State of California
California Natural Resources Agency
Department of Water Resources

Model Water Efficient Landscape Ordinance

A report to the Legislature pursuant to AB 1881 Section 65595 (a) (2)

January 14, 2009

Arnold Schwarzenegger
Governor
State of California

Mike Chrisman
Secretary for Resources
California Natural
Resources Agency

Lester A. Snow
Director
Department of Water Resources

Copies of this report are available from:

State of California
Department of Water Resources
Post Office Box 942836
Sacramento, California 94236-0001

Also available on the web at:

Office of Water Use Efficiency and Transfers
http://www.owue.water.ca.gov/landscape/index.cfm

Contents

Appendices

State of California
Arnold Schwarzenegger, Governor

California Natural Resources Agency
Mike Chrisman, Secretary for Resources

Department of Water Resources
Lester A. Snow, Director

Susan Sims
Chief Deputy Director

Kasey Schimke
Assistant Director

Timothy Haines
Deputy Director

Ralph Torres
Deputy Director

David Sandino
Chief Counsel

Gerald E. Johns
Deputy Director

Mark Cowin
Deputy Director

Rick Soehren
Chief, Water Use and Efficiency Branch

This report was prepared by:
Simon Eching, Senior Land and Water Use Scientist
Kent Frame, Senior Land and Water Use Scientist

Under the Supervision of:
Manucher Alemi, Land and Water Use Program Manager

Assisted by:
Peter Brostrom, Staff Land and Water Use Scientist
Judy Colvin, Associate Land and Water Use Scientist
Julie Saare-Edmonds, Associate Land and Water Use Scientist
Gwen Huff Associate Land and Water Use Scientist
Bekele Temesgen, Staff Land and Water Use Scientist

Conservation is one of the key ways to provide water for Californians and protect and improve the Delta ecosystem. A number of efforts are already underway to expand conservation programs, but I plan to direct state agencies to develop this more aggressive plan and implement it to the extent permitted by current law. I would welcome legislation to incorporate this goal into statute.

Governor Arnold Schwarzenegger
February 2008

INTRODUCTION

This report is respectfully submitted to the Legislature pursuant to the requirements of the Assembly Bill (AB) 1881, the Water Conservation in Landscaping Act of 2006 (Laird). This act requires, among other actions, that the Department of Water Resources (DWR) report on: (1) the extent to which local agencies have complied with the existing Model Water Efficient Landscape Ordinance (Model Ordinance), pursuant to AB 325 Water Conservation in Landscaping Act of 1990 (Clute); and (2) DWR's recommendations regarding the landscape water budget component of the updated Model Ordinance, pursuant to AB 1881. These topics are presented in Chapter 1 and 2, respectively.

Landscape Irrigation Efficiency

California Water Plan Update 2005: *A Framework for Action*, states,
"To minimize the impacts of water management on California's natural environment and ensure that our state continues to have the water supplies it needs, Californians must use water efficiently to get maximum utility from existing supplies. Californians are already leaders in water use efficiency measures such as conservation and recycling. Because competition for California's limited water resources is growing we must continue these efforts and be innovative in our pursuit of efficiency. Water use efficiency will continue to be a primary way that we meet increased demand."

Approximately one-third of all urban water use is for landscape irrigation (source: California Water Plan Update 2005). Other sources put that number as high as 50 percent. Volume 2 of the Water Plan describes eight resource management strategies that have the potential to generate water supply benefits. Of those eight strategies, Urban Water Use Efficiency is the option with the highest additional annual supply potential.

A State-sponsored study conducted by the Pacific Institute in 2003 estimates that California could reduce outdoor residential water use by 25 to 40 percent through improved landscape management, hardware improvements and landscape design (*Waste Not, Want Not,* 2003). "We estimate that 25 to 40 percent of this water *(outdoor residential water use)* could quickly and economically be saved through proven approaches, a reduction of 360,000 to 580,000 AF/yr or even more."

LEGISLATIVE HISTORY

AB 325 Water Conservation in Landscaping Act 1990 (Clute)

The Water Conservation in Landscaping Act, (Assembly Bill 325, Clute) was signed into law on September 29, 1990. The 1990 Statute directed DWR to convene an advisory task force to develop and adopt a Model Ordinance by January 1, 1992. The premise was that landscape design, installation, and maintenance can and should be water efficient. Some of the provisions specified in the statute included plant selection and groupings of plants based on water needs and climatic, geological or topographical conditions, efficient irrigation systems, practices that foster long term water conservation and routine repair and maintenance of irrigation systems. DWR convened a task force, developed and adopted the Model Ordinance in June of 1992. One element of the Model Ordinance adopted by DWR was a landscape water budget. In the water budget approach, a Maximum Applied Water Allowance (MAWA) was established based on the landscape area and the climate where the landscape is located.

AB 325 required that, if by January 1, 1993 a local agency has not adopted a water efficient landscape ordinance or has not adopted findings based on climate, geological or topographical conditions, or water availability, which state that a water efficient landscape ordinance is unnecessary, the Model Ordinance adopted by DWR shall take effect and shall be enforced by the local agency and has the same force and effect as if adopted by the local agency. The local agencies who adopt an ordinance after adoption of the Model Ordinance, shall consider the provisions of the Model Ordinance.

AB 2717 California Urban Water Conservation Council: Stakeholders Taskforce 2004 (Laird)

AB 2717 was passed in 2004 and requested the California Urban Water Conservation Council (CUWCC) to convene a stakeholder task force, comprised of public and private agencies, to evaluate landscape water conservation and recommend proposals for improving the efficiency of water use in new and existing urban irrigated landscapes in California.

In a report submitted to the Governor and Legislature the Task Force adopted a comprehensive set of 43 recommendations, many of which addressed the updating of the State Model Ordinance pursuant to AB 325. Two of these recommendations are specific to this Legislative report.

Recommended action 10.1 specifies that DWR should maintain the existing Model Ordinance Water Budget approach; make it more user friendly; provide a variety of training opportunities and resources on a regional basis; and produce simple and attractive educational materials including a Model Ordinance Technical Manual and “companion brochures” for various audiences.

Recommended action 12.1 specifies DWR should reduce the ET Adjustment Factor in the Model Ordinance by 2010 for new non single-family development, based on the results of a three-year study of new and established landscapes designed to meet a variety of ET Adjustment Factors and a mix of plant factors (including the 0.5 plant factor) and other data as available. If State funds are not available, DWR should seek funding from other sources to support the study and if the study is not funded, DWR should proceed based on best available data. Furthermore, DWR is to review the ETAF every 10 years for further reductions. Additionally, the Task Force's Irrigation Work Group made a specific recommendation to reduce ETAF to 0.70, from its current value of 0.80, based on an expected increase in irrigation efficiency from 62.5 percent to 71 percent. To guide the study, DWR convened a stakeholder advisory group with broad representation that included the landscape industry, environmental groups, water suppliers, the building industry, universities and other parties as appropriate.

AB 1881 Water Conservation in Landscaping Act 2006 (Laird)

The Water Conservation in Landscaping Act of 2006 (AB 1881) enacts many, but not all of the Task Force recommendations reported to the Governor and Legislature.
AB 1881 requires DWR, not later than January 1, 2009, by regulation, to update the Model Ordinance in accordance with specified requirements, reflecting the provisions of AB 2717. AB 1881 requires local agencies, not later January 1, 2010, to adopt the updated Model Ordinance or equivalent or it will be automatically adopted by statute. Also, the AB 1881 requires the California Energy Commission, in consultation with DWR, to adopt, by regulation, performance standards and labeling requirements for landscape irrigation equipment, including irrigation controllers, moisture sensors, emission devices, and valves to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy or water.

The Statutes of 2006, Section 65595, directed DWR to maintain the water budget component in the Model Ordinance for determining landscape water use. The Statutes directed DWR to submit a report to the Legislature its recommendation for the water budget component of the updated Model Ordinance and on the extent to which local agencies have complied with the Model Ordinance adopted pursuant to Chapter 1145 of the Statutes of 1990. DWR has developed a recommendation for the water budget component of the Model Ordinance and conducted a survey of local agencies to determine the local agencies' compliance with AB 325. The following sections of this report responds to the Legislature's requirement of DWR.

Chapter 1- Status of Compliance with the Model Water Efficient Landscape Ordinance Adopted Pursuant to Chapter 1145 of the Statutes of 1990

Survey Construction and Methodology:

DWR mailed and emailed surveys to 548 addresses including all city and county land use planning agencies and water purveyors in California. Since, in some locations the local water provider is implementing a landscape ordinance, DWR included water suppliers and municipal water or public works departments in its survey. To make the survey process as simple as possible and encourage greater participation, a web-based survey form was developed. However, hard copies of the survey form were also sent by mail to the 548 addresses. One hundred and ninety six returned the completed surveys either through the website or as hard copies mailed back to DWR. One hundred and ninety six surveys constitute a return rate of 36 percent.

The survey results are presented in Appendix A. The summary of the survey findings are as follows:

Of the 196 who responded, 169 adopted an ordinance, adopted findings, or took other actions. 96 agencies responded that they were in compliance with AB 325 by adopting the Model Ordinance (14), adopting a local ordinance (74), or adopting legal findings (8). Seventy three agencies attempted to ensure some measure of water use efficiency by developing landscape guidelines (47), adopting a resolution (4), or other means (22). While technically not in full compliance with AB 325, these agencies have shown some good faith effort by attempting to guide landscape development towards resource efficiency. Without knowing the full nature and enforcement means of their various guidelines, it can be assumed some of these agencies may in fact be enforcing guidelines that have the effect of an ordinance in action. Conversely, the eight agencies reported compliance with AB 325, by producing legal findings that an Ordinance was not necessary, may be doing little to promote water use efficiency in landscape development. The remaining 27 are agencies reporting that they were not responsible for implementing a water efficient landscape ordinance.

Of those agencies that do comply with AB 325 requirements most are able to do plan checks but few are able to conduct field inspections and fewer still are able conduct follow up monitoring. One innovative approach a city is using requires the project applicant to provide financial security for a contracted period of two years when applying for a permit. The Planning Division reviews for compliance with the Water Efficient Landscape Design, Development, and Maintenance guidelines at plan check. At the end of the two years, if a city planner determines that the project's landscape elements and irrigation system were maintained in good condition, the city will release the financial security.

Some local agencies are able to do both a plan check and water use monitoring. This is most easily accomplished when a local agency is both the land use agency and a water provider.

Other strategies used by agencies include:

- random inspections to check compliance of the landscape site
- stormwater and engineering requirements
- responses to water waste complaints
- tiered rate structures to encourage efficient water use

This survey shows that although there is some compliance with the requirements of AB 325, a majority of the agencies are in noncompliance. All of the provisions required in AB 325, however, are used by some of the agencies. The most common locally used provision (establish conditions prohibiting use of certain plant species) is expressly prohibited in AB 325 [section 65597 (a)] and AB 1881 for inclusion in the updated Model Ordinance. Nonetheless, local agencies have found plant lists to be effective for several reasons. In some regions, prohibiting certain fire prone plants is an effective measure in a fire prevention program. Likewise, plant lists that prohibit plants with invasive tendencies can aid local agencies by preventing the establishment of horticultural plants into sensitive habitats. Lists of approved plants also make plan checking procedures easier for local agency staff. By limiting the plant choices to a short list, effectively eliminates the question of whether the plants specified in a landscape design are water conserving or appropriate for the local climate. However, plant lists can limit design choices and bio-diversity.

The most widely used provisions are:

- Plant lists
- Hydrozones
- Soil stabilization and erosion control
- Mulching
- Recycled water
- Rain Sensors
- Educational materials

The least widely used provisions are:

- Regional differences, fire prevention
- Water budget
- Irrigation based on CIMIS
- Exemption for historical sites and cemeteries
- Pressure regulation
- Stormwater reuse and retention
- Routine maintenance and irrigation audits

A report by Western Policy Research in 2001 found deficiencies in implementing the AB 325 Model Ordinance. These include a lack of education about the ordinance, maintenance contractors are described as frequently inaccurate in their scheduling of irrigation, and that "maintenance" is the weakest link in the design, installation, and maintenance segments of landscape development. Routine irrigation maintenance and audits had an affirmative response rate of 15 percent in this survey, confirming Western

Policy Research's assertion that maintenance is the weakest link in the design, installation, and maintenance aspects of a landscape.

Local agencies reported that they experienced problems in implementing water efficient landscape ordinances. The problems reported include:

- Some responders cited problems with maintaining billing and water use databases for a long enough period to track water use and long term compliance.
- Designers often design plans without consulting the city about their requirements.
- Landscape architects and landscape contractors lack knowledge and experience to develop water efficient landscapes.
- Developers often circumvent the permit process.
- Developers often change landscapes after sign-off to one that would not meet a water budget.
- Plan check fees don't recover all costs.
- Difficulties with water budget calculations.
- Planning departments often rely on consulting landscape architects to review plans resulting in additional costs to local agencies.
- Difficulty creating an ordinance that will work in large counties with varied environmental conditions (deserts, mountains, etc.).
- Achieving consistency between various municipal code sections e.g. Building Code vs. Water Code.
- Planning departments can't get water use data from water suppliers.
- Some cities lack interdepartmental communication between planning and water units.
- Need for better water waste ordinances to enforce runoff and overspray prohibitions.
- One city anticipates some problems with integrating graywater use and artificial turf into existing landscape codes.
- Some respond that they have some interagency coordination, but no follow-up.
- The most common difficulty faced by local agencies is lack of staff and monetary resources.
    - Lack of knowledgeable and experienced staff for plan check of irrigation design and scheduling, plants choices, etc.
    - Lack of code enforcement officers and inspectors
    - Lack of funding for audits and auditors

In contrast, 26 responders cited few or no problems implementing an ordinance and reported the following successful actions:

- Some agencies have good interagency and intradepartmental communication and coordination.
- Some agencies are able to accomplish inter departmental review of project plans: e.g.-planning, parks, and water departments may all review landscape plans for compliance in different subject areas.

- Some cite success increased after a public education program. DWR did perform some outreach activities including presentations from 1991-1993. In addition to presentations, Cal Poly added a component to the landscape irrigation auditor training to cover water budgets and other items associated with the Model Ordinance. Hundreds of calls from planning agencies and water districts the first year or so were fielded. There was, however, no additional funding or staff support added to the DWR budget to cover any additional actions.
- Some agencies have landscape architects on staff to certify the technical aspect of landscape plans.
- Some agencies have had an ordinance in place for more than 12 years.
- Some agencies cited that the implementation of the ordinance was achievable without undue hardship.

The results of both this survey and the Western Policy Research study indicate that although there is some compliance with the requirements of AB 325, it appears that noncompliance is more common on the part of local agencies. The results of both this survey and the Western Policy Research study indicate that local agencies should concentrate efforts to improve their abilities to inspect and monitor water use and maintenance practices. Communication within agencies and with the public regarding landscape requirements is also an important consideration.

After adoption of the Model Ordinance, DWR will be partnering with other State and local agencies to begin a series of workshops, training sessions, and providing a guide book to assist local agencies in preparing and implementing the model ordinance in compliance with AB 1881. DWR will also encourage academic and professional organizations to develop educational and certification programs for landscape professionals.

Chapter 2- DWR Recommendation for the Landscape Water Budget Component of the Updated Model Water Efficient Landscape Ordinance Pursuant to AB 1881

Water budgeting is a simple way to determine water used by plants. It is very much like balancing a checkbook where water applied through precipitation or irrigation is a deposit and water withdrawn by plant water use and evaporation is debited. By tracking water use it is easy to efficiently manage water applied to the landscape and ensures that excessive water is not applied.

This water budget component of the existing Model Water Efficient Landscape Ordinance (AB 325) also known as the Maximum Applied Water Allowance (MAWA), is based on the landscape area (LA), reference evapotranspiration (ETo*) and the Evapotranspiration Adjustment Factor (ETAF**).

$$MAWA = 0.8 \times ETo \times LA \times 0.62$$

Where:

MAWA = Maximum Applied Water Allowance (gallons per year)

- *ETo is Reference Evapotranspiration (inches per year) - the combined amount of water evaporated at the soil surface and transpired through standardized plant material.
- *0.8 is the Evapotranspiration Adjustment Factor (ETAF). When applied to ETo, ETAF adjusts the amount of water needed to be applied, accounting for plant needs and irrigation efficiency. The value used for ETAF in the existing model ordinance is 0.8.
- LA is the landscape area (square feet).
- 0.62 is a conversion factor that converts the amount of water to gallons per year.

The ETAF for the existing model ordinance is based on a plant factor of 0.5 and irrigation efficiency of 0.625 and therefore the ETAF value is 0.8 (=0.5/0.625). The existing model ordinance established the plant factor (PF) of 0.5 which is determined by having a landscape with a plant mix of 1/3 high water using plants, 1/3 medium water using plants, and 1/3 low water using plants with a crop coefficient of 0.8, 0.5, and 0.2 respectively and therefore the average PF is 0.5 (= (0.8 + 0.5 + 0.2) / 3). The existing model ordinance also established an irrigation efficiency of 0.625, therefore the ETAF value of 0.8 (=0.5/0.625). It is important to note that the values of the plant factor and irrigation efficiency were not based on a scientific study conducted by DWR, but based on the best available information at the time including studies conducted by various universities and consultants, best available technological and management practices and through discussions among stakeholders.

To update the water budget component of the model ordinance, DWR considered the following alternatives:

Alternative 1 - Maintain the plant factor value of 0.5 and irrigation efficiency of 0.625 and adopt the updated model ordinance with an ETAF of 0.8. This alternative was rejected because DWR was required by AB 1881 to update the water budget component. Furthermore, the Landscape Task Force Report recommended an ETAF value of less than 0.8 and for DWR to conduct a study and if one could not be conducted to make a recommendation based on existing data and information.

Alternative 2 - Maintain the plant factor of 0.5 and irrigation efficiency of 0.625, and ETAF of 0.8 and adopt the ordinance, but conduct a long-term field study to update the ETAF value by modifying the plant factor and irrigation efficiency. Alternative 2 was rejected because there is sufficient technical evidence that a landscape irrigation efficiency higher than 0.625 is achievable. Furthermore, if DWR adopts the updated model ordinance with ETAF of 0.8 and completes the study to update the ETAF, it would significantly delay the water savings that can be achieved through higher irrigation efficiency presently achievable.

Alternative 3 - Lower the ETAF based on a plant factor of less than 0.5 and an irrigation efficiency higher than 0.625. Some local agencies have adopted a plant factor that is lower than 0.5. Although, we have sufficient information to demonstrate that irrigation efficiency higher than 0.625 is achievable, Alternative 3 was rejected because DWR wanted to look into lowering the ETAF while maintaining the 0.5 plant factor.

Alternative 4 - Lower the ETAF based on an irrigation efficiency higher than 0.625 and maintain the plant factor at 0.5. DWR recommends Alternative 4. DWR has conducted literature and other data review and, using this published information, calculated the distribution uniformity and irrigation efficiency and recommends an irrigation efficiency of 0.71 (see section 6- DWR Recommendation for the ETAF Value of the Water Budget). DWR has initiated a contract to study the effects on landscape by lowering the ETAF value and to look into various plant factors and their water saving potential. Unfortunately this contract has been delayed for various reasons so the study will not be completed in time for this updated Model Ordinance. Alternative 4 will allow DWR to update the water budget component based on achievable improvements in irrigation efficiency and adopt the updated Model Ordinance as required by law by 2009. This approach allows DWR to consider continued advances in improving landscape irrigation and reducing landscape water demand while studying the effects that further lowering of the plant factor will have on landscapes.

Alternative 4 is the selected option based upon existing research, studies, manufacturer specifications, industry landscape certification, all indicate that proper design, installation and maintenance of irrigation systems will lead to improved irrigation efficiency. Additional reasons for increasing the irrigation efficiency from 0.625 to 0.71 and for DWR recommending the lowering of ETAF to 0.7 without altering the plant factor include the new requirements in the updated Model Ordinance, utilization of advanced technologies for irrigation design, and the implementation of local agency BMPs.

In implementing Alternative 4 DWR has done the following:

In 2007 DWR formed an ETAF Technical Advisory Committee (TAC) to receive input in developing an ETAF study project proposal and assist DWR in the development of a new water budget component of the updated Model Ordinance. The TAC members represented a wide diversity of interested parties. The TAC met several times and reviewed DWR’s scope of work for a project to be conducted statewide and provided input into the ETAF White Paper and the calculation of ETAF.

DWR and the University of California (UC) are entering into a contract to conduct a long-term study of landscapes irrigated under a variety of ET Adjustment Factors and a mix of plant factors (including the 0.5 plant factor) in several locations statewide. This study was scheduled to begin in the winter of 2008. Therefore, study results will not be available to apply to the update of the Model Ordinance to be adopted by DWR by January 1, 2009, pursuant to AB 1881. However, these results will be available for future reviews of the ETAF. DWR will continue working with UC and other researchers to pursue its long-term study of the ETAF and develop a more refined ETAF in the future. If it becomes necessary, DWR will begin a rule making process to revise its Model Ordinance.

DWR also conducted an extensive literature review for data and other information on landscape irrigation efficiency, distribution uniformity, irrigation system design criteria, and management and maintenance practices, and consulted with the ETAF TAC. After reviewing the literature, DWR developed an ETAF White Paper*: Evapotranspiration Adjustment Factor, January 25, 2008*, DWR and revised it September 10, 2008. See Appendix B for the *White Paper*. The White Paper concludes that there is sufficient information in the literature to achieve a higher irrigation efficiency than 0.625.

For the updated Model Ordinance**,** DWR recommends that the water budget component of the ordinance for the new landscape be based on a MAWA with an ETAF of 0.7. DWR has kept the plant factor of the existing ordinance at 0.5 and has modified the irrigation efficiency of the existing ordinance from 0.625 to 0.71. This modification of the irrigation efficiency is based on the literature review, improvements in irrigation technologies, management, and maintenance practices and also is based on the expectation that the provisions of the updated model ordinance will result in improved irrigation efficiencies. This is also consistent with the Task Force Report recommendation. To further support lowering the ETAF, actions within the Model Ordinance will strengthen the design criteria for irrigation systems; require proper irrigation scheduling and maintenance and management of the irrigation system. All of these actions have been reported to increase irrigation efficiency if properly implemented. For a more detailed description of DWR activities and reasoning for lowering the ETAF, see Appendix B.

ETAF for Special Landscape Areas

DWR recommends that Special Landscape Areas be allowed additional water and shall use an ETAF not to exceed 1.0. Special Landscapes are landscapes dedicated to edible plants, such as orchards or vegetable gardens and areas dedicated to active play or recreation, where turf serves a high use recreational purpose. To encourage the use of recycled water, and in recognition of the saline content of recycled water, areas irrigated with recycled water are also designated as Special Landscape Areas.

Maximum Applied Water Allowance (MAWA)

The updated Model Ordinance, as currently drafted, stipulates that to meet the MAWA above, project applicants shall do the following:

1) For the calculation of Maximum Applied Water Allowance and Estimated Total Water Use, a project applicant shall use the ETo values from the Historical Reference Evapotranspiration to be provided in the updated model ordinance or the CIMIS Eto zone map provided by DWR at: http://wwwcimis.water.ca.gov/cimis/info.jsp.
2) The plant factor used shall be from Water Use Classification of Landscape Species (WUCOLS, University of California Cooperative Extension, August 2000) publication.
3) All landscape water features shall be included in the high water use hydrozone and temporarily irrigated areas shall be included in low water use hydrozone, Special

Landscape Area (SLA), as defined in this report, shall be identified and its water use calculated as described in this section.

4) The ETAF for Special Landscape Area shall not exceed 1.0.
5) Furthermore, the landscape project's MAWA at the time of installation is calculated using historical ETo data provided in the Model Ordinance. However, for purposes of irrigation scheduling, audit and tracking water use, the MAWA is calculated from current ETo data using CIMIS or equivalent data.
6) The requirement in the updated Model Ordinance is that the total amount of water to be applied through the irrigation system should be less than or equal to the MAWA.

The proposed landscape Maximum Applied Water Allowance shall be calculated as:

MAWA = (ETo) (0.62) [0.7 x LA + 0.3 x SLA]

where:

MAWA = Maximum Applied Water Allowance (gallons per year)
ETo = Reference Evapotranspiration (inches per year)
0.7 = ET Adjustment Factor
LA = Landscaped Area (includes Special Landscape Area, square feet)
0.62 = Conversion factor (to gallons per square foot)
SLA = Portion of the Landscape Area identified as Special Landscape Area (square feet)
0.3 = the additional ET Adjustment Factor for Special Landscape Areas.

Effective Precipitation (Eppt) as Part of MAWA

The calculation of MAWA above does not include Effective Precipitation (Eppt); that is, contribution of rain to the water budget is not considered. Effective Precipitation, or usable rainfall, is the portion of total precipitation that is used by plants; it can contribute to some degree towards water needs of the landscape. If a local agency considers Effective Precipitation (calculated as 25 percent of annual precipitation) in areas where precipitation is significant, it shall use the following equation to calculate Maximum Applied Water Allowance:

MAWA= (ETo – Eppt) (0.62) [0.7 x LA+0.3 x SLA]

Example Calculations

To illustrate how water budget (MAWA) calculation is done, two examples are presented below. These calculations are hypothetical to demonstrate the proper use of the equations and do not represent an existing and/or planned landscape project.

1) A hypothetical landscape project in Fresno, California with an irrigated landscape area of 5,000 square feet without any Special Landscape Areas (SLA= 0, no edible plants, recreational areas or use of recycled water). The annual ETo value for Fresno is 51.1 inches (ETo Data from the Appendix A of the Model Ordinance).

MAWA= (ETo) (0.62)[ETAF x LA+0.3 x SLA]
MAWA= (51.1 inches)(0.62)[0.7 x 5000 square feet + 0.3 x 0]

= 110,887 gallons per year

2) Total Landscape area in Fresno is 5,000 square feet and 1,000 square feet of which is planted with edible plants, this area is considered Special Landscape Area.

MAWA = (ETo) (0.62)[ETAF x LA+0.3 x SLA]
MAWA = (51.1 inches)(0.62)[0.7 x 5000 square feet +0.3 x 1,000 square feet]
=120,391 gallon per year

.

Appendix A - Survey Results

Survey Results: The survey questions and responses are presented as follows:

Question 1. Is your agency a city, county or water supplier?

	Response Percent	Response Count
City	90%	177
County	9%	17
City and Water Supplier*	4%	8
Water supplier	1%	2
Answered question		196

*Cities may have dual responsibility of planning function and water provider
.
This question was intended to identify the type of agency that the survey reached. Of the 548 forms mailed out, a total of 196 city, county, and water suppliers answered the question.

Question 2. Is your agency responsible for implementing a water efficient landscape ordinance on new or retrofitted commercial, industrial and multi-family construction?

	Response Percent	Response Count
Yes	81%	159
No	16%	31
Answered Question	97%	190
Skipped Question	3%	6

The purpose of this question and Question 3 is to identify the type of agency that the survey reached. In most locations the local land use agency is responsible for implementing a water efficient landscape ordinance and complying with the requirements of AB 325.

Question 3. If your agency is responsible for implementing a water efficient landscape ordinance, but did not adopt one, did your agency adopt findings that an ordinance was not necessary?

This question was intended to identify the reasons why agencies did not adopt an ordinance. AB 325 gave the option to local agencies to adopt a local ordinance or the Model Ordinance would take effect by default. Local agencies were allowed to adopt legal findings that an ordinance was not necessary due to climatic, geological, or topographical conditions or water availability. Of the 159 agencies that were found to be responsible for implementing an ordinance 8 agencies reported that they adopted a findings that an ordinance was not necessary.

Question 4. Does Your Agency Implement….?

	Response Percent	Response Count
The State Model Water Efficient Landscape Ordinance (AB 325)	9%	14
A water efficient Landscape Ordinance adopted by my agency	46%	74
Landscape Guidelines	29%	47
Resolution	3%	4
Other	14	22
Answered question		161

The purpose of this question was to determine what type of landscape ordinances or other landscape review procedures are in effect throughout California. Responses to “Other” include plant lists, landscape regulations, stormwater rules and combinations of measures. Of the 196 agencies that completed the survey forms, 161 responded to question 4. Over 46 percent of the 161 agencies that responded to this question, state they implement a local ordinance or other locally derived guidance in landscape development. Locally derived ordinances can be very effective for a region due to local conditions, demographics and other factors. However, a report by Western Policy Research has shown that local ordinances and guidelines are often less stringent than the Model Ordinance. More agencies indicated they may in fact be in compliance, but the nature of the responses make it impossible to tell if the various guidelines and resolutions are equivalent in scope to the Model Ordinance or local ordinances.

Question 5. If you adopted a water efficient landscape ordinance (local or AB 325) what level of implementation are you able to achieve?

	Response Percent	Response Count
Plan Check	66%	105
Field Inspection	54%	86
Water Use Data Monitoring	18%	18
Other	18%	18
Explained “Other” in text box	18%	28

Of the 159 who responded, that are responsible for implementing an ordinance 105 agencies that answered the question are able to do plan checks prior to construction. Eighty six are able to follow up with a field inspection but only 18 do any type of water use monitoring. Of those that explained their response under “other,” several innovative approaches are used as follow-up. One responder stated that the local agency requires a two-year agreement with irrigation and maintenance improvements and financial security is held until a planner inspects the site and deems the site to be in acceptable condition. Other responses include random inspections to check compliance, responding to water waste complaints, and implementing tiered water rates to encourage efficient water use by the landscape owner or manager. Some local agencies are able to do both plan check and water use monitoring. This is most easily accomplished when a local agency is both the land use agency and a water provider.

Question 6. If you implement an Ordinance, Guidelines, etc. other than the State Model Water Efficient Landscape Ordinance (AB 325), do you have provisions for? Check all that apply:

	Response Percent	Response Count
Hydrozones-plant grouping for water efficiency	38%	75
*Conditions regarding using certain plant species, suggested plant lists	53%	104
Soil stabilization to reduce erosion and runoff	39%	76
Mulching specifications	38%	75
Regional differences, including fire prevention	21%	42
Recycled Water	30%	59
Water Budget approach	18%	36
Irrigation schedules based on CIMIS data and environmental factors	21%	41
Rain Sensors	28%	54
Educational Materials	29%	56
Exemption for Historical Sites and Cemeteries	13%	26
Pressure Regulation	22%	44
Stormwater retention and reuse	20%	40
Maintenance practices to prevent overspray	33%	64
Routine irrigation maintenance and audits	15%	30
* not required in AB 325		

Although this question was limited to agencies that did not adopt AB 325, some of the agencies that adopted AB 325 ordinance answered the question as well. Of the 196 agencies that completed the survey, 133 answered the question.

Prior research, for example; a report by Western Policy Research, has shown that many local agencies have developed local ordinances and guidelines (see responses to Question No. 4). Question No. 6 asks local agencies to check all provisions that are found in their local landscape ordinances or guidelines. All of the provisions required in AB 325 are used by some of the agencies. The most commonly locally used provision (establish conditions prohibiting use of certain plant species) is expressly prohibited in AB 325 (section 65597 (a)) and AB 1881 for inclusion in the updated Model Ordinance. Nonetheless, local agencies have found plant lists to be effective for several reasons. In some regions, prohibiting certain fire prone plants is an effective measure in a fire prevention program. Likewise, plant lists that prohibit plants with invasive tendencies can aid local agencies by preventing the establishment of horticultural plants into sensitive habitats. Lists of approved plants make plan check procedures easier for local agency staff. By limiting the plant choices to a short list, this in effect eliminates the question of whether the plants specified in a design are water conserving or appropriate for the local climate. However, plant lists can limit design choices and bio-diversity. Routine irrigation maintenance and audits had response rate of 15 percent. This confirms that maintenance is the weakest link in the long term sustainability of water efficient landscapes.

Question 7. Have you coordinated with other agencies (cities, counties, and water districts) in your service area to achieve consistent ordinances?

	Response Percent	Response Count
Yes	32%	51
No	65%	104
Answered Question	97%	155
Skipped Question	3%	4

Of the 159 agencies that said they are responsible for implementing an ordinance, 51 coordinated with others. Coordination and communication among agencies and others is essential to ensure a Landscape Ordinance is successfully implemented. Question No. 7 shows that in many cases local agencies do not coordinate with other agencies. However, 32 percent of responders do communicate with other agencies and departments. Many landscape architects and contractors work in multiple jurisdictions, many water suppliers provide water to more than one city and many cities and most counties have multiple water suppliers. Lack of coordination of ordinances with and communication between local agencies can be a disadvantage in regions with multiple ordinances and where adjacent regions have different sets of rules.

Question 8. What technical, administrative or legal issues have you encountered in the adoption and implementation of a water efficient landscape ordinance?

Response Count	86
Answered Question	86
Skipped Question	110

Eighty six of the 196 responded and filled in text boxes explaining difficulties or the lack thereof implementing a water efficient landscape ordinance. The responses are as follows:

- Some responders cited problems with maintaining billing and water use databases for long enough period to track water use and long term compliance.
- Designers often design plans without consulting the city about their requirements.

- Landscape architects and landscape contractors lack of knowledge and experience to develop water efficient landscapes.
- Developers often circumvent the permit process.
- Plan check fees don't recover all costs.
- Difficulties with water budget calculations.
- Planning departments often rely on consulting landscape architects to review plans.
- Difficulty creating an ordinance that will work in large counties with varied environmental conditions (deserts, mountains, etc.)
- Achieving consistency between various municipal code sections e.g. Building Code vs. Water Code.
- Planning departments can't get water use data from water suppliers.
- Some cities lack inter-departmental communication between planning and water units.
- Need for better water waste ordinances to enforce runoff and overspray prohibitions.
- One city anticipates some problems with integrating graywater use and artificial turf into existing landscape codes.
- Some respond that they have some interagency coordination, but no follow-up.
- The most common difficulty faced by local agencies is lack of staff and monetary resources.
  - Lack of knowledgeable and experienced staff for plan check of irrigation design and scheduling, plants choices, etc.
  - Lack of code enforcement officers and inspectors.
  - Lack of funding for audits and auditors.

In contrast:

- Numerous responders cited few or no problems implementing an ordinance or standards.
- Some agencies have good interagency and intradepartmental communication and coordination.
- Some agencies are able to accomplish inter departmental review of project plans: e.g.-planning, parks, and water departments may all review landscape plans for compliance in different subject areas.
- Some cite success increased after a public education program.
- Some agencies have landscape architects on staff to certify the technical aspect of landscape plans.

Appendix B - White Paper

White Paper: Evapotranspiration Adjustment Factor

Prepared by Department of Water Resources staff in support of the updated Model Water Efficient Landscape Ordinance

1. Introduction.

The evapotranspiration adjustment factor (ETAF) is a coefficient that adjusts reference evapotranspiration (ETo) values based on a plant factor (PF) and irrigation efficiency (IE) and is used to calculate the maximum amount of water that can be applied to a landscape. ETo is a combination of evaporation and transpiration from standardized grass surfaces on which weather parameters are measured and ETo is then calculated. The plant factor is similar to a landscape coefficient factor in that it includes the effects of plant type, plant density, and microclimate on the water demand of a landscape. The plant factor as used in this calculation is a value that denotes the water use capacity of any given plant species. Irrigation efficiency is the amount of water that is beneficially used divided by the total amount of water applied. For purposes of this paper IE is estimated from Distribution Uniformity (DU) and irrigation management efficiency (IME). DU is a measure of the uniformity of irrigation water that is applied to the landscape and theoretically ranges in value from zero to 100 percent. IME is an indicator of how well the irrigation water is being managed. Irrigation management efficiency can be defined as applying the right amount of water at the right time to the right place. ETAF, therefore, is determined by quantifying all of these factors and dividing the plant factor by IE to get ETAF (PF / IE = ETAF). This white paper was prepared to describe how DWR, using the best available resources, updated the ETAF value in the Model Ordinance.

2. Background.

In 1990, California was in a fourth consecutive year of drought and Assembly Bill 325, Water Conservation in Landscaping Act of 1990, was signed. This bill required DWR, by February 1, 1991, to appoint an advisory task force to work with DWR in drafting a model water efficient landscape ordinance. After holding public hearings, and based on recommendations of the task force, DWR adopted the State Model Ordinance in 1992. By January 1993, local agencies were required either to adopt a local water efficient landscape ordinance, adopt the State Model Water Efficient Landscape Ordinance, or make a statement as to why the ordinance was not necessary. Prior to the Model Ordinance of 1992, local agencies were not required to adopt a landscape water conservation ordinance.

In 2001, a report by Western Policy Research (WPR) (Bamezai et al., 2001) concluded that nearly 90 percent of new development between 1992 and 1999 took place in agencies that had adopted a water efficient landscape ordinance. WPR also found deficiencies in AB 325 due to a lack of education about the ordinance, maintenance contractors rarely irrigating accurately, and that “maintenance” was the weakest link in the “design, installation, and maintenance” of water efficient landscape. The biggest problem that the researchers found, however, was the lack of irrigation monitoring or enforcement of the maximum applied water allowance in the field. Partly because of this report, AB 2717 was proposed to address some of the deficiencies of AB 325.

AB 2717 was passed in 2004 and requested the California Urban Water Conservation Council (CUWCC) to convene a stakeholder Task Force, comprised of public and private agencies, to evaluate and recommend proposals by December 31, 2005, for improving the efficiency of water use in new and existing urban irrigated landscapes in California. The Task Force adopted a comprehensive set of 43 recommendations for updating the State Model Ordinance pursuant to AB 325. The Task Force also recommended that DWR form a stakeholder work group with broad representation to study the ETAF as a part of updating the landscape Model Ordinance.

The existing Model Ordinance, prepared through a consensus stakeholder process, established a water budget for new construction and rehabilitated landscapes based on size of the landscape, reference evapotranspiration (ETo), and an ETAF with a specified plant mix. To be approved by the local Planning Department, new and rehabilitated landscapes must be designed and installed to meet the water budget. The existing Model Ordinance utilizes a statewide plant factor of 0.5, representing a mix of 1/3 high, 1/3 moderate, 1/3 low water using plants. The irrigation efficiency for purposes of the ETAF in the existing ordinance is 0.625 (or 62.5 percent). The ETAF is then obtained by dividing the average plant factor of 0.5 by the average irrigation efficiency of 62.5 percent, resulting in an ETAF of 0.8.

The Task Force Recommendation 12 specifically states that "DWR should reduce the ET Adjustment Factor in the Model Ordinance by 2010 for new non-single – family development, based on the results of a three-year study of new and established landscapes designed to meet a variety of ET Adjustment Factors and a mix of plant factors (including the 0.5 plant factor) and if the study cannot be funded to use the best other data available". Most acknowledge that the ETAF can easily be lowered by altering the plant mix and still many local agencies have chosen to limit landscape water use by constraining plant selection or limiting the amount of certain types of plants that can be planted.

For example:

- City of Santa Barbara limits turf to 20 percent in residential and 0 percent in commercial.
- City of Livingston requires 90 percent of the plants to be native.
- City of Adelanto limits turf to 10 – 20 percent depending upon the type of development.
- City of Oakley limits turf to no more than 25 percent.
- City of Santa Monica limits turf and high water using plants to no more then 20 percent.

Furthermore the Task Force's Irrigation Work Group recommended reducing ETAF to 0.70 from its current value of 0.80 based on an expected increase in irrigation efficiency from 62.5 percent to 71 percent. In this paper, however, DWR will examine if the ETAF can be lowered based upon improved irrigation efficiency through the utilization of improved irrigation system technologies, design and better management and maintenance practices while maintaining a plant mix of 0.5.

Governor Arnold Schwarzenegger signed the Water Conservation in Landscaping Act of 2006, AB 1881, on September 28, 2006. The bill charges the DWR, among other things, to update the Model Ordinance. The Water Conservation in Landscaping Act (Laird, Chapter 559, Statutes of 2006) includes some of the recommendations by the Task Force. The 2006 Act requires DWR, no later than January 1, 2009, to update the Model Ordinance in accordance with the recommendations of the Task Force. The 2006 Act also requires the California Energy Commission (CEC), in consultation with DWR, to adopt, by regulation, performance standards and labeling requirements for landscape irrigation equipment, including irrigation controllers, moisture sensors, emission devices, and valves to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy or water. The 2006 Act also requires DWR, not later than January 1, 2009, to prepare and submit a report to the Legislature relating to the status of water efficient landscape ordinances adopted by local agencies and on DWR's recommendation regarding the landscape water budget component that establishes the maximum amount of water to be applied through the irrigation system, based on climate, landscape size, irrigation efficiency, and plant needs (AB 1881, section 65595 (a)(2) and (B), section 65596 (b)). DWR is in the process of preparing the updated Model Ordinance in consultation with stakeholders and through the rule making process.

In 2007 DWR formed an ETAF Technical Advisory Committee (TAC) to receive input in developing an ETAF study project proposal and assist DWR in the development of a new water budget component for the updated Model Ordinance. The TAC members represented a wide diversity of interested parties. The TAC has met several times and reviewed DWR's scope of work for a project to be conducted statewide. DWR has initiated a contract with the University of California (UC) researchers to establish a comprehensive long-term study of new and established landscapes designed to meet a variety of ET Adjustment Factors and a mix of plant factors (including the 0.5 plant factor) in several locations state wide.

DWR intends to adopt the updated Model Ordinance by January 2009, as required by the law. The long-term study, however, requires more time. Therefore, as recommended by the Landscape Task Force, DWR is using the best available data and information in order to establish an appropriate ETAF.

3. Literature Review and Information Gathered

The bulk of the information DWR obtained from the literature review regarding (DU) and IE was from irrigation audits of existing landscape systems. Some of the reviewed data and information are published in scientific journals and others are either in the process of publication or are collected by local agencies for internal use.

The final report of AB 2717 Task Force cited that residential irrigation audits indicate very low DUs, with an average of 45 percent in a survey of 300 sites by Santa Clara Valley Water District and 55 percent by a consultant Chris Wilig (500 sites). Golf courses, on the other hand, are, generally, well maintained and managed with DUs of 75-90 percent, according to the report.

The reviewed literatures indicated that the irrigation systems were at least several years old and DUs for sprinkler systems were generally low but ranged from 20 to 80 percent. The primary reasons cited for lower DUs were poor irrigation system design and installation, poor equipment selection, little or no maintenance, and inadequate management. In some cases, improvements in DUs and IEs were reported after making changes to the system. For example; simply replacing older nozzles with newer and upgraded nozzles (Zoldoske, 2003; and Mecham et al., 2004) resulted in efficiency improvements. Zoldoske (2003), also reported significant water savings in golf course studies but DU data was not presented. Mecham et al. (2004) found that rotor sprinklers generally had higher irrigation efficiency compared with fixed spray devices. Improvements in DU, emission uniformity (EU) water emission device uniformity, and IE have been reported at controlled study sites with manufacturer recommended design and testing criteria (Micker, 1996; Hla et al., 1998), further affirming that most of the problems that reduce IE can be overcome. Mecham (http://www.ncwcd.org/ims/ims_info/theeff1d.pdf), for example, used a well designed teaching and training field in Colorado and evaluated the effects of matched precipitation rate (MPR) nozzles and measured DUs ranging from 57 percent to 78 percent.

The reviewed literatures also indicated that the choice of landscape plants can influence the amount of water used. It was shown, for example, that warm season turf can save as much as 20 percent water compared to the cool season species (Pittenger and Shaw, 2003; Ervin and Koski, 1998; Feldhake et al., 1983; Meyer and Gibeault, 1986; and Stewart et al., 2004). Many of these studies have also shown that using different irrigation treatments, with the right combination of irrigation frequency, cutting height, and fertilizer application, some warm season turf varieties can be irrigated at 60 percent of ETo and cool season varieties at 80 percent of ETo (Pittenger and Shaw, 2003; Bushman et al., 2007; Ervin and Koski, 1998; Brown et al., 2004; Feldhake et al., 1983; Meyer and Gibeault, 1986; and Devitt et al.,1992). Feldhake et al. (1983), for example, determined that a grass mowed at 5 cm had an ET rate of 13 percent higher than that mowed at 2 cm and that a nitrogen deficient treated grass used 14 percent less water than the adequately fertilized grass.

Some studies have further suggested the use of the low half distribution uniformity in irrigation scheduling rather than the low quarter distribution uniformity as is currently being practiced (Kissinger and Solomon, 2005; Kumar et al., 2006; Irrigation Association, 2005). These studies found that soil moisture has similar distribution uniformities to the low half DU of sprinklers mainly because the water redistributes laterally once it enters the soil. Using the low half DU for irrigation scheduling does result in higher values of DU and IE.

Other developments in landscape irrigation and maintenance that have significantly improved irrigation efficiency include advances in sprinkler technology (example, multi-stream, multitrajectory rotating (MSMTR) sprinklers) and irrigation controllers (example, weather based irrigation controllers and soil moisture sensors). Several studies have shown that these new developments have increased irrigation efficiency

(Solomon et al., 2006; Irvine Ranch Water District). Solomon et al. (2006) conducted over 50 field audits and observed that by converting from fixed spray to multi-stream, multi-trajectory rotating sprinklers, average DU changed from 44 percent to 67 percent after conversion. The improvement in DU ranged from a low of 4 percent to a high of 52 percent. A 2003 study by the Pacific Institute also estimates that California could reduce outdoor residential water use by 25 percent to 40 percent through improved landscape management practices and better application of available technology (Gleick et al., 2003).

Additional information was also obtained from various sources regarding landscape planning, design, installation, and maintenance practices that can save water (Hartin and McArthur, Irvine Ranch Water District, Coachella Valley Water District, Capistrano Water District, HydroPoint Data Systems, Inc., and Irrisoft). The information gathered from these groups indicated that newer technologies in emission devices and weather based irrigation controllers have improved irrigation system efficiency substantially. The data from these sources also included manufacturer's specifications and default IE values that the manufacturers of weather based irrigation controllers use today.

Furthermore, the California State University, Fresno's Center for Irrigation Technology performed tests on irrigation controllers. The Center for Irrigation Technology has been working closely with water purveyors statewide and the Irrigation Association as part of their "Smart" Water Application Technology" (SWAT). The tests included 14 different weather based controllers that irrigated at average 99 percent efficiency. It should be noted that there are many in the irrigation industry that do not incorporate irrigation management efficiency (IME) when calculating a water budget. However, as explained below a 90 percent IME factor is used in calculating ETAF.

Weather based irrigation controller manufacturers use high IE values ranging from 70 percent – 90 percent as a default in scheduling irrigation. The following is an example of IEs from HydroPoint Data Systems, Inc. for the WeatherTRAK controller:

- Spray head = 70%
- Stream spray = 70%
- Stream rotors = 75%
- Full/Part/Mixed circle rotors = 80%
- Full/Part/Mixed circle impact = 85%
- Bubbler = 90%
- Drip emitter = 90%

Other work done by Phil Regli, as cited in "Distribution Analysis Methodology", illustrates that some simple improvements in sprinkler spacing and irrigation system operating pressure increased irrigation system efficiency. For example, using the same nozzle when the sprinkler head spacing was adjusted for optimum performance the DU increased to 76.3 percent. When operating pressure is adjusted to maximize performance increases of 18 percent improvements were noted. The technology that was used to maximize and test these design improvements is an application that is readily available to landscape professionals.

Data supporting improved irrigation efficiency were also received from local water agencies from their dedicated metered landscape based on billing invoices. Most of these data illustrated that in real life scenarios landscapes were often being watered well below the current 80 percent of ETo (see appendix B1 for reference list and details). Data from these sources, however, did not specify what plant palettes were used.

Other ETAF values agencies utilize in their local model ordinances include:

- San Diego County Water Agency, has proposed a draft model ordinance with an ETAF factor of 0.7.
- The Coachella Valley Water District has adopted a more stringent approach with an ETAF of 0.5 by allowing a change in plant mix and a plant factor of less than 0.5 and an expected IE of 0.75.
- City of La Quinta ETAF of 0.5.
- The City of Morgan Hill has an ETAF of 0.7.
- US Environmental Protection Agency (EPA) Water Sense proposes in their Draft-Water Efficient Single - New Family Home Specifications limiting ETAF to 0.6.
- City of Palm Desert has an ETAF of 0.5.

4. Analysis.

The studies reviewed and the data collected from different sources demonstrate that existing landscape irrigation system design, maintenance, and management are often poor and result in low distribution uniformity and irrigation efficiency. The wide range of DUs and IEs observed by many investigators, and cited in this white paper, indicate that there are ample opportunities for irrigation improvements. The review process has clearly indicated that if the problems resulting in low DUs and IEs are corrected, landscapes can be irrigated more efficiently. There is also enough evidence to show that there have been major changes in irrigation technology, landscape design, and irrigation management in recent years that if applied, higher irrigation efficiency and therefore greater water conservation can be achieved. Some of these developments include:

1. The increased use and acceptance of low volume irrigation systems in landscape irrigation;
2. Improved sprinkler systems, matched nozzles, and multi trajectory rotators;
3. Technological advances in irrigation controllers leading to improved irrigation management efficiency (example, weather-based irrigation controllers and soil moisture sensors);
4. Increased use and promotion of low water use native vegetation and xeriscaping;
5. Use of the low half distribution uniformity for sprinkler irrigation rather than the low quarter DU for irrigation scheduling; and
6. Better understanding and management of soil properties and soil-plant-atmosphere interactions by landscape designers and managers.

Moreover, the California Energy Commission is required by the 2006 Act to establish performance standards and labeling requirements for landscape irrigation equipment, including but not limited to; irrigation controllers, moisture sensors, emission devices, and valves to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy or water. The updated Model Ordinance will also require some specific measures (higher efficiency devices, irrigation controllers, irrigation audits, inspection, better irrigation system design and maintenance, use of water efficient plants, erosion and runoff control, etc.) that when incorporated into the landscape design, management, and maintenance will achieve irrigation efficiency greater than 62.5 percent, a value that is the basis for the ETAF factor of 0.8 in the existing Model Ordinance.

5. Summary.

The studies reviewed and the data collected from different sources demonstrate that existing landscape irrigation system design, maintenance, and management are often poor and result in low distribution uniformity and irrigation efficiency. The wide range of DUs and IEs observed by many investigators, and cited in this white paper, indicate that there are ample opportunities for irrigation improvements.

The review process has clearly indicated that if the problems resulting in low DUs and IEs are corrected, landscapes can be irrigated more efficiently. There is also enough evidence to show that there have been major changes in irrigation technology, landscape and irrigation design, and irrigation management in recent years that if applied, higher irrigation efficiency can be achieved. Technological advances in irrigation controllers are leading to improved irrigation management efficiency. Other developments in landscape irrigation that have significantly improved irrigation efficiency include advances in sprinkler technology. Educational and certification programs that local agencies, the California Landscape Contractors Association, Irrigation Association, and other institutions, are providing will lead to better design, maintenance and management.

Moreover, the California Energy Commission is required by the 2006 Act to establish performance standards and labeling requirements for landscape irrigation equipment therefore leading to market place transformation that will require the use of these better performing technologies. With increased water conservation awareness, technical assistance and education, and the implementation of water conservation best management practices better irrigation efficiency can be achieved.

The ETAF for the existing Model Ordinance is based on a plant factor of 0.5 and irrigation efficiency of 0.625 and therefore the ETAF value is 0.8 (=0.5/0.625).
The existing Model Ordinance established the plant factor (PF) of 0.5 which is determined by having a landscape with a plant mix of 1/3 high water using plants, 1/3 medium water using plants, and 1/3 low water using plants with a crop coefficient of 0.8, 0.5, and 0.2 respectively and therefore the average PF is 0.5 (= (0.8 + 0.5 + 0.2) / 3). The existing Model Ordinance also established an irrigation efficiency of 0.625, therefore the ETAF value of 0.8 (=0.5/0.625).

Therefore, to update the water budget component, the value of ETAF can be reviewed and updated. The value of ETAF depends on the plant factor and irrigation efficiency. If landscape is irrigated more efficiently, the irrigation efficiency used in calculation of applied water will be higher and therefore the applied water requirement will be less. Another approach would be to incorporate more low water using plants in the landscape resulting in less applied water.

To update the water budget component of the model ordinance, DWR considered the following alternatives:

Alternative 1 - Maintain the plant factor value of 0.5 and irrigation efficiency of 0.625 and adopt the updated Model Ordinance with an ETAF of 0.8. This alternative was rejected because DWR was required by AB 1881 to update the water budget component. Furthermore, the Landscape Task Force Report recommended an ETAF value of less than 0.8 and for DWR to conduct a study and if one could not be conducted to make a recommendation based on existing data.

Alternative 2 - Maintain the plant factor of 0.5 and irrigation efficiency of 0.625, and ETAF of 0.8 and adopt the ordinance, but conduct a long-term field study to update the ETAF value by modifying the plant factor and irrigation efficiency. Alternative 2 was rejected because there is sufficient technical evidence that a landscape irrigation efficiency higher than 0.625 is achievable. Furthermore, if DWR adopts the updated Model Ordinance with ETAF of 0.8 and completes the study to update the ETAF, it would significantly delay the water savings that can be achieved through higher irrigation efficiency presently achievable.

Alternative 3 - Lower the ETAF based on a plant factor of less than 0.5 and an irrigation efficiency higher than 0.625. Some local agencies have adopted a plant factor that is lower than 0.5. Although, we have sufficient information to demonstrate that irrigation efficiency higher than 0.625 is achievable, Alternative 3 was rejected because DWR wanted to look into the lowering the ETAF while maintaining the 0.5 plant factor.

Alternative 4 - Lower the ETAF based on an irrigation efficiency higher than 0.625 and maintain the plant factor at 0.5. DWR recommends Alternative 4. DWR has conducted literature and other data review and, using this published information, calculated the distribution uniformity and irrigation efficiency and recommends an irrigation efficiency of 0.71 (see section 6 - DWR Recommendation for the ETAF Value of the Water Budget). DWR has initiated a contract to study the effects on landscape by lowering the ETAF value and to look into various plant factors and their water saving potential. Unfortunately this contract has been delayed for various reasons so the study will not be completed in time for this updated Model Ordinance. Alternative 4 will allow DWR to update the water budget component based on an improved irrigation efficiency that is achievable and adopt the updated model ordinance as required by law by 2009. This approach allows DWR to consider continued advances in improving landscape irrigation and reducing landscape water demand while studying the effects that further lowering of the plant factor will have on landscapes.

Alternative 4 is the selected option based upon existing research, studies, manufacturer specifications, industry landscape certification, all which indicate that proper design, installation and maintenance of irrigation systems will lead to improved irrigation efficiency. Additional reasons for increasing the irrigation efficiency from 0.625 to 0.71 and for DWR recommending the lowering of ETAF to 0.7 without altering the plant factor include the new requirements in the updated Model Ordinance, utilization of advanced technologies for irrigation design, and the implementation of local agency BMPs.

6. DWR's Recommendation for the ETAF Value of the Water Budget.

The minimum operational lower quarter distribution uniformities for spray, rotor, and drip/micro-spray cited by the Irrigation Association Best Management Practices Guidelines are 55 percent, 70 percent, and 80 percent, respectively. Based on the advances cited above, the findings from literature review, IA's minimum operational DUs, and with expectations of better landscape design, proper installation, improved management and maintenance in the future, landscape low quarter distribution uniformities of 62 percent for the high water use plants irrigated with spray heads and rotors and emission uniformities of 80 percent for the medium and low water use plants irrigated with drip and micro-spray systems are reasonable. In this white paper, the statewide average plant factor of 0.5 from the existing model ordinance is retained with the 1/3 high, 1/3 medium, and 1/3 low plant mix. Accordingly, ETAF calculations for a landscape with a 1/3 plant mix each of high, medium, and low water use plants is as follows:

For high water use plants irrigated with spray-heads and rotors, DUlq = 62 percent. For reasons discussed above, it is suggested that distribution uniformities of the low half be used for irrigation scheduling. The Irrigation Association uses the following equation to convert DUlq to DUlh:

$$DUlh = 38.6 + (0.614)(DUlq)$$

Kumar et al. (2006) verified the accuracy of this equation by simultaneously measuring distribution uniformities of the soil and the sprinklers. Therefore, the above equation is used here to convert DUlq to DUlh. DUlh for high water use plants with spray/rotor irrigation systems is 38.6+(0.614)(62) = 77%. For medium and low water use plants irrigated with drippers and micro-sprayers, emission uniformities, EU = 80 percent were used. Therefore, the average uniformity for the landscape is [(77 + 80 + 80) / 3] = 79 %.

To calculate landscape irrigation efficiency, an Irrigation Management Efficiency (IME) needs to be determined. Zoldoske (2005) used an IME of 90 percent in calculating IE for the existing model ordinance and the paper presented to the AB 2717 Task Force . Also, the Irrigation Association http://www.irrigation.org/gov/pdf/liswm_part 2 of 3.pdf rates an IME of 90 percent as "very good". Because there have been technological advances since the existing model ordinance was adopted that have improved IME (example, ET controllers and soil moisture sensors), we have retained the 90 percent value for the IME. The irrigation efficiency for purposes of the model ordinance is therefore calculated as:

IE = (DU) (IME)

IE = (79)(90)/100 = 71%

Finally, the ET Adjustment factor is:

ETAF = Plant Factor/IE = (0.5/71)100 = 0.70.

Appendix B1- List of References White Paper ETAF

Summary of Reviewed Literatures including a brief description of the findings for some of the references

1. Bamezai, A., Perry, R., and C. Pryor. (2001) Water Efficient Landscape Ordinance (AB 325): A Statewide Implementation Review. Western Policy Research

2. Baum, M. C., Dukes, M.D., and Miller, G.L. (2005) "Analysis of Residential Uniformity". Journal of Irrigation and Drainage Engineering 131:4,336-341.

The following studies were referred to by Baum et al., 2005:

Utah (citing Aurasteh et al., 1984): DUlq = 0.30 for hand move and 0.37 for solid set in residential irrigation audits.

Georgia (citing Thomas et al., 2002): 24 percent over irrigation was discovered due to nozzle mismatch and poor management because of too high irrigation timing.

California (citing Pitts et al., 1996): mean DUlq for all systems was 0.64. Average DUlq for non-agricultural turf grass sprinklers (residential lawns) was 0.49. Reasons for low DUlq were maintenance and faulty sprinkler heads, mixed equipment types in zones (spray and rotor), excessive pressure variations, and poor head-to-head coverage, listed in order of frequency.

Florida (citing Micker, 1996): average DUlq ranged from 0.38 in Lake County to 0.71 in South Dade. Minimum DUlqs ranged from 0.11 for Hillsborough to 0.40 for Fort Myers, whereas the maximum DUlqs ranged from 0.71 for Hillsborough to 0.89 for South Dade. Tests in Florida were conducted using Mobile Irrigation Labs (MIL).

The test for residential settings in Florida by Baum et al., 2005 showed the mean DUlq for the rotor zones was 0.49 and the mean DUlq for the sprays was 0.41. They also tested at a controlled site at the University of Florida and found that under ideal testing conditions (as recommended by manufacturers) the DUlq was 0.58 for rotary sprinklers and 0.53 for spray nozzles.

3. Brown, C.A., Devitt, D.A. and Morris, R. L., (2004) Water Use and Physiological Response of Tall Fescue to Water Deficit Irrigation in an Arid Environment. HortScience 39(2) 388-393.

Reducing leaching fraction (LF) and Irrigation (I) to ETo ratio with twice-weekly irrigation schedule saved 20-47 percent of water for tall fescue. A loss in color and cover was observed when I/ETo ratio dropped below 0.80.
In Colorado (citing Fry and Butler, 1989) – color and cover ratings could be maintained while saving water at 75 percent and 100 percent ETo but loss in ratings occurred when irrigation were at 50 percent of ETo.

In Colorado (citing Ervin and Koski, 1998) – water could be conserved on tall fescue while maintaining acceptable turf grass quality, if irrigation occurred every 3 days using a crop coefficient of 0.70.

4. Burt, C.M., A.J. Clemmons, T.S. Strelkoff, K.H. Solomon et al (1997) Irrigation performance measures: efficiency and uniformity. Journal of Irrigation and Drainage Engineering 123(6): 423-442

Describes irrigation system efficiencies in various agricultural applications. Some of these systems are utilized in both large and small urban landscapes.

5. Bushman, B.S. B. L. Waldron, J. G. Robins and K. B. Jensen (2007) Color and shoot regrowth of turf-type Crested Wheat grass managed under deficit irrigation. Applied Turf Science. Doi:10.1094/ATS-2007-0418-01-RS

It was documented that it is possible to maintain an active green growth in Crested Wheat grass using weekly deficit irrigation levels greater than or equal to 60 percent ET replacement. Dormancy and unacceptable browning occurs in Crested Wheat grass at irrigation of less than 60 percent ET replacement. They did not study, however, the effect of frequency and duration of irrigation interval. It should be noted that their ETo was estimated using the Hargreaves equation. Hargreaves equation has a good agreement with the Penman-Monteith equation on timely time steps such as this.

6. California Department of Water Resources. (2005) California Water Plan Update. Bulletin 160-05.

7. Capistrano Water District. Personal Communication

Of the 446 records with allocations in the original billing, 37 accounts went over their allocation; only 3 of those by more than 100 ccf, 369 accounts used less than 70 percent of allocation that was 96 percent of ETo. When the allocation is experimentally reduced to 70 percent of ETo, 75 accounts went over, but only 5 of these by more than 100 ccf. For 55 of these customers, the additional Tier 2 use was 50 ccf of less.

8. Carrow, R.N (2006) Can we maintain turf to customer satisfaction with less water? Agricultural Water Management 80:(1-3)117-131.

Citing several papers, Carrow 2005 documented landscape coefficient (K_L) for cool-season grasses as 0.70-0.95 and warm season grasses as 0.65-0.85 when the irrigation regime is 3-7 days between events. It was stated that as K_L values decreased below these general ranges using a similar irrigation schedule, turf performance rapidly declined. One way of reducing K_L while maintaining good quality turf was by irrigating more frequently. This avoided surface drying.

9. Coachella Valley Water District Personal Communication

Initially the inspections showed that 69 percent of the 16 sites were within their maximum water allowance. Thirty-one percent exceeded it. CVWD is looking at those sites that exceeded MAWA to determine why they were too high. On some sites, they are still in the establishment period. Some have landscaped more area than was approved for a particular meter. One specific site planted turf where it was not indicated on the plans.

The sites were plan checked under their older Ordinance 1302 which has an ET adjustment factor of 0.5.

10. Devitt, D.A., R.L.Morris and D.C. Brown. (1992) Evapotranspiration, Crop Coefficients, and Leaching Fractions of Irrigated Desert Turfgrass Systems. Agronomy Journal 84:717-723.

This research was conducted in southern Nevada on Bermuda grass over seeded with perennial Rye. The Penman combination equation was used to estimate ETo. A park site with similar soils, water quality, and grass species as two other golf courses used 29 percent less water due to less fertilizer application at the park site. Monthly Kc values ranged from as low as 0.43 in winter months to as high as 0.89 in summer months for the golf course sites. For the low management park site, it ranged from as low as 0.33 to as high as 0.60.

11. Dukes, Michael. Types and Efficiency of Florida Irrigation Systems.

Describes efficiency in various agricultural irrigation systems that can be utilized in large landscapes.

12. Ervin, E. H. and A.J. Koski. (1998) Drought Avoidance Aspects and Crop Coefficients of Kentucky Blue grass and Tall Fescue Turfs in the Semiarid West. Crop Science 38:78-795

Using different irrigation treatments on Kentucky Blue grass (KBG) and Tall Fescue (TF) in Colorado, the authors were able to determine crop coefficients that can be used to save water while maintaining the turf at an acceptable quality. The coefficients were 0.60-0.80 for KBG and 0.50-0.80 for TF. The reason for differences between the two was that TF has deeper roots hence extracting water from deeper layers during water shortage. It should be noted that the Kimberly-Penman equation was used to calculate reference evapotranspiration on alfalfa reference (ETr).

13. Feldhake, C.M., Danielson, R.E. and Butler,J.D. (1983) Turfgrass Evaporation, I. Factors Influencing Rate in Urban Environment. Agronomy Journal 75(5):824-830.

Warm season grasses used about 20 percent less water than cool-season grasses under identical management and microenvironment conditions. Grass mowed at 5 cm had an ET rate of 13 percent higher than that mowed at 2 cm. Nitrogen deficient

treatment used 14 percent less water than the adequately fertilized grass. The research was conducted at Colorado State University.

14. Gleick, P.H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G., Cushing, K.K., and A. Mann. (2003) Waste not, Want Not: The Potential for Urban Water Conservation in California. Pacific Institute.

15. Green, R. L. (2005) Trends in Golf Course Water Use and Regulation in California. Reports on Topical Issues. University of California, Riverside Turf Grass Research. http://ucrturf.ucr.edu/topics/trends_in_golf_course_water_use.pdf

Discusses the feasibility of increasing irrigation efficiency and DU in golf courses and how regulators may set water budgets to be followed.

16. Hartin, J. and K. McArthur. (2007) Conserving Water and Improving Plant Health in Large Southern California Landscapes. Progress Report. 2004 Proposition 50 Water Use Efficiency Grant. Grant No. 4600004211.

In early 2007 30 site visits were conducted by William Baker and Associates (subcontractor for UCCE) at parks, golf courses and school districts. These sites were surveyed; including a catch can test of distribution uniformity and precipitation rates. Several visits are planned for each site, with recommendations of improvements to be made after each visit.

Some of the types of irrigation issues discovered include Poor DU due to uneven spacing of heads, unmatched precipitation rates, unmatched nozzles, too low pop-up, tilting, slow infiltration rate of soils.

A few sites were surveyed with exceptional efficiency rates, for example one golf course, had a DU Lq at 83 percent. Recommendations for high achieving sites were minimal and included items such as topdressing, aeration, checking pressure on non-conforming stations, etc.

Initial DUs for the 30 sites varied from 41 percent to 86 percent. 14 of the 30 sites had DU above 70 percent.

Conclusions reached so far (no final report yet): many sites have low DU but with large potential for easy improvements (low tech, low cost) improvements such as cleaning filters, straightening alignment, resolving pressure. A few will need capital improvements such as equipment replacement and correcting improper spacing.

17. Hla, A.K. and P.M. Waller. Efficiency Analysis of Urban Microirrigation Systems in Phoenix Metropolitan Area. Presented at the1998 American Society of Engineers Annual International Meeting. Paper No. 982045. ASAE 2950 Niles Road. St. Joseph, MI 49085-9659 USA.

This research was conducted in Phoenix, AZ to determine the operational effectiveness of micro irrigation systems. It was concluded that drip irrigation is very inefficient and non-uniform in urban landscape irrigation in Phoenix. The researchers estimated crop coefficients as 0.25 for low water-use desert adapted plants, 0.33 for semi-arid plants, and 0.5 for medium water-use plants. ETo rates were also estimated for summer (8 mm/d), spring (7 mm/d), winter (2 mm/d) and fall (5 mm/d). The average distribution uniformity (low quarter) for all zones was 18 percent. Reasons for low uniformity included improper number of emitters with respect to canopy area, degradation of emitters, differential rates of canopy growth, and failure to adjust the number of emitters as canopy diameter increases. In contrast, the distribution uniformity at the two control sites was 86 percent.

18. HydroPoint Data Systems, Inc., provider of WeatherTRAK. Personal Communication (2007).

Default settings for the WeatherTRACK weather based automated ET controller information on sprinkler efficiency:

- Spray head = 70 percent
- Stream spray = 70 percent
- Stream rotors = 75 percent
- Full/Part/Mixed circle rotors = 80 percent
- Full/Part/Mixed circle impact = 85 percent
- Bubbler = 90 percent
- Drip Emitter = 90 percent

19. Irrisoft. (2007) Personal Communication.

Irrisoft uses the IA's DU table to develop the default uniformity numbers. It also uses the DU lower half in scheduling and has found it to work very well.

20. Irvine Ranch Water District - Personal Communication

Systems installed prior to 1995 on public landscapes included 457 meters installed on 846.25 acres with an average of 30.01 inches of water/year (including effective precipitation) representing 64 percent of ETo as determined by CIMIS. The metered years included 2002 – 2007.

Systems installed prior to 1995 on private landscapes included 1858 meters installed on 293.77 acres with an average of 42.20 inches of water/year (including effective precipitation) representing 89 percent of ETo as determined by CIMIS. The metered years included 2002 – 2007.

Systems installed post 1995 on public landscapes included 230 meters installed on 870.04 acres with an average of 25.31 inches of water/year (including effective precipitation) representing 54 percent of ETo as determined by CIMIS. The metered years included 2002 – 2007.

21. Kissinger, J. and K.H. Solomon. Performance and Water Conservation Potential of Multi-Stream, Multi-Trajectory Rotating Sprinklers for Landscape Irrigation. Presented at 2006 American Society of Agricultural and Biological Engineers Annual International Meeting, July 2006. Paper No. 062168

Over 50 field audits were presented comparing the performance of traditional fixed spray heads with multi-stream, multi-trajectory rotating (MSMTR) sprinklers. Distribution Uniformity (DU) and Run Time Multiplier (RTM) were used in the comparison. The following table was extracted from Solomon et al., 2006 and shows changes in DUlq due to conversion to MSMTR sprinklers.

Result	Range	Average	Median
Before conversion (fixed spray heads)	22-72	44	43
After conversion	46-88	67	67
Improvement due to conversion	4-52	23	23

22. Kumar, R., S. Mitra, and E. Vis. (2006) Comparison of Distribution Uniformities of Soil Moisture and Sprinkler Irrigation in Turf grass. Final Report.
California Landscape Contractors Association Environmental Research Funding Program. H:\CLCAFinalFiles2_06\CLCAFinal RPT3-17-06.

This project report was funded by the CLCA Environmental Research Funding Program and conducted in California. Soil moistures were measured using TDR and DU was measured using catch cans. On average (for 3 plots), the soil DUlq was 85 percent whereas the average DUlq for the catch cans was 70 percent. The researchers then calculated DUlh using two methods. Using the equation in Irrigation Association resulted in DUlh of 82 percent whereas calculating from the catch can data resulted in DUlh of 80 percent. In any case, DUlh was closer to the DUlq of the soil. It was estimated that using DUlh instead of DUlq for irrigation scheduling would result in 17 percent less water applied.

23. Little, G.E., Hills, D.J., and B.R.Hanson. (1993) Uniformity in Pressurized Irrigation Systems Depends on Design, Installation. California Agriculture May-June 47(3) 18-21.

Evaluated 258 agricultural irrigation systems by mobile Labs in 5 So. Cal. RCDs. Found average DU for drip to be 75 percent and micro spray 72 percent representing all types of terrain. The 13 sprinkler system on nonundulating terrain the average DU was 82 percent.

24. Mecham, B. Q. The effects of Matched Precipitation Rate Nozzles on DU , Northern Colorado Water Conservancy District, Loveland, Colorado.
http://www.ncwcd.org/ims/ims_info/CaseStudy.pdf

Could not find any direct correlation to nozzle and better DU. Some zones do improve with MPR and others do not. Notes DU were ranged from 62 percent - 78 percent. DU is affected by many things; attention needs to be paid to design, proper installation, and adjustment of the head and maintenance.

25. Mecham, B.Q. (2004). A Summary Report of Performance Evaluations on Lawn Sprinkler Systems. Northern Colorado Water Conservancy District. http://www.ncwcd.org/ims/ims_info/SummaryEvaluationSprinklerSystems.pdf

Residential		Fixed Spray		Rotors	
Location	No. of audits	Avg. DUlq, %	Range, %	Avg. DUlq, %	Range, %
Utah	4500	52		58	
Utah, USU	164	52	18-80	49	15-86
Colorado	973	53	20-89	54	19-92
Oregon	398	55*		54*	
Florida MIL	576	54	11-89		
U of FL case study	19	40		48	
California case study	19	41	16-54		
Commercial		Fixed Spray		Rotors	
Location	No. of audits	Avg. DUlq, %	Range, %	Avg. DUlq, %	Range, %
Utah	166	55	7-82	55	8-84
Colorado	20	52	6-77	50	3-88
Arizona	7			41	20-56
Texas	6			58	27-79

*reflects the lower third distribution uniformity (usually, 3-9 percent higher than lower quarter, according to the author of the Oregon study).

These data were collected from 1999 through 2005.

26. Mecham, B. Q. and Boyd, R. (2004) Landscape Irrigation Efficiency of Nine Model Homes. Northern Colorado Water Conservancy District. http://www.ncwcd.org/ims/ims_info/CaseStudy.pdf

Three model homes had traditional sprinklers and 3 had sub-surface drip irrigation. Initial DU was poor in sprinklers ranging 12-65 percent with an average of 40 percent. Took one yard and worked with existing system and increased DU from 35 percent to 50 percent. Took this same system and installed MP Rotator and achieved a 73 percent DU after tuning it. Paper also goes into detail about factors contributing to poor DU.

27. Meyer, J.L. and V.A. Gilbeault. (2006) Turfgrass Performance Under Reduced Irrigation. California Agriculture July-August 2006, pg. 19-20.

This research was conducted at the University of California South Coast Field Station, Irvine. It was found that there was no significant difference in cool-season grass performance between the 100 percent and 80 percent regimes (i.e., 100 percent of ETo and 80 percent of ETo). The 60 percent (0.6*ETo) regime significantly reduced the turf quality of the three cool-season grasses tested. Thirty-six percent less water was applied to the warm-season species than to the cool-season season species for acceptable turf quality.

28**.** Miller, G.L., N. Pressler and M.D. Dukes. (2003) How Uniform is Coverage from Your Irrigation System? Golf Course Management. August 2003. pp. 100-102.

Evaluated five golf courses in central Florida with an average DU of 57 percent for trees, 50 percent for fairways, and 60 percent for greens. Through retrofitting system to achieve average 70 percent DU needed head to head coverage adjusted pressure, nozzles breaks, improper tilt, size, & etc.

29. Pittenger, D. and D. Shaw. (2003) What We Know About Landscape Water Requirements. CO-HORT Summer 2003 vol. 5.2

Pittenger and Shaw have published the following table for crop coefficient (Kc) values of cool-season and warm-season turf grasses. Note that the authors did not specify sources for these numbers. The cool-season species include tall fescue, Rye grass, bent grass, and Kentucky Blue grass. The warm-season species include Bermuda grass, Moesia grass, and St. Augustine grass. Authors also documented that many universally used landscape species maintain their aesthetic and functional value when irrigated within a range of 20-80 percent of ETo. For landscape species with unknown water requirements, they recommended setting initial irrigation schedules at 50 percent of ETo for established non-turf landscape plantings adjustments made as needed.

Month	Cool-Season	Warm-Season
January	0.61	0.55
February	0.64	0.54
March	0.75	0.76
April	1.04	0.72
May	0.95	0.79
June	0.88	0.68
July	0.94	0.71
August	0.86	0.71
September	0.74	0.62
October	0.75	0.54
November	0.69	0.58
December	0.60	0.55
Annual Average	0.80	0.60

30. Pitts, D., K. Peterson, g. Gilbert and R. Fastenau. (1996) Field Assessment of Irrigation System Performance. Applied Engineering in Agriculture. 12(3):307-313.

After conducting DU measurements on 385 irrigation system evaluations for agricultural and landscape irrigations in Santa Barbara and San Luis Obispo counties, they found that the mean DU for all systems was 64 percent. DU average for the 174 micro-irrigation (drip emitters and micro-sprayers) system evaluations was 70 percent. Commonly observed problem categories for micro-irrigation systems were emitter plugging, maintenance, and improper retro-fitting (e.g., mixed emitters).

The average DU for 37 turf irrigation systems was 49 percent. Over 40 percent of the turf irrigation systems evaluated had DUs less than 40 percent. The turf areas tested ranged from 0.4 to 12 ha (1 to 30 acre). The low DUs for turf irrigation systems were attributed to the following (in the order of frequency of occurrence): (1) maintenance, malfunctioning sprinkler heads, (2) mixed sprinklers, altered from original design, and (3) design problems, excessive pressure variations and insufficient sprinkler overlap. Many of the irrigators were unaware of turf ET and uncertain of the application rate, so irrigation scheduling was most frequently based on the turf's appearance.

31. Stewart, J. R., R. Kjelgren, P. G. Johnson and M. R. Kuhns. (2004) Soil-water-use Characteristics of Precision-irrigated Buffalo grass and Kentucky Blue grass. Online Applied Turf grass Science doi: 1094/ATS-2004-1118-01-RS.

The research was conducted in Logan, Utah to characterize the relationship between foliage and air temperatures of Buffalo grass and Kentucky Blue grass under well-watered conditions and during a period without irrigation to determine the soil water content at the point of incipient water stress. Kentucky Blue grass reached incipient water stress when nearly 50 percent of the total water was depleted in its 0.6 m deep root zone. Buffalo grass reached incipient water stress after 22 days of soil drying when it had depleted nearly 60 percent of soil water to a 0.9 m depth. Ninety-four percent of the Kentucky Blue grass root system was in the top 0.3 m of the soil compared to 62 percent for Buffalo grass. The average DU for the gear drive heads used to irrigate the study site was 63 percent across all 20 plots.

32. Waller, P. Tree and Shrub Irrigation. http://ag.arizona.edu/abe/northernarizona/Tree_and_Shrub_Irrigation.html

Uses irrigation efficiency of 78 percent while discussing water use for some woody plants and the effects of droughts on irrigation scheduling.

33. Water Management Committee of the Irrigation Association. (2005) Landscape Irrigation Scheduling and Water Management. Irrigation Association. http://www.irrigation.org/gov/pdf/IA_LISWM_MARCH_2005.pdf

34. Zoldoske, D.F. (2003) Improving Golf Course Irrigation Uniformity: a California Case Study. California Agricultural Technology Institute Publication No. 030901

Five golf courses participated for a time span of one year prior to nozzle change and one year afterwards in the study. Replacement nozzles were provided either as an upgrade by the manufacturer or by a third party vendor.

Calculated savings = 9 percent based on the calculated DUlq.

Gross annual water savings reported on the 18-hole course ranged from 55.5 acre feet to minus 22.8 acre feet. Average gross water savings per course was 16.6 ac-ft. The gross water savings was calculated as the annual water applied to the turf grass before the nozzle change less the annual water applied after the nozzle change.

Estimated total gross water savings for all the participants, without adjusting for useful rainfall, was 99.8 ac-ft of water, or 6.5 percent of applied water. Adjusting for useful rainfall, the estimated savings falls to 5.7 percent of the applied water.

There is a discussion about DU in the paper but no indication of measuring it at the study site.

35. Zoldoske, 2005. Reduced Water Budgets and Implications for Landscape Irrigation
International Center for Water Technology, CA State University, Fresno
Review of Implications to Proposed Change of ET Adjustment Factor. Paper presented to the AB 2717 Landscape Task Force.
http://www.cuwcc.org/Uploads/committee/ET_Adjustment_Calulation_Draft_3_05-08-05.pdf

Discussed the different components of ETAF and presented scenarios under which an ETAF of 0.7 can be achieved.

Appendix C – Report References

Assembly Bill 325, Clute. (1990): The Water Conservation in Landscaping Act

Bamezai, A., Perry, R., and Pryor, C. (2001): Water Efficient Landscape Ordinance (AB 325): A Statewide Implementation Review. Western Policy Research

California Department of Water Resources. (2005): California Water Plan Update. Bulletin 160-05

California Urban Water Conservation Council, (2005): Water Smart Landscapes for California: AB 2717 Landscape Task Force Findings, Recommendations, & Actions, A Report to the Governor & Legislators

Gleick, P.H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G., Cushing, K.K., and A. Mann. (2003): Waste not, Want Not. The Potential for Urban Water Conservation in California. Pacific Institute.