DRAFT Technical Memorandum

To: *Eric Hecox/CWCB*

From: *Jacob Bornstein/CWCB, Kevin Reidy/CWCB, Nicole Rowan/CDM*

Date: *March 03, 2010*

Subject: *Calculating Per Capita Water Demand Savings from Density Increases to Residential Housing for Portfolio and Trade-off Tool*

Abstract: Increases in population density are inversely correlated with water use in gallons per capita per day (gpcd). Assuming that for single family homes 50 percent of the water is used indoors and 50 percent outdoors, water savings can be estimated with each increment of density increase. The general rule implies that a 20 percent increase in density would yield a 10 percent per capita water savings. Although significant savings can result from changes in density, these changes are usually outside of the control of water providers. CWCB proposes calculating water savings from available density data. This methodology was applied to the Denver Metro Area based off the Denver Regional Council of Government's (DRCOG) Metro Vision 2035, which predicts a 10 percent increase in density by 2035. The above methodology then indicates that a total savings of approximately 5 percent would result for current and existing uses. Applying this level of savings solely to the new population results in a savings off new demand of just over 10 percent for the Metro area. The portfolio tool now has the capacity to incorporate density data as available on a county by county basis, using this methodology.

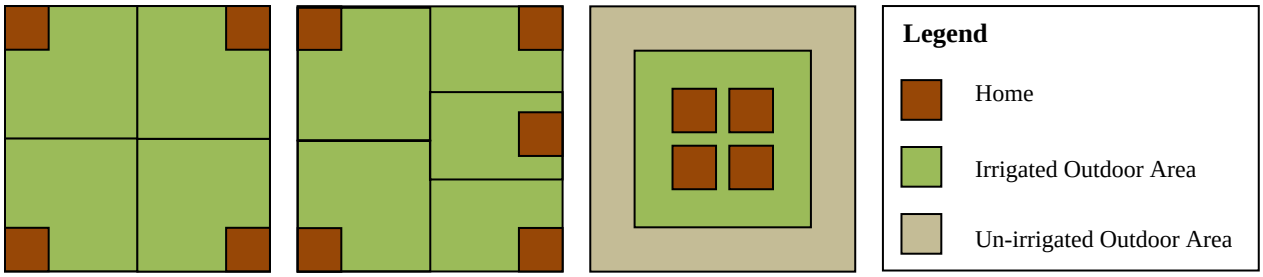
Introduction

In 2008 the IBCC indicated its interest in determining what benefit future land use changes may have on Colorado's municipal water demands. Subsequently, the Colorado Water Conservation Board and the Department of Natural Resources partnered with the Western States Water Council to conduct a symposium on the subject of integrating land use and water supply planning in October of 2009. In addition the CWCB conducted a study to determine what is already happening within the state of Colorado regarding land use and water supply. (This report will be available on CWCB's website mid March.)

There are many current examples and several additional opportunities for Colorado to integrate land use planning and water supply planning. One of the most fruitful avenues is to determine how increases in density may affect Colorado's future water supply demands. This effort follows the methodology used by some water providers, such as Denver Water, which separate demand savings from passive conservation, active conservation, and changes in socio-demographics, such as density.

Following is a description of the methodology used to incorporate a reduction factor in water usage based on increasing population density between now and 2050 for the CWCB Portfolio and Trade-Off Tool. This method is very generalized and intended for use in the reconnaissance level planning being conducted by the CWCB in assessing 2050 Water Needs for the State of Colorado. This method can continue to be refined through additional data gathering efforts that test the link between density and per capita water usage estimates with empirical data.

This approach focuses only on the potential reduction in water usage if future growth is denser than current land use patterns. The methodology does not take into account that there is an opportunity for "Green Developments", which may be new or redeveloped housing which uses both more water efficient indoor fixtures and reduced outdoor water usage through changes in landscape. These water savings are taken into account in the conservation portion of the portfolio and trade-off tool (see Figure 1).



Example 1: Typical Development (4 lots per 0.6 acres)

Example 2: Denser Development (5 lots per 0.6 acres; 20% denser)

Example 3: Green Cluster Development (4 lots per 0.6 acres; 0% denser)

Figure 1: Representation of typical, denser, and green developments.

Municipal and industrial water demands in 2050 will significantly increase at a basin and regional level. This method takes a broad geographical approach. While increased density may in fact mean more acre-feet are needed to supply water to a small area or even a water provider's service area, on a basin level reducing per capita demand will mean that overall less water is needed to supply a growing population (see Figure 2).

General Approach

In order to calculate the theoretical savings projected by increased density, savings off new demand are calculated using the approach below. Density numbers are applied to the single family homes because multifamily homes do not yield the same savings (see Figures 2 and 4). The approach takes the following steps:

Calculation

1. *Density of Current Population* = Current Population / Current Urban Area

   Explanation

   The density for an area's current population is calculated to provide a baseline.

   Calculation

2. *Density of Net New Population* = (Total New Population - Current Population) / Net New Urban Area

   Explanation

   The portfolio tool calculates new water demand. In order to determine a quantity of water to take out of new water demand, density calculations must be applied to the net new population. To determine the density of the net new population, the number of additional people is determined and divided by the new urban area that will receive growth and development.

Calculation

3. *Percent Increase in Density for Net New Population* = 100 * ((Density of Net New Population / Density of Current Population) – 1)

Explanation

In order to determine how dense the new population would have to be to accommodate for the entire increase in density, the increase in density for the net new population is calculated.

Calculation

4. *Water Savings Division Factor* = 20% / Theoretical Percent Savings at 20% Increase in Density by Unit Category

Explanation

It is often assumed that on an annual basis the interior west uses 50 percent of residential water use on outdoor irrigation and 50 percent for indoor uses.[1] As part of its water plan, California has considered the impact of land use and density as a resource management strategy. California reports "As a rule of thumb, landscaping irrigation accounts for almost half of residential water use. An increase in residential density from 4 units per acre to 5 reduces the landscaping area by 20 percent, which should cut water usage by roughly 10 percent compared to the lower density development" (see Table 1 status quo and Figure 1).[2] The increase in density for the net new population is therefore simply divided by two to determine the overall percentage of water savings. This would indicate a "Water Savings Division Factor" of two (2).

This is applicable only to single family homes, and should not be applied to multi-family homes since there are diminishing returns on outdoor water savings as more and more people exist on the same lot size (See Figure 2 and Table 1).

A theoretical curve of water savings was developed based off increases of density (# of residents/area) by 20% increments. Figure 2 illustrates a hypothetical example where the area being irrigated outdoors remains the same, despite increasing density values. It charts gallons per capita per day (gpcd), increase in population on the lot, and annual water consumption (AF). In the first case (1 unit) 81 gpcd are used indoors and 81 gpcd are used outdoors to reflect the gpcd of 162 in the Metro Basin. As more people come on line, their per capita indoor use remains the same, but their proportion of the outdoor use, and therefore outdoor per capita water use, continues to fall. In this case, without technology changes or other conservation efforts, values cannot go below the value for indoor water use (81 gpcd), no matter how many residents occupy that land area.

The more units, the higher the "water savings division factor," indicating less savings with higher and higher increases in density.

[1] Western Resource Advocates. 2009. New House New Paradigm: A Model for How to Plan, Build, and Live Water-Smart.

[2] http://www.waterplan.water.ca.gov/docs/cwpu2009/1009prf/v2ch24-landuse_planning_pf_09.pdf

Table 1. Theoretical justification for reduction values by units

Unit Category	Number of Residents	Incremental Increase in Density	Annual Water Use (AF)	GPCD	Per Capita Water Savings	Division Factor
1 unit (status quo)	2.94		0.53	162.00		
1 to 2 units	3.68	20%	0.60	145.80	-10.00%	-2.00
1 to 2 units	4.60	20%	0.68	132.84	-8.89%	-2.25
1 to 2 units	5.75	20%	0.79	122.47	-7.80%	-2.56
3 to 4 units	7.18	20%	0.92	114.18	-6.77%	-2.95
3 to 4 units	8.98	20%	1.08	107.54	-5.81%	-3.44
3 to 4 units	11.22	20%	1.29	102.23	-4.94%	-4.05
3 to 4 units	14.03	20%	1.54	97.99	-4.15%	-4.81
5 to 9 units	17.53	20%	1.86	94.59	-3.47%	-5.77
5 to 9 units	21.92	20%	2.26	91.87	-2.87%	-6.96
5 to 9 units	27.40	20%	2.75	89.70	-2.37%	-8.45
10 to 19 units	34.25	20%	3.37	87.96	-1.94%	-10.31
10 to 19 units	42.81	20%	4.15	86.57	-1.58%	-12.64
10 to 19 units	53.51	20%	5.12	85.45	-1.29%	-15.55
20 or more units	66.89	20%	6.34	84.56	-1.04%	-19.19
20 or more units	83.61	20%	7.85	83.85	-0.84%	-23.74
20 or more units	104.52	20%	9.75	83.28	-0.68%	-29.42

Calculation

5. *Percentage of Savings off New Demand* = (Proportion of 1 Unit Detached Lots * Percent Increase in Density for Net New Population / 1 Unit Detached Water Savings Division Factor) + (Proportion of 1 Unit Attached Lots * Percent Increase in Density for Net New Population / 1 Unit Attached Water Savings Division Factor) + (Proportion of 1 Unit Detached Lots * Percent Increase in Density for Net New Population / 1 Unit Detached Water Savings Division Factor) + (Proportion of 2 Units Lots * Percent Increase in Density for Net New Population / 2 Units Water Savings Division Factor) + (Proportion of 3-4 Units Lots * Percent Increase in Density for Net New Population / 3-4 Units Water Savings Division Factor) + (Proportion of 5-9 Units Lots * Percent Increase in Density for Net New Population / 5-9 Units Water Savings Division Factor) + (Proportion of 10-19 Units Lots * Percent Increase in Density for Net New Population / 10-19 Units Water Savings Division Factor) + (Proportion of 20 or More Units Lots * Percent Increase in Density for Net New Population / 20 or More Units Water Savings Division Factor)

Explanation

The above equation applies the percent savings that can be achieved with increased density to the proportion of homes that exist in each unit category. The U.S. Census provides information at the county level on housing demographics, which indicate how many homes are single family, duplex, triplex, etc., up to over 20 or more units. This is summarized at the basin level in the Table 2 below. Data for mobile homes, RV's, boats, vans and other home types are not included in the table or the analysis. Using the curve developed in Figure 2, future savings can be calculated and applied to the housing stock.

In some cases an average is used.[3] Unless other data is available, this approach assumes the same proportion of single family homes to multi-family ones in 2050 as exists today.

Table 2: U.S. Census Estimates of Colorado Housing Data[4]

Basin	1 Unit Detached	1 Unit, Attached	2 Units	3-4 Units	5-9 Units	10-19 Units	20 or More Units
Arkansas	67.7%	4.4%	2.2%	4.4%	3.3%	3.6%	6.7%
Colorado	50.5%	7.6%	2.9%	6.0%	6.5%	6.4%	10.5%
Gunnison	67.0%	2.6%	2.5%	3.0%	2.5%	1.8%	2.1%
Metro	59.4%	7.9%	1.6%	3.1%	5.1%	7.2%	13.3%
North Platte	78.9%	1.0%	1.7%	1.0%	0.6%	0.5%	0.0%
Rio Grande	69.3%	1.7%	2.7%	2.2%	2.0%	1.4%	1.3%
San Juan/Dolores	61.7%	4.2%	2.6%	3.5%	3.6%	2.6%	3.3%
South Platte	67.2%	4.8%	2.4%	4.1%	4.4%	4.3%	5.8%
Yampa	55.9%	5.6%	2.8%	3.3%	6.3%	5.4%	7.5%

[3] Table 1 calculates increases in residents by incremental 20% steps. In some cases there are several instances of resident populations that each fall within the unit category. For these instances, and average water savings was used.
[4] Units in residential structures - www.dola.state.co.us/dlg/demog/census_topics3eco.html

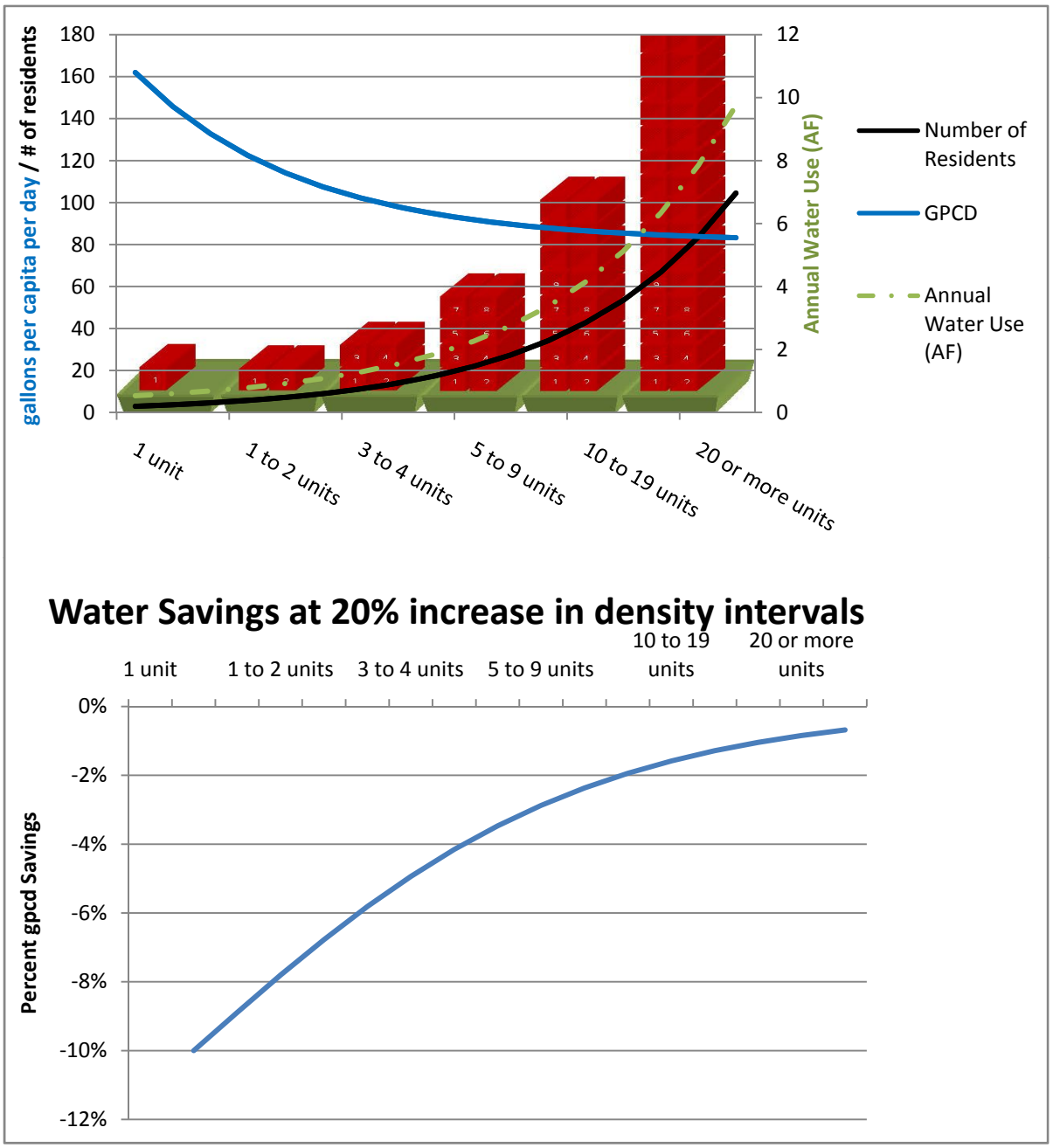


Figure 2. Diminishing GPCD reductions when increasing the density of multi-family units in 20% intervals.

Validation:
Initial review of the limited data available in Colorado which compare water usage rates between neighborhoods with different densities suggest that on average, a twenty percent increase in density does yield approximately a 10% decrease in water consumption.

The methodology also includes basic validation of work provided by land use planners, ensuring that population estimates from the CWCB and land use planners yield the same increase in density. CWCB's process incorporates the state demographer's projections into municipal demands to 2050. When population numbers differ, state demographer numbers are used. However, new land area occupied by future growth is adjusted to yield the increased density provided by land use planners in order to normalize the data and reflect infill of existing urban areas.

Application to Denver-Metro Area

The Denver Regional Council of Governments' Metro Vision 2035 anticipates that the metro area will achieve a 10 percent increase in overall density between 2000 and 2035 (figure 3).[5] Since the Metro region is expected to increase its population by 55% in 2035, we can deduce that new homes will be on average about 28% denser than existing homes in the Denver Metro area.

> Percent Increase in Density for Net New Population = 100 * ((Density of Net New Population / Density of Current Population) – 1)
>
> or in the case of the Denver Metro area
>
> 28% = 100 * **(** ((3,688,680 ppl - 2,374,700 ppl) / 310 square miles) / (2,374,700 ppl / 717 square miles) – 1 **)**

The above equation indicates that approximately 310 square miles of area will need to accommodate the new population, approximately one third of which will be infill.

Utilizing results from Table 2 and Figure 2's resulting curve, the estimated impact that projected density increase may have on water use is about 10% off new Metro basin demand in 2035. By assuming the same level of new home density will, conservatively, extend to 2050, the 10% savings could be applied to new 2050 water demands (see Table 3).

> *Percentage of Savings off New Demand* = (Proportion of 1 Unit Detached Lots * Percent Increase in Density for Net New Population / 1 Unit Detached Water Savings Division Factor) + … (Proportion of 20 or More Units Lots * Percent Increase in Density for Net New Population / 20 or More Units Water Savings Division Factor)
>
> or in the case of the Denver Metro area
>
> 10.38% = (58.43% * 28% / -2) + (7.79%% * 28% / -2.25) + (1.46%% * 28% / -2.56) + (3.05% * 28% / -4.03) + (5.38% * 28% / -6.89) + (8.12% * 28% / -12.48) + (13.42% * 28% / -23.40)

The proportions of unit category and overall water savings can be found in Table 3, which extends Table 2 data to show the water savings for each U.S. Census Data Unit Category.[3]

[5] Denver Regional Council of Governments. 2007. Metro Vision 2035 Plan.

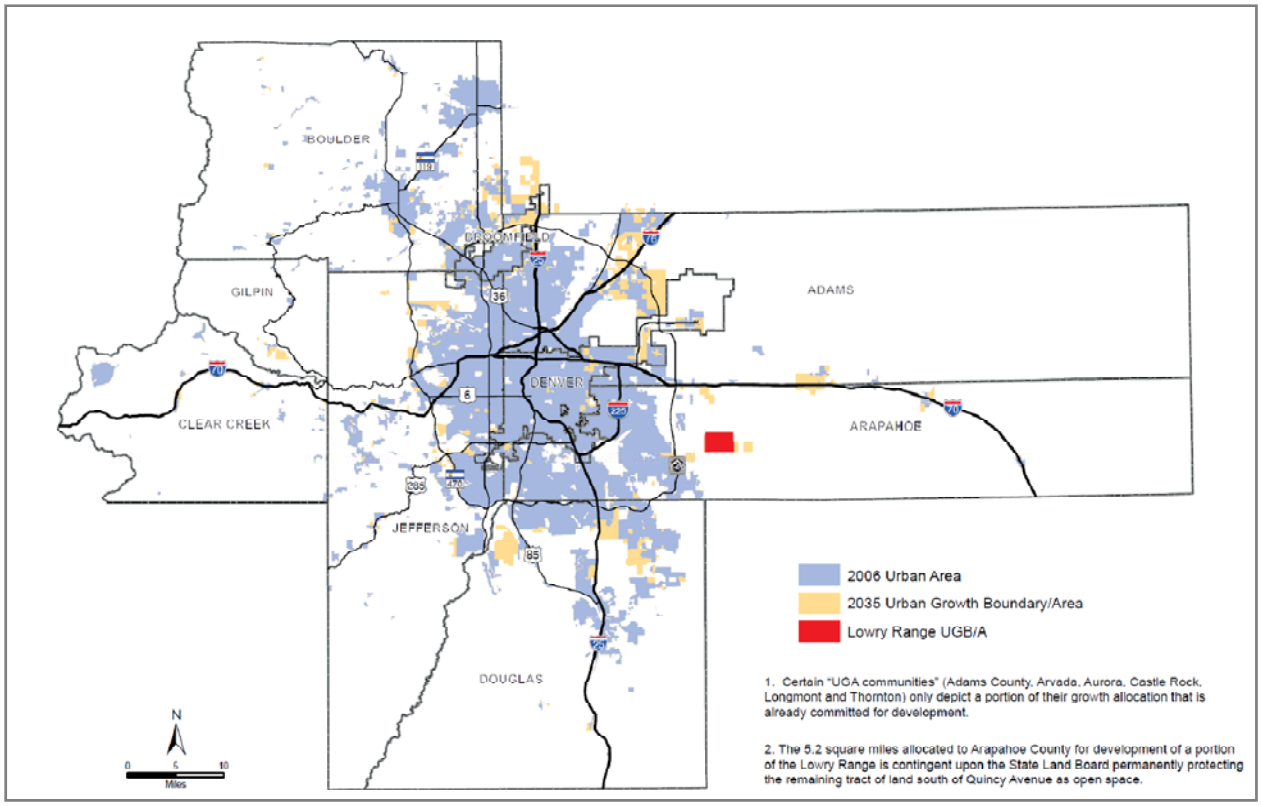


Figure 3: Metro Vision 2035's 2006 and 2035 Urban Area and Growth Boundary.[4]

Table 3. Denver Metro Area Water Savings[6]						
Unit Category	**Number of Units**	**Proportion of Unit Category**	**Net New Proportion of Denser**	**Water Savings for 20% Denser**	**Division Factor**	**Actual Net New Water Savings**
Total housing units	907,036					
1-unit, detached	529,984	58.43%	16.85%	-10.00%	-2.00	-8.43%
1-unit, attached	70,617	7.79%	2.25%	-8.89%	-2.25	-1.00%
2 units	13,237	1.46%	0.42%	-7.80%	-2.56	-0.16%
3 or 4 units	27,639	3.05%	0.88%	-4.97%	-4.03	-0.22%
5 to 9 units	48,756	5.38%	1.55%	-2.90%	-6.89	-0.22%
10 to 19 units	73,687	8.12%	2.34%	-1.60%	-12.48	-0.19%
20 or more units	121,759	13.42%	3.87%	-0.85%	-23.40	-0.17%
Total Net New Water Savings:			**28%**			**-10.38%**
2035 Total Net New Water Savings (AF):						**24,152**
2050 Low Net New Water Savings (AF)						**31,909**
2050 Medium Net New Water Savings (AF)						**41,991**
2050 High Net New Water Savings (AF)						**46,643**

[6] Note that the numbers here are slightly different than those for the Metro Basin reflected in Table 2. This reflects the different boundaries of the metro region reflected in the roundtable process and the Metro Vision 2035 process. The roundtable includes the counties of Adams, Arapahoe, Broomfield, Denver, Douglas, Elbert (SP Portion), and Jefferson. The Metro Vision 2035 also includes Boulder, Clear Creek, and Gilpin counties, but not Elbert.

The portfolio tool represents a 10 percent savings off new water demands for the metro area, and is capable of applying density savings to other basins in the state if local density data is available.

Next Steps

In order to apply this methodology to other areas in the state overall increases in density would need to be gathered or assumed. In order to assess the availability of data, CWCB proposes to consult with each of the following for data availability: Colorado Department of Transportation, Colorado Department of Local Affairs, Colorado Municipal League, and Colorado Counties Inc., and each of the council of governments. Should increases in density be available, this estimate may be applied over a broader geographical region, county by county.

This method of estimating savings could be more robust if more data was collected on water usage rates by density. While the two communities for which CWCB has obtained data for confirm the theoretical results, additional confirmation would further validate the results. A water savings per unit category curve could be developed to ground truth the amount of expected savings on a community by community level. . This could then be applied to expected increases in density. Initial thinking suggests that 1) for rural areas, increased density may not adequately predict water savings since the amount of irrigated lawn does not likely decrease linearly; 2) for urban and suburban single family homes, savings can be estimated using the 50% indoor / 50% outdoor rule of thumb; and 3) for multi-family homes a curve may be used to estimate savings (see Figure 2). The CWCB and/or IBCC may consider whether an investment of technical time and resources to confirm these assumptions should be pursued.