5/27/2009

The Landscape Water Budget Calculation: A Misunderstood and Misused Tool

A White Paper by Tim Wilson CSWP, CID, CIC, CLIA, CGIA, CTT+

Water budgeting is a valuable tool to further water conservation efforts. It has been gaining in popularity for the last 15 years or so. The purpose of this paper is to better define what the water budget formula does, what goes into it and how it is being misused by many in the industry. By better understanding how the formula works we can correct some of its misuses.

Let us start by understanding the desired outcome of a water budget formula. The purpose is to estimate how much water a site *should* be using. By taking into account the area, efficiency & plant water use, one can come up with a number of units of water that the site in question should be using. This can be calculated by day, week, month, season or year. Of course caution should be used when defining a water budget as, "what a site *should* be using". What has happened in recent years is that some well meaning individuals and agencies have inserted their own variables into the water budget formula that give an answer of what *they think a site should* be using.

In essence, the water budget formula can, and is, being used as a *water restriction* through manipulation of the formula and its variables.

Once this number is calculated then a water agency or other governing organization can tell an end-user how much water they should be using and base water rates on this number. Some states have actually written the water budget formula into laws and regulations. It can also be calculated by end-users themselves to better manage their own water. Where regulations are not in place it can be used as a guide to see how much a site is over-watering and serve as a baseline to work towards in conservation efforts.

While there are several different versions, they all contain the same basic information: Area, ET, Species Factor or Crop Coefficient & Efficiency.

One version is as follows:

$$\frac{ET_o * K_s}{IE} = WB$$

Where:

ETo = Plant water requirement in inches
Ks = Species factor as a decimal
IE = System Efficiency
WB = Water budget in inches

Another version of the basic annual water budget calculation looks like this:

$$SWB_{adj} = \frac{ET_O \ x \ C_{wb} \ x \ A}{C_u}$$

Where:

SWB_{adj}	=	Site Water Budget (adjusted) (CCF or Per 1000 gals.)
ET_0	=	Reference Evapotranspiration (inches per year)
C_{wb}	=	Water Budget Adjustment Factor (decimal) (See formula below)
A	=	Total landscaped area of site (square feet or acres)
C_u	=	Conversion Factor (see table below)

	CCF	**1000 gals.**
Square Feet	1200	1604.3
Acres	0.0275	0.0368

I like this version because it allows you to choose your billing units (ccf or K Gal) and it also allows you to choose the area unit of measurement (square ft. or acres).

The most misunderstood part of the formula is the water budget adjustment factor. This is the "magic" number that is being hotly debated in the industry.

Water Budget Adjustment Factor:

The formula for calculating the C_{wb} is:

$$\frac{K_s}{IE} = C_{wb}$$

Where:

C_{wb}	=	Water Budget Adjustment Factor
K_s	=	Species Factor (crop coefficient)
IE	=	System Efficiency

As an example, if the result of the above calculation was .80 than the water budget formula would look like this:

$$\frac{ET_o * .80 * Area}{C_u}$$

We can see from this that the .80 essentially reduces the ET_o by 20%. The desired result here then would be to say to end-users that they are allowed to use 80% of ET_o. That would be a mistake to take such a simplistic view of the Water Budget calculation.

Let's back up and take a more detailed look at this portion of the water budget formula. Again, it looks like this:

$$\frac{K_s}{IE} = C_{wb}$$

Where:

C_{wb}	=	Water Budget Adjustment Factor
K_s	=	Species Factor
IE	=	System Efficiency

What we are doing here is "inflating" the Species Factor due to less than perfect efficiency. Notice that I used the word *efficiency*, not *uniformity*. Many professionals in the industry have taken to using the terms uniformity and efficiency interchangeably. That is incorrect. Uniformity strictly deals with hardware imperfections in the system. Efficiency deals with both the hardware and the management and/or scheduling of the system. Efficiency is defined as follows:

Irrigation Efficiency Calculation:

$$IE = \frac{water\_used\_beneficially\_by\_the\_plant}{water\_applied}$$

In regard to the "water applied" let us ask ourselves, "What goes into the application of water?" When applying water to a site one has to use hardware and then schedule it correctly. As an example, if a system was 100% uniform (impossible, but let's assume this) it would still be possible to waste water just by letting it run too long. This is where the whole process gets interesting.

Another way to arrive at efficiency might be to say that:

$$Uniformity * Management = IE$$

Where:

Uniformity = The measurement of hardware as in DU_{LQ}, CU or SC

Management = The operation or scheduling efficiency of the system (the *Human Factor*)

IE= Irrigation efficiency

The practical application issue with this is that you would have to assign a "Management Efficiency" number to the person or persons who manage the system and deal with the scheduling. Whatever number is used, it is safe to say that it would be less than 100%, since no one is perfect in his/her operation of a system. Some people, in fact, are horrible and never change the schedule, while others are highly trained and use cutting edge technology. Either way, it is clear that even with the best people and technology, the highest numbers used for the "management efficiency" would probably be 80%-90%.

As an example, let's assume a system with an average uniformity of 80%. Granted, this is essentially impossible since it means that some zones would be less than 80% (very likely) and some would be over 80% (very unlikely). In fact I have only seen a conventional irrigation zone with 80% uniformity once in my life. The vast majority of zones that I have audited are anywhere from 30% to 70%. For this example we will use 80% uniformity to make a point.

If the uniformity is 80%, we would now pick a management efficiency as a multiplier. This is because, as mentioned earlier, the budget formula asks for the system *efficiency*, not the system *uniformity*. As a reminder, efficiency is defined as the water used beneficially by the plant, divided by the water applied. For this example we will assume the person managing the system does so at a 75% management efficiency. We might then have an equation as follows:

$$.80 * .75 = .60$$

This means that the system has a *uniformity* of 80% but an *efficiency* of 60%. The fact is that no matter what the system uniformity, the system efficiency will always be lower. This is because no human or machine is perfect in his/her management and scheduling of a system.

Before we go much further I would like to deviate for a moment so as to clarify the issue of watering at more or less than 100% efficiency. Technically, it would be possible to water at, or above, 100% efficiency. This could be done if one was watering at what is called *deficit irrigation*. Deficit irrigation is when one waters less than what the plants need to grow and be healthy.

This is sometimes done in agriculture for specific reasons. It is sometimes required in the landscape under severe drought restrictions. Deficit irrigation is not normally practiced in the landscape since the whole purpose behind landscape plantings and irrigation is to maintain appearance. It would be important also not to confuse deficit irrigation with supplemental irrigation. Supplemental irrigation is used in areas where most of the year rainfall provides almost all of the needed water and the irrigation system is used only sporadically to supplement rainfall.

The reason deficit irrigation can result in 100% or greater efficiency is because if you irrigate less than what the plant needs, then all, or almost all, of the water applied will be used beneficially by the plant.

Deficit irrigation aside, based on the previously mentioned facts we can see that one must pay close attention to the Water Budget Adjustment Factor that one decides to use in a water budget calculation. Based on these points listed so far, and from my own field experience, the efficiency numbers being used in most water budget calculations for the Water Budget Adjustment Factor for regulatory purposes are far too low. Just consider the example above. What sites do you know of that would have an average uniformity of 80% and a management efficiency of 75%? The result of the example calculation for IE is 60%. The most common reason for these errors is that uniformity and efficiency are being used interchangeably which is incorrect given the definition of efficiency.

Continuing this example we will assume that a site is all shrub (not very common in most of the US, but let's assume this for this example).

Now you would take the 60% efficiency and a .50 species factor (for the shrubs) and put that into the following equation:

The formula for calculating the C_{wb} is:

$$\frac{K_s}{IE} = C_{wb} \qquad \text{Equation 4-2}$$

where:

C_{wb}	=	Water Budget Adjustment Factor
K_s	=	Species Factor
IE	=	System Efficiency

So our calculation would look like this:

$$\frac{.50}{.60} = .83$$

In other words, a site with 80% uniformity, 75% management efficiency, and all shrubs would have a Water Budget Adjustment Factor of .83, or as some people like to look at it, 83% of ET_o.

What about a site that has an overall average uniformity of 65% and a management efficiency of 70%, that is mostly turf?

First, we will multiply the uniformity by the management efficiency:

.65 * .70 = .46 or 46% IE

Now we will take a species factor of .65 for a site that is mostly turf and divide it by the system efficiency of 46%:

$$\frac{.65}{.46} = 1.41$$

In this case the site would require 41% more than ET_o, and this would be for an above average site and system. Below is a table showing what the Water Budget Adjustment Factor (C_{wb}) would be for different efficiencies and species factors.

	Estimated K_s	Estimated Irrigation Efficiency (IE)			
		0.70	**0.75**	**0.80**	**0.85**
All turf	0.75	1.07	1.00	0.94	0.88
Mostly Turf	0.70	1.00	0.93	0.88	0.82
Equal turf - shrub	0.65	0.93	0.87	0.81	0.76
Mostly Shrub	0.60	0.86	0.80	0.75	0.71
All shrub	0.50	0.71	0.67	0.63	0.59

What is happening in many areas is that people, professionals and regulatory agencies are picking a Water Budget Adjustment Factor without really understanding what goes into it and how all of the numbers come together.

The result being a water budget that is essentially impossible to reach. In many instances the regulatory agency is purposely picking a water budget that is impossible or very difficult to reach because they want the end-user to make drastic changes to the system, scheduling and/or the landscape.

What is not being communicated to the end-user in these instances is what exactly is expected of them. In other words, if a water budget number is based on the desire of a regulatory agency to have a site be only 25% turf, with a system uniformity of 80% and 90% management efficiency, then that needs to be communicated up front.

If this is not communicated up front, then the end-user will struggle trying to make changes without really knowing what and why they are doing them, and spending thousands of dollars in the process; all the while probably not being successful.

In addition, the regulatory agency might garner support from end-users and industry groups for a *number* to be used in the water budget formula without the end-users and the industry really knowing what they are committing to in regards to bringing their sites into compliance with the water budget restrictions.

At this point, some might say that the beauty of a water budget is that the regulatory agency does not care, nor does it want to, regulate specifics as far as system types landscape design, plant varieties, percent of turf and shrub etc. While that is a good thought, the reality is that when one creates a water budget there are some preconceived conditions in mind from the outset. You cannot create a budget without that preparation.

Without communicating the details behind the math in the water budget end-users will naturally install whatever landscape and irrigation system they are comfortable with or have the dollar budget for and just assume that if they are careful and efficient they can reach a budget. The reality is that with many budgets it would take a herculean effort and major advanced design steps for both the landscape and irrigation system to meet a budget. At least general, basic guidelines can be communicated.

I would recommend that if an agency is going to require a specific water budget adjustment factor in their formula that they specifically list what conditions they used to arrive at that number. For example, when publishing a water budget an agency might use wording as follows:

This budget is based on a site being 50% shrub and 50% turf.
It is based on all shrubs being native, drought tolerant.
It is based on all turf being hybrid, low water use varieties.
It is also assuming a 75% overall system DU and an 85% management efficiency.
It is based on an annual ETo of 52 inches.
It assumes 6 inches of effective rainfall a year.

This will help everyone involved to understand clearly what is being proposed. Even if they are just guidelines, at least the end-user or professional will have an idea of what the budget is based on.

It will:

- Help designers create landscapes and systems that will meet the water budget.
- Help end-users know what the financial repercussions will be in meeting a budget.
- Help the creators of the budget numbers themselves to understand the repercussions of what they are asking.
- Help legislators understand what they are voting on and passing into law.

In summary, the water budget formula is a valuable tool to help many stakeholders use landscape water more efficiently. To do so, however, requires a detailed understanding of what goes into the formula so as to calculate a water budget number that makes sense and is realistic. In addition, a detailed understanding is needed so that the desired goals for calculating a budget are reached.

There are four main uses for a water budget:

1. End-users that have:
    a. Good irrigation systems
    b. Well-designed landscapes
    c. Professional scheduling technology and skills
    Under these conditions a water budget can help them ensure that they are irrigating efficiently and staying on track with their water use.

2. End-users that have:

   a. Bad, inefficient systems
   b. Water wasting landscapes
   c. Poor scheduling tools and skills

   Under these conditions a water budget will provide a goal to work for and inform the end-user on how much they are wasting and potentially how much water and money might be saved.

3. Regulatory agencies can use a budget to encourage end-users to improve their landscapes, irrigation systems, and scheduling practices. In this way a budget serves to also help set tiered water pricing and punish water wasters.

4. Irrigation and landscape designers can use a budget at the outset of a design to help guide them in the design process so they do not create landscape or irrigation systems that cannot possibly meet a set budget.

In all of the above mentioned items a clear understanding of the water budget formula is key to achieving any or all of the goals.

A better and clearer understanding of the water budget formula will help all parties involved in this important topic make more realistic, and intelligent decisions about reducing, managing and regulating site water use using water budgets.

Tim Wilson CSWP, CID, CIC, CLIA, CGIA, CTT+
2008 Sycamore Dr.
Eagle Mountain, UT 84005
509-981-6441
timw@h2o-ss.com
www.h2o-ss.com