State of California
The Natural Resources Agency
Department of Water Resources
Division of Statewide Integrated Water Management
Water Use and Efficiency Branch

# DRAFT

# A Methodology for Quantifying the Efficiency of Agricultural Water Use

**A report to the Legislature pursuant to Section 10608.64 of the California Water Code**

December 21, 2011

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# List of Acronyms

| | |
|---|---|
| AN | Agronomic Needs |
| ASC | Agricultural Stakeholders Committee |
| AW | Applied Water |
| AWMP | Agricultural Water Management Plan |
| CARCD | California Association of Resource Conservation Districts |
| CCUF | Crop Consumptive Use Fraction |
| CIMIS | California Irrigation Management Information System |
| CWC | California Water Code |
| DU | Distribution Uniformity |
| DWR | Department of Water Resources |
| Etc | Crop Evapotranspiration |
| ETo | Reference Evapotranspiration |
| ETAW | Evapotranspiration of Applied Water |
| EN | Environmental Needs |
| FGD | Farm Gate Deliveries |
| GRP | Gross Revenue of Crop Production |
| Kc | Crop Coefficient |
| PAW | Production of Applied Water |
| RF | Recoverable Flow |
| SBX7-7 | Senate Bill X 7-7 |
| SWRCB | State Water Resources Control Board |
| TWS | Total Water Supplies |
| TWUF | Total Water Use Fraction |
| USBR | US Bureau of Reclamation |
| USDA-NRCS | US Department of Agriculture, Natural Resources Conservation Service |
| VAW | Value of Production |
| WCP | Weight of Crop Production |
| WMF | Water Management Fraction |
| WPU | Water Plan Update |

# Executive Summary

The Water Conservation Act of 2009 (Senate Bill X7-7) directs the Department of Water Resources (DWR), in consultation with the Agricultural Water Management Council, academic experts, and environmental stakeholders, to develop and report to the Legislature a proposed methodology for quantifying the efficiency of agricultural water use, as well as a plan of implementation including roles and responsibilities and the data and funding that would be needed to implement the methodology. The legislation does not authorize DWR to implement the methodology.

To accomplish this and other provisions of SBX7-7, DWR formed an Agricultural Stakeholder Committee (ASC) consisting of agricultural water suppliers, academic experts, and environmental stakeholders. Since 2010, DWR has held numerous public listening sessions, stakeholder committee and subcommittee meetings, and public workshops to develop the methodology.

The purpose of the methodology proposed in this report is to describe consistent and practical methods for quantifying the efficiency of agricultural water use by irrigated agriculture that can help evaluate current conditions and strategies for improving agricultural water management. The anticipated users of these methods are farmers, water suppliers, and regional water management groups, as well as nongovernmental organizations and local, state, federal and tribal planners. The methods are not intended for non-irrigated agriculture such as dairies, on-farm processing, or other agricultural operations not directly related to irrigated lands.

In addition to a methodology for quantifying the efficiency of agricultural water use, which is comprised of four methods, this report describes a companion indicator of irrigation system performance and two supplemental indicators of crop productivity. The methods and indicators are applicable at one or more spatial scales - statewide, regional, county, water supplier, or field - as described in the report and summarized in the two tables below.

## Methodology for Quantifying the Efficiency of Agricultural Water Use

To develop the methods, DWR and the ASC considered the components of a water balance at three spatial scales - regional, water supplier and field - to understand how and how much water enters and leaves these areas. As a result, DWR proposes the following four methods to help identify opportunities for improving the efficiency of various parts of the water balance at different spatial scales (see table for details).

- Crop Consumptive Use Fraction (CCUF) - this method evaluates the relationship between the consumptive use of a crop and the quantity of water applied for that purpose. It is appropriate for the regional, water supplier or field scales.

- Total Water Use Fraction (TWUF) - this method expands on the CCUF by including water for crop agronomic needs and to meet environmental objectives. It is appropriate for the regional, water supplier or field scales.
- Water Management Fraction (WMF) - this method evaluates the recoverable water available for reuse at another place or time in the system. It is appropriate for the regional or water supplier scales.
- Delivery Fraction (DF) - this method evaluates the relationship between the water delivered to an area and the total applied surface or groundwater. It is appropriate for the water supplier scale.

# Companion Indicator of Irrigation System Performance

DWR also proposes the following companion indicator of irrigation system performance which does not measure the efficiency of agricultural water use:

- Distribution Uniformity (DU) - this indicator evaluates the performance and effectiveness of an irrigation system to evenly deliver or distribute water to a field. it is appropriate for the field scale, however, field scale data can be aggregated to the water supplier scale or regional scales and reported to water suppliers to include in their Agricultural Water Management Plans or other plans submitted to DWR.

## Roles and Responsibilities

DWR would develop data standards, data collection protocols, and schedules for the methods for all spatial scales; and it would provide assistance to agricultural water suppliers and growers to implement the appropriate methods and companion indicator. DWR would maintain a database managing and disseminating the information.

- Regional Scale - DWR would be responsible for quantifying and reporting the regional scale methods - CCUF, TWUF and WMF. DWR would also determine and report the regional statistical mean (average) and standard deviation of the field scale methods CCUF and TWUF and the DU companion indicator. This would require a minimum of100 samples per region in order for the assessment to be a statistically represented sampling. The sampling could be achieved by utilizing the proposed Mobile Labs to conduct new field evaluations or to utilize existing data from irrigation system evaluations.

- Water Supplier Scale - The water supplier would be responsible for quantifying and reporting the water supplier scale methods -- CCUF, TWUF, and WMF, as well as the DF. If water suppliers provide on-farm irrigation system evaluation, the water supplier would also report the mean and standard deviation of the field scale CCUF, TWUF and DU in its service area. This would require sufficient samples to be statistically representative. The sampling could be achieved by utilizing the proposed Mobile Labs to conduct new field evaluations or to utilize existing data mobile la irrigation system evaluations.

- Field Scale - DWR proposes that the field scale methods be encouraged but voluntary -- CCUF and TWUF, as well as the DU companion indicator. The voluntary approach would use a Mobile Lab program, such as the one run by the National Resource Conservation Service (NRCS), in partnership with State and federal agencies. To be effective, this would require an expanded Mobile Lab program to provide participating farmers local technical and financial support for quantifying and reporting the field scale methods. Aggregated field scale data would be submitted to water suppliers and reported in the Agricultural Water Management Plans or other plans submitted to DWR and available for educational and planning purposes.

DWR could implement the regional scale methods and companion indicators at county and statewide scales and include the information in the Water Plan Updates.

The existing legislation (section 10608.48(d) and (h) requirements provide a mechanism for the agricultural water suppliers to submit the calculations of the water use efficiency methods in their Agricultural Water Management Plans to DWR. The agricultural water suppliers could report the calculations proposed in this methodology (CCUF, TWUF, WMF, and DF) as well as the mean and standard deviation of the values of the field scale CCUF, TWUF, DU in their service areas in their AWMP. Furthermore, as DWR updates the EWMPs per CWC 10608.49(h), DWR could include the calculation of the above methods as a metric of reporting estimate of water use efficiency improvements in the agricultural water suppliers AWMPs.

DWR has also recommended a funding priority, giving field scale implementation the highest priority, support for agricultural suppliers less than 25,000 acre the second priority and DWR database the third priority.

The methods, companion indicator, and Plan of Implementation including needed funding and proposed schedule are summarized in the table below.

# Methods for Quantifying the Efficiency of Agricultural Water Use and Companion Indicator of Irrigation System Performance

**Table 1.**

| | | Recommended Geographic Scales [1] | | |
|---|---|---|---|---|
| | | **Regional[2]** | **Supplier [3]** | **Field [4]** |
| **Water Use Efficiency Methods** | **Crop Consumptive Use Fraction (CCUF)**<br>*Method evaluates the relationship between the consumptive use of a crop and the quantity of water applied for that purpose.*<br>**CCUF = ETAW/(AW-AN-EN)** | DWR | Supplier | Voluntary / Mobile Lab |
| **Water Use Efficiency Methods** | **Total Water Use Fraction (TWUF)**<br>*Method expands on the CCUF by including water for crop agronomic needs and to meet environmental objectives.*<br>**TWUF = (ETAW+AN+EN)/AW** | DWR | Supplier | Voluntary / Mobile Lab |
| **Water Use Efficiency Methods** | **Water Management Fraction (WMF)**<br>*Method evaluates the recoverable water available for reuse at another place or time in the system.*<br>**WMF = (ETAW+ RF)/TWS** | DWR | Supplier | |
| **Water Use Efficiency Methods** | **Delivery Fraction (DF)**<br>*Method evaluates the relationship between the water delivered to an area and the total applied surface or groundwater.*<br>**DF = FGD/TWS** | | Supplier | |
| Irrigation System **Indicator** | **Distribution Uniformity (DU)**<br>*Indicator evaluates the performance and effectiveness of an irrigation system*<br>**DU = Dawlq/Daw** | DWR | Supplier | Voluntary / Mobile Lab |
| **Costs** | *These geographic scale costs are further explained in Section 5.4.* | 0.5M/y | >$1.0 M/y | $1.7 – 2 M |
| **Schedule** | *Methods would be implemented at the appropriate geographic scales using existing programs and reporting mechanisms to the extent possible (e.g., Water Plan Update and Agricultural Water Management Plans).* | CA Water Plan 2013, 2018 | Ag Water Mgmt Plans 2015, 2020 | Ag Water Mgmt Plans 2015, 2020 |

(1) Frequency of Calculations and Reporting: all Regional scale calculations would be done every five years and reported in the Water Plan Update; Supplier's DF calculations would be done yearly; and Field Scale calculations would be done following a sampling plan starting with a pilot program and a phased approach to reach representative numbers of fields and samples.

(2) Regional CCUF and TWUF calculations are based on the regional values and also based on the mean and standard deviation of field scale values. DU is mean of field scale values for the region. The WMF is computed using regional estimates of ETAW, RF, and TWS.

(3) Only required from suppliers serving more than 25,000 acres of irrigated land and those serving more than 10,000 acres of irrigated land when funding is made available to them. CCUF, TWUF, and DF would be calculated based on aggregated farm gate deliveries (required to per AB 1404). DU, CCUF, and TWUF would be statistically calculated over the entire supplier's service area based on the mean and standard deviation of available field scale calculated values, if supplier provides on-farm evaluation of irrigation systems.

(4) This would be accomplished by a State, federal, and supplier joint mobile lab / field evaluation program based on voluntary farmer participation. When locally cost-effective, program shall be sponsored by supplier if serving more than 25,000 acres of irrigated land. For suppliers serving more than 10,000 but less than 25,000 acres of irrigated land, participation is proposed only when funding is made available.

**<u>Acronyms</u>: AN**: agronomic needs; **AW**: applied water at field scale (at supplier or regional scale, AW consists of all water supplies including groundwater but excluding non-crop uses); **CCUF**: crop consumptive use fraction; **Daw**: the average depth of applied water across the field; **Dawlq**: the average lower quarter depth of applied water; **DF**: delivery fraction; **DU**: distribution uniformity; **EN**: environmental needs; **ETAW**: evapotranspiration of applied water; **FGD**: total farm gate deliveries; **RF**: recoverable flow; **TWS**: total surface and groundwater supplier delivered or diverted into the boundary; **TWUF**: total water use fraction; **WMF**: water management fraction.

## Supplemental Indicators of Crop Productivity

During ASC and subcommittee meetings, two indicators relating crop productivity to applied water were identified and discussed. DWR has reported statewide trends for these indicators in the 2009 update of the California Water Plan. These indicators do not quantify the efficiency of agricultural water use. They however provide additional information about the relationship and trends of crop yield and/or the monetary value of crops to the volume of irrigation water applied during production. They can indicate long-term changes or trends in agricultural production and income relative to irrigation at large spatial scales.

DWR cautions that these indicators not be used to draw conclusions about regional crop selection because many factors other than applied water affect crop production and income in any given year and location and with changing crop markets. The purpose and limitations of these productivity indicators are described in this report.

As a result, DWR proposes the following two indicators of crop productivity (summarized in the table below) as supplemental to the methods and companion indicator described above:

- Productivity of Applied Water Fraction (PAW) - this indicator illustrates the relationship between crop production in tonnage and the volume of applied water. It is appropriate for county and statewide scales.
- Value of Applied Water Fraction (VAW) - this indicator illustrates the relationship between gross crop value in dollars and the volume of applied water. It is appropriate for county and statewide scales.

DWR would be responsible for quantifying the two supplemental productivity indicators and reporting them in the five-year updates of the California Water Plan to illustrate trends of agricultural production as it relates to water use.

# Supplemental Indicators of Crop Productivity Related to Applied Water

**Table 2.**

| | | Recommended Geographic Scales (1) | |
|---|---|---|---|
| | | **Statewide** | **County** |
| **Productivity Indicators** | **Productivity of Applied Water (PAW)**<br>*Indicator illustrates the relationship between crop production in tonnage and the volume of applied water*<br>**PAW = WCP/AW** | DWR | DWR |
| | **Value of Applied Water (VAW)**<br>*Indicator illustrates the relationship between gross crop value in dollars and the volume of applied water.*<br>**VAW = GRCP/AW** | DWR | DWR |
| **Costs** | *Cost of computing the productivity indicators* | 0.1 M/y | 0.1 M/y |
| **Schedule** | *Indicators would be implemented at the county scale and statewide and reported in the Water Plan Update.* | CA Water Plan 2013, 2018 | CA Water Plan 2013, 2018 |

(1) **Statewide and county scale calculations would be done every five years and reported in the CA Water Plan Update**.

**<u>Acronyms</u>: AW**: applied water on field (computed by DWR at county and statewide scales); **GRCP**: Gross revenue of crop production; **PAW**: productivity of applied water; **VAW**; value of applied water; **WCP**: Weight of crop production.

# 1.0 Introduction

The Department of Water Resources (DWR) has been directed by the Legislature upon enacting Section 10608.64 of the California Water Code to “develop a methodology for quantifying the efficiency of agricultural water use.” This report, prepared by DWR for the Legislature, provides legislators, public interests, and agricultural and other stakeholders with a methodology for quantifying the efficiency of agricultural water use. The report improves the understanding of agricultural water use and provides illustrative examples to demonstrate the complexity of quantifying the efficiency of agricultural water use.

This report is organized with the following key sections:

**Background, purpose and approach** – context, purpose, and process for developing a methodology and appropriate spatial scales.

**Methods for quantifying agricultural water use efficiency** – a discussion of the methods developed to quantify the efficiency of agricultural water use and example calculations.

**Supplemental productivity indicators** – a discussion of supplemental productivity indicators, their uses and limitations, and example calculations.

**Plan of Implementation** – roles and responsibilities, data and funding needed for implementation and proposed schedule.

## 1.1 Purpose of Quantifying the Efficiency of Agricultural Water Use

The purpose of the methodology proposed in this report is to describe consistent and practical methods for quantifying the efficiency of agricultural water use by irrigated agriculture that can help evaluate current conditions and strategies for improving agricultural water management. The anticipated users of these methods are farmers, water suppliers, and regional water management groups, as well as nongovernmental organizations and local, state, federal and tribal planners. The methods are not intended for non-irrigated agriculture such as dairies, on-farm processing, or other agricultural operations not directly related to irrigated lands.

## 1.2 Legislative Direction and Declarations from Senate Bill x7-7 (Statutes of 2009)

Quantifying the efficiency of agricultural water use was directed by policy statements and other language in the 2009 legislation – SB x7-7. Specifically, §10608.64 of the Act states:

> *The Department… shall develop a methodology for quantifying the efficiency of agricultural water use.*
>
> *… the Department shall report to the Legislature on a proposed methodology and a plan for implementation. The plan shall include the estimated implementation costs and the types of data needed to support the methodology.*

Direction concerning methodological approach is also included in the Act.

> *Alternatives to be assessed shall include, but not be limited to, determination of efficiency levels based on crop type or irrigation system distribution uniformity.*

DWR identified further legislative direction in *Chapter 1, General Declarations and Policy* of the 2009 legislation. This chapter provided guidance in the assessment of methodology and development of an implementation plan for quantifying efficiency of agricultural water use that included the following:

> *§10608. The Legislature finds and declares all of the following:*
>
> *(a) Water is a public resource that the California Constitution protects against waste and unreasonable use.*
>
> *(b) Growing population, climate change, and the need to protect and grow California's economy while protecting and restoring our fish and wildlife habitats make it essential that the state manage its water resources as efficiently as possible.*
>
> *(c) Diverse regional water supply portfolios will increase water supply reliability and reduce dependence on the Delta.*
>
> *(d) Reduced water use through conservation provides significant energy and environmental benefits, and can help protect water quality, improve streamflows, and reduce greenhouse gas emissions.*
>
> *(e) The success of state and local water conservation programs to increase efficiency of water use is best determined on the basis of measurable outcomes related to water use or efficiency.*
>
> *(f) Improvements in technology and management practices offer the potential for increasing water efficiency in California over time, providing an essential water management tool to meet the need for water for urban, agricultural, and environmental uses.*
>
> *§10608.4. It is the intent of the Legislature, by the enactment of this part, to do all of the following:*

*(a) Require all water suppliers to increase the efficiency of use of this essential resource.*

*(e) Establish consistent water use efficiency planning and implementation standards for urban water suppliers and agricultural water suppliers.*

*(i) Require implementation of specified efficient water management practices for agricultural water suppliers.*

*(j) Support the economic productivity of California's agricultural, commercial, and industrial sectors.*

*(k) Advance regional water resources management.*

*§10608.8.*

*(c) This part does not require a reduction in the total water used in the agricultural or urban sectors, because other factors, including, but not limited to, changes in agricultural economics or population growth may have greater effects on water use. This part does not limit the economic productivity of California's agricultural, commercial, or industrial sectors.*

*§10800*

*(e) There is a great amount of reuse of delivered water, both inside and outside the water service areas.*

*(f) Significant noncrop beneficial uses are associated with agricultural water use, including streamflows and wildlife habitat.*

*(h) Changes in water management practices should be carefully planned and implemented to minimize adverse effects on other beneficial uses currently being served.*

The complete list of sections can be found in Appendix I.

## 1.3 Process

DWR began the process of developing methodologies for quantifying the efficiency of agricultural water use by forming a subcommittee (known as A1) comprised of Agricultural Water Management Council, academic experts, and environmental stakeholders. The A1 subcommittee is a subgroup of the larger Agricultural Stakeholder Committee (ASC) that was formed to advise the DWR on implementation of the agricultural water conservation and planning provisions of Senate Bill X 7-7, the statutes of 2009. Both A1 and ASC meet on an as needed basis to discuss progress in developing the methodologies. DWR staff and hired consultants formed a project work team (PWT) that met regularly to discuss and address the information and comments provided by the A1 and ASC members. The ASC and A1 subcommittee met several times throughout the process of developing the methodology for this report. Additionally DWR conducted three public workshops to receive public input with the goal of receiving comment from a broad spectrum of interested parties. Public comments were considered by DWR in preparing this report.

# 2.0 Water Use and Use Efficiency in Agriculture

Water for agricultural uses comes from surface water diversion, ground water pumping, and precipitation. Surface water and ground water used for irrigation of crops are commonly referred to as applied water (AW). The purpose of irrigation is to maintain soil moisture and soil salinity at levels that do not restrict crop growth and produce the maximum crop yield..

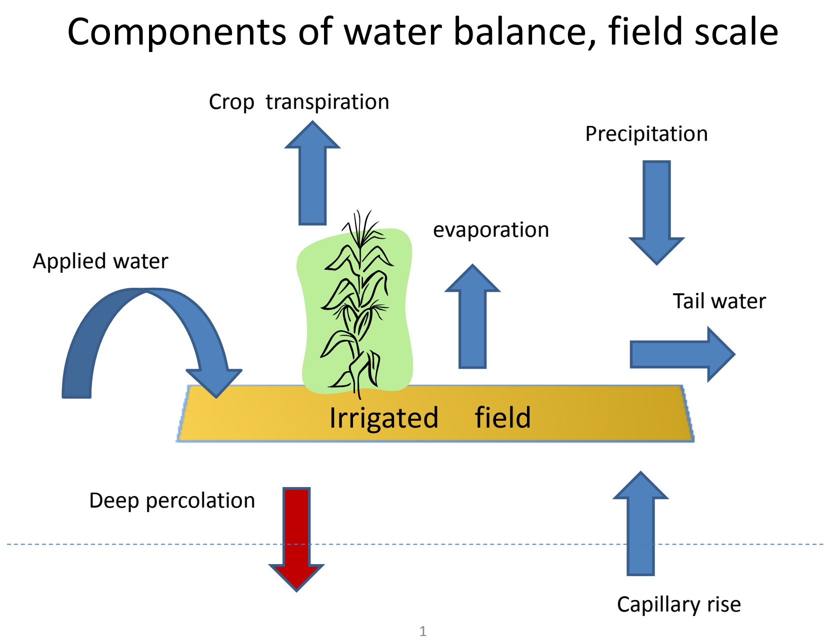


**Figure 2.1**

## 2.1 Field Scale Water Balance

The water balance at a field scale is shown in Figure 2.1. Irrigation water applied (applied water) to the field is used to meet the various types of crop requirements including crop evapotranspiration (transpiration from crops and evaporation from soil surface), soil salinity leaching requirement, and other agronomic requirements. Some of the applied water may percolate beyond the root zone and may not be available for crop uptake. Alternatively, soil water below the water table may move into the root zone by capillary rise for crop uptake. Excess surface flows may flow out of the field and be recycled on-farm or used elsewhere or may be lost to non-beneficial evepotranspiration or salt sinks. Some of the crop water requirements may be met through rainfall. Depending on the slope, soil type, timing, and frequency of precipitation, only a fraction of the total rain is being used by crops. In some cases some of the applied water may be used for environmental purposes. The quantification of some components of the water balance such as evaporation, deep percolation are not practical, therefore various fractions or ratios of the water balance components recommended to quantify the efficiency of water use are based on the quantifiable components of the water balance.

Agricultural water use that benefits crop production include crop evapotranspiration, leaching requirement, climate control (cooling and frost protection), soil preparation, and evapotranspiration by non-crops that are used as wind breaks.

Crop evapotranspiration (ETc) is water that enters the atmosphere by the combined processes of evaporation from crop and soil surfaces and transpiration from crops. It can either be measured or estimated using theoretical and empirical equations.

Some amount of the applied water is used to flush excess amounts of salt that is present in the soil below the root zone to make an optimum condition for crop production. Different crop types and different varieties of the same crop can have different tolerances to salinity. This leaching requirement is the amount of water required to remove salts from the root zone area is estimated using the ratio of the electrical conductivities of irrigation water (applied water) and drainage water. Water applied in excess of the leaching requirement that goes to deep percolation reduces field scale water use efficiency. In this report, it is assumed that leaching requirements are applied efficiently and any excess application of the leaching requirements is considered an inefficient use of water.

Depending on temperature, humidity, wind speed and other factors, some portion of agricultural water may also be used for cooling of crops and frost protection. The amount of water used for cooling and frost protection depends on crop type and weather parameters such as humidity and temperature. Although significant amount of water used for climate control may evaporate, the rest infiltrate into the soil and become available for crops to consume.

Other uses for water include agronomic uses such as water application prior to seeding, flooding fields to hasten the decomposition of straw which has a dual environmental purpose of providing habitat for migrating fowl. Other environmental uses may include sustaining riparian habitat and endangered species support.

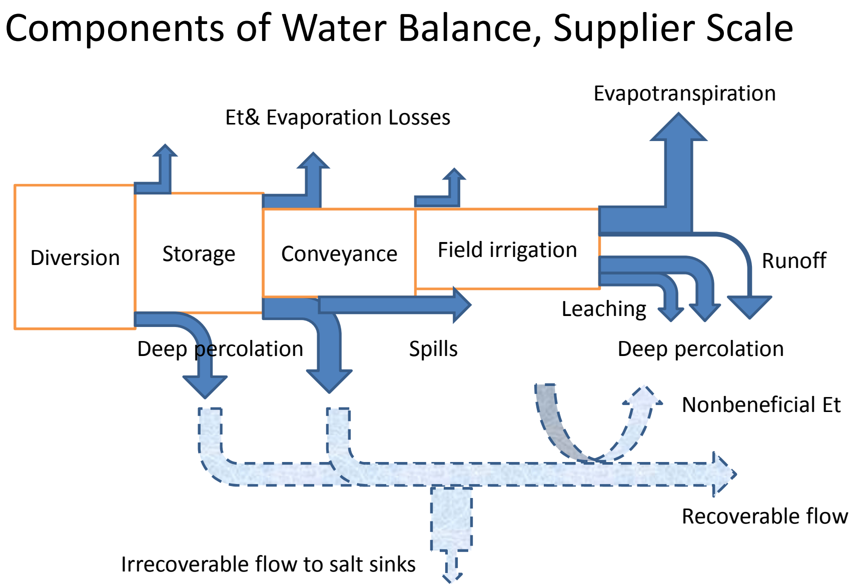


**Figure 2.2**

## 2.2 Water Supplier Scale Water Balance

The components of the water balance at a supplier scale is shown in Figure 2.2. Water diverted into a suppliers service area may be stored in a flow regulatory reservoir from which water may be lost by evaporation or infiltrate into aquifer as deep percolation. Water supplies from the storage or directly from the source, weather surface or groundwater, is conveyed to suppliers' customers by supplier and farm-level conveyance systems. Water also leaves these conveyance system as evaporation and deep percolation. Conveyance systems also have spills during the operation that may be captured and recycled or it may flow into other streams or infiltrate into groundwater aquifers. The water delivered to farms is used for irrigation of crops to meet the crop consumptive use and agronomic needs. Some water may also be used at the farm level for environmental purposes. Environmental water either evaporates or flows into streams or infiltrate into groundwater.

Evaporation and deep percolation that enters unusable groundwater, and runoff (surface flows) that flow to salt sinks (ocean or terminal points) or used by nonbeneficial evapotranspiration are considered irrecoverable flows.  The irrecoverable flows are depleted from agricultural system. Prevention or reduction of irrecoverable flow creates water savings that can be used for other beneficial uses.  Some of the deep percolation and runoff may recharge groundwater aquifers or flow into streams and rivers creating source of supply for other water users, this flow is called recoverable flow. Water suppliers use the recoverable flow in a recycling system or flows to downstream suppliers. Although some of surface and subsurface flows are recoverable, reduction of the non beneficial evaporation and transpiration losses, runoff from fields, spills, and excess deep percolation is desired for efficient use of water and for its co-benefits at the field, supplier and regional scales.

The quantification of water use efficiency needs to recognize and consider the fate and interrelationship of all water beneficially used at different levels. The water balance discussed here provide a useful framework for these analyses. Quantification of all the water balance components at the water supplier is not practical, therefore the components of the water balance used to quantify the efficiency of water use are based on the quantifiable components of the water balance.

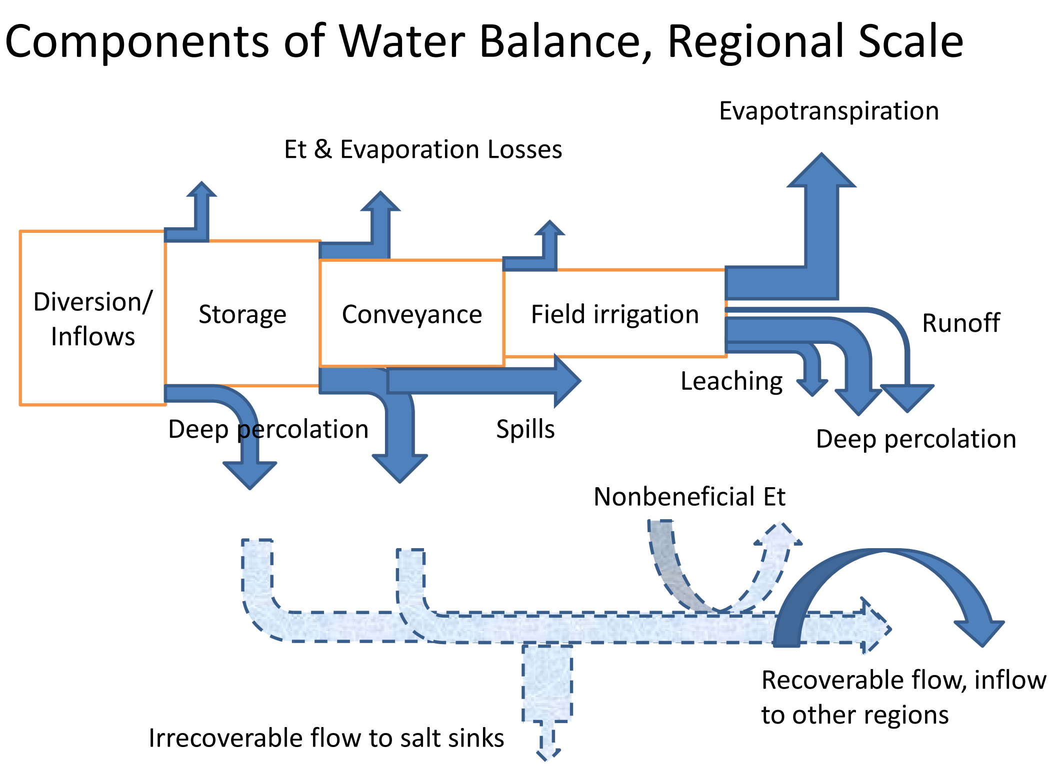


**Figure 2.3**

## 2.3 Regional Scale Water Balance

The water balance at the regional scale is shown in Figure 2.3.

In a regional scale water is used on one or more water supplier areas. Each supplier may have its own independent water supplies. But the recoverable flows from one supplier may be used as a source of water supply for another supplier in the region. All other attributes of the water balance are similar to the water supplier scale water balance described above.

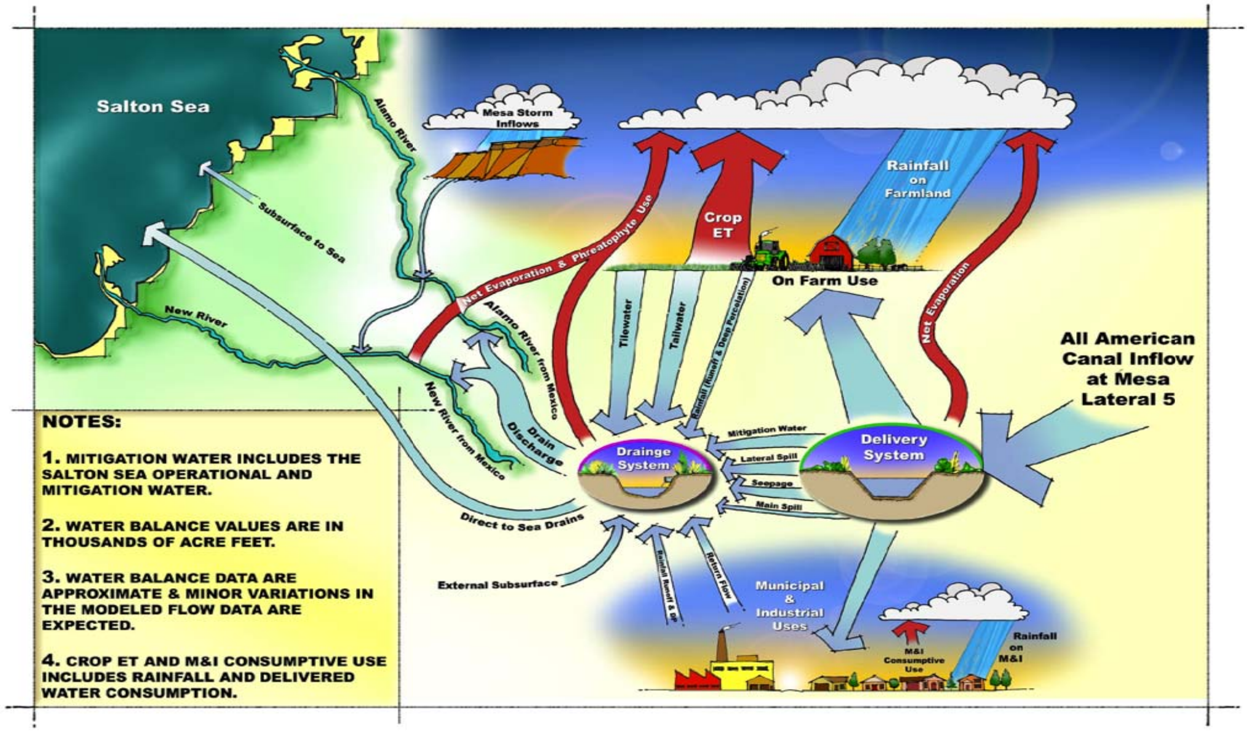


**Figure 2. 4 -** Example of a Water Balance – Imperial Irrigation District

Figure 2.4 is presented to demonstrate an example of an actual agricultural water balance for Imperial Irrigation District.

## 2.4 Understanding Water Use Efficiency

Water conservation refers to reducing the amount of water use and water use efficiency refers to reducing non-beneficial uses. Water conservation and water use efficiency result in water savings or co-benefits including improved water quality, energy savings, and reduced green house gas emission. Saved water can be used to meet agricultural, urban and environmental water demands. To develop a methodology to quantify the efficiency of agricultural water use a water balance approach was considered to look into the various components of water use in agriculture. Ratios of output component(s) to input component(s) of the water balance were developed to quantify the efficiency of agricultural water use.

For agricultural water use efficiency purposes, outputs and inputs are quantified in water units (volume or depth) to create certain products. Agricultural water use efficiencies that consider outputs in water units are referred to as hydraulic efficiency, engineering efficiency, and water management efficiency in different literatures. In this report, all water use efficiency fractions that indicate a ratio of output from an agricultural system to an input to the agricultural system in volumes and/or depths of water were considered for the methods of quantifying the efficiency of agricultural water use. Outputs from agricultural systems, in water units, include evapotranspiration from crops (ETc), agronomic needs (such as leaching salts), climate control (frost protection and cooling), runoff, deep percolation, evaporation from open water surfaces, evapotranspiration by non-crops (weeds, for example), and subsurface outflow. Input from an agricultural system is the volume or unit of applied water. Some of these outputs cannot easily be quantified such as non crop evaporation and are not quantified directly in this methodology. All other uses of water in agriculture (example, dairy, washing products, etc.) are ignored because they represent small fractions of total water use in most cases and are difficult to quantify.

When outputs from agricultural systems are considered as products, they are expressed either as total yield (biomass and/or dry matter) or dollar values of crop yield, whereas inputs are always in units of water units. The ratio of crop yield and/or value of a crop as an output to the volume of applied water as input is categorized as supplemental productivity indicator in this report. It is understood that many other factors such as climate, soil conditions, water quality, crop type, crop management, market conditions affect the productivity and value of agricultural crops. These other factors were not considered in quantifying the productivity of water use, since these factors are out of scope of this report. Therefore, the productivity indicators may only be used as an indicator of productivity as a function of water use and not a measure of water use efficiency.

In order to quantify the inputs and outputs of an agricultural system, it is necessary to establish physical boundaries. These boundaries are referred to as spatial scales in this report.

## California farmers and ranchers – an economic and nutritional powerhouse

Farming is the backbone of our economy and our daily lives, providing healthy fruits and vegetables, nuts, dairy, grains, lean meats and dairy protein that we eat and drink, cotton and wool for the clothes we wear, the flowers and trees that brighten our days, and energy to power our lives. California produces more than 400 crops on 81,700 farms employing 800,000 people in all stages of the farming and ranching economy – from the field to our tables. California farmers and ranchers serve diverse customer needs – from small farmers producing for local markets to robust international trade.

At a time when many sectors of the economy are faltering, agriculture is strong. California agriculture is a $37.5 billion annual industry generating 12 percent of total U.S. agricultural revenue. In addition, California exports 23 percent of the products grown and harvested in the state, making it a trading powerhouse. California agricultural trade is vital to the nation, comprising 12 percent of the nation's agricultural trade and producing millions of jobs on and off the farm. The top ten crops for export are almonds, rice, wine, pistachios, walnuts dairy, table grapes, processing tomatoes, oranges, lettuce.

California, one of only five Mediterranean growing regions in the world, is able to provide an abundance of crops – over half the nation's fruits, nuts and vegetables alone. Today, with a renewed interest in nutrition and its role in preventing chronic disease, California's farms are even more important. Numerous studies show that eating healthy foods – fruits, vegetables and nuts – decrease rates of chronic diseases, providing a more vital workforce and saving funds that would otherwise be spent on health care. This resurgence is building bridges between our food policy network, our rural communities and food deserts, between farms and urban environments, and between nutritionists and farmers, allowing us to achieve our goal of having California-grown healthy foods for all Californians and many Americans in their communities and homes.

Our farmers and ranchers protect our natural resources while dramatically increasing their productivity to feed a global population projected to climb to more than nine billion people within the next few decades. They are constantly innovating, readily adopting the latest technologies, improving efficiencies and reducing costs of production. Utilizing federal conservation funding, in fiscal year 2009-2010 alone, California farmers: reduced nitrous oxide emissions in the San Joaquin Valley by 5.5 tons, equal to taking 408,000 cars off the road; paid for 71 miles of hedgerows, providing habitat for 1,500 species of pollinators and wildlife; and improved irrigation efficiency by 25 percent on over 200 billion gallons of water, enough to fill over 1 million swimming pools[CITE REFERENCE].

Our farmers and ranchers grow crops that feed, clothe and power California, the nation and the world, leading the world in sustainability and innovation.

**California Agricultural Water Stewardship - A Systems Approach**

California is facing significant challenges around the management of water for all users. For agricultural water use, understanding water systems means thinking about the use of water in agriculture and in the larger watershed. Agricultural water stewardship can be thought of as:

> *The responsible use and management of water that optimizes agricultural water use while addressing the co-benefits of water or food production, the environment and human health.*

This definition has been developed by a diverse group of California stakeholders, including policy, environmental and agricultural leaders, affiliated with the California Roundtable for Food and Water Supply, who understand that agricultural water management decisions need to consider the broader ecological, social and economic context.

Thinking about water in a systems approach recognizes that simply reducing applied agricultural water may not necessarily result in a net benefit at the farm or watershed levels, and that effective stewardship may provide multiple ecosystem services. While growers are continually making improvements in their operations to ensure profitability and the resource base – they are doing so in a system – and gains in overall sustainability may mean the increased use of applied water or other input.

As an example, many growers in California use cover crops to provide nitrogen and improve soil quality. Cover crops may in fact require additional applied water, depending on the crop, rainfall, planting date and other factors. However the overall resource base may be improved, by reducing applied synthetic nitrogen and improved soil quality.

Making smart water use decisions while minimizing environmental impacts and balancing all the trade-offs will help ensure the long-term viability of agricultural production for California.

*For more information see http://agwaterstewards.org/*

# 3.0 Quantifying the Efficiency of Agricultural Water Use

As discussed above, quantifying the efficiency of agricultural water use requires quantifying the inputs into and the outputs from the system at various spatial scales. The components of the water balances at field, water supplier, and regional scales are used to quantify the ratio of outputs to inputs at each scale. The water use efficiency methodology considers water entering and leaving the boundary of each scale as volumes or depths.

A water balance is a representation of all sources and dispositions of water into, within, and out of a defined boundary over a defined period of time. From these water flow elements, various relationships can be evaluated to describe the current water management conditions and assess opportunities for change.

However, since hydrologic, regulatory, distribution, and other features reflected in a water balance are unique to the specific boundary being evaluated, each water balance can look different from another, reflecting the unique circumstances faced by different boundaries, but include common elements that allow for relationships between different “water in” and “water out” components to be evaluated

When viewing the water balance from different water management and water use boundary conditions – the field, the water supplier, or the region – a different set of “water in” and “water out” conditions exists. Because of this variability, understanding all components of a water balance and their relationships within a defined boundary is fundamental to understanding the efficiency of the water used. Furthermore, given the multiple flow paths into and out of a boundary, differing sets of ins and outs can be related through equations to evaluate current water management and use conditions. There is no single equation to represent the efficiency of agricultural water use at all scales. As the area within a boundary (scale) increases, the complexity and amount of data needed to calculate a water balance or water use efficiency generally increases. Finally, the water use efficiency at a smaller scale cannot be aggregated to arrive at water use efficiency at a larger scale. For example averaging the water use efficiency from fields within a water supplier boundary, while it indicates the average field conditions in the supplier’s service area, it should not be used to arrive at water use efficiency of the water supplier.

## 3.1 Spatial Scales

For purposes of developing a methodology, DWR considered the following spatial scales that closely align with crops, delivery systems, and regional water management.

### 3.1.1 DWR Hydrologic Region Scale

The Hydrologic Region (regional) scale allows an assessment of a variety of attributes associated with regional water use and management within the regional boundary. For purposes of defining a methodology at this scale, one prominent use would be the California Water Plan Update (Update). In the Update, DWR gathers and assesses information at a regional boundary called the Detailed Analysis Unit (DAU). DWR then aggregates the information to larger regional boundaries, the Hydrologic Region, and the State as a whole.

### 3.1.2 Water Supplier Scale

The water supplier scale allows an assessment of attributes associated with the operation and management of a water delivery and drainage system within the defined service area of a water supplier. The goal of an agricultural water supplier is to use infrastructure and management (e.g., operation or pricing) to reliably deliver available water supplies to the fields. Information regarding water flows at this scale allows for evaluation of the relation between water brought into the boundaries and the effectiveness of meeting the primary goal of delivering water to the fields and additionally providing for efficient delivery of the water suppliers system to improve water use efficiency as intended by the 2009 legislation. Water supplier is defined by the CWC as follows: Section 10608.12 (a) of CWC defines “Agricultural water supplier” means a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding recycled water. “Agricultural water supplier” includes a supplier or contractor for water, regardless of the basis of right, that distributes or sells water for ultimate resale to customers. “Agricultural water supplier”

does not include the department. Section 53.1 (b) of the CWC defines “Agricultural water supplier” means a supplier either publicly or privately owned, supplying 2,000 acre-feet or more of surface water annually for agricultural purposes or serving 2,000 or more acres of agricultural land. An agricultural water supplier includes a supplier or contractor for water, regardless of the basis of right, which distributes or sells water for ultimate resale to customers.

### 3.1.3 Field Scale

The field scale, a term used to define the boundary of a parcel(s) of land served by an irrigation method or system, allows an assessment of a variety of attributes associated with irrigation system(s) and management within a field. Field scale assessments allow an operator to evaluate the performance of an irrigation system for a particular crop at a particular point in time or across a defined time period, such as a growing season. This assessment will allow an operator to assess the effectiveness of the existing irrigation system and management of it to meet the water needs of the crop and minimize the deep percolation and non beneficial evaporation and surface outflows.

In some cases, more than one field is irrigated from the same supplier turnout. If all fields are using the same kind of irrigation system to irrigate the same crop, the group of fields can be assessed as one field. If the individual fields are growing different crops or using different kinds of irrigation systems, they should not be grouped into a single measurement/evaluation. If the field-level efficiency is to be quantified for one or more such fields, additional effort is required to measure or estimate the water delivered to each of the fields.

## 3.2 Methodology for Quantifying the Efficiency of Agricultural Water Use

The methodology proposed by DWR consists of a number of methods and associated procedures to quantify the efficiency of agricultural water use. The Distribution Uniformity, while a water management action, is considered as indicator of performance of irrigation system and therefore indicator of field water use efficiency. The set of methods are intended to evaluate the efficiency of agricultural water use for different purposes at different scales. These methods are:

1- Water Use Efficiency Methods applicable at the regional scale:
  - Crop Consumptive Use Fraction (CCUF)
  - Total Water Use Fraction (TWUF)
  - Water Management Fraction (WMF)

2- Water Use Efficiency Methods applicable at the water supplier scale:
  - Crop Consumptive Use Fraction (CCUF)
  - Total Water Use Fraction (TWUF)
  - Water Management Fraction (WMF)
  - Delivery Fraction (DF)

3- Water Use Efficiency Methods applicable at the field scale:
  - Crop Consumptive Use Fraction (CCUF)
  - Total Water Use Fraction (TWUF)
  - Companion Indicator of Irrigation System Performance applicable at the field scale
    - Distribution Uniformity (DU)

Each method is described below in detail. The appropriate elements used to calculate the methods are identified and further described in APPENDIX B and the purpose and examples of each method are provided at each applicable geographic scale in APPENDIX C.

## 3.3 Water Balance Components

The primary approach for quantifying the efficiency of agricultural water use is through evaluating the relationship of particular components of a water balance. These relationships may include volume of water use attributed to ET, leaching, frost protection, and other agronomic as well as environmental uses compared to the volume of applied water to the boundary of the scale under consideration. The water use efficiency method evaluates the efficiency of water applied to a specific area, intended for irrigated agriculture and environmental objectives.

Components of a water balance are used in the water use efficiency methods for quantifying the efficiency of agricultural water use. These components are:

1. **Crop Evapotranspiration (ETc)** - is a loss of water to the atmosphere by the combined processes of evaporation from crop and soil surfaces and transpiration from crops. It is the amount of water that the crop needs for optimal growth and to produce yield. In quantifying the efficiency of agricultural water use at all spatial scales, the implementing entity can either measure ETc or estimate it using theoretical and/or empirical equations.

2. **Agronomic needs** – is portion of applied water directed to produce a desired agricultural commodity, such as water applied for salinity management or frost control, decomposition, and other water applications essential for production of crops. The quantity of applied water estimated for intended agronomic needs is based on accepted professional practices. **Leaching Requirement (LR**)- some amount of the total applied water is used to flush excess salt that is present in the soil out of the root zone to make an optimum condition for crop production. Different crop types and different varieties of the same crop can have different tolerances to salinity. The amount of water required to remove salts from the root zone area is estimated using the ratio of the electrical conductivities of irrigation water (applied water) and drainage water. **Climate Control** - depending on temperature, humidity, wind speed and other factors, some portions of agricultural water may be used for cooling of crops and frost protection. The amount of water used for cooling and frost protection depends on crop type and weather parameters such as humidity and temperature. Application of water for climate control should start when temperature reaches critical points for each crop and continue until the temperature becomes more favorable. Weather stations networks such as CIMIS can provide the temperature and humidity data that needs to be tracked to determine when to turn the sprinklers on and off. An entity that implements the water use efficiency methodology developed in this report should establish the threshold temperatures at which the climate controls are turned on and off for different crops in different regions. Although significant amount of water used for climate control may evaporate, the rest will infiltrate into the soil and become available for crops to consume. Currently there is no clear standard objectives or standard procedures to estimate the amount of water needed for climate control and also the estimate of portion of climate control water that will be consumed by plants.

3. **Environmental needs** - portion of applied water directed to environmental purposes within a defined scale, that is not meeting ETAW of the irrigated commodity, including such uses as; water to produce and/or maintain wetlands, riparian or terrestrial habitats, where the quantity of water consumed or used for intended objectives is based on accepted professional practices. Applied water associated with a mandated environmental objective but ultimately used for ETAW or agronomic needs in the production of any agricultural commodity would not be characterized as applied water for an environmental need. Currently there is no clear standards for environmental water needs or standard procedures for estimating EN, unless the EN is prescribed by regulation or permit conditions.
4. **Evapotranspiration of Applied Water (ETAW)** – is crop evapotranspiration minus the amount of water supplied to the crop by precipitation. Since some part of the precipitation is lost as runoff, deep percolation, and evaporation, only a fraction of the total precipitation is available to satisfy crop water needs. The fraction of precipitation water that is available for crops to use is known as effective precipitation (Pe). Pe depends on many factors including the slope of the land, soil type, rainfall characteristics, weather conditions, plant type, etc.
5. **Applied Water (AW)** Applied water is the total amount of water that is diverted from any source to meet the demands of water users without adjusting for water that is used up, returned to the developed supply and irrecoverable flows (unproductive evaporation or percolation to salt sinks). At the field, AW would consist of water deliveries to the field including water pumped or diverted onto the field for irrigation. AW at the field scale is calculated from supplier's measured deliveries (adjustments are needed if the entire delivery is not applied to the field) and groundwater pumping. Alternatively, AW at the field may be measured with a water measurement device. AW at the water supplier and regional scale is the measured total water supplies (TWS) delivered to the supplier or the region excluding water used for non-agricultural crop uses (Municipal and Industrial (M&I), dairy, etc.).
6. **Recoverable Flows (RF)** Recoverable flows consist of the amount of water leaving a given area as surface flows to non-saline bodies or percolation to usable groundwater and is available for supply or reuse. RF is calculated from surface return flows using gauge data and estimates of deep percolation using information on applied water quality and leaching requirements; while excluding evaporation losses and flows to salt sinks.
7. **Total Water Supply (TWS)** Total water supply consists of the measured total surface and groundwater that is delivered or diverted into a given area (supplier's service area or region) for irrigation purposes. TWS is calculated from diversion records and the quantity of supplier and privately pumped groundwater (measured or estimated from the change in groundwater elevations). Deliveries to non-irrigation agriculture and M&I are excluded.

8. **Distribution Uniformity (DU)** Distribution uniformity is a measure of how uniformly water is applied to the area being irrigated, commonly expressed as the ratio of the average depth infiltrated in the 1/4 of the field with the lowest infiltrated depths by the average infiltrated depth in the whole field. DU evaluation is based on a statistical process. Field samples are taken and DU is calculated from those samples. DU is quantified by Mobile Labs during field evaluation.

9. **Irrecoverable Flows**- measured or estimated quantity of water leaving a defined scale boundary as surface flow, unproductive evaporation or deep percolation to salt sinks*.*

## 3.4 Methods

The water use efficiency methods provide valuable information to the respective scale users: local users, associated agricultural water suppliers, and to the extent methods are reported beyond the field or supplier scale, they also provide insight and understanding to regional, state and federal policy makers and planners. These methods are not intended for non irrigated agriculture such as dairies, on-farm processing, or other agricultural operations not directly related to irrigated land.

These methods cannot be viewed independently. Each method provides a unique understanding of the performance of agricultural water use at a defined scale. In fact, using these methods in tandem allows not only for quantifying each water use fraction separately, but for comparing the proportions of water used for different purposes (e.g., consumptive use, agronomic use). Such comparisons will in turn help to characterize existing water uses and allow identifying areas of inefficiency and inform water management decisions in relation to potential efficient water management practice (EWMP) alternatives (e.g., modifying irrigation systems, mechanical rice straw stomping versus field flooding).

The first two agricultural water use efficiency methods are applicable at each of the three identified scales (the input data will vary by scale):

- Method 1: Crop Consumptive Use Fraction (CCUF) = [ETAW]/[AW-AN-EN]. – This method allows for evaluation of the relationship between the consumptive use of a crop and the quantity of water brought into the boundary for the purpose of crop consumptive use. The numerator of the equation would be the estimated crop consumption of water applied at the field scale (ETAW or Evapotranspiration of Applied Water), and the denominator would be the quantity of water brought into the boundary (applied water for field scale and measured total water supply for supplier and regional scale) minus the agronomic and environmental needs at the respective scales.

- Method 2: Total Water Use Fraction (TWUF) = [ETAW+AN+EN]/[AW] – This method includes agronomical (AN) and environmental (EN) water needs to account for the applied water at the field, water supplier, or Regional scale. The additional water must be intended to meet agronomic and environmental needs. For this method, the denominator remains the measured quantity of water brought into the boundary, but the additional water directed toward intended AN and EN needs are added to the ETAW in the numerator. For instance, with water used to leach salts, the portion of water applied to push salts below the root zone would be considered the additional water needed to grow a crop. In contrast, some of the water applied for an agronomic need such as climate control might refill the root zone and ultimately be consumed by the crop. Only some of the climate control application would be considered additional agronomic use (i.e., the net agronomic water from an application of water for climate control would be less than the total applied for climate control). While ideally one intends to supply sufficient water to meet the agronomic needs, in practice such ideal goal is not possible under the variable field conditions. In other words, the practice of applying water to meet crop agronomic needs may have water losses beyond the agronomic needs.

- Method 3: Delivery Fraction (DF) =[FGD]/[TWS] – This method allows the evaluation of the relationship between the water delivered to irrigated agriculture (all fields) in a defined boundary to the total surface or groundwater water brought into the boundary of the water supplier conveyance system plus return flows less water used for non-agricultural crop uses in the service area. Under California Water Code §531.10, many water suppliers are required to provide DWR with aggregated farm-gate deliveries. When water delivered to irrigated field is related to the total water brought into the boundary, understanding of the supplier's or region's water delivery system can be obtained. In some instances, due in part to reuse occurring within the defined boundary, this fraction can exceed 100 percent. DF= (FGD)/(TWS), where FGD is the measured total farm-gate delivery and TWS is measured total surface and groundwater supplies delivered into the water supplier boundary plus return flows less urban diversion or non-agricultural crop uses.
- Method 4: Water Management Fraction (WMF) = (ETAW+ RF)/(TWS) - This method provides an opportunity to recognize that a portion of water diverted by a water supplier or into a region but not used may be recoverable flow. The numerator in this equation would include both the consumptive use of the crops in the water supplier's boundary (regional boundary) and the quantity of recoverable flow, which would be divided by the total water brought into the boundary. RF is recoverable flow used in the supplier or region boundary or used in another supplier or regional boundary. TWS is as defined above. In regions where there is little recoverable flow (i.e. water exits the defined boundary to salt sinks or other degraded water bodies), the value would be closer to that evaluated under Method 1. This method recognizes that unconsumed water may be useable elsewhere or at another time within the water management system.

## 3.5 Companion Indicator for Irrigation Performance

Companion Indicator 1: Distribution Uniformity (DU) = Dawlq/Daw: This Indicator allows for the evaluation of how effective an irrigation system is across an individual field for uniformly distributing the water. Dawlq is ¼ lower values of depth or applied water or infiltrated water and Daw is average depth of applied water to the field or infiltrated into soil. This Indicator only applies to field scale.

# 4.0 Supplemental Indicators for Crop Productivity

When outputs from agricultural systems are considered as products, they are expressed either as total yield (biomass and/or dry matter) or dollar values of crop yield, whereas inputs are always in units of water units. The ratio of crop yield and/or value of a crop as an output to the volume of applied water as input is categorized as productivity approach in this report. It is understood that many other factors such as climate, soil conditions, water quality, crop type, crop management, market conditions affect the productivity and value of agricultural crops. These other factors were not considered in quantifying the productivity of water use, since these factors are out of scope of this report. Therefore, the productivity approach only may be used as an indicator of productivity as a function of water use and not a measure of water use efficiency.

Indicators of agricultural production are Productivity of Applied Water Fraction and Value of Applied Water Fraction. It should be noted that definitions and equations used for these fractions might be different from text book definitions in some cases. The reason for these differences is that the current development considers the practicality of implementing the different theoretical formulations and excludes parameters that cannot be quantified. Detailed descriptions of these fractions and the parameters they use are described in this report.

Two indicators are intended to evaluate the efficiency of agricultural water use. These indicators are:

Productivity indicators applicable to the field, county and statewide scale:

- Productivity of Applied Water
- Value of Applied Water

The purposes of the indicators include:

- Evaluate crop production (in weight or gross crop revenue) per acre-foot of applied water within a defined scale.
- Evaluate how production (in weight or gross crop revenue) per acre-feet changed over time within a defined scale.

Crop productivity and the value of production may be indicators of efficiency of water use for crop production but they do not quantify the efficiency of water use. Therefore, the productivity and value of production are referred to as “indicators of water use efficiency”. The crop productivity and value of production depend on several factors other than the quantity of water used. Specifically, productivity and value of production vary among regions and over time. Crop varieties, pest infestations, weather, and crop market shifts are only a few of the factors that have a large influence on crop productivity and value of production. Therefore, while crop productivity and value of production can be calculated as indicators of efficiency of water use for crop production but they are not an accurate measure of water use efficiency. Crop production and crop productivity are not proposed to be used as a method of quantifying efficiency of water use.

The productivity and value of production ratios described above should not be viewed as measuring economic efficiency in the way that economists define the term “economic efficiency”. In general, economic efficiency is not a single, quantifiable value that is measurable on an absolute or relative scale, but rather is a set of conditions relating input use and output. The ratios described above are productivity indicators that relate to, but are not the same as, the economic efficiency of agricultural water use, and can illustrate broad comparisons between regions or crops or over time. Economic efficiency conditions rely on marginal responses and rates of trade-off. Generally, these are not directly observable using aggregate data or even producer-scale or field-scale data. Any approach to quantifying the economic efficiency of agricultural water use may assign too much of any apparent inefficiency to water use. Individual constraints on crop production (such as shortages of other factors of production), variation in land quality incomplete understanding of risk and uncertainty can appear to analysts to be inefficiency. If water use is the focus of the analysis, there can be a tendency to blame or credit to water use efficiency in crop production rather than other factors. These indicators may be used to help guide public policy and public investment, but with an understanding of their limitations.

The productivity indicator is calculated by dividing the weight of crop production at a given scale by the volume of water applied at that scale. The inflation-adjusted dollars of gross agricultural revenue per acre-foot of applied water is used to determine production value. An analysis in Volume 4 of DWR’s California Water Plan Update 2009 used this measure to illustrate the increasing economic productivity of California agricultural water use.

Because agricultural production is done through field survey of crops and reported to the county commissioners. Productivity indicators spatial scales are the, county, and statewide boundaries.

This section describes each indicator. The appropriate elements used to calculate the indicator are identified and the purpose and examples of each indicator are provided at each applicable geographic scale.

# 4.1 Supplemental Productivity Indicators

An indicator of illustrating efficient use of water is to demonstrate the relation between crop productivity or gross crop revenue and associated water use. Applied water along with measures of productivity is proposed for determining the productivity indicators. The measures of productivity are:

1. Gross revenue of crop production - Gross revenue is the weight of production sold multiplied by the price per unit of weight received by the grower.
2. Weight of crop production - Total production sold of each crop during the time frame, usually one or more production seasons, measured in tons or hundredweight.

The following agricultural productivity indicators are applicable at the county and statewide scale:

- Indicator 1: Productivity of Applied Water (PAW) – This indicator illustrates the relationship between irrigated agricultural production and the quantity of applied water in a county boundary to meet the crop needs. The numerator of the equation would include the total crop production by weight or other recognized measure of yield, and the denominator would be the total applied water used for agricultural crop production within the boundary. This indicator must be calculated separately for each crop to avoid adding together disparate physical units of different crops. As a result, the total applied water also needs to be estimated separately by crop. Few irrigated areas in California maintain any standard record of groundwater use on a crop-specific basis. Some, but not all, suppliers maintain records of crop-specific deliveries to fields. Therefore, in most cases, estimates would have to rely on growers' field records. Suppliers' delivery records could be used if they could be matched to a particular crop and if the supplier or analyst were confident that no private pumping or other diversions were used to irrigate the crop. In the absence of the detailed data, county level production from agriculture commissioner's report and applied water calculated at county and statewide scales by DWR for WPU may be used to compute the productivity indicator.
- Indicator 2: Value of Applied Water (VAW) – This indicator illustrates the relationship between the gross crop value of irrigated agricultural and the quantity of applied water in a county boundary or statewide. The numerator of the equation would include the total gross crop value of irrigated agricultural (price multiplied by yield), where the denominator would be the total applied water. The

total gross crop value of irrigated agriculture for a county is used in this indicator given the difficulty of estimating applied water by county directed towards a specific crop type. The denominator would be the delivered water and groundwater pumping for irrigated agriculture within a county or statewide computed by DWR for the WPU.

Estimating crop-specific productivity and economic value is a technical challenge because information needed to attribute groundwater use, and, in some cases surface water delivery, to an individual crop types is sparse. Both total value of production and total applied water (including measured or estimated groundwater use) can be estimated within a defined boundary, so VAW can be calculated at a county level using aggregate data. Some gross estimates of applied water by individual crop can be obtained from University of California Cooperative Extension crop production budgets. However, these are characterized as example budgets with example, or typical, water use estimates – they are not claimed to be based on careful, statistically valid measurements. These estimates can be used initially to provide a very general comparison. However, field-level data from individual grower records is the only reliable source, in most cases, of accurate and comprehensive water use for crop-specific estimates. These field-level, if available, an then be aggregated to generate estimates at larger scales such as counties. Because of lack of crop production and applied water data needed to compute field scale productivity indicator, it is not recommended for implementation.

# [Placeholder – entire application text is anticipated sidebar discussion]

**Water Supplier Level – An Example of Application of Water Use Efficiency Methods**

**Scenario**: A water supplier in the Sacramento Valley has recently installed distribution system improvements to help reduce spill out of the end of the distribution system as one of its efforts to implement locally cost-effective efficient water management practices [see CWC §10608.48(c)(7)]. As required reporting in its subsequent Agricultural Water Management Plan, the supplier intends to use these improvements to help document an estimate of the water use efficiency improvements that have occurred since the last report, [as required by CWC§10608.48(d)].

**Chosen method**: Because the implemented measure directly impacts delivery system operations, the supplier has chosen to calculate the Delivery Fraction to demonstrate the efficiency improvements that have occurred.

***Data required:***

**Aggregated Farm gate Deliveries**: Section §531.10 of the CWC requires water suppliers to report farm-gate delivery data to DWR. The values for delivery year prior to and following system improvement are considered (may be an average of several years prior and several years after, depending on timing of the AWMP and variations in cropping or other factors that might impact the before/after comparison). It is assumed that the supplier does not have a water reuse system during the evaluation period.

**Water Total Water Supplies (TWS):** For each of the years corresponding to the aggregated farm gate delivery values, the quantity of diversions reported to the SWRCB.

**SIDEBAR TABLE 1**
**Total Diverted Water**
***Quantifying the Water Supplier Efficiency of Agricultural Water Use***

| Year | Aggregated Farm gate Delivery, AF/Y | Water Supplier Total Diverted (net), AF/Y | Delivery Fraction |
|---|---|---|---|
| 2008 | 45,670 | 56,745 | 80% |
| 2008 | 48,038 | 59,986 | 80% |
| 2009 | 43,946 | 55,012 | 80% |
| Average | 45,884 | 57,248 | 80% |
| 2010 | 46,732 | 56,349 | 83% |

**Results**:

Supplier Delivery Fraction = Aggregated Farm Gate Deliveries/Total Diverted (net)

1. Prior to installation DF = 80% (average of prior 3 years)
2. Post installation DF = 83%

The supplier Delivery Fraction is estimated to have increased three percentage points as a result of the implemented EWMP. The Supplier would report this information in its upcoming AWMP.

**Regional Level – Example Application of Methods**

**Scenario**: The California Water Plan Update 2013 development is underway, anticipating a draft to be published in April of 2013. The Department wants to publish "current condition" information to illustrate the efficiency of regional agricultural water use. The information would be determined using the existing Detailed Analysis Unit (DAU) boundaries, but reported at the Hydrologic Region level in each of the Regional Reports.

**Chosen method**: To provide a broad understanding of current efficiency of agricultural water use at the regional level, the Department will calculate the CCUF, TWUF. The combination of these methods to understand current regional water management conditions will help establish the foundation for future water balances at the regional scale in subsequent California Water Plan updates.

***Data required**:*

ETAW: The Department's regional staff currently develops water balances at the DAU level, including determinations of ETAW. This information will be used to populate regional ETAW values.

**Agronomic Water (net)**: Using water balances generated at the DAU scale, Department regional staff will estimate crop agronomic needs as currently reflected in various agronomic practices around the state. For instance, based on local knowledge, staff in the South Central Region office understands the current leaching practices which vary with water source, crop, and soil conditions throughout the southern San Joaquin Valley. This knowledge is used to estimate agronomic needs such as leaching. Consistently using an approach to determining agronomic needs will allow comparable values as determined in future Water Plan updates.

**Environmental Water**: Similar to the agronomic water data determinations, water directed toward intended environmental purposes will be derived by the Department's regional staff using information from the DAU water balances.

**Regional Total Applied Water (AW or TWS)**: This value is already developed as part of the Department's regional water balance efforts.

**Results**: This representation (not actual data) of regional agricultural water use relationships provides a basis for comparative trends in future California Water Plan updates.

**SIDEBAR TABLE 2**
**Regional Scale Efficiency of Agricultural Water Use**
***Quantifying the Efficiency of Agricultural Water Use***

| Regional Efficiency Values of Agricultural Water Use (not actual data) | | |
|---|---|---|
| Region | CCUF | TWUF |
| North Coast | 75% | 77% |
| San Francisco Bay | | |
| Central Coast | | |
| South Coast | | |
| Sacramento River | 79% | 86% |
| San Joaquin River | 77% | 84% |
| Tulare Lake | 85% | 88% |
| North Lahontan | | |
| South Lahontan | | |
| Colorado River | 78% | 89% |

**Field Level – An Example of Application of Methods**

**Scenario**: A local environmental coalition is confident improvements in on-farm irrigation management can reduce diversions on a small stream so water can be left instream to benefit identified ecosystem objectives without affecting existing farming productivity. The coalition is interested in demonstrating to the local water users that these improvements can be funded through water conservation grants, but need to demonstrate the improvements in efficiency that would result from the projects, as required in the grant application. Local users have voluntarily agreed to help the coalition pursue grant funds to implement on-farm irrigation system improvements.

**Chosen method**: The coalition will document the existing CCUF of four different fields served by four unique stream diversions. An estimated reduction in applied water from modified irrigation management will be shown to reduce one of the factors – applied water – and show an improvement in CCUF.

***Data required***:

**ETAW**: Using ETo and precipitation data from a local CIMIS station, coupled with detailed farmer-provided crop information,  coalition is able to calculate ETAW for the existing crops served by the existing stream diversions.

**Applied Water**: Each farmer has records for their respective diversions that are provided to the coalition to support the grant application. The diversions are all appropriative water rights under the authority of the State Water Resource Control Board with reporting of permittee or licensee as applicable to each diverter.

**Results**: As shown in the table, the coalition's anticipated on-farm irrigation improvements will have noticeable improvements in the CCUF. This information will be provided, along with detailed descriptions of the planned improvements, in the coalition's grant application.

**SIDEBAR TABLE 3**

## Field Scale Application of Efficiency of Agricultural Water Use

***Quantifying the Efficiency of Agricultural Water Use***

| | Existing ETAW | Existing AW, AF/Y | Existing CCUF | Anticipated AW, AF/Y | New AW saved, AF/Y, CCUF | |
|---|---|---|---|---|---|---|
| Field 1 | 654 | 865 | 76% | 810 | 81% | 55 |
| Field 2 | 432 | 687 | 63% | 550 | 79% | 137 |
| Field 3 | 1475 | 2150 | 69% | 1950 | 76% | 200 |
| Field 4 | 846 | 1291 | 66% | 1100 | 77% | 191 |

# 5.0 Plan for Implementation

## 5.1 Implementation Requirements

The legislation did not authorize implementation of the methodology and did not identify any source of funding for implementation. DWR proposes that if methodology is authorized for implementation, necessary sources of funding should be identified to support the implementation at all scales. In the implementation cost section, DWR estimates an approximate level of new funding for implementation.

Although Section 10608.64 of the California Water Code does not specify the implementing agency, DWR proposes that it assume the following responsibilities, if and when the implementation is authorized and the necessary resources are provided. DWR would assume this role because it can provide consistency in implementation and can help in maintaining and disseminating the quantification of efficiency of agricultural water use information reported to it by the agricultural water suppliers or others.

1. Develop data standards, data collection protocols, schedules, quality control, and quality assurance and provide assistance to agricultural water suppliers, growers, and other cooperating agencies in implementation of the report recommendations.
2. Quantify and report the regional scale methods for quantifying the efficiency of agricultural water use. The Water Plan Update process can provide the means for data collection and analysis needed to quantify the regional methods.
3. Quantify and report the supplemental productivity indicators at the county and statewide scales. DWR's Water Plan Update process can provide the means for data collection and analysis needed to quantify statewide and county scale productivity indicators.

Collect and maintain the data submitted to DWR in a database and disseminate the information.

DWR recommends that the implementation of this methodology should be carried out by using existing programs to the extent possible, by expanding them, creating new programs, and/or reviving past programs as needed.. Existing programs may include agricultural water suppliers' preparation of agricultural water management plans required by CWC 10820, implementation of efficient water management practices required by section 10608.48, and agricultural water suppliers' reports of estimated efficiency improvements as required by 10608.48 (d). Other existing programs include aggregate water delivery reported under CWC 531.10 and preparation of the California Water Plan Update. Implementation would includes collaboration with the Agricultural Water Management Council, agricultural water suppliers, academic and research institutions and California universities, and other cooperating agencies.

These legislative requirements provide a mechanism for the agricultural water suppliers to submit the calculations of the water use efficiency methods to DWR. The agricultural water suppliers could report the calculations proposed in this methodology (CCUF, TWUF, WMF, and DF) as well as the mean and standard deviation of the values of the field scale CCUF, TWUF, DU in their service areas in their AWMP. Furthermore, as DWR updates the EWMPs per CWC 10608.49(h) DWR could include the calculation of the above methods as a metric of reporting estimate of water use efficiency improvements in the agricultural water suppliers AWMPs.

Key elements of the plan for implementation include:

- Methods and indicators to be implemented and the appropriate geographic scales
- Entities identified to implement the methodology, and coordination with existing data and reporting activities. A description of data needed to support the methodology, the data sources, and the quality and limitations of data
- The schedule and frequency of applying the methodology, including appropriate phasing
- Data needed to support the methodology (methods and indicators).
- The estimated cost of implementing methodology.
- Priorities.

## 5.2 Water Use Efficiency Methods

For supplier scale methods, agricultural suppliers can use information collected for and provided in agricultural water management plans, plus other available agricultural water use data (e.g., aggregate farm-gate deliveries submitted to DWR pursuant to CWC 531.10). Some of the data elements needed to calculate water management methods are reported under suppliers agricultural water management plans. Crop-specific water use and methods can be estimated by some suppliers using their own delivery records, and others may be able to use aggregated field-level data as it becomes available. Collaboration between DWR and agricultural water suppliers may be necessary for calculation of certain supplier scale methods.

For field scale methods, field scale data would be collected through a voluntary program. Program objectives are twofold: 1) provide farmers with useful data and an assessment of their water use efficiency in order to improve their operations; and 2) provide State and local water management and planning entities with aggregate water use data. The program will be in the form of technical assistance offered to willing participants from the farming community. Collected data will be aggregated and all information identifying specific fields, growers or landowners removed to protect privacy.DWR may partner with cooperating agencies, including the Agricultural Water Management Council, agricultural water suppliers, Resource Conservation Districts, University of California Cooperative Extension, and other research institutions such as

Cal Poly I. Training and Research Center or the Center for Irrigation Technology at California State University, Fresno. Evaluations will be offered to voluntary participating growers, and will be similar to the mobile lab program that DWR has supported through cost-sharing arrangements. The mobile labs combined with additional field level data constitute the best approach for acquiring reliable field level water use data.

## 5.2.1 DWR Hydrologic Region Scale

### 5.2.1.1 Data needed to support the methodology

Data needed to support the methodology at this scale include reference evapotranspiration (Eto), crop coefficient (Kc), effective precipitation, land use data, water use data including measured applied water, agronomic needs, environmental needs, and recoverable flows. The data needed is for the detailed analysis units (DAUs) for the WPU. Data required for determining ETAW could be provided by the DWR CIMIS program or other models such as CAL SIMETAW II, CUP or the CAL AG (see APPENDIX B).

### 5.2.1.2 Data Sources, Quality, and Limitations

DWR land and water use analysis is conducted in support of the California Water Plan Update. This is an extensive, ongoing activity that gathers water use and supply data at various regional scales, develops estimates of water use or supply quantities that are not directly measured, and uses the information to construct water balances. Water use and supply estimates are made at the level of detailed analysis units (DAUs) as defined in the California WPU and at subareas of DAUs delineated by county lines. These estimates are aggregated into 10 larger areas called hydrologic regions (HRs), corresponding to the state's major water drainage basins. The quality of existing data needed to implement the methodology varies significantly across regions and data categories. This presents the largest challenge to generating useful information from the regional methods. Some data are measured with a high degree of accuracy, some at a lower accuracy, and some important data are not measured at all and must be estimated. DWR currently uses estimated seasonal irrigation efficiencies and calculated values of the ETAW to estimate the applied water at the DAU and regional scales. Sometimes additional data are available (water supply or measured applied water) and utilized in making these determinations. The seasonal irrigation efficiencies are important components in the analysis of agricultural water demands for DWR's regional water balances. They can be informed by the field and supplier scale CCUF and TWUF and WMF (supplier). Therefore, the field evaluations of irrigation systems and supplier calculations of mean and standard deviation of field scale CCUF, TWUF are critical in improving values of seasonal irrigation efficiencies the agronomic needs, environmental needs and applied water and recoverable flows from water suppliers in the region are used for quantification of regional scale CCUF, TWUF, and WMF.

The major limitations are regional groundwater pumping estimates, components of agronomic use, and environmental uses and estimation of recoverable flows.

Groundwater pumping is a particularly important part of overall agricultural water use that is not measured directly for the majority of irrigated areas in California. Other components such as reuse, return flow, and seepage are generally estimated with varying degrees of accuracy. Even crop evapotranspiration estimates used for regional water balances may rely on generalized coefficients in the absence of good, localized estimates that are aggregated to a regional scale.

Agronomic uses are already estimated by some suppliers, but the estimation procedure is likely not standardized. Just as some of the water applied to refill the root zone runs off or percolates, some of the water applied for, say frost control may exceed the amount needed. Environmental uses are not generally estimated except as part of a targeted study. Calculations of the Agronomic Needs and Environmental Needs and Crop Consumptive Use Fraction and Total Water Use Fractions will necessarily be limited and qualified in early implementation years.

Table 5-1 provides a summary of likely sources of data for regional scale, and identifies options and needed improvements.

The schedule of implementation includes recommendations for improved data collection and estimation of some water flows in order to support the methodology. However, some data components likely will continue to be difficult to quantify accurately and precisely.

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**TABLE 5-1**

## Regional Scale Data Sources and Options

## Quantifying the Efficiency of Agricultural Water Use

| Data Component | Source or Options | Notes |
|---|---|---|
| Crop ET and ETAW | Regional ET:<br>Option 1: regional-level ETo and Kc<br>Option 2: aggregate from more detailed ETo and Kc<br>Option 3: processed satellite imagery | |
| Applied Water/TWS | Surface water data from suppliers.<br>Private water rights diversions from SWRCB<br>Groundwater estimated | CWC 531.10 reporting as it becomes available may apply<br>GW use is unmeasured. Improved ways to estimate use are needed. |
| Agronomic Uses | Options: reported by suppliers; estimated by DWR | Is a standard estimation procedure needed? Could address in data |

| | | |
|---|---|---|
| | | assessment phase. |
| Environmental Uses | Limited studies and estimates available | DWR to work with suppliers, California DWR of Fish and Game and U.S. Fish and Wildlife Service, CARCD, and other groups to develop estimation procedure. |
| Recoverable Flows | Estimated as part of the water balance, e.g., total return flows minus estimate of evaporation and flow to salt sinks | Is a standard estimation procedure needed? Could address in data assessment phase. |

#### 5.2.1.3 Data Collection Responsibility

DWR recommends that the regional scale methods be incorporated into its existing land and water use analysis process conducted by DWR. Most of the data required for the regional scale methods are already collected or estimated during this process, and DWR's land and water use analysts have substantial experience and local knowledge needed to implement the methods effectively. DWR also recommends that the regional scale data collection be coordinated with the data collected and reported by water suppliers, either through their existing reporting processes (e.g., CWC 531.10) or any new data collection associated with supplier-level efficiency methods. DWR will collect, maintain and disseminate the data reported to it by water suppliers and others in a database for public use and for its planning.

#### 5.2.1.4 Schedule of Implementation

Implementation of the regional methods should occur in phases, extending over a period of five years. Phasing will allow the use of existing data to prepare initial estimates of the regional methods while data improvements are identified and implemented.

**Phase 1: Complete by 2013**

- Use existing data and estimates of water use at the regional scales, based on existing regions used by the DWR in its planning. This information will be used to calculate the Consumptive Use Fractions, Total water Use Fraction and Water Management Fraction.
- Characterize the uncertainty of the estimated fractions, and identify the data sources in each region that contribute the greatest amount to the uncertainty.
- Develop a plan to improve the key limiting data in Phase 2. This plan would not be needed if a supplier demonstrates its improvement in water use efficiency fractions is not locally cost effective.
- Plan to incorporate the data from the water suppliers and others in the standardized data reporting portal and database.

**Phase 2: Complete by 2018**

- Based on priorities and available funding, implement data improvement recommendations from Phase 1. Priorities could be based on data categories or regions of the State.

**Phase 3: Begin after 2018**

- Apply improved data collection and estimation processes and implement methods. Frequency and timing shall be coordinated with analyses done for CWP Updates.

Table 5-2 provides a summary of the implementation plan for the regional scale.

**TABLE 5-2**

## Summary of Implementation Plan Elements for Regional Scale Methods

## Quantifying the Efficiency of Agricultural Water Use

| Implementation Plan Element | Details | Notes |
|---|---|---|
| Methods | Crop Consumptive Use Fraction,<br>Total Water Use Fraction,<br>Water Management Fraction | |
| Implementing Entities | DWR land and water use analysis units | Coordinate data reporting process with suppliers within region |
| Data Sources | See Table 5-1 | |
| Schedule and frequency | Initial phase (by 2013): calculate using best available data and estimates. Identify priorities for improved data.<br>Second phase (by 2018): fund and implement data improvement plan<br>Ongoing after 2018: calculate methods as part of CWP update process, and report with the CWP update ( every five years) | Data improvement plan associated cost and other implications.<br>Data priorities could include: improved GW estimates, accepted methods and estimates of environmental uses. |
| Cost | See implementation cost section | |

### 5.2.2 Water Supplier Scale

#### 5.2.2.1 Data needed to support the methodology

Data needed to support the methodology at this scale include reference evapotranspiration (Eto), crop coefficient (Kc), effective precipitation, land use data, water use data including applied water, agronomic needs, environmental needs, recoverable flows, (flow outside the boundary of supplier or deep percolation), recycled water and any storage or depletion from the supplier reservoirs.

If water suppliers, as required by the section 10608.48 provide on-farm evaluation a statistical analysis is recommended. A mathematically accepted approach towards achieving a science based outcome. In this approach one could derive a supplier or regional scale TWUF by performing field irrigation system evaluations to determine a statistical mean and standard deviation regional efficiency. This would require a minimum of 100 random samples at the regional scale that would represent irrigation system types in order for the assessment to be statistically sound. The sampling could be achieved by utilizing Mobile labs to conduct new evaluations or to utilize existing data if there is a history and a clear trend towards implementing new technologies such as micro spray, drip emitters or other approaches with a known and proven efficiency standard.

#### 5.2.2.2 Data Sources, Quality, and Limitations

Water suppliers would report data they already gather and report in their AWMPs every five years. This could include data on diversions, deliveries to irrigated fields, operational spill, seepage, supplier-level reuse, and  estimates it has made of water uses within its boundaries, including ETAW, private groundwater pumping, agronomic needs, and environmental uses. Cooperation between DWR and water suppliers may be necessary for additional information as needed such as recoverable flows to calculate the supplier-level methods to quantify efficiency of agricultural water use.

Supplier scale data rely on estimates and measurements which are reported byin AWMPs and section 531.10 reports. For water use estimates not provided by suppliers, GIS and other analytical tools would be used to parse DWR’s regional scale estimates into supplier scale estimates. The formal coordination of the regional and supplier estimates will serve as a cross check on different data sources and result in improved understanding of water uses at both scales.

The quality of existing data needed to implement the methodology varies significantly suppliers to suppliers and across data categories. This presents the largest challenge to generating useful information from the methodology. Some data are measured with a high degree of accuracy, some at a lower accuracy, and some important data are not measured at all and must be estimated. Table 5-3 provides a summary of likely sources of data for supplier level methods, and identifies options and needed improvements.

Groundwater pumping is a particularly important part of overall agricultural water use that is not measured directly for the majority of irrigated areas in California. Other components such as reuse, return flow, seepage, and operational spill are generally estimated, with varying degrees of accuracy. Even crop evapotranspiration estimates used for supplier water budgets reported in AWMPs may rely on generalized coefficients in the absence of good, localized estimates.

Agronomic uses are already estimated by some suppliers, but the procedure is likely not standardized. Just as some of the water applied to refill the root zone runs off or percolates, some of the water applied for, say frost control, exceeds the amount needed . Environmental uses are not generally estimated except as part of a targeted study. Calculations of the Agronomic needs, Environmental Needs and Crop Consumptive Use Fraction and Total Water Use Fractions at supplier scale will necessarily be limited and qualified in early implementation years. The schedule of implementation includes recommendations for improved data collection and estimation of some water flows to support the overall methodology.

**Table 5-3**

## Supplier Scale Data Sources and Options

## Quantifying the Efficiency of Agricultural Water Use

| Data Component | Source or Options | Notes |
|---|---|---|
| Crop ET and ETAW | Supplier-level ET:<br>Option 1: supplier-level ETo and Kc<br>Option 2: aggregate from detailed field-level data<br>Option 3: processed satellite imagery | Aggregated field data gathered from field evaluations (see field-level implementation). More than one source available for processed satellite imagery. |
| Applied Water/TWS | Option 1: surface water data from suppliers;<br>Private water rights diversions from SWRCB; groundwater estimated<br>Option 2: aggregate from detailed field-level data | Use aggregate reporting of delivery as it becomes available<br>GW use is unmeasured or supplier delivery records. |
| Agronomic Needs | Options: aggregated from field scale evaluations; reported by suppliers; estimated by DWR | standard estimation procedure need to be addressed in data assessment phase. |
| Environmental | Information could be | DWR work with suppliers, DFG and |

| | | |
|---|---|---|
| Needs | collected during field evaluation.<br>Typical for the local conditions, though limited studies and estimates available. | USFWS, and other groups to develop estimation procedure. Estimating best engineering practices. |
| Aggregated farm-gate delivery and total diverted water | Reported by suppliers | Use aggregate reporting of delivery as it becomes available; data reported in AWMPs; SWRCB, USBR diversion reports. |

#### 5.2.2.3 Data Collection Responsibility

Data collection at the water supplier scale is the responsibility of the agricultural water suppliers required to prepare and submit agricultural water management plans. Agricultural water suppliers subject to the water management planning provisions of SBx7-7 (greater than 25,000 irrigated acres, and between 10,000 and 25,000 irrigated acres if sufficient funding is provided) would already be providing much of the information in their Agricultural Water Management Plans (AWMPs) which are needed to support the methodology. For suppliers smaller than 10,000 acres and more than 2,000 acres are required to measure farm-gate delivery only, section 531.10 of CWC.

It is recommended that the existing NRCS and CARCD protocols for the Mobile Lab activities be utilized. Mobile Labs were established in CA to perform activities such as DU and onsite irrigation system evaluation for efficiency. DU is a measure of the uniformity with which irrigation water is distributed to different areas in a field. The evaluation takes one day to complete, covers the entire field evaluated and includes standardized data collection and analysis (Yolo Co. RCD). The primary field activities for evaluating DU and system efficiency are pressure measurements, flow rate measurements, and the determination of applied water.

#### 5.2.2.4 Schedule of Implementation

The methods will be calculated and included in AWMPs (CWC 10826) using data collected and reported in the AWMPs. Phasing will allow the use of existing data to prepare initial estimates of the supplier level methods while data improvements are identified and implemented.

**Phase 1: Complete by 2015**

- Identify suppliers with existing data to make initial calculations of methods, suppliers would have relatively good existing data on delivery records, reuse, seepage, and operational spill, plus some existing estimates of private groundwater pumping, agronomic uses, and environmental uses.
- DWR and cooperators identify important data needs and set priorities for improvements. Priorities could be based on data components (e.g., agronomic

uses and environmental uses), crop categories, regions, or other factors. Priorities could also be based on statewide or regional water management considerations.

- Develop a plan to improve the key limiting data in Phase 2, based on expected costs or on a range of potential costs and available funds

**Phase 2: Complete by 2020**

- Suppliers to implement the data improvement recommendations and apply the methods using the improved data. The suppliers report results in their 2020 AWMPs.
- DWR, cooperating entities and suppliers, and other experts assess results and revise data improvement recommendations if necessary.

**Phase 3: Begin after 2020**

- All suppliers implement data improvement plan, calculate supplier-level methods and report to DWR to be maintained in a water use database available to the public.

**Table 5-4**

## Summary of Implementation Plan Elements for Supplier Scale Methods

## Quantifying the Efficiency of Agricultural Water Use

| Implementation Plan Element | Details | Notes |
|---|---|---|
| Methods | CCUF,<br>Total Water Use Fraction<br>Delivery Fraction<br>Water Management Fraction | |
| Implementing Entities | Water suppliers. DWR regional land and water use analysis units and/or statewide unit could provide data and technical assistance. | Coordination process to be developed. |
| Data Sources | See Table 5-3 | |
| Schedule and frequency | Initial phase: by 2015 cooperating suppliers calculate using best available data and estimates. Develop program to improve supplier-level water use information.<br>Second phase: by 2020, fund and implement data improvement plan. All | Data improvement plan to focus on groundwater, agronomic uses, and environmental uses. Plan could provide options to the legislature, with associated cost and other |

| | | |
|---|---|---|
| | suppliers use best available data to calculate methods and report in 2020.<br>Ongoing: if available suppliers should include the aggregated field scale results as part of AWMP every 5 years. | implications.<br>Pilot testing to focus on high priority regions or crops; incorporate aggregated field-level data as it becomes available. |
| Cost | See cost estimate section | |

## 5.2.3 Field Scale

### 5.2.3.1 Data needed to support the methodology

The field scale methods use data collected from individual fields or estimated to represent categories of individual fields. Categories can be defined by region, crop type, irrigation system, soil type, and other factors. Data needed at this scale is Eto, Kc, effective precipitation, agronomic use, environmental needs and applied water.

### 5.2.3.2 Data Sources, Quality, and Limitations

Growers often measure and use information on applied water, crop water use, soil moisture, distribution uniformity, and return flow. They use these data to manage irrigation and production and to understand and control costs. They generally do not provide this information to others. There is a wide variation in the techniques used to measure or estimate field-level water use. They may use different techniques to measure or estimate field water use.

The availability and quality of field level water use data varies significantly. Some data are measured with a high degree of accuracy by some growers but lower accuracy by others. Some growers may calculate crop ET, and some may keep track of water applied for specific, non-consumptive agronomic uses. Environmental uses of water that are incidental to crop irrigation activities would generally not be monitored or estimated by growers, whereas water applied specifically for environmental uses (such as winter field flooding for waterfowl) might be recorded.

Field-level water applications include water delivered to the field by the water supplier, groundwater pumped from private wells, and water reused from other fields (if it has not been delivered through the supplier's system). Many water suppliers maintain records of their water deliveries by field, but may not record the crop grown or the planting and harvest dates. Other water suppliers measure and record deliveries to turnouts but not necessarily to individual fields. Growers view individual field records as proprietary business information, and suppliers do not release information by field, though some could provide aggregated data by crop. For most irrigated lands in California, private groundwater use by field is recorded only by the growers themselves. On-farm reuse of water would be recorded if done by the grower. As a result, quantification of field-level water use efficiency must rely on grower-supplied data, data gathered during voluntary field-level studies, or new data gathered from field-level measurements such as through mobile lab evaluations.

Table 5-5 provides a summary of likely sources of data for field methods, and identifies options and needed improvements.

Calculations of the Crop Consumptive Use and Total Water Use Fractions will necessarily be limited and qualified in early implementation years. The next section includes recommendations for improved data collection and estimation of some water flows in order to support the methodology.

**Table 5-5**

## Field Scale Data Sources and Options

## Quantifying the Efficiency of Agricultural Water Use

| Data Component | Source or Options | Notes |
|---|---|---|
| Distribution Uniformity | Quantified by mobile labs during field evaluation | |
| Crop ET and ETAW | Option 1: Using available CIMIS station data and typical Kc for crop<br>Option 2: Using results from field evaluation to calculate field-specific Kc and/or reference ET<br>Option 3: Using processed satellite imagery to calculate for specific field | More than one source available for processed satellite imagery. |
| Applied Water | Results from field evaluation. Grower or supplier records. | Suppliers' individual field delivery records are generally private. GW use on individual fields is not reported and may not be measured. |
| Agronomic Needs | Results from field evaluation, grower records Standard or typical agronomic uses could be calculated for local conditions. For example, leaching requirement depend on applied water quality, crop, soil and drainage conditions. See appendix II. | A standard estimation procedure could be developed during data assessment phase. |
| Environmental Needs | Collect information during field evaluation. | DWR work with suppliers, DFG and USFWS, and |

**Table 5-5**

## Field Scale Data Sources and Options

## Quantifying the Efficiency of Agricultural Water Use

| Data Component | Source or Options | Notes |
|---|---|---|
| | Typical environmental uses could be calculated for local conditions, though limited studies and estimates available. Include environmental needs required and quantified for regulatory or permit processes. | other groups to develop estimation procedure during data assessment phase. |

### 5.2.3.3 Data Collection Responsibility

DWR recommends that the field scale methods be implemented through a co-operative cost share program for cooperative self-enrolled growers. A field evaluation service provided on a voluntary basis to growers, the growers would be selected to provide a representative sample of fields by region, crop, irrigation system, and other appropriate factors. The data collected would be provided to the growers for making improvements in their water management practices. Collected data stripped from any personal or business information will also be used by participating local and State agencies for improving local, regional, and statewide water management planning. DWR has in the past funded mobile labs in a cost share arrangement with water suppliers. This can be a phased approach starting with supporting the existing mobile labs and potentially expanding to additional mobile labs to provide a larger and more representative sample of fields.

DWR recommends a cost share program in cooperation with interested entities such as the Agricultural Water Management Council, water suppliers, cooperating federal agencies, university cooperative extensions, or other entities to provide an irrigation and water use evaluation service, modeled on the Mobile Labs, to cooperating growers. Protocols for confidentiality would be developed to ensure that information identifying individual fields, owners, or operators is improperly disclosed.

Participating agencies would develop aggregated data including mean and standard deviation of field scale vales of CCUF, TWUF, and DU and submit to DWR.

### 5.2.3.4 Schedule of Implementation

Data availability, quality, and consistency are a clearly identified need for useful implementation for all of the geographic scales. DWR recommends that implementation of the field methodology occur in phases. An initial assessment is needed that collects and assesses the existing data, and develops priorities for the collection of improved field data. Representative samples of fields would be developed based on the priorities, available resources, and growers' willingness to participate. The second phase would focus on collecting new field estimates of water uses and flows, using detailed field evaluations that include Mobile Lab estimates of irrigation system performance and distribution uniformity. Resources would be allocated according to the priorities developed in Phase 1. The second, data improvement phase can be scaled to match resources available by adjusting the sample size of fields evaluated and by narrowing or broadening the number of priorities addressed simultaneously (the effect would be to lengthen the number of years over which the data would be improved during this phase). Quantification methods could be applied and updated on a regular basis during this phase. DWR would refine the methods and data standards and protocols as needed.

**Phase 1: Complete by 2015**

- Identify cooperating agencies with existing field-level data from Mobile Labs and water supplier delivery records. Cooperators use this data to make initial assessment of programs.
- DWR and cooperators identify important data needs and priorities for improvements. Priorities could be based on data components (e.g., field-level ET estimates versus water applied versus agronomic uses), crop categories, hydrologic regions, irrigation methods, or other factors. Priorities could also be based on statewide or regional water management considerations.
- Develop a plan to improve the key limiting data. Based on expected budget or on a range of potential budgets, develop a sampling plan to identify representative numbers of fields according to the priorities.
- Identify existing Mobile Lab resources and develop a funding plan to expand as needed to match priorities and budget.

**Phase 2: Complete by 2020**

- Based on priorities and available funding, DWR and cooperating agencies implement the data improvement recommendations from Phase 1.
- Select a region and/or crop as a pilot test to apply the methods using the improved data. Assess results and revise data improvement recommendations if necessary.
- Calculate methods and update regularly as improved data is collected.

**Phase 3: Begin after 2020**

- As funding allows apply improved data collection and estimation processes and implement methods for all regions and crops. An ongoing voluntary field sampling program would be part of this phase. Methods would be calculated on a regular basis.

Table 5-6 provides a summary of the implementation plan for the field scale.

**Table 5-6**

## Summary of Implementation Plan Elements for Field Scale Methods Quantifying the Efficiency of Agricultural Water Use

| Implementation Plan Element | Details | Notes |
|---|---|---|
| Methods | Distribution Uniformity<br>Crop Consumptive Use Fraction,<br>Total Water Use Fraction | Methods calculated by crop type and irrigation system. Results aggregated by region, supplier, or other scale |
| Implementing Entities | Growers or Water suppliers, and other willing cooperators, using data collected by mobile lab field evaluations, | Coordinate aggregate data reporting process with suppliers and other cooperators within region |
| Data Sources | See Table 5-5 | Privacy of data from individual fields protected |
| Schedule and frequency | Initial phase: by 2015 make calculation using best existing data and estimates. Develop program to improve and expand database of field-level water use information.<br>Second phase: by 2020, fund and implement data improvement plan. Implement mobile lab (or similar) program.<br>Ongoing: : if available agricultural water suppliers should include the aggregated field scale results as part of agricultural water management plan. Aggregated regional results reported in CWP update every 5 years. | Data improvement plan could provide options to the legislature, with associated cost and other implications.<br>Options could include: focus on high priority regions or crops; broad implementation at moderate pace; or broad implementation at more rapid pace. |
| Cost | See Cost Estimate section | |

## 5.3 Supplemental Productivity Indicators

Productivity will be quantified at the county scale and statewide using two indicators: crop production per acre-foot of applied water and the value of crop production per acre-foot of applied water. These are called indicators rather than methods because they do not quantify the economic efficiency of agricultural water use. Rather, they can indicate broad changes or trends over time in the agricultural production and value produced by irrigation (see earlier chapters for the uses and limitations of these indicators).

### 5.3.1 Data needed to support the indicators

The Productivity indicators would be quantified at the county and statewide scale and included in the WPU. The indicators may be calculated on an annual basis if DWR determines that it has sufficient annual water supply data, otherwise the indicators will be calculated for a five-year cycle coincident with the CWP Update. Data need include crop production at the county level, crop value and applied water.

### 5.3.2 Data Sources, Quality, and Limitations

Crop production and value are reported annually in County Crop Reports produced by the county agricultural commissioner. The U.S. Department of Agriculture National Agricultural Statistical Service (NASS) also reports production and prices for major commodities. For initial calculations of applied water, DWR will use its estimates from county and DAU level water balances produced for the CWP Update. DWR will also use crop applied water estimates provided by U.C. Cooperative Extension and water suppliers. As improved field-level data become available, these will become the source of both aggregate and crop-specific applied water estimates. Applied water estimates will be based on DWR's estimate from the water balances calculations.

**Table 5-7**

**Productivity Indicators Data Sources and Options**

**Quantifying the Efficiency of Agricultural Water Use**

| Data Component | Source or Options | Notes |
|---|---|---|
| Crop production and value | Annual County Crop Report:<br>USDA NASS reports<br>Optional: local surveys of growers, processers | More than one source may be used |
| Applied Water | Estimates used in DWR County/DAU water balances.<br>Field-level data as it becomes available | Estimated by DWR land and water use analysts |

### 5.3.3 Data Collection Responsibility

DWR will be responsible for collecting all data from existing sources and for compiling and aggregating field-level data up to county and statewide scale as it becomes available from field evaluations.

### 5.3.4 Schedule of Implementation

DWR has already provided some of these indicators in its CWP Update, 2009. County and statewide productivity indicators will be reported in the subsequent CWP Updates, every five years.

***Phase 1: Complete by 2013***

- DWR will calculate and reports in the 2013 CWP Update
- DWR will develop a priority list to determine a useful set of comparisons over time and among regions that will inform the public and policy makers.

***Phase 2: Complete by 2018***

- DWR will calculate the indicators according to the priorities developed in Phase

**Table 5-8**

**Summary of Implementation Plan Elements for Productivity Indicators**

**Quantifying the Efficiency of Agricultural Water Use**

| Implementation Plan Element | Details | Notes |
|---|---|---|
| Indicators | Productivity of Applied Water,<br>Value of Applied Water | |
| Implementing Entities | DWR economists, with assistance from land and water use analysis units | |
| Data Sources | See Table 5-7 | |
| Schedule and frequency | Initial phase (by 2013): calculate initial set of indicators. Develop priority list of crops and comparisons.<br>Second phase (2018 and after): calculate and report in subsequent CWP updates | Appropriate comparisons over time and across crops or regions should be described and limitations noted. |
| Cost | See implementation cost section | |

# 5.4 Estimated Implementation Costs

## Data Standards and Improvement Plan

The data standards and improvement plan will primarily be based on existing DWR programs.

### Data Management and Reporting Costs

Decision needs to be made concerning who will lead the data reporting and dissemination. Although the cost estimate will be determined as if DWR is reporting and disseminating the information other possible candidates could include U.C. Cooperative Extension, Cal Poly, etc.

The estimated Mobile Lab activity costs discussed below are not cumulative. In other words the capital outlay and the annual operations costs are shared across the three spatial boundaries described in this report. It is also anticipated that those suppliers with less than 25,000 irrigated acres that the costs to support mobile lab activities would be absorbed by participating State, federal or local agencies. For example, the cost of establishing and implementing standards and potential improvements for data collection and methods may be partially based on DWR's "Cold Water Rice" program an in support of the CA Water Plan update. The data standards and improvement plan will allow for methods to continually be updated.

DWR will assist in developing data standards, data collection protocols, schedules, quality control, and quality assurance and provide assistance to agricultural water suppliers and the growers in implementation of the methodologies or in the case of field methodologies utilize existing data collection activities.

### Standards and Protocol for Estimating Irrigated Agriculture Water Use

The estimated irrigated agricultural water use will be based on AW, Etc, groundwater pumping, acres of irrigated agriculture, and other field level data necessary to estimate total water use.

### Methodology and Standards for Estimating Agronomic Water Use

The estimated agronomic water use will be based on accepted professional practices and be a part of the mobile lab activities, unless specified in this report.

### Methodology and Standards for Estimating Environmental Water Use

The estimated environmental water use will be based on accepted professional practices and be a part of the mobile lab activities.

### Data Improvement

The development of a standardized water use reporting data base is essential to the successful outcome of online water use and water management plan submittal. The capital outlay for this project will be approximately $750,000 with annual operation and maintenance and data management costs of approximately $180,000.

**Implementation Plan**

Implementation of studies in a phased approach is possible.

Other costs and options are listed below for each scale boundary.

**DWR Hydrologic Region Scale**

**Regional Characteristics**

Describe Regional boundary

**Calculations**

CCUF = ETAW/Applied Water

TWUF = ETAW + Agronomic needs + environmental needs/Applied water

WMF = (ETAW + RF)/TWS

Data requirements:

ETAW = Total Etc of the crop minus effective precipitation for the time scale being evaluated, here effective precipitation is based on accepted professional practices

Applied water = the total water delivered onto the field to grow the crop or meet other agronomic or intentional environmental objectives.

Agronomic needs = additional portion of AW directed to help produce the desired agricultural commodity that is not ETAW, where the quantity is determined by accepted professional practices

Environmental needs = additional portion of AW directed to help environmental needs not ETAW, where the quantity is determined by accepted professional practices

**Regional Evaluations, Data Management and Costs**

Costs are based upon the DWR existing statewide Land and Water Use programs contribution to the water use component of the Water Plan Update. Approximately $2,000,000 annually is spent on performing 4 – 6 county land use surveys to classify crops and irrigation system types Statewide. Using this data and other County Ag Commissioner data crop water use projections are calculated. To complete land use surveys of the entire State requires a 7 – 10 year cycle with annual calculations for water use projections. Computation of CCUF, TWUF, WMF at the regional scale may require additional costs, presently estimated at 250,000/year.

Option 2 may include additional data collection and reporting based on updated data collection standards and methodology. This could include a more robust data collection process that DWR is currently under taking for the water plan update or utilizing new technologies such as incorporating remotely sensed aerial imagery into the analysis. Either way, this would be very costly. As more information becomes available a more detailed assessment of costs can be estimated.

**Water Supplier Scale**

**Supplier Characteristics**

Describe water supplier

**Calculations**

CCUF = ETAW/[Applied Water-AN-EN]

TWUF = [ETAW + Agronomic needs + environmental needs]/Applied water

Delivery Fraction= FGD/TWS

Water Management Fraction= [ETAW+RF]/TWS

Data requirements:

ETAW = Total ET of the crop minus effective precipitation for the time scale being evaluated, here effective precipitation is based on accepted professional practices

Applied water = the measured total water supplies delivered onto the field to grow the crop or meet other agronomic or intentional environmental objectives.

Agronomic needs = addition portion of AW directed to help produce the desired agricultural commodity that is not ETAW, where the quantity is determined by accepted professional practices

Environmental needs = additional portion of AW directed to help environmental needs not ETAW, where the quantity is determined by accepted professional practices

**Supplier Evaluations and Costs**

Identify the water suppliers that will be included at the water supplier scale (> 25,000 acres, < 25,000, < 10,000 and <CVP contractors). Also, identify the water suppliers that will be included as the program is phased in.

Option 1 would be to calculate the CCUF, TWUF, and DF within the supplier's boundary. This allows for the assessment of the relationship between the water delivered to irrigated agriculture and the total water, both surface and ground water, brought into the suppliers service area. If there is recoverable water to account for the WMF would be calculated and reported. Suppliers greater than 25,000 acres are currently required to report components of the CCUF, TWUF, and WMF in teir AWMPs. No new costs are expected except some costs for carrying out the computations. Costs associated with this approach are expected to be minimal based upon the reporting of water diversions into a supplier's service area and measuring ground water pumped by the supplier and the billing or measurement of water delivered to the customer.

For suppliers less than 25,000 acres additional measurement devices may be required to effectively calculate AW. Existing legislation requires collection of this data if funding is available. There are about 130 water suppliers that are less than 25,000 acres comprising of 1.1 million acres. Some of these are CVP contractors and already measure water. These suppliers need to install water measurement device to measure deliveries. Additionally, these suppliers need to calculate CCUF and TWUF and DF at the supplier scale. Total initial cost of installing devices to measure water is estimated to be xx. The cost of data collection and computation of CCUF, TWUF, DF, WMF for these suppliers is estimated to be $1,000,000 first year and $250,000 per year after year one (IID Tailwater Education program estiomates may be a model).

Option 2 may include additional data collection and reporting based on updated data collection standards and methodology such as the mobile lab approach.

### 2.2.1 Field Scale

The field scale methodology– a term used to define the boundary of a parcel of land served by an irrigation method/system - allows for an assessment of a variety of attributes associated with irrigation system(s) and water management within a field.

Field scale data would be collected and that data would remain with the grower requesting the system evaluation while aggregated anonymous data would then be submitted to water suppliers and government agencies in the Agricultural Water Management Plans and used for education, extension, and planning purposes.

#### 2.2.1.1 Crop Consumptive Use Fraction (CCUF) and Total Water Use Fraction (TWUF)

#### 2.2.1.2 Calculations

CCUF = ETAW/[Applied Water-AN-EN]

TWUF = [ETAW + Agronomic needs + environmental needs]/Applied water

DU=Dawlq/Daw

Data requirements:

ETAW = Total ET of the crop minus effective precipitation for the time scale being evaluated, here effective precipitation is based on accepted professional practices

Applied water = the total water delivered onto the field to grow the crop or meet other agronomic or intentional environmental objectives.

Agronomic needs = addition portion of AW directed to help produce the desired agricultural commodity that is not ETAW, where the quantity is determined by accepted professional practices

Environmental needs = additional portion of AW directed to help environmental needs not ETAW, where the quantity is determined by accepted professional practices

#### 2.2.1.3 Field Evaluations

**Field Level Data**

Filed level data may include AW, Etc, agronomic and environmental needs, irrigated acres, and other filed level data necessary to estimate total water use. Field level data will be based on point of use (may need to include purchase and installation of measurement device) for one crop. Suggest this builds off of the Surface Renewal and CIMIS program work. The data requirements would include the determination of ETAW and irrigation efficiency at the field scale. Data required for determining ETAW could be provided by the DWR CIMIS program or other models such as CAL SIMETAW II, CUP or the CAL AG. This and other data would be collected and compiled by the mobile labs as a part of their service. Applied water (AW) would be the most difficult data set to create as this requires a measured component which is where the Mobile labs come in or the use of other means to collect land use data to calculate CCUF and TWUF.

**Mobile Lab**

The mobile lab costs are based on capital and operation/maintenance per lab. It is recommended that the existing NRCS and CARCD protocols for the Mobile Lab activities be utilized. Mobile Labs were established in CA to perform activities such as DU and onsite irrigation system evaluation for efficiency. DU is a measure of the uniformity with which irrigation water is distributed to different areas in a field. The evaluation takes one day to complete, covers the entire field evaluated and includes standardized data collection and analysis (Yolo Co. RCD). The primary field activities for evaluating DU and system efficiency are pressure measurements, flow rate measurements (in and out), and the determination of applied water. CCUF and TWUF and DU would be estimated based upon the irrigation system evaluation.

#### 2.2.1.4 Program Cost

**Program 1**

There are currently five (5) Mobile Labs operating in various regions of CA. For the purposes of water planning DWR has identified 10 distinct hydrologic regions. The cost to establish new mobile labs is approximately $200,000 each. Consequently to have one mobile lab representing each hydrologic region the associated start up costs would be approximately $1,000,000. The ongoing operations and maintenance for the 10 mobile labs would run approximately $1,700,000 - $2,000,000 annually. This would include sampling 100 fields in each of the 10 regions and completing the analysis, computations and reporting necessary for water suppliers to comply with the AWMP requirements stated in SBX7 7. Currently, the existing mobile labs receive funding from the USDA NRCS and local agencies and occasionally through a State grant.

**Program 2**

High-end estimate of spending per year based on per unit costs.

**Productivity Indicators**

#### 2.2.1.5 Data Collection

Discuss existing data collection and reporting.

**California Water Plan Update**

Discuss coordination with regional analysts and field evaluation coordinators.

This proposed indicator measures the value of total crop production in a county per AF of applied water.

[Need to determine if the variable of interest is total crop production or irrigated crop production]

According to Section 2279 of the California Food and Agriculture Code:

2279. The commissioner shall compile reports of the condition, acreage, production, and value of the agricultural products in his county. The commissioner may publish such reports, and shall transmit a copy of them to the director.

Every County Agricultural Commissioner compiles and publishes an Annual Crop and Livestock Report that reports the value of agricultural production in that county. These include estimates, for each significant crop, of harvested acres, average crop yields, and average prices received by the farmers. These County Crop Reports are collected by the DWR. Some staff time would be required to obtain the value of individual and total crop production from the Annual Crop and Livestock Reports and create a spreadsheet for analysis. Additional staff time would be required to disaggregate the value of irrigated agriculture from total crop production for certain crops.

DWR also can produce an estimate of applied water by county.

Table 5-X summarizes the data acquisition and analysis costs for the Value of Applied water Fraction.

TABLE 5-X
**Data Acquisition and Analysis Costs for Value of Applied Water Fractions**
**Quantifying the Efficiency of Agricultural Water Use**

| Data Needs | Source | Staff Time (hours per county) | Total Hourly (Cost per county) in dollars | Cost per county in dollars |
|---|---|---|---|---|
| Value of Total Crop Production | County Agricultural Commissioner | 4 | 98 | 392 |
| ETAW | DWR Land and Water Use Scientists | 20 | 120 | 2400 |
| Analyzing data | DWR | 1 | 98 | 98 |

TABLE 5-X
**Data Acquisition and Analysis Costs for Value of Applied Water Fractions**
**Quantifying the Efficiency of Agricultural Water Use**

| Data Needs | Source | Staff Time (hours per county) | Total Hourly (Cost per county) in dollars | Cost per county in dollars |
|---|---|---|---|---|
| Total cost per county | | | | 2890 |
| State wide cost | | | | 167,620 |

Schedule of data reporting

DWR proposes that the results of the quantification of efficiency of agricultural water use be maintained by DWR and disseminated through the Water Plan Update and other DWR planning and education documents. Water suppliers could submit the information in their AWMPs to DWR. Certain water suppliers are required to submit aggregated farm-gate deliveries to DWR. DWR would maintain the data in a database for planning and education purposes.

A brief description of various reporting requirements is described below.

The CA Water Plan Update- The plan, updated every five years, presents the status and trends of California's water-dependent natural resources; water supplies; and agricultural, urban, and environmental water demands for a range of plausible future scenarios. The current update cycle will be published in 2013 and then every five years thereafter.

Agricultural Water Management Plan (AWMP) and Efficient Water Management Practices (EWMP's) Reporting

AWMP's per SBX7-7 Chapter 3 Article 1 10820 (a) states that an agricultural water supplier shall prepare and adopt an agricultural water management plan on or before December 31, 2012 and shall update that plan by December 31 2015 and on or by December 31 every five years thereafter. These plans and EWMP's are to be submitted to the DWR.

Agricultural Water Measurement Regulation

Subdivision 10608.48(a) of SBx7-7 sets July 31, 2012 as the date by which agricultural water suppliers shall implement efficient water management practices that include measuring the volume of water delivered to customers.
Furthermore; Section 531.10(a) of the California Water Code (CWC), requires that:

> *(a) An agricultural water supplier shall submit an annual report to the department that summarizes aggregated farm-gate delivery data, on a monthly or bi-monthly basis, using best professional practices.*

- **Agricultural water suppliers providing water to less than 10,000 irrigated acres, excluding acres that receive only recycled water,** are not subject to the water measurement requirements. They remain subject to measurement requirements of Section 531 of the Water Code if they deliver more than 2000 acre feet of water or irrigate 2000 or more acres of land. The schedule of submittal of the farm-gate delivery will coincide with the schedule of the AWMP submittals.
- **Agricultural water suppliers providing water to 10,000 or more irrigated acres but less than 25,000 irrigated acres, excluding acres that receive only recycled water,** are not required to implement the water measurement requirements unless sufficient funding is provided specifically for that purpose.
- **Agricultural water suppliers providing water to 25,000 irrigated acres or more, excluding acres that receive only recycled water,** shall measure water deliveries consistent with the water measurement requirements.

SBX7-7 requires DWR to develop a standardized data reporting form water suppliers may use to submit water use data to agencies. DWR could include the results of the calculations of water use efficiency in the database.

**Funding Priorities:**

- Highest priority- DWR recommends that the funding needed for field scale quantification water use efficiency methods should have the highest priority to carry out the Mobile Lab in cooperation with water suppliers and other cooperating agencies. The field scale values of CCUF and TWUF help suppliers to determine field water use efficiency and potential water management modifications. Field and supplier scale CCUF, TWUF, recoverable flows, DF will be used by DWR as it quantifies the regional scale CCUF, TWUF and WMF. This data helps DWR to improve its database, where DWR currently uses seasonal estimates of water application efficiency to estimate AW in a DAU and a

Hydrologic Region. Funding should also be provided to Phase 1 tasks identified at alls scales.

- Second priority is funding should be provided to water suppliers smaller than 25,000 acres to develop AWMPs and provide on-farm irrigation system evaluation and implementation of field scale methods.
- Third priority- Funding should be provided to DWR to expand its standardized data reporting forms and database to accommodate the needs of data management for this project.

# References

California DWR of Water Resources (DWR). 2009. California Water Plan Update. Sacramento, California.

Add IID reference

# APPENDIX A

## Selected Sections of California Water Code

### Sections of the CWC enacted by the SB X7-7:

*§10608. The Legislature finds and declares all of the following:*

*(a) Water is a public resource that the California Constitution protects against waste and unreasonable use.*

*(b) Growing population, climate change, and the need to protect and grow California's economy while protecting and restoring our fish and wildlife habitats make it essential that the state manage its water resources as efficiently as possible.*

*(c) Diverse regional water supply portfolios will increase water supply reliability and reduce dependence on the Delta.*

*(d) Reduced water use through conservation provides significant energy and environmental benefits, and can help protect water quality, improve streamflows, and reduce greenhouse gas emissions.*

*(e) The success of state and local water conservation programs to increase efficiency of water use is best determined on the basis of measurable outcomes related to water use or efficiency.*

*(f) Improvements in technology and management practices offer the potential for increasing water efficiency in California over time, providing an essential water management tool to meet the need for water for urban, agricultural, and environmental uses.*

*§10608.4. It is the intent of the Legislature, by the enactment of this part, to do all of the following:*

*(a) Require all water suppliers to increase the efficiency of use of this essential resource.*

*(e) Establish consistent water use efficiency planning and implementation standards for urban water suppliers and agricultural water suppliers.*

*(i) Require implementation of specified efficient water management practices for agricultural water suppliers.*

*(j) Support the economic productivity of California's agricultural, commercial, and industrial sectors.*

*(k) Advance regional water resources management.*

*§10608.8.*

*(c) This part does not require a reduction in the total water used in the agricultural or urban sectors, because other factors, including, but not limited to, changes in agricultural economics or population growth may have greater effects on water use. This part does not limit the economic productivity of California's agricultural, commercial, or industrial sectors.*

*§10800*

*(e) There is a great amount of reuse of delivered water, both inside and outside the water service areas.*

*(f) Significant noncrop beneficial uses are associated with agricultural water use, including streamflows and wildlife habitat.*

*(h) Changes in water management practices should be carefully planned and implemented to minimize adverse effects on other beneficial uses currently being served.*

## Sections of the CWC enacted by AB 1404:

*531.10. (a) An agricultural water supplier shall submit an annual report to the department that summarizes aggregated farm-gate delivery data, on a monthly or bimonthly basis, using best professional practices.*
*(b) Nothing in this article shall be construed to require the implementation of water measurement programs or practices that are not locally cost effective.*

*531. Unless the context otherwise requires, the definitions set forth in this section govern the construction of this article.*
*(a) "Aggregated farm-gate delivery data" means information reflecting the total volume of water an agricultural water supplier provides to its customers and is calculated by totaling its deliveries to individual customers.*
*(b) "Agricultural water supplier" means a supplier either publicly or privately owned, supplying 2,000 acre-feet or more of surface water annually for agricultural purposes or serving 2,000 or more acres of agricultural land. An agricultural water supplier includes a supplier or contractor for water, regardless of the basis of right, which distributes or sells water for ultimate resale to customers.*

## Agricultural water management planning and implementation enacted by SBX7-7:

*10820. (a) An agricultural water supplier shall prepare and adopt an agricultural water management plan in the manner set forth in this chapter on or before December 31, 2012, and shall update that plan on December 31, 2015, and on or before December 31 every five years thereafter.*
*(b) Every supplier that becomes an agricultural water supplier after December 31, 2012, shall prepare and adopt an agricultural water management plan within one year after the date it has become an agricultural water supplier.*

*10826. An agricultural water management plan shall be adopted in accordance with this chapter. The plan shall do all of the following:*
*(a) Describe the agricultural water supplier and the service area, including all of the following:*

*(1) Size of the service area.*
*(2) Location of the service area and its water management facilities.*
*(3) Terrain and soils.*
*(4) Climate.*
*(5) Operating rules and regulations.*
*(6) Water delivery measurements or calculations.*
*(7) Water rate schedules and billing.*
*(8) Water shortage allocation policies.*
*(b) Describe the quantity and quality of water resources of the agricultural water supplier, including all of the following:*
*(1) Surface water supply.*
*(2) Groundwater supply.*
*(3) Other water supplies.*
*(4) Source water quality monitoring practices.*
*(5) Water uses within the agricultural water supplier's service area, including all of the following:*
*(A) Agricultural.*
*(B) Environmental.*
*(C) Recreational.*
*(D) Municipal and industrial.*
*(E) Groundwater recharge.*
*(F) Transfers and exchanges.*
*(G) Other water uses.*
*(6) Drainage from the water supplier's service area.*
*(7) Water accounting, including all of the following:*
*(A) Quantifying the water supplier's water supplies.*
*(B) Tabulating water uses.*
*(C) Overall water budget.*
*(8) Water supply reliability.*
*(c) Include an analysis, based on available information, of the effect of climate change on future water supplies.*
*(d) Describe previous water management activities.*
*(e) Include in the plan the water use efficiency information required pursuant to Section 10608.48.*

*10608.48. (a) On or before July 31, 2012, an agricultural water supplier shall implement efficient water management practices pursuant to subdivisions (b) and (c).*
*(b) Agricultural water suppliers shall implement all of the following critical efficient management practices:*
*(1) Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).*
*(2) Adopt a pricing structure for water customers based at least in part on quantity delivered.*

*(c) Agricultural water suppliers shall implement additional efficient management practices, including, but not limited to, practices to accomplish all of the following, if the measures are locally cost effective and technically feasible:*
*(1) Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.*
*(2) Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.*
*(3) Facilitate the financing of capital improvements for on-farm irrigation systems.*
*(4) Implement an incentive pricing structure that promotes one or more of the following goals:*
*(A) More efficient water use at the farm level.*
*(B) Conjunctive use of groundwater.*
*(C) Appropriate increase of groundwater recharge.*
*(D) Reduction in problem drainage.*
*(E) Improved management of environmental resources.*
*(F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.*
*(5) Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance, and reduce seepage.*
*(6) Increase flexibility in water ordering by, and delivery to, water customers within operational limits.*
*(7) Construct and operate supplier spill and tailwater recovery systems.*
*(8) Increase planned conjunctive use of surface water and groundwater within the supplier service area.*
*(9) Automate canal control structures.*
*(10) Facilitate or promote customer pump testing and evaluation.*
*(11) Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress reports.*
*(12) Provide for the availability of water management services to water users. These services may include, but are not limited to, all of the following:*
*(A) On-farm irrigation and drainage system evaluations.*
*(B) Normal year and real-time irrigation scheduling and crop evapotranspiration information.*
*(C) Surface water, groundwater, and drainage water quantity and quality data.*
*(D) Agricultural water management educational programs and materials for farmers, staff, and the public.*
*(13) Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.*
*(14) Evaluate and improve the efficiencies of the supplier's pumps.*

*(d) Agricultural water suppliers shall include in the agricultural water management plans required pursuant to Part 2.8 (commencing with Section 10800) a report on which efficient water management practices have been implemented and are planned to be implemented, an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five and 10 years in the future. If an agricultural water supplier determines that an efficient water management practice is not locally cost effective or technically feasible*

*10608.48*
*(d) Agricultural water suppliers shall include in the agricultural water management plans required pursuant to Part 2.8 (commencing with Section 10800) a report on which efficient water management practices have been implemented and are planned to be implemented, an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five and 10 years in the future. If an agricultural water supplier determines that an efficient water management practice is not locally cost effective or technically feasible, the supplier shall submit information documenting that determination.*

*(e) The data shall be reported using a standardized form developed pursuant to Section 10608.52.*

*(f) An agricultural water supplier may meet the requirements of subdivisions (d) and (e) by submitting to the department a water conservation plan submitted to the United States Bureau of Reclamation that meets the requirements described in Section 10828.*

*(h) The department may update the efficient water management practices required pursuant to subdivision (c), in consultation with the Agricultural Water Management Council, the United States Bureau of Reclamation, and the board. All efficient water management practices for agricultural water use pursuant to this chapter shall be adopted or revised by the department only after the department conducts public hearings to allow participation of the diverse geographical areas and interests of the state.*

# APPENDIX B

## Parameter Descriptions and Calculations

**Crop Evapotranspiration (ETc)** - is a loss of water to the atmosphere by the combined processes of evaporation from crop and soil surfaces and transpiration from crops. It is the amount of water that the crop needs for optimal growth and to produce yield. In quantifying the efficiency of agricultural water use at all spatial scales, the implementing entity can either measure ETc or estimate it using theoretical and/or empirical equations. Measurement methods use complex equipment such as Eddy Covariance, Bowen Ratio, and lysimeters, which are very complex and therefore costly. The most commonly used approach for estimating ETc is to use reference evapotranspiration (ETo) and crop coefficients (Kc).

$$ETc = Kc * ETo$$

ETo is evapotranspiration from standardized grass surfaces and is calculated using theoretical and empirical equations that utilize weather parameters measured on such surfaces. To convert ETo into ETC, one needs to use a crop factor commonly known as a crop coefficient. Kc is developed for various crops through research. An important source of ETo and Kc data for California is the California Irrigation Management Information System (CIMIS). CIMIS is a network of over 140 automated weather stations scattered throughout California that provide ETo and weather data to the public free of charge (http://wwwcimis.water.ca.gov/cimis/welcome.jsp). CIMIS also provides spatially distributed values of ETo at 2-km grids by coupling remotely sensed satellite data with point measurements.

**Remote Sensing of ET** – recent developments in remote sensing have enabled researchers to estimate both ETo and ETc and derive spatially distributed values at various resolutions. In other words, remotely sensed data is used to generate ETo and/or ETc maps. Some of the remote sensing methods use energy balance approach and calculate ET as a residual. Others couple remotely sensed parameters with numerical models or point measurements to generate ET information. It is recommended that any remote sensing method selected for implementation of agricultural water use efficiency be verified for accuracy in an environment where it is to be utilized.

**Evapotranspiration of Applied Water (ETAW)** – is crop evapotranspiration minus the amount of water supplied to the crop by precipitation. Since some part of the precipitation is lost as runoff, deep percolation, and evaporation, only a fraction of the total precipitation is available to satisfy crop water needs. The fraction of precipitation water that is available for crops to use is known as effective precipitation (Pe). Pe depends on many factors including the slope of the land, soil type, rainfall characteristics, weather conditions, plant type, etc.

$$ETAW = ETc - Pe$$

There are many methods available for estimating Pe from total precipitation. California's Model Water Efficient Landscape Ordinance, for example, recommends the use of 25% of the total annual precipitation to be effective. This is an average value for the state and actual values may vary depending on many factors. It is highly recommended that a method that has shown proven accuracy for estimating Pe for the area of interest must be used. In other words, an entity that implements the methodology should be able to verify the accuracy of the Pe equation used.

**Leaching Requirement (LR)-** some amount of the total applied water is used to flush excess salt that is present in the soil out of the root zone to make an optimum condition for crop production. Different crop types and different varieties of the same crop can have different tolerances to salinity. The minimum amount of water required to remove salts from the root zone area is estimated using the ratio of the electrical conductivities of irrigation water (applied water) and drainage water.

$$LF = \frac{ECiw}{ECdw}$$

where ECiw is the electrical conductivity of irrigation water (dS/m) and ECdw is the electrical conductivity of drainage water (dS/m). Any amount of water in excess of the leaching requirement that goes to deep percolation is non-beneficial and reduces water use efficiency at that scale. It should be noted, however, that due to uncertainties in quantifying leaching requirements and due to low distribution uniformities of applications, some amount of water in excess of leaching requirement may be considered as reasonable.

**Climate Control** - depending on temperature, humidity, wind speed and other factors, some portions of agricultural water may be used for cooling of crops and frost protection. The amount of water used for cooling and frost protection depends on crop type and weather parameters such as humidity and temperature. Application of water for climate control should start when temperature reaches critical points for each crop and continue until the temperature becomes more favorable. Weather stations networks such as CIMIS can provide the temperature and humidity data that needs to be tracked to determine when to turn the sprinklers on and off. An entity that implements the water use efficiency methodology developed in this report should establish the threshold temperatures at which the climate controls are turned on and off for different crops in different regions. Although significant amount of water used for climate control may evaporate, the rest will infiltrate into the soil and become available for crops to consume.

**Environmental needs** - the portion of applied water directed to environmental purposes within a defined scale, that is not meeting ETAW of the irrigated commodity, including such uses as; water to produce and/or maintain wetland, riparian or terrestrial habitat, where the quantity of water consumed or used for intended objectives is based on accepted professional practices. Applied water associated with a mandated environmental objective but ultimately used for ETAW or agronomic needs in the production of any agricultural commodity would not be characterized as applied water for an environmental need.

**Applied Water (AW)** Applied water is the total amount of water that is diverted from any source to meet the demands of water user(s) without adjusting for water that is used up, returned to the developed supply and irrecoverable flows (unproductive evaporation or percolation to salt sinks). At the field, AW would consist of water deliveries to the field ( water pumped or diverted). AW at the field scale is calculated from supplier's measured deliveries (adjustments are needed if the entire delivery is not applied to the field) and groundwater pumping. Alternatively, AW at the field may be measured with a water measurement device. AW at the water supplier is the total water supplies delivered to the supplier.

**Recoverable Flows (RF)** Recoverable flows consist of the amount of water leaving a given area as surface flows to non-saline bodies or percolation to usable groundwater and is available for supply or reuse. RF is calculated from surface return flows using gauge data and estimates of deep percolation using information on applied water quality and leaching requirements; while excluding evaporation losses and flows to salt sinks.

**Total Water Supply (TWS)** Total water supply consists of the total surface and groundwater that is delivered or diverted into a supplier's service area or region. TWS is calculated from diversion records and the quantity of supplier and privately pumped groundwater (measured or estimated from the change in groundwater elevations). Deliveries to non-irrigation agriculture and M&I are excluded.

**Distribution Uniformity (DU)** Distribution uniformity is a measure of how uniformly water is applied to the area being irrigated, commonly expressed as the ratio of the average depth infiltrated in the 1/4 of the field with the lowest infiltrated depths by the average infiltrated depth in the whole field. DU evaluation is based on a statistical sampling. Field samples are taken and DU is calculated from those samples. DU is quantified by mobile labs during field evaluation.

## Models and Data Sources

**CIMIS:** An important source of ETo and Kc data for California is the California Irrigation Management Information System (CIMIS). CIMIS is a network of over 140 automated weather stations scattered throughout California that provide ETo and weather data to the public free of charge (http://wwwcimis.water.ca.gov/cimis/welcome.jsp). CIMIS also provides spatially distributed values of ETo at 2-km grids by coupling remotely sensed satellite data with point measurements.

**CIMIS/Remote Sensing of ET** – recent developments in remote sensing have enabled researchers to estimate both ETo and ETc and derive spatially distributed values at various resolutions. In other words, remotely sensed data is used to generate ETo and/or ETc maps. Some of the remote sensing methods use energy balance approach and calculate ET as a residual. Others couple remotely sensed parameters with numerical models or point measurements to generate ET information. It is recommended that any remote sensing method selected for implementation of agricultural water use efficiency be verified for accuracy in an environment where it is to be utilized.

**CALSIMETAW:** The CALSIMETAW computer model estimates crop evapotranspiration (ETc) and evapotranspiration of applied water (ETaw) for use in California Water Plan Update. The model accounts for soils, crop coefficients, rooting depths, seepage, etc. that influence crop water balance. It provides spatial soil and climate information and it uses historical crop category information to provide seasonal water balance estimates by combinations of county and detailed analysis units (DAU/County). The seasonal water balance is used to estimate the ETaw by crop and crop category for each DAU/County combination over the State. The model uses near real-time ETo information from Spatial-CIMIS, which is a model that combines CIMIS weather station data and remote sensing to provide a grid of Reference evapotranspiration (ETo) information. In addition to using daily Spatial-CIMIS data, CALSIMETAW can use daily PRISM (USDA-NRCS) data or a weather generator to estimate daily maximum and minimum air temperatures and rainfall from monthly means. ETo is estimated from a calibrated Hargreaves-Samani equation that accounts for spatial climate differences. The model uses SSURGO soil data (SSURGO, 2011). Up to Twenty four land-use categories are used to determine weighted crop coefficients to estimate ETc using the single crop coefficient approach. A daily water balance is computed using input soil and crop information and ETc. The model determines effective rainfall and ETaw which is an estimate of the seasonal irrigation requirement assuming 100% application efficiency

**SIMETAW:** The Simulation of Evapotranspiration of Applied Water (SIMETAW) simulates many years of daily weather data from monthly climate data and estimates ETo and ETc with the simulated data or with observed data. In addition, daily rainfall, soil water holding characteristics, effective rooting depths, and ETc are used to determine effective rainfall and to generate hypothetical irrigation schedules to estimate the seasonal and annual ETaw , where ETaw is an estimate of the crop evapotranspiration minus any water supplied by effective rainfall. SIMETAW is a user-friendly program that (1) calculates reference evapotranspiration (ETo) from simulated or observed weather data, (2) determines crop coefficient (Kc) values for a wide range of irrigated crops, (3) accounts for factors affecting the Kc values, (4) calculates crop evapotranspiration (ETc), (5) computes a hypothetical irrigation schedule for each of the simulated years of data, (6) estimates the effective rainfall and the irrigation water requirement (ETaw), and (7) calculates the mean ETaw over a specified number of years. When ETaw is divided by the application efficiency, the result is a site-specific total irrigation requirement.

**CUP Plus:** A user-friendly Microsoft Excel application program “Consumptive Use Program +” or “CUP+” estimates daily soil water balance to determine ETc and ETaw for agricultural crops and other surfaces that account for ET losses, water contributions from seepage of groundwater, rainfall, and irrigation within a study area over the period of record. The application computes ETo from daily solar radiation, maximum and minimum temperature, dew point temperature, and wind speed using the daily Penman-Monteith equation. In addition, the program uses a curve fitting technique to derive one year of daily weather data from the monthly data and to estimate daily ETo. CUP+ accounts for the influence of orchard cover crops on Kc values and it accounts for immaturity effects on Kc values for tree and vine crops. The water balance model is similar to that used in the SIMETAW application program. The application outputs a wide range of tables and charts that are useful for irrigation planning.

**AG Model:** The Agricultural Water Use Model was developed by the DWR's Northern Region to use monthly pan evaporation and pan coefficient data to estimate monthly ETc and ETaw for 20 crop categories by DAU/County. Currently, Northern Region and South Central Region Offices are using the Ag Model to develop their annual agricultural water use data for 20 crop categories for the CWPU 2013.

# APPENDIX C

# Calculation Examples of the Methods and Indicators

## C.1 Calculation Examples of Quantifying the Efficiency of Agricultural Water Use

Understanding the potential purposes at each scale provides insight into the use of the methodology. To help understand the applicability of the methods, the following provides purposes, coupled with detailed examples of calculating the various methods. For description and calculation of parameters used in the calculation see Appendix II.

### C.1.1 DWR Hydrologic Region Scale

#### Purposes

Purposes for evaluating agricultural water use relationships at the regional scale include:

1. Determine the relationship between the amount of water applied within the region and that consumed by the crops.
2. Quantify how water applied for agronomic and environmental uses changes regional scale efficiency of agricultural water use.
3. Assess opportunities to modify current water management systems and operations.

#### Calculations

To provide insight into the use of the methods at the regional scale, the following example was developed. Under this example, a regional scale represents agricultural water use in a DAU in the Sacramento Valley. Note, several DAUs would comprise a DWR Hydrologic Region. The example DAU represents a mixture of permanent, row, and rice crops over 200,000 acres, and is primarily served with surface water from the Sacramento River diverted under several contracts and water rights. Groundwater is pumped for about 15% of the land as a sole source and for about 20% as a back-up to surface supplies. The region is home to a federal managed refuge. The aquifer is not actively managed, so regional changes in storage only include water stored in surface reservoirs within the regional boundary. However, the region does not have reservoirs within the boundaries. Using this example, each method is calculated at the regional scale in Table C-1.

**Table C-1**

## Regional Scale Example of Water Use Efficiency Methods (see also table 3-3 for additional applicable details)

## Quantifying the Efficiency of Agricultural Water Use

| Data Element | Calculation | Result |
|---|---|---|
| ETAW | Example calculation with Option 1 – Using ETo and Kc data for general crop types, multiply all the crop acreages by ETAW, derive total ETAW, and subtract effective precipitation.<br>Example Option 2 – Use processed satellite data to obtain total crop water use. | Example Option 1 = 795,000 AF per year<br>Example Option 2 = 807,300 AF per year |
| Agronomic | Each crop type has an agronomic need, based on prior analysis and field investigations. Approximated at 7% of crop ETAW per acre of crop. | Approx = 62,000 AF per year |
| Environmental | Supplier - Garter snake habitat maintained on canal banks; plants assumed to use water like a grass hay such as Sudan (4 AF/ac); approximately 1,500 acres of habitat;<br>Field – several fields are flooded in fall/winter to provide habitat for migratory birds. Approximately 6-inches per acre of net water for 60,000 acres in region's boundary are used. Since a portion of this is considered agronomic to break down the rice stubble, additional environmental water is estimated at 3-inches per acre.<br>5,000 acre federal refuges at 4.5 AF/ac;<br>Required to maintain 6 cfs flows down drain from June 1 through October 30 for habitat (approx. 12 AF/day). | Canal habitat = 6,000 AF per year<br>Field = 15,000 AF per year<br>Refuge = 22,500 AF per year<br>Drain flows = 1,800 AF per year |
| Recoverable Flows | Value is estimated using several sources of data and calculations.<br>First, data is obtained from gauges on major drains, which represented approx. 90% of the surface return flows.<br>Second, using information on delivered water quality and estimates of the portion of agronomic water used to leach salts, an estimate of deep percolation associated with beneficial agronomic uses is derived.<br>Third, using the results of the $RBUF_T$ equation, the remaining portion of the | Drain data = 14,560 AF per year<br>Estimated deep percolation from leaching = 33,330 AF per year (2 inches per acre)<br>Estimated additional deep percolation (not from leaching) =<br>Step 1 = 986,990-924,800 = 62,190 AF<br>Step 2 = assume 20% of this evaporates from delivery system and/or is ET |

Table C-1

# Regional Scale Example of Water Use Efficiency Methods (see also table 3-3 for additional applicable details)

## Quantifying the Efficiency of Agricultural Water Use

| Data Element | Calculation | Result |
|---|---|---|
| | total delivered water that is not crop ET, agronomic water or intended environmental water is identified. Of this, an estimate is made as to how much of this water evaporates or is used by non-crop plants that are not part of intentional environmental objectives. The portion remaining is considered returning as additional deep percolation to that from intentional leaching. | of incidental plants within regional boundary.<br>Step 3 = 80% (62,190)<br>= 49,752 AF per year<br>Total estimated recoverable flows = 14,560 + 33,330 + 49,752<br>= 97,642 AF per year |
| Regional Scale Applied Water (total water supply) | The total quantity diverted by the suppliers and water right holders in the region is derived from records maintained for filing to the SWRCB or USBR or DWR accounts. The quantity of privately pumped groundwater is estimated from the change in groundwater elevation between spring and fall readings in several monitoring wells within the regional boundary combined with hydro-geological data from prior studies relating elevation change to volumes. Total deliveries to non-irrigation agriculture and Municipal and Industrial (M&I) are subtracted from the total. Delivered water also excludes groundwater recharge and accounts for the net change in surface storage. | Supplier diversions = 676,890 AF per year<br>Private diversion = 245,600 AF per year<br>Refuge diversions = 30,000 AF per year<br>Estimated GW pumped = 134,500 AF per year<br>Supplier non-irrigation agricultural deliveries = 80,000 AF per year<br>Supplier M&I deliveries = 20,000 AF per year<br>No groundwater recharge or net change in surface storage.<br>Applied water per year= 986,990 AF per year |
| Equations: | | |
| CCUF=ETAW/[AW-AN-EN] | = {795,000/(986,990-62,000-43500)}x 100 | = 90% |
| TWUF=[ETAW+AN+EN]/[AW] | = {900,500/986,990} x 100 | = 91% |
| WMF= [ETAW+RF]/TWS | = {(795,000 + 97,642) /986,990}x 100 | = 90% |

DWR also includes mean and standard deviation of field scale values of CCUF, TWUF and DU from field evaluations in the region.

### C.1.2 Water Supplier Scale

#### Purpose

Several purposes have been identified that draw directly from policy statements and other language in the enabling legislation to evaluate agricultural water use relationships at the water supplier scale, including:

1. Assess the relationship of the total quantity diverted into a water supplier boundary, including that pumped by the water suppliers and private entities, to the quantity actually consumed by the crops being grown.
2. Assess the total quantity diverted into the water supplier boundary to the needs of both crop and environmental uses.
3. Assess opportunities to reduce the total quantity diverted into a water supplier boundary while sustaining crop productivity and intended environmental benefits by investigating the portion of water diverted that is not directly meeting crop and non-crop beneficial uses.
4. Compare the amount of water delivered to the supplier to the amount that the supplier delivers to its customers' fields for crop production.
5. Assess the effect of recoverable losses on the suppliers overall efficiency of water use.

#### Calculations

The following example was developed to provide insight into the use of the methods at the water supplier scale. Under this example, a water supplier serves 45,000 acres of permanent and seasonal row crops irrigated with surface water and groundwater. The supplier operates groundwater wells; in addition private wells are used in some instances to supplement supplier deliveries. The supplier maintains one side of all delivery canals for habitat benefit. The supplier is required to maintain certain flows in long-standing drains to maintain beneficial riparian habitat. The supplier also provides water for livestock production and municipal, commercial and industrial users within its service area. Using this example, each method is calculated at the water supplier scale in Table C-2.

**Table C-2**

## Water Supplier Scale Example of Water Use Efficiency Methods (see also Table C-3 for additional applicable details)

## Quantifying the Efficiency of Agricultural Water Use

| Element | Calculation | Result |
|---|---|---|
| ETAW | Example Option 1 – Using ETo and Kc data for general crop types, multiply all the crop acreages by the ETAW, derive a total ETAW, and subtract effective precipitation.<br>Example Option 2 – Use processed satellite data to obtain total crop water use (this value is shown with a higher result to indicate that it is possible for micro-climates to exist that are not reflected in CIMIS or other ETo data) | Example Option 1 = 126,000 AF per year<br>Example Option 2 = 134,300 AF per year |
| Agronomic | Each crop type has an assumed agronomic need, based on prior analysis and field investigations. Approximated at 7% of crop-specific ETAW per acre of crop (stakeholder and personal communication). The agronomic needs depend on many including crop type, climate, soil and water quality. Therefore, the agronomic needs are site specific and should be computed based on methods provided (Appendix II) and professional practices. | Approx = 9,000 AF per year |
| Environmental | Supplier - Garter snake habitat maintained on canal banks; plants assumed to use water like a grass hay such as Sudan (4 AF/ac); approximately 50 acres of habitat;<br>Field – Several fields are flooded in fall/winter to provide habitat for migratory birds. Approx 6-inches per acre of net water for 8,000 acres in supplier's boundary are used<br>Required to maintain 6 cfs flows in drain from June 1 through October 30 for habitat (approx. 12 AF/day) | Canal habitat = 200 AF per year<br>Field habitat = 4,000 AF per year<br>Drain flows = 1,800 AF per year<br>Total EN= 6,000 af per year |
| Aggregate Field Scale Applied Water | Estimate provided by water supplier in monthly measured billings. Field level groundwater pumping and net change in surface storage and/or soil moisture accounted for. | Aggregate Field Scale AW per year = 148,555 |
| Recoverable Flows | This value is estimated using several sources of data and calculations.<br>Using data from gauge on the drain, | Drain data = 1,800 AF per |

**Table C-2**

## Water Supplier Scale Example of Water Use Efficiency Methods (see also Table C-3 for additional applicable details)

## Quantifying the Efficiency of Agricultural Water Use

| Element | Calculation | Result |
|---|---|---|
| | represented approx. 90% of the surface return flows.<br>Using information on delivered water quality and estimates of the portion of agronomic water used to leach salts, an estimate of deep percolation associated agronomic needs is derived.<br>the remaining portion of the total delivered water that is not crop ET, agronomic water environmental water is identified.<br>Of this, an estimate is made as to how much of this water evaporates or is used by non-crop plants that are not part of intentional environmental objectives.<br>The portion remaining is considered returning as additional deep percolation to that from intentional leaching. | year<br>Estimated deep percolation from leaching = 7,500 AF per year (2 inches per acre)<br>Estimated additional deep percolation (not from leaching) =<br>Step 1 = 160,920-141,000 = 19,920 AF<br>Step 2 = assume 20% of this evaporates from delivery system and/or is ET of incidental plants within Regional boundary.<br>Step 3 = 80% (19,920)<br>= 15,936 AF per year<br>Total estimated recoverable flows = 1,800 + 7,500 + 15,936<br>= 25,236 AF per year |
| Supplier Scale Applied Water | Total quantity diverted by the supplier is derived from records maintained for filing to the SWRCB. The quantity of supplier and privately pumped groundwater is estimated from the change in groundwater elevation between spring and fall readings in several monitoring wells within the suppliers boundary combined with hydro-geological data from prior studies relating elevation change to volumes.<br>Total deliveries to non-irrigation agriculture and M&I are subtracted from the total. Delivered water also excludes groundwater recharge and accounts for the net change in surface storage within the water supplier's boundaries. | Supplier diversions = 156,420 AF per year<br>Estimated GW pumped = 19,500 AF per year<br>Supplier non-irrigation agricultural deliveries = 10,000 AF per year<br>Supplier M&I deliveries = 5,000 AF per year<br>No groundwater recharge or net change in surface storage.<br>Applied water per year = 160,920 AF per year |

**Table C-2**

**Water Supplier Scale Example of Water Use Efficiency Methods (see also Table C-3 for additional applicable details)**

**Quantifying the Efficiency of Agricultural Water Use**

| Element | Calculation | Result |
|---|---|---|
| Equations: | | |
| CCUF=ETAW/[AW-AN-EN] | = {126,000/(160,920-9,000-6,000)} x 100 | = 86% |
| TWUF=[ETAW+AN+EN]/AW | ={(126,000+9,000+6,000)/160,920} x 100 | = 88% |
| DF=FGD/TWS | ={ (148,555)/160,920} x 100 | = 92% |
| WMF=[ETAW+RF]/TWS | = {(126,000+25,236)/160,920} x 100 | = 94% |

Water supplier also includes mean and standard deviation of field scale values of CCUF, TWUF, and DU from the farm evaluation of irrigation system in its service area.

## C.1.3 Field Scale

### Purposes

Drawing directly from policy statements and other language in the enabling legislation, the purposes for evaluating agricultural water use at the field scale are:

1. Determine the relationship between the amount of water applied to a field and that being consumed by the crop.
2. Quantify how water applied for irrigation, agronomic and environmental uses affects field scale efficiency of agricultural water use.
3. Assess opportunities to reduce applied water while still enabling crop productivity and any intended environmental benefits.
4. Assess the performance of irrigation and water management practices by comparing results of CCUF, TWUF and DU quantifications among fields growing similar crops under similar conditions (e.g. same soils, water quality, and supply reliability).
5. Water use efficiency methods for assessing the field scale efficiency (when applied to individual fields) only demonstrate the water management for the specific irrigation event at that location or the water management condition for the specific field during a season. However, by utilizing the sampling methods described in this report the mean and standard deviation of the values are indicators of water management condition at a larger scale such as supplier, regional or statewide.

### Calculations

To provide insight into the use of the methods at the field scale, the following example was developed. Under this example, the field consists of 125 acres of processing tomatoes; planted from seed in raised beds and furrow irrigated. The field scale deliveries are augmented with groundwater pumping and the net change in surface storage and soil moisture are accounted for. Using this example for a single growing season, each method is calculated at the field scale in Table C-3.

**Table C-3**

## Field Scale Example of Water Use Efficiency Methods

## Quantifying the Efficiency of Agricultural Water Use

| Data Element | Calculation | Result |
|---|---|---|
| ETAW | Example Option 1 – ETo X Kc using CIMIS and available crop coefficients to estimate crop consumptive use. This method assumes uniformity and subtracts estimate of effective precipitation from crop consumptive use. ETAW, if calculated for one irrigation event, is the total ETAW from the date of previous irrigation.<br>Example Option 2 – Field-specific analysis using remote sensing techniques that account for non-uniformity of crop response in a field due to varied soil, applied water or other conditions that change the ET of the plant compared to other areas of the field (and thus may reduce ET). See Appendix II for more details. | Example Option 1 = 2 AF/ac = 250 AF per season<br>Example Option 2 = 235 AF per season (recognized that the field had areas where the plant was underperforming, resulting in less ETAW than ideal |
| Agronomic | Water and soil quality are good, so minimal leaching is assumed, leaching requirement is assumed based on accepted professional practices to be 5% of Etc. Seed bed needs wetting to allow plant to break soil crust, adding another 2-inches or about 17 AF. This crop does not have frost control water needs, thus it is not included. If a crop needs frost protection the portion of the frost control water that will be consumed by crop should be subtracted from the climate control water use and the remainder included in agronomic need. | LR = 12 AF per season<br>Seed bed preparation= 17 AF per season<br>Total = 29 AF per season (of this amount, 10 AF of the seed bed water doubles as water for ETAW, which results in a net agronomic quantity of 19 AF). Net agronomic needs=19 af/year |
| Environmental | Small wetland and garter snake habitat maintained on field edges; plants assumed to use water like a grass hay such as Sudan, 4 AF/Y; approximately 5 acres of habitat | Habitat = 20 AF per year |
| Distributional Uniformity | Determine the average low quarter applied water depth of a field relative to the average | Average low quarter depth = 2.8 inches per irrigation event |

**Table C-3**

## Field Scale Example of Water Use Efficiency Methods

## Quantifying the Efficiency of Agricultural Water Use

| Data Element | Calculation | Result |
|---|---|---|
| | depth of water applied to the entire field for one irrigation event. | Average applied water depth = 3.8 inches per irrigation event |
| Field Scale Applied Water | Estimate provided by water supplier in monthly measured deliveries if the entire delivery is applied to the field. Field level groundwater pumping and net change in surface storage and/or soil moisture accounted for. Alternatively, for field evaluation the applied water may be measured with a water measurement device. | 373 AF AW per season<br>[10 AF per season of private groundwater pumping<br>10 AF per season put to field scale surface storage<br>3 AF soil moisture in the field from previous season. For a total of 350 AF surface delivery] |
| Equations: | | |
| DU= Dawlq/Daw | ={2.8/3.8} x 100 | =74% |
| CCUF= ETAW/(AW-AN-EN) | = {250/(373-19-20)} x 100 | = 75% |
| TWUF =(ETAW+AN+EN)/AW | = {(250+19+20)/373} x 100 | = 77% |

## C.2 Calculation Examples of Productivity Indicators

The purpose of the indicators are:

1. Evaluate crop production (in weight or gross crop revenue) per acre-foot of applied water within a defined scale.
2. Evaluate how production (in weight or gross crop revenue) per acre-feet changed over time within a defined scale.

An example of the productivity indicators are calculated for a 73,000 acres county scale in Table C-4[to be replaced with a current data example for two counties].

**TABLE C-4**

## Calculation of Productivity as Indicators of Agricultural Water Use Efficiency

| Data Element | Calculation | Result |
|---|---|---|
| Weight of crop production | Example Option 1 – use County Ag Commissioner reports and USDA NASS data, area-weighted for overlying counties<br>Example Option 2 – survey of growers, local processers | Option 1 = 44.5 tons/acre x 73,000 acres = 3.25 million tons<br>Option 2 = 46.2 tons/acre x 78,200 acres = 3.61 million tons |
| Gross revenue of crop production | Example Option 1 – Use Ag Commissioner reports and USDA NASS data, area-weighted for overlying counties<br>Example Option 2 – survey of growers, local processers | Option 1 = $56.70 $/ton x 44.5 tons/acre x 73,000 acres = $184.2 million<br>Option 2 = $58.20 $/ton x 46.2 tons/acre x 78,200 acres = $210.3 million |
| County Applied Water | provided by DWR from the Water Plan Update water balance studies | Option 1 = 135,050 AF |
| Equations: | | |
| PAW | Calculate range for both methods of estimating production | Low: 3.25 MT/135,050 AF<br>= 24 tons/AF<br>High: 3.61 MT/135,050 AF<br>= 26.75 tons/AF |
| VAW | Calculate range for both methods of estimating gross revenue of production | Low: $184.2 million/135,050 AF<br>= $1,362/AF<br>High: $210.3/135,050 AF<br>= $1,557/AF |