres)	1,150	0	1,150
Number of Structures Flooded			
Residential (Single Story)	441	0	441
Residential (Two Plus Story)	551	0	551
Square Footage of Structures Flooded			
Commercial	896,911	0	896,911
Industrial	4,574,150	0	4,574,150
Number of Structures Flooded			
Length of Arterial Roads Inundated (miles)	4.5	0	4.5
Length of Major Roads Inundated (miles)	2.3	0	2.3
Length of Minor Roads Inundated	3.2	0	3.2

(miles)			
Duration of Flooding (Days)[1.)]	1	0	1

Notes:
1.) Flood inundation areas, further described in Attachment 7, are not part of a low-lying area or a basin, as such, flood water are expected to drain in 1 day.

Type of Benefit: Recharge of Stormwater and Recycled Water
Measure of Benefit (units): acre-feet
Additional Information about Benefit: -

(a)	(b)	(c)	(f)
Year	**Without Project**	**With Project**	**Change Resulting from Project (c)-(b)**
2012	0	3,800	3,800
2013	0	3,800	3,800
2014	0	3,800	3,800
2015	0	3,800	3,800
2016	0	3,800	3,800
2017	0	3,800	3,800
2018	0	3,800	3,800
2019	0	3,800	3,800
2020	0	3,800	3,800
2021	0	3,800	3,800
2022	0	3,800	3,800
2023	0	3,800	3,800
2024	0	3,800	3,800
2025	0	3,800	3,800
2026	0	3,800	3,800
2027	0	3,800	3,800
2028	0	3,800	3,800
2029	0	3,800	3,800
2030	0	3,800	3,800
2031	0	3,800	3,800
2032	0	3,800	3,800
2033	0	3,800	3,800
2034	0	3,800	3,800
2035	0	3,800	3,800
2036	0	3,800	3,800
2037	0	3,800	3,800
2038	0	3,800	3,800
2039	0	3,800	3,800
2040	0	3,800	3,800
2041	0	3,800	3,800
2042	0	3,800	3,800
2043	0	3,800	3,800
2044	0	3,800	3,800
2045	0	3,800	3,800
2046	0	3,800	3,800

2047	0	3,800	3,800
2048	0	3,800	3,800
2049	0	3,800	3,800
2050	0	3,800	3,800
2051	0	3,800	3,800
2052	0	3,800	3,800
2053	0	3,800	3,800
2054	0	3,800	3,800
2055	0	3,800	3,800
2056	0	3,800	3,800
2057	0	3,800	3,800
2058	0	3,800	3,800
2059	0	3,800	3,800
2060	0	3,800	3,800
2061	0	3,800	3,800
		Total:	**190,000**

Notes:

1.) See Attachment 7 for a narrative explaining this table and attached table for detailed recharge estimate.

Type of Benefit: Avoided Green House Gas Emissions

Measure of Benefit (units): metric tons of CO_2 per year

Additional Information about Benefit: -

(a) Year	(b) Without Project	(c) With Project	(f) Change Resulting from Project (c)-(b)
2012	0	5,400	5,400
2013	0	5,400	5,400
2014	0	5,400	5,400
2015	0	5,400	5,400
2016	0	5,400	5,400
2017	0	5,400	5,400
2018	0	5,400	5,400
2019	0	5,400	5,400
2020	0	5,400	5,400
2021	0	5,400	5,400
2022	0	5,400	5,400
2023	0	5,400	5,400
2024	0	5,400	5,400
2025	0	5,400	5,400
2026	0	5,400	5,400
2027	0	5,400	5,400
2028	0	5,400	5,400
2029	0	5,400	5,400
2030	0	5,400	5,400
2031	0	5,400	5,400
2032	0	5,400	5,400
2033	0	5,400	5,400
2034	0	5,400	5,400

2035	0	5,400	5,400
2036	0	5,400	5,400
2037	0	5,400	5,400
2038	0	5,400	5,400
2039	0	5,400	5,400
2040	0	5,400	5,400
2041	0	5,400	5,400
2042	0	5,400	5,400
2043	0	5,400	5,400
2044	0	5,400	5,400
2045	0	5,400	5,400
2046	0	5,400	5,400
2047	0	5,400	5,400
2048	0	5,400	5,400
2049	0	5,400	5,400
2050	0	5,400	5,400
2051	0	5,400	5,400
2052	0	5,400	5,400
2053	0	5,400	5,400
2054	0	5,400	5,400
2055	0	5,400	5,400
2056	0	5,400	5,400
2057	0	5,400	5,400
2058	0	5,400	5,400
2059	0	5,400	5,400
2060	0	5,400	5,400
2061	0	5,400	5,400
		Total:	**270,000**

Notes:

1.) See Attachment 7 for a narrative explaining this table and attached table for detailed recharge estimate.

Project O: Francis Street Storm Drain and Ely Basin Flood Control and Aquifer Recharge Project (City of Ontario)

Summary of Physical Benefits:

The proposed Project will provide the following physical benefits:

a. **Flooding Protection**
b. **Enhance Water Supply**
c. **Air Quality Improvement through Green House Gas Emissions Reduction**
d. **Water Quality Improvement**

Description of Physical Benefits:

The expected Project physical benefits are more specifically describe in the following section. Refer to Table 9 for quantified project benefit details.

I. Flooding Protection

Historically, flooding has been experienced in areas south of Francis Street during various storm events. The flooded area is generally bounded by Campus Avenue on the west, Francis Street on the north, Grove Avenue on the east, and Interstate 60 on the south. Flooding in this area is well documented by photos and newspaper articles, as shown in Attachment 7-2 from the local paper, the Inland Daily Bulletin (photos were obtained from the Bulletin). The Francis Street Storm Drain will convey 1,423 cfs of runoff from the 956 acre tributary area. Using existing topography, storm drain master plan data, street drainage conveyance capacities, and City maintenance records, the flood inundation area was determined and is shown on Attachment 7-1. The referenced exhibit highlights a 277 acre area along and immediately south of Francis Street experience flood inundation up to 2 feet. The Project will provide 100 year flood protection to this inundation area. Areas which flood protection is enhanced includes commercial, industrial, single family and multi-family residential developments, and arterial, major, and minor streets. See Table 9 for flood protection provided during various storm events. Additionally, there are no uncertainties related to the project benefits and the Project will not create any adverse effects.

II. Enhance Water Supply

The City of Ontario is dependent on costly imported water supplies to meet demand. Approximately 25% of demand is met by import water in the City. The Project creates new groundwater yield through stormwater capture and recharge. Recharged stormwater will increase groundwater supplies and address overdraft in the Chino Basin. The Project will capture and recharge 772 acre-feet of stormwater during an average rainfall year.

The Project intends to construct the necessary improvements to enhance regional groundwater recharge. Annual storm runoff for the Project's 956 acre tributary area is estimating using the historic annual rainfall of 17 inches and applying a loss rate of 43% to account for evapotranspiration, based on Chino Basin Watermaster's 2010 Recharge Master Plan, see attached table. Approximately 772 acre-feet of storm water is expected to reach the Ely Basins annually for recharge. Without the project, no new yield will be captured with projected amounts as presented above. Beneficiaries are all water producers from Chino Basin that include an estimated 2.2 million people. Annual Project physical benefits for the life of the Project are highlighted in Table 9.

III. Air Quality Improvements through Green House Gas Emissions Reduction

The Project provides for reduction in greenhouse gas emissions through development of local water supplies that eliminates the need for imported water to be delivered from the Bay-Delta of the same quantity. The Project conserves local water reducing dependence on imported water in the amount of approximately 772 acre-feet per year. By avoiding delivery through the state's system, a significant reduction in greenhouse gas emissions is attained. According to the California Air Resource Control Board, the energy required to deliver State Water Project water to Southern California is 3,519 kW/hrs per acre-foot. Using the recommended conversion unit amount of 0.0004 kWh to tons of CO2, green house gas emissions reduction of approximately 1,100 tons CO_2 per year for the project will be achieved. Three different sources and conversion factors were used to ensure accuracy, as shown on the attached table. Annual Project physical benefits for the life of the Project are highlighted in Table 9.

IV. Water Quality Improvement

The Project will reduce urban runoff discharge pollutants including sediment, nutrients, trash, metals, bacteria and virus, oil and grease, organics, and pesticides. Impervious surfaces associated with development increase the rate and volume of stormwater runoff that may increase downstream erosion potential and associated potential water quality impairment. Urban runoff flows to the Santa Ana River which is on the Santa Ana Regional Water Quality Control Board 303(d) List of Water Quality Limited Segments. Pollutants that settle on the impervious pavements and rooftops are washed untreated into nearby stream channels, increasing pollution in receiving water bodies. The Project will reduce approximately 772 acre-feet per year of stormwater runoff and subsequent pollutant discharge through the use of infiltration basins (Ely Basins) to infiltrate the runoff into the groundwater aquifer.

Infiltration basins use the natural filtration to remove pollutants in stormwater runoff. Filtration provides for high pollutant removal efficiency.

Table 9 - Annual Project Physical Benefit

Project: Francis Street Storm Drain and Ely Basin Flood Control and Aquifer Recharge Project

Type of Benefit:	Flood Damage Reduction
Measure of Benefit (units):	Multiple, See Below
Additional Information about Benefit:	For the 1 in 100 year event

(a)	(b)	(c)	(f)
Measure of Benefit Claimed	**Without Project**	**With Project**	**Change Resulting from Project (b)-(c)**
100-year Flood Inudation Area (Acres)	277	0	277
Number of Structures Flooded			
Residential (Single Story)	136	0	136
Residential (Two Plus Story)	374	0	374
Square Footage of Structures Flooded			
Commercial	668,042	0	668,042
Industrial	2,308,286	0	2,308,286
Duration of Flooding (Days)[1.)]	1	0	1

Notes:

1.) Flood inundation areas, further described in Attachment 7, are not part of a low-lying area or a basin, as such, flood water are expected to drain in 1 day.

Type of Benefit:	Stormwater Capture and Storage
Measure of Benefit (units):	acre-feet
Additional Information about Benefit:	-

(a)	(b)	(c)	(f)

Year	Without Project	With Project	Change Resulting from Project (c)-(b)
2012	0	772	772
2013	0	772	772
2014	0	772	772
2015	0	772	772
2016	0	772	772
2017	0	772	772
2018	0	772	772
2019	0	772	772
2020	0	772	772
2021	0	772	772
2022	0	772	772
2023	0	772	772
2024	0	772	772
2025	0	772	772
2026	0	772	772
2027	0	772	772
2028	0	772	772
2029	0	772	772
2030	0	772	772
2031	0	772	772
2032	0	772	772
2033	0	772	772
2034	0	772	772
2035	0	772	772
2036	0	772	772
2037	0	772	772
2038	0	772	772
2039	0	772	772
2040	0	772	772
2041	0	772	772
2042	0	772	772
2043	0	772	772
2044	0	772	772
2045	0	772	772
2046	0	772	772
2047	0	772	772
2048	0	772	772
2049	0	772	772
2050	0	772	772
2051	0	772	772
2052	0	772	772
2053	0	772	772
2054	0	772	772
2055	0	772	772
2056	0	772	772
2057	0	772	772

2058	0	772	772
2059	0	772	772
2060	0	772	772
2061	0	772	772
		Total:	**38,600**

Notes:

1.) See Attachment 7 for a narrative explaining this table and attached table for detailed recharge estimate.

Type of Benefit:	Avoided Green House Gas Emissions
Measure of Benefit (units):	metric tons of CO_2 per year
Additional Information about Benefit:	-

(a) Year	(b) Without Project	(c) With Project	(f) Change Resulting from Project (c)-(b)
2012	0	1,100	1,100
2013	0	1,100	1,100
2014	0	1,100	1,100
2015	0	1,100	1,100
2016	0	1,100	1,100
2017	0	1,100	1,100
2018	0	1,100	1,100
2019	0	1,100	1,100
2020	0	1,100	1,100
2021	0	1,100	1,100
2022	0	1,100	1,100
2023	0	1,100	1,100
2024	0	1,100	1,100
2025	0	1,100	1,100
2026	0	1,100	1,100
2027	0	1,100	1,100
2028	0	1,100	1,100
2029	0	1,100	1,100
2030	0	1,100	1,100
2031	0	1,100	1,100
2032	0	1,100	1,100
2033	0	1,100	1,100
2034	0	1,100	1,100
2035	0	1,100	1,100
2036	0	1,100	1,100
2037	0	1,100	1,100
2038	0	1,100	1,100
2039	0	1,100	1,100
2040	0	1,100	1,100
2041	0	1,100	1,100
2042	0	1,100	1,100
2043	0	1,100	1,100
2044	0	1,100	1,100

2045	0	1,100	1,100
2046	0	1,100	1,100
2047	0	1,100	1,100
2048	0	1,100	1,100
2049	0	1,100	1,100
2050	0	1,100	1,100
2051	0	1,100	1,100
2052	0	1,100	1,100
2053	0	1,100	1,100
2054	0	1,100	1,100
2055	0	1,100	1,100
2056	0	1,100	1,100
2057	0	1,100	1,100
2058	0	1,100	1,100
2059	0	1,100	1,100
2060	0	1,100	1,100
2061	0	1,100	1,100
		Total:	**55,000**

Notes:

1.) See Attachment 7 for a narrative explaining this table and attached table for detailed recharge estimate.

Project P: Commercial/Industrial/Instritutional Performance-Based Water Use Efficiency Program (Metropolitan Water District of Orange County)

I. Technical Justification

Summarize reports and studies prepared for the proposed water use efficiency project or explain what has been done to determine the project's feasibility.

A variety of reports and studies have been produced or referenced to support implementation of the proposed Program. In 2009, USBR completed a five volume report called the Water Energy Efficiency Program (WEEP) for CII Customer Classes in Southern California. The WEEP Study confirmed that integrated resource management programs can foster gains in water and energy efficiency among targeted CII sectors. This report recommended offering integrated water and energy efficiency programs, as well as engineering support, to CII sectors. During a review of sanitation district wastewater flow data, CII sectors were identified as having large potential for water savings in Orange County. Primary recommendations for improvement include: Equipment upgrades (i.e., replacing existing equipment with new equipment characterized as more water or energy efficient); Operating and maintenance practices to ensure that site equipment is used as intended and consistent with load demands; Design, expand, or change new or existing processes and facilities to achieve greater levels of water and energy efficiency in building designs and manufacturing related activities. MWDOC is currently evaluating our Hotel (audit and incentive) Program, which has been implemented within Orange County since 2008 and which achieved 107% of the water savings goal of 453acre-feet per year (AFY). The proposed CII and School Program would utilize the success of and build upon the Hotel Program process. CII water demands make up a significant percentage of total demand within the MWDOC service area.

As recommended by the California Urban Water Conservation Council's (CUWCC) Potential BMPs, the Program is developed as a holistic approach to landscape water use efficiency that provides incentives and technical resources, with monitoring and reporting of water use.

According to the State Water Resources Control Board, there is more dry weather runoff in the storm drains than stormwater runoff. Landscape-attributed dry weather runoff reduction and NPS pollution reduction are anticipated to be greater than 50%, as documented in MWDOC's 2004 Residential Runoff Reduction (R3) Study. Reduced urban runoff also benefits water quality within local creeks and streams. The R3 Study found that a reduction in total pollutant migration could be achieved by reducing total dry season urban runoff. To further test the feasibility of landscape programs, MWDOC has successfully implemented a standalone residential and commercial non-functioning turfgrass removal program since November 2010 that has resulted in more than 436,600 ft^2 of turf removed and replaced with California Friendly plantings. To date 39 sites have participated, with an additional 82,800 ft^2 of turf removal pending, yielding an average of approximately 13,800 ft^2 per site. Utilizing this experience and data derived from these programs, MWDOC has applied historical participation statistics to calculate the proposed numbers for this Program.

An additional benefit associated with holistic landscape projects is the emphasis on proper irrigation. Replacement of a standard irrigation controller with a weather-based irrigation controller (a.k.a. smart timer), standard pop-up spray heads with water efficient rotating nozzles, or the complete removal of irrigation at the conversion site can achieve quantifiable and sustained water savings in urban landscapes, specifically in commercial landscapes throughout Orange County, California. Through a 2012 statistical evaluation of past programs conducted on rebate program participants, MWDOC has measured water savings of more than 27% at commercial accounts, averaging 727 gallons per day (gpd) per installation of a smart timer (with respect to weather normalization) and additional 1 to 4 gpd per rotating nozzle.

Local Water Demand

The Municipal Water District of Orange County (MWDOC) purchases imported water from the Metropolitan Water District of Southern California (Metropolitan). Metropolitan obtains this water from the Colorado River and State Water Project. Water from the State Water Project passes through the Delta facilities before entering the California Aqueduct and coming to Southern California. Imported supplies (5 year average) provided by the Metropolitan include the Colorado River (69% of imported supply or 163,500 AF) and Bay-Delta via the State Water Project (31% of import supply or 73,500 AF). MWDOC's ability to influence diversions from the Bay-Delta include maximizing water use efficiency as proposed herein, increasing use of reclaimed water, and development of other local supplies including ground, ocean water desalination, indirect potable reuse of recycled water, and runoff reuse.

Currently, the Program's water is either CII wastewater discharged into the ocean via sanitation district or LL runoff, containing non-point source pollutants, entering the municipal storm drain systems and aquatic ecosystems during wet/dry weather. Conserved water from the proposed Program could result in decreased demand on Delta diversions; however, more likely, conserved water will remain in storage for use in a future dry year when Delta diversions are restricted due to drought and/or regulatory restrictions.

II. Project Physical Benefits

The Program will: provide reliable water supplies by reducing dependency on imported water; meet water demands during all hydrologic conditions; and maximize potable/recycled water use efficiency and onsite process water reuse. It will preserve and enhance ecological function of open-space and water-related habitats. Additionally it will: promote sustainable water solutions by linking land and water use; promote use of appropriate source for water use; reduce GHG emissions and energy consumption; and promote urban greening projects. The Program will ensure high quality water for all users by matching quality with intended uses and managing rainfall as a resource, thus maximizing beneficial use through low impact development and increased onsite infiltration. The Program will promote stewardship, a benefit to the business will be lower operating costs, thereby giving them a competitive edge, as well as this benefit enticing participation; they can tout improved sustainability.

Statewide benefits, include off-sets to Bay-Delta pumping, build on existing water use efficiency programs implemented in Orange County, and provide support for the implementation of BMPs. The Program will preserve local flexibility by implementing water use management improvements at local and regional levels to maximize beneficial use of existing water supplies. In addition to our traditional imported and groundwater supplies, water agencies in Orange County recognize the need for a balanced water supply portfolio that includes water recycling/reuse and water conservation.

- **Improve Water Reliability and Reduce Reliance on Imported Water (primary benefit)**

  Water Savings: Total performance-based Program water savings goal is estimated at 450 AFY. Where, 400 AFY is attributed to water use efficiency and 50 AFY will result from onsite recucling or reuse of process water. This will be achieved by targeting comprehensive water reductions at CII and LL sites over the Program period. The Program goal is composed of the following individual project-type goals: Industrial process improvements are expected to provide 75 AFY with a 10 year life; Commercial and Institutional devise replacements will provide 170 AFY with a savings life up to 20 years (based on the industry accepted specific device life); and the Landscape projects will contribute to 205 AFY savings with a 10 year life.

- **Improve Water Quality and Salt Balance**

  MWDOC has found similar Programs to yield a 50% reduction of landscape water runoff, which results in non-point source pollution entering municipal storm drain systems and aquatic ecosystems. This Program is expected to yield 0.2 mgd of runoff water.

  Water Quantity: Reduced Runoff and Pollutants: The proposed Program will remove turfgrass at LL sites that require more than 4 feet of supplementary irrigation each year. This turfgrass will be replaced with California Friendly plantings or ground covers that require less than half the water needed by turf. If these new plantings require irrigation, they will be irrigated with low-volume emitters and will be adequately mulched to retain soil moisture. This will result in a reduction in landscape irrigation runoff and related non-point source pollution. Reductions in urban runoff will also have considerable benefits on water quality within Orange County's creeks and streams (Source: Residential Runoff Reduction (R3) Study, 2004, MWDOC and Irvine Ranch Water District), an important local issue. Reduced urban runoff also benefits water quality within local creeks and streams. For this Program the estimated NPS reduction is 0.05 million gallons per day.

  In-stream Flow: The R3 Study found that a reduction in total pollutant migration could be achieved by reducing total dry season urban runoff. Since State Water Project supplies from the Bay-Delta are considered MWDOC's marginal supply source, we assume that saved water could stay in-stream, resulting in increased in-stream flows. The quantity of water attributed to in-stream flows would be directly proportional to the water saved through the Program.

- **Climate Change**

  According to the California Energy Commission's 2005 Integrated Energy Policy Report, energy savings associated with water conservation programs is 3,300 kWh per acre-foot of water saved. The proposed Program is estimated to save 450 AF annually. Using the CEC Energy Policy Report energy savings estimate, the proposed Program will save an estimated 847,620 kWh annually.

  Greenhouse Gas Reduction: The reduced water need can result in a GHG emission reduction of 116 metric tons of CO_2 emissions per year, calculated from the associated water savings and reduced energy need. This Program is expected to yield a reduction of 584 metric tons of CO_2e per year of greenhouse gas emissions achieved from water management activities versus baseline.

  Climate Adaptation: The Program will contribute to adapting to the effects of climate change by modifying existing water-intensive landscapes to California Friendly landscapes that are appropriate to our region and water supply situation. Existing landscape are more turf intensive than the region's existing water supplies can accommodate. The desired landscape for the region will include smaller functional turf areas and larger California Friendly tree, shrub, and groundcover-based areas. Participants in the Program will serve as an example for others to follow, thereby fostering a California Friendly landscape transformation.

- **Manage Flood Waters**

  This Program will improve the natural hydrology over a 35 acre area and is consistent with the water use efficiency and watershed management goals contained in the California Water Plan, TMDLs, CALFED Bay-Delta program objectives, AB 32, and local land use planning. The Program will protect surface and groundwater quality by: (1) reducing the rate of dry weather runoff and pollution from existing landscapes; (2) employing landscape water use techniques that promote the infiltration and beneficial use of water; and (3) decreasing the rate of process water discharged to sanitation districts. The Program will promote the region-wide utilization of non-structural Best Management Practices, appropriate to non-point-source pollutants and land use types, to prevent potential pollutants from entering municipal storm drain systems and aquatic ecosystems during both wet and dry weather.

- **Uses LID or other resource-efficient land use**

  Low Impact Development: Program will integrate water management with land use planning by going beyond local landscape ordinance(s) (AB1881) requirements to increase water use efficiency on existing landscapes through the decrease of non-beneficial landscape water use and the decrease of dry weather runoff resulting in pollution. Program will promote the utilization of Bs, appropriate to land use type, to eliminate nuisance runoff and reduce the discharge of pollutants from municipal storm drain systems into downstream aquatic ecosystems during both wet and dry weather. Program contributes to the following: 1) reduce the rate of dry weather runoff resulting in pollution prevention from existing landscapes; 2) encourage the use of low impact development practices in the landscape to help preserve sustainability and watershed health; and 3) increase water use efficiency by using landscape water beneficially, and not wastefully, thereby resulting in sustainable water resource management.

- **Positive Impacts to natural hydrology and alluvial fans**

  Impacts to Natural Hydrology: MWDOC's Residential Runoff Reduction Study (July 2004) and SmarTimer and Edgescape Evaluation Study(October 2008) have each demonstrated water quality benefits that significantly reduce both dry-weather runoff volume and non-point source pollutants entering local creeks, ultimately leading to the Pacific Ocean. The Residential Runoff Reduction Study quantified a 50% reduction in dry-weather runoff and non-point source pollutants with a 10% penetration of landscape improvements yielding sediment removal rand water quality improvement. Follow-up studies, with five-years post installation will verify that the water savings persistence.

- **Indirect Benefits**

  Implementation of the Program will result in an indirect benefit of increased carryover storage. Water saved through implementation of this Program could be kept in storage for use in the future.

  Reduced Likelihood of Water Shortage Impacts: MWDOC relies upon Metropolitan for imported water supplies. Metropolitan's Integrated Water Resources Plan (IRP) ensures reliability through adverse hydrologic conditions, such as prolonged droughts, but it does not address the potential threat of shortage due to catastrophic system failure or unprecedented climate impacts. Non-climate-related events like earthquakes, floods, or terrorist activities could lead to serious disruption of imported supplies from the Colorado River Aqueduct or State Water Project. In a presentation made to the California Bay-Delta Authority in October of 2004, Dr. Jeffrey Mount of the University of California, Davis reported a two-in-three chance of a catastrophic failure in the Bay-Delta system due to flood or earthquake by the year 2050. This type of failure would completely cut off the supply of water Metropolitan receives from Northern California. Under these circumstances, Metropolitan's Eastside Reservoir Project Final Environmental Impact Report (EIR) suggests that most regional imported demands could be met through in-region storage projects. This EIR assumes a 25% reduction in retail demands during the facility outage. While the EIR shows that Metropolitan is planning for extraordinary, non-hydrologic events, it does not ensure 100% reliability if they occur. The assumed reduction in demands during the facility outage represents a shortage to Metropolitan's customers.

  The Program provides benefits under these conditions in multiple ways. The Program helps reduce Orange County's need for imported supplies from Metropolitan. These lower demands will help ease the strain on supplies if a catastrophic event impacts Metropolitan's delivery system. The reduced demands will allow stored water supplies to last longer through the emergency and forestall the threat of greater impacts. It is difficult to quantify the monetary benefits of avoiding water shortage. From a qualitative perspective, the benefits come in the form of reduced risk of business disruption or residential impact from water shortage in time of a crisis caused by catastrophe or unforeseen hydrologic events.

- **Additional Benefits**

  Promoting Stewardship: A benefit to the business will be lower operating costs, thereby giving them a competitive edge, as well as this benefit enticing participation; they can tout improved sustainability.

  Reduced Tier 2 Supply Costs: MWDOC is allowed to buy approximately 280,592 acre-feet per year at Metropolitan's lower Tier 1 supply rate of $847/AF. Any purchases in excess of 280,592 acre-feet are charged at a Tier 2 cost, which is approximately $150/AF more than the Tier 1 supply rate. This incentive encourages agencies to stay within their Tier 1 annual limit. Factors impacting MWDOC's need to purchase higher-cost Tier 2 supplies from Metropolitan include weather, groundwater and other local supplies, and the economy.

  Build on existing water use efficiency Projects: MWDOC currently implements a variety of regional commercial, industrial, and institutional water use efficiency programs. This CII/LL Performance-Based Program will build on existing programs that have included the Water Smart Industrial Water Program, Water Smart Hotel Program, SoCal Water$mart Program (f.k.a. Save Water Save A Buck), and various landscape programs. These programs are complementary and work collaboratively to achieve maximum landscape water conservation results.

III. Annual Physical Benefits

Table 9 – Annual Project Physical Benefits Project Name: CII Performance-Based Water Use Efficiency Program Type of Benefit Claimed: Water Savings (primary benefit) Measure of Benefit Claimed (Name of Units): Acre-Feet per Year (AFY) Additional Information About this Measure: Individual project lives vary from 10 to 20 years.			
(a)	**(b)**	**(c)**	**(d)**
	Physical Benefits		
Year	**Without Project**	**With Project**	**Change Resulting from Project (b) – (c)**
2014	0	450	450
2015	0	450	450
2016	0	450	450
2017	0	450	450
2018	0	450	450
2019	0	450	450
2020	0	450	450
2021	0	450	450
2022	0	450	450
2023	0	450	450
2024	0	170	170
2025	0	170	170
2026	0	170	170
2027	0	170	170
2028	0	170	170
2029	0	170	170
2030	0	170	170
2031	0	170	170
2032	0	170	170
2033	0	170	170
Comments: The project is composed of three parts: Industrial process improvements are expected to provide 75 AFY with a 10 year life; Commercial and Institutional devise replacements will provide 170 AFY with a 20 year life; and the Landscape projects will contribute to 205 AFY savings with a 10 year life.			

Project Name: CII Performance-Based Water Use Efficiency Program
Type of Benefit Claimed: Reduces Energy Cost
Measure of Benefit Claimed (Name of Units): Kilo-watt Hour per year (kWh/yr)
Additional Information About this Measure: Benefit accrued to Metropolitan as a State Water Project contractor.

(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (b) – (c)
2014	0	847620	847620
2015	0	847620	847620
2016	0	847620	847620
2017	0	847620	847620
2018	0	847620	847620
2019	0	847620	847620
2020	0	847620	847620
2021	0	847620	847620
2022	0	847620	847620
2023	0	847620	847620
2024	0	351756	351756
2025	0	351756	351756
2026	0	351756	351756
2027	0	351756	351756
2028	0	351756	351756
2029	0	351756	351756
2030	0	351756	351756
2031	0	351756	351756
2032	0	351756	351756
2033	0	351756	351756

Comments: The project is composed of three parts: Industrial process improvements are expected to provide benefits with a 10 year life; Commercial and Institutional devise replacements will provide benefits with a 20 year life; and the Landscape projects will contribute to benefits with a 10 year life.

Project Name: CII Performance-Based Water Use Efficiency Program **Type of Benefit Claimed: Reduces Energy Cost** **Measure of Benefit Claimed (Name of Units):Metric tons of CO_2** **Additional Information About this Measure: Benefit accrued to Metropolitan as a State Water Project contractor.**			
(a)	**(b)**	**(c)**	**(d)**
	Physical Benefits		
Year	**Without Project**	**With Project**	**Change Resulting from Project (b) – (c)**
2014	0	585	585
2015	0	585	585
2016	0	585	585
2017	0	585	585
2018	0	585	585
2019	0	585	585
2020	0	585	585
2021	0	585	585
2022	0	585	585
2023	0	585	585
2024	0	243	243
2025	0	243	243
2026	0	243	243
2027	0	243	243
2028	0	243	243
2029	0	243	243
2030	0	243	243
2031	0	243	243
2032	0	243	243
2033	0	243	243
Comments: The project is composed of three parts: Industrial process improvements are expected to provide benefits with a 10 year life; Commercial and Institutional devise replacements will provide benefits with a 20 year life; and the Landscape projects will contribute to benefits with a 10 year life.			

Project Name: CII Performance-Based Water Use Efficiency Program **Type of Benefit Claimed: Non-Point Source Reduction** **Measure of Benefit Claimed (Name of Units): Million gallons per year** **Additional Information About this Measure: Water Treated**			
(a)	**(b)**	**(c)**	**(d)**
	Physical Benefits		
Year	**Without Project**	**With Project**	**Change Resulting from Project (b) – (c)**
2014	0	73	73
2015	0	73	73
2016	0	73	73
2017	0	73	73
2018	0	73	73
2019	0	73	73
2020	0	73	73
2021	0	73	73
2022	0	73	73
2023	0	73	73
Comments: Only the Landscape projects will contribute to this benefit with a 10 year life.			

Project Q: Peters Canyon Channel Water Capture and Reuse Pipeline (City of Irvine)

Physical Project Benefits Narrative

The Peters Canyon Wash Water Capture and Reuse Pipeline is designed to capture and permanently divert discharges of nitrate and selenium-laden groundwater at four locations. Flows will be transported through an underground pipeline to the Orange County Sanitation District (OCSD) Fountain Valley facility via the Main Street Trunk Sewer for treatment and subsequent discharge to the Orange County Water District (OCWD) Groundwater Replenishment System (GWRS). The flows will ultimately be reused through infiltration in either injection wells to create a seawater intrusion barrier or to OCWD's percolation basins in Anaheim.

The Project pipeline will begin at Walnut Avenue where discharges from the Caltrans 261 Tollway GWTF will be collected. The proposed alignment will run along the east side of Peters Canyon Channel approximately 10,000 feet from Walnut Avenue to Barranca Parkway. In this reach low flows from Como Channel, Edinger Circular Drain, and Valencia Drain will be added to the pipeline. At Barranca Parkway, the pipeline will cross the channel and travel along the its west side past the confluence with San Diego Creek approximately 6,000 feet to the Orange County Sanitation District's (OCSD) Main Street sewer. At the OCSD treatment facility, discharges will receive secondary treatment and be transferred to the co-located OCWD Groundwater Replenishment System (GWRS). At the GWRS flows will be purified using a three-step advanced treatment process consisting of micro-filtration, reverse osmosis and ultraviolet light with hydrogen peroxide and either injected through wells to create a seawater intrusion barrier or to OCWD's percolation basins in Anaheim.

Total Maximum Daily Loads (TMDLs) for both selenium and nitrogen are in place for the Newport Bay watershed including Peters Canyon Channel. Historically, a natural occurring geologic marsh known as Cienega de las Ranas or Swamp of the Frogs covered the project area. During geologic time naturally occurring selenium from the foothills was collected and immobilized in this marshy lowland, which stretched from Upper Newport Bay over 8 miles upstream to Red Hill in Tustin. Today, this area is no longer a marsh, but selenium-lade groundwater exfiltrates into surface water drainages and stormdrains and may create a biological risk for birds and fish throughout the watershed. Nitrate levels are elevated in groundwater throughout the area due to historical agricultural application.

The physical benefits of the Project will be diverted nitrate and selenium loads (pounds/year) captured prior to discharge into Peters Canyon Channel; water diverted for beneficial reuse through infiltration in either injection wells to create a seawater intrusion barrier or OCWD's percolation basins in Anaheim (acre feet/year), and reductions in greenhouse gas emissions due to reductions imported water (metric tons of CO_2/year). The diverted nitrate and selenium loads and gallons of water diverted for beneficial reuse have been estimated from *Lower Peters Canyon Wash Selenium Mass Balance Study, Irvine Ranch Water District Peters Canyon Channel Water Capture and Reuse Pipeline Concept Feasibility Study* Section III Flow Rates and Water Quality, and data from the California Department of Transportation Groundwater Treatment Facility. The loadings included in table 9 are conservative estimates based on the data from the above referenced studies and taking into account the anticipated need to shut the proposed diversions down during wet weather. A conservative estimate of 330 days of operation per year was used in the loading calculations which will result in values slightly different from the referenced studies. Reductions in greenhouse gas emissions are estimated from the anticipated reduced need for imported water due to groundwater replenishment.

No levels of future physical benefits without the project are anticipated. No other projects that would result in reductions of nitrate and selenium loading are known. The estimated physical benefits of nitrate and selenium load reduction directly depend on the construction of the proposed project. The actual amount of diverted water ultimately used for groundwater replenishment depends on continuing agreements between Orange County Sanitation District and Orange County Water District, and the continued successful operation of the Groundwater Replenishment System. No significant potential adverse physical effects are anticipated. The diversion of the proposed flows is not anticipated to negatively affect creek habitat or function in Peters Canyon Channel.

Table 9 – Annual Project Physical Benefits			
Project Name: Peters Canyon Channel Water Capture and Reuse Pipeline Type of Benefit Claimed: Nitrate load diverted Measure of Benefit Claimed (Name of Units): Pounds per year Additional Information About this Measure: Load estimated assuming 330 days of operation per year based on average water quality concentrations			
(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (b) – (c)
2012	0	0	0
2013	0	0	0
2014	0	0	0
2015-2034	0	250606	250606 lbs/year Nitrate diverted
Last Year of Project Life	0	250606	250606 lbs/year Nitrate diverted
Comments: Project anticipated to be operational in 2015			

Table 9 – Annual Project Physical Benefits			
Project Name: Peters Canyon Channel Water Capture and Reuse Pipeline Type of Benefit Claimed: Selenium load diverted Measure of Benefit Claimed (Name of Units): Pounds per year Additional Information About this Measure: Load estimated assuming 330 days of operation per year based on average water quality concentrations			
(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (b) – (c)
2012	0	0	0
2013	0	0	0
2014	0	0	0
2015-2034	0	229	229 lbs/year Selenium diverted
Last Year of Project Life	0	229	229 lbs/year Selenium diverted
Comments: Project anticipated to be operational in 2015			

Table 9 – Annual Project Physical Benefits			
Project Name: Peters Canyon Channel Water Capture and Reuse Pipeline Type of Benefit Claimed: Water diverted for beneficial reuse Measure of Benefit Claimed (Name of Units): acre feet per year Additional Information About this Measure: Estimate assumes 330 days of operation per year			
(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (b) – (c)
2012	0	0	
2013	0	0	
2014	0	0	
2015-2034	0	1,774	1,774 acre feet/year diverted for beneficial reuse
Last Year of Project Life	0	1,774	1,774 acre feet/year diverted for beneficial reuse
Comments: Project anticipated to be operational in 2015			

Table 9 – Annual Project Physical Benefits			
Project Name: Peters Canyon Channel Water Capture and Reuse Pipeline Type of Benefit Claimed: Reduction of greenhouse gas emissions Measure of Benefit Claimed (Name of Units): metric tons CO2e/year Additional Information About this Measure: Estimated from water management activities vs baseline			
(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (b) – (c)
2012	0	0	
2013	0	0	
2014	0	0	
2015-2034	0	1,350	1,350 metric tons CO_2/year reduced
Last Year of Project Life	0	1,350	1,350 metric tons CO2/year reduced
Comments: Project anticipated to be operational in 2015			

Project R: Soboba Band of Luiseño Indians Wastewater Project (Soboba Tribe)

The Soboba Wastewater Treatment Facility Development Plan does not claim any physical benefits as it is only a feasibility study to determine, if, how, and when the Tribe can construct a wastewater management facility to serve the tribal community. The physical benefits of such a facility will become clear after the feasibility study has been completed. Thus, at this juncture, Soboba has nothing to report in regards to benefits claimed, without-project conditions, methods used to estimate physical benefits, actions used to obtain physical benefits, uncertainty of benefits, or any description of potential adverse effects.

Table 9 – Annual Project Physical Benefits

Project Name: Soboba Wastewater Treatment Facility Development Plan

Type of Benefit Claimed: Determine physical benefits if wastewater facility is constructed

Measure of Benefit Claimed (Name of Units):Non-applicable to the Development Plan since it is only a feasibilty study

Additional Information About this Measure:N/A

(a)	(b)	(c)	(d)
	Physical Benefits		
Year	Without Project	With Project	Change Resulting from Project (b) – (c)
2012	N/A	N/A	N/A
2013	N/A	N/A	N/A
2014	N/A	N/A	N/A
Etc.	N/A	N/A	N/A
Last Year of Project Life	N/A	N/A	N/A

Comments: The funds requested are only for a feasibility study of a wastewater treatment facility. This feasibility study will give Soboba the necessary information to make annual projected physical benefits of the potential treatment facility.

Project S: Recycled Water Project Phase I (Arlington-Central Avenue Pipeline) (Eastern Municipal Water District)

The physical benefits being claimed for this project are as follows:

- Recycled water use at 6,100 AFY
- Greenhouse gas reduction at 6,060 metric tons CO_2e/yr
- Water use efficiency at 6,100 AFY
- Water Supply Reliability
- Groundwater recharge and management (Neighboring agencies)

Historically Riverside has relied on local groundwater basins to meet its water supply needs. However, prolonged drought and depleting groundwater supplies coupled with increased water demands has put a severe strain on the City's water supply. The demand for consumable water, a diminishing natural resource throughout California, is expected to increase in the Riverside area by nearly 20% by the year 2020. Moreover, water demands will increase considerably from 84,000 AFY to 110,000 AFY by year 2035. Without phase I of this recycled water project the City is expected to have a 26,000 AFY short fall; of which will need to be supplemented with import water supplies.

This project will distribute recycled water produced at the City's Regional Water Quality Control Plant to irrigate landscape within selected areas throughout the City. In addition, recycled water will be supplied to neighboring agencies for landscape irrigation and groundwater recharge projects. This project is similar to all other recycled water projects in this proposal as they all reduce demand on import water supplies. In addition to reducing the City's demand for import water this project will provide recycled water to Western Municipal Water District and neighboring cities, which will in turn reduce their demand on energy intensive import water.

The physical benefits of this project were estimated by the development of the City's Recycled Water Facilities Plan. The plan evaluated the amount of recycled water that could be used by the City for beneficial use and the amount of water that could be distributed to neighboring agencies. At build out, the City's recycled water system is estimated to reuse approximately 20,000 AFY of recycled water, nearly meeting the City's 2035 estimated water demands.

The City will be constructing a new recycled water pipeline and associated infrastructure which will extend from its wastewater treatment plant in the western portion of the city and terminate at the northeastern city boundary. This pipeline will serve as the main artery to distribute recycled water throughout the city and to neighboring agencies. Factors that lead to uncertainty of benefits of this project are consumer demand behavior. For example, the City's conservation programs may reduce consumption, thus reducing the amount of recycled water used and the amount of recycled water generated at the wastewater treatment plant. There are no potential adverse physical effects of this project.

Project T: Wilson III Basins Project and Wilson Basins/Spreading Grounds (City of Yucaipa)

Summary of Physical Benefits:

The proposed Project will provide the following physical benefits:

a. **Flooding Protection**
b. **Enhanced Water Supply**
c. **Air Quality Improvement through Green House Gas Emissions Reduction**
d. **Preserve Open Space and Increase Recreation and Environmental Education Opportunities**
e. **Water Quality Improvement**

Description of Physical Benefits:

The expected Project physical benefits are more specifically described in the following section. Refer to Table 9 for quantified project benefit details.

I. Flooding Protection

Historically, flooding has been experienced in areas southeast of the Wilson Basin along the Wilson Creek during various storm events. The flooded area is generally bounded by Yucaipa Boulevard on the north, Oak Glen Road on the east, 15th Street on the west, and Interstate 10 on the south. Flooding in this area is well documented by FEMA Flood Insurance Mapping. The Wilson Creek will convey 5,070 cubic feet per second of runoff from the 3,021-acre tributary area. Using existing topography, existing hydrology, FEMA flood mapping, creek cross sections, and City maintenance records the flood inundation area was determined to be approximately 562 acres, as shown on Attachment 7-1. The referenced exhibit highlights areas downstream of the Project experiencing flood inundation up to 1.5 feet. The Project will provide 100-year flood protection to this inundation area. Areas where flood protection is enhanced includes a school, churches, single family and multi-family residential developments, and major and minor streets. See Table 9 for flood protection provided during various storm events. Additionally, there are no uncertainties related to the project benefits and the Project will not create any adverse effects.

II. Enhance Water Supply

The City of Yucaipa is dependent on costly imported water supplies to meet demand. Approximately 28% of demand is met by import water in the City. The Project creates new groundwater yield through stormwater capture and recharge. Recharged stormwater will increase groundwater supplies and decrease the dependence on supplemental water supplies. The Project will capture and recharge approximately 1,000 acre-feet of stormwater during an average rainfall year.

The Project intends to construct the necessary improvements to enhance regional groundwater recharge. Annual storm runoff for the Project's 3,021 acre tributary area is estimating using the historic annual rainfall of 14 inches and applying a loss rate of 43% to account for evapotranspiration, based on Chino Basin Watermaster's 2010 Recharge Master Plan, see attached table. Approximately 2,009 acre-feet of storm water is expected to reach the Wilson III Basin annually for recharge. The basin recharge capacity of 200 acre-feet and the enhanced Wilson Spreading Basin recharge capacity of 50 acre-feet will not infiltrate the entire 2,009 acre-feet per year, however, it is estimated that 1,250 acre-feet will be recharged during average rainfall years. Without the project, no new yield will be captured with projected amounts as presented above. Beneficiaries are all water producers from the Yucaipa Basin. Annual Project physical benefits for the life of the Project are highlighted in Table 9.

III. Air Quality Improvements through Green House Gas Emissions Reduction

The Project provides for reduction in greenhouse gas emissions through development of local water supplies that eliminates the need for imported water to be delivered from the Bay-Delta of the same quantity. The Project conserves local water reducing dependence on imported water in the amount of approximately 1,250 acre-feet per year. By avoiding delivery through the state's system, a significant reduction in greenhouse gas emissions is attained. According to the California Air Resource Control Board, the energy required to deliver State Water Project water to Southern California is 3,519 kW/hrs per acre-foot. Using the recommended conversion unit amount of 0.0004 kWh to tons of CO2, green house gas emissions reduction of approximately 1,500 tons CO_2 per year for the project will be achieved. Three different sources and conversion factors were used to ensure accuracy, as shown on the attached table. Annual Project physical benefits for the life of the Project are highlighted in Table 9.

IV. Preserve Open Space and Increase Recreation Opportunities

In 2012, City Council awarded a design contract to RBF for the Wilson III Basin Improvements Project, which included an alternatives analysis to evaluate and determine which basin and channel design would be the most feasible, appropriate and cost effective. In January 2013, City Council reviewed the analysis and determined the preferred design as Alternative 6. Alternative 6 provided the required flood control volume while preserving open space and allowing any basin export material to remain within the proposed 100-acre site in an effort to reduce costs and environmental impacts associated with hauling the material off-site and properly disposing of the material. Alternative 6 will provide a recreational asset to the community by providing 25 acres of new recreational use that will connecting to existing multi-purpose trails. The recreational design will include approximately 5,000 feet of multi-purpose trails, permanent water pond with naturalized streambed, viewing and seating areas, trail markers and identification, native landscaping and habitat educational signage.

V. Water Quality Improvement

The Project will reduce urban runoff discharge pollutants including sediment, nutrients, trash, metals, bacteria and virus, oil and grease, organics, and pesticides. Impervious surfaces associated with roadways and developments increase the rate and volume of stormwater runoff that may increase downstream erosion potential, sediment transport, and associated potential water quality impairment. Urban runoff flows to the Santa Ana River which is on the Santa Ana Regional Water Quality Control Board 303(d) List of Water Quality Limited Segments. Pollutants that settle on the impervious pavements and rooftops are washed untreated into nearby stream channels, increasing pollution in receiving water bodies. Approximately 2,009 acre-feet of stormwater runoff, including sediments and pollutants, will flow through the basins per year. Basin routing and recharge efforts will use the natural filtration to remove pollutants in stormwater runoff and reduce sediment transport.

Table 9 – Annual Project Physical Benefits			
Project Name: Wilson III Basins/Spreading Grounds			
Type of Benefit Claimed: Flood Damage Reduction			
Measure of Benefit Claimed (Name of Units): See Below.			
Additional Information About this Measure: Project will mitigate 100-year Strom Event flooding and related damage			
Physical Benefits	**Without Project**	**With Project**	**Change Resulting from Project (b) – (c)**
100-year Flood Inudation Area (Acres)	562	0	562
Number of Structures Flooded			
Residential (Single Story)	180	0	180
Square Footage of Structures Flooded			
Industrial	73,418	0	73,418
Commercial	294,234	0	294,234
Length of Roads Inundated (miles)			
Arterial Roads	0.9	0.0	0.9
Major Roads	1.9	0.0	1.9
Minor Roads	3.9	0.0	3.9
Duration of Flooding (Days)[1.)]	1	0	1
Comments: **1.) Flood inundation areas, further described in Attachment 7, are not part of a low-lying area or a basin, as such, flood water are expected to drain in 1 day.**			

Type of Benefit Claimed: Stormwater Recharge			
Measure of Benefit Claimed (Name of Units): Acre-Feet per Year			
Additional Information About this Measure: Stormwater inflitrated by Project			
(a)	**(b)**	**(c)**	**(d)**
	Physical Benefits		
Year	**Without Project**	**With Project**	**Change Resulting from Project (b) – (c)**
2012	0	1,000	1,000
2013	0	1,000	1,000
2014	0	1,000	1,000
2015	0	1,000	1,000
2016	0	1,000	1,000
2017	0	1,000	1,000
2018	0	1,000	1,000
2019	0	1,000	1,000

2020	0	1,000	1,000
2021	0	1,000	1,000
2022	0	1,000	1,000
2023	0	1,000	1,000
2024	0	1,000	1,000
2025	0	1,000	1,000
2026	0	1,000	1,000
2027	0	1,000	1,000
2028	0	1,000	1,000
2029	0	1,000	1,000
2030	0	1,000	1,000
2031	0	1,000	1,000
2032	0	1,000	1,000
2033	0	1,000	1,000
2034	0	1,000	1,000
2035	0	1,000	1,000
2036	0	1,000	1,000
2037	0	1,000	1,000
2038	0	1,000	1,000
2039	0	1,000	1,000
2040	0	1,000	1,000
2041	0	1,000	1,000
2042	0	1,000	1,000
2043	0	1,000	1,000
2044	0	1,000	1,000
2045	0	1,000	1,000
2046	0	1,000	1,000
2047	0	1,000	1,000
2048	0	1,000	1,000
2049	0	1,000	1,000
2050	0	1,000	1,000
2051	0	1,000	1,000
2052	0	1,000	1,000
2053	0	1,000	1,000
2054	0	1,000	1,000
2055	0	1,000	1,000
2056	0	1,000	1,000
2057	0	1,000	1,000
2058	0	1,000	1,000
2059	0	1,000	1,000
2060	0	1,000	1,000

2061	0	1,000	1,000
2062	0	1,000	1,000
2063	0	1,000	1,000
		Total for Project Life:	**52,000**
Comments:			

Type of Benefit Claimed: Avoided Green House Gas Emissions Measure of Benefit Claimed (Name of Units): Metric Tons of CO_2 per Year Additional Information About this Measure: Avoided Import Water			
(a)	**(b)**	**(c)**	**(d)**
	Physical Benefits		
Year	**Without Project**	**With Project**	**Change Resulting from Project (b) – (c)**
2012	0	1,500	1,500
2013	0	1,500	1,500
2014	0	1,500	1,500
2015	0	1,500	1,500
2016	0	1,500	1,500
2017	0	1,500	1,500
2018	0	1,500	1,500
2019	0	1,500	1,500
2020	0	1,500	1,500
2021	0	1,500	1,500
2022	0	1,500	1,500
2023	0	1,500	1,500
2024	0	1,500	1,500
2025	0	1,500	1,500
2026	0	1,500	1,500
2027	0	1,500	1,500
2028	0	1,500	1,500
2029	0	1,500	1,500
2030	0	1,500	1,500
2031	0	1,500	1,500
2032	0	1,500	1,500
2033	0	1,500	1,500
2034	0	1,500	1,500
2035	0	1,500	1,500
2036	0	1,500	1,500
2037	0	1,500	1,500
2038	0	1,500	1,500
2039	0	1,500	1,500

2040	0	1,500	1,500
2041	0	1,500	1,500
2042	0	1,500	1,500
2043	0	1,500	1,500
2044	0	1,500	1,500
2045	0	1,500	1,500
2046	0	1,500	1,500
2047	0	1,500	1,500
2048	0	1,500	1,500
2049	0	1,500	1,500
2050	0	1,500	1,500
2051	0	1,500	1,500
2052	0	1,500	1,500
2053	0	1,500	1,500
2054	0	1,500	1,500
2055	0	1,500	1,500
2056	0	1,500	1,500
2057	0	1,500	1,500
2058	0	1,500	1,500
2059	0	1,500	1,500
2060	0	1,500	1,500
2061	0	1,500	1,500
2062	0	1,500	1,500
2063	0	1,500	1,500
		Total for Project Life:	**78,000**