

HOLISTIC APPROACH TO SUSTAINABLE WATER MANAGEMENT IN NORTHWEST DOUGLAS COUNTY

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EXECUTIVE SUMMARY

Coloradoans recognize that our long-term economic health hinges on the availability of adequate, clean, reliable water supplies. As future demands for municipal, recreational, agricultural, and industrial uses continue to increase throughout the state, providing adequate water supplies will become more challenging. The water supply situation in northwest Douglas County serves as an example of the challenge of providing an adequate municipal water supply. Current and future residents are faced with a declining nonrenewable groundwater supply and limited options for renewable water supplies. The recommendations in this report provide an innovative approach toward balancing water supply and demand.

This study identifies two water management techniques that, particularly when paired together, offer an overlooked renewable water supply alternative for Colorado: precipitation management through rainwater and snowmelt harvesting and outdoor water demand management through use of water efficient landscaping and irrigation practices. Rainwater harvesting is being practiced in at least seven other western states.

The study objectives were to research existing studies and apply identified algorithms to show:

- The potential of precipitation as a water supply,
- The potential water savings for a new residential development from outdoor water demand management and the ability of rainwater harvesting to meet the demands for the three landscape scenarios shown below, and



Traditional



Moderate Conservation



Water Wise

- The potential water savings from rainwater harvesting for existing developments that currently rely on nontributary groundwater supplies.

Recommendations are made for ways to implement rainwater harvesting and protect existing water rights through utilizing the legal framework of an augmentation plan.

Study Findings

1. The average annual yield from precipitation in northwest Douglas County is 17.5 inches and the “sustainable”, or dry year, yield is over 10 inches per year.
2. Only a portion of the total precipitation that falls on an undeveloped site returns to the stream system through groundwater and surface water. At the study site, 100% of the annual precipitation is lost to evapotranspiration (ET) and sublimation in a dry year. A maximum of about 15% of the precipitation returns to the stream system in a wet year and on average, around 3% returns to the stream through groundwater and surface water.

3. Significant savings can be realized by managing the outdoor water demand through limiting irrigated area, using water efficient landscaping, and improving irrigation techniques. The outdoor water demand can be reduced by over 50% with moderate conservation and by over 75% with water wise conservation. With rainwater harvesting, outdoor water demand is reduced by approximately 65% with moderate conservation and approximately 88% with water wise conservation.
4. For existing well users, rainwater harvesting provides an opportunity to reduce withdrawals from non-tributary aquifers with declining water levels and to provide a supplemental supply, especially for irrigation and fire suppression.
5. Individual residential cisterns were evaluated in this study; other rainwater capture methods on a regional basis may provide additional options for particular projects.
6. Credit for the portion of precipitation that did not historically return to the stream system (i.e., lost to ET and sublimation) can be incorporated into augmentation plans without injuring existing water rights.

Although this study focuses on the water supply needs in northwest Douglas County, the methods presented are anticipated to be applicable throughout the county and state. A toolbox of algorithms is presented that can be used to: (a) calculate water supplies created through rainwater harvesting and the use of outdoor water demand management, and (b) calculate augmentation requirements that reflect historic stream contributions.

Study Recommendations

In summary, the study found that rainwater harvesting does have potential as a sustainable water management approach in northwest Douglas County, particularly when paired with outdoor water demand management practices. Existing literature shows that physically, not all of the precipitation falling on an undeveloped site returns to the stream system. However, current Colorado law does not allow rainwater harvesting to be utilized to its full advantage as one source of a sustainable water supply. Recommendations from the study include:

1. Douglas County should provide alternative water demand assumptions that recognize reduced outdoor water demand. Results of this study show that outdoor water demand can be reduced by more than 75% using only outdoor water demand management. Additional savings are possible with rainwater harvesting.
2. A pilot project should be identified that would incorporate rainwater harvesting with efficient landscaping and irrigation practices to verify the conclusions in this study. The pilot project would measure actual precipitation consumption and runoff patterns and verify the water savings created through outdoor demand management techniques.
3. Legislative action should be pursued to authorize a pilot program that would codify rainwater harvesting in a way that incorporates appropriate balancing and control considerations and harmonizes rainwater harvesting with protection of other valuable state resources.

ACKNOWLEDGEMENTS

Leonard Rice Engineers, Inc., Meurer and Associates, Inc., and Ryley, Carlock and Applewhite (**study team**) would like to acknowledge the funding agencies that made it possible to study precipitation management and outdoor water use conservation in Douglas County. Dominion Water and Sanitation District, Castle Pines North Metropolitan District, and Douglas County (**study applicants**) received matching funds from the Colorado Water Conservation Board (CWCB), pursuant to C.R.S. § 37-60-126, under the HB05-1254 Water Efficiency Grant Program. The study applicants were also financially supported by Thunderbird Water and Sanitation District and Plum Valley Heights Home Owners Association. A copy of the grant proposal is provided as **Attachment A**.

We would also like to thank the **Advisory Committee** and **Peer Review Committee** for their time, suggestions, and guidance during the study process. We appreciate the committee members' input, advice, and comments, which came from a variety of perspectives based upon the agencies they represented, as shown in **Table 1**. Mr. Isaac Piño shared information based on his experience with the Rancho Viejo project in Santa Fe, New Mexico and Mr. Terry McMains (President, AquaHarvest) provided information on rainwater harvesting systems and cistern installation. This information was particularly valuable from a practical standpoint and we appreciate all of their insights. Finally, we would like to thank several other interested parties who also contributed to the study in a variety of ways (Table 1).

Table 1. Advisory and Peer Review Committee Participants.

Name	Affiliation
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1.0 INTRODUCTION

Douglas County residents' primary water supply is provided by the Denver Basin Aquifers, a series of deep groundwater reserves located below the County. As future demands increase and groundwater supplies are depleted, it will become more difficult and costly to produce sufficient water to maintain delivery at existing demand levels, in addition to meeting projected future demands. Already, some individual well users located in northwestern portions of the County are witnessing dramatic drops in the water table and reduced production rates.

The purpose of the study is to evaluate the benefits of a more holistic approach to maximizing sustainable water supplies for outdoor water demands in the design of water supply systems in northwest Douglas County. This introduction provides general background information and an overview of the study process. The focus of each of the subsequent chapters is summarized as follows:



- Chapter 2 – The holistic benefits of precipitation capture as a water supply.
- Chapter 3 – Legal issues related to using precipitation as a water supply and the need for scientific algorithms to quantify the portion of the sustainable yield that can be utilized without injuring other water rights.
- Chapter 4 – Calculation of dependable yield of precipitation in northwest Douglas County, water budget components associated with precipitation under pre-development conditions, and identifying algorithms that can be used to quantify the individual components of precipitation.
- Chapter 5 – Outdoor water demands and identifying algorithms that can be used to quantify potential outdoor demand reductions with various combinations of water conservation measures.
- Chapter 6 – Components of rainwater harvesting infrastructure, with a focus on using cisterns to store precipitation.
- Chapter 7 – The algorithms developed in Chapters 4 and 5 are applied to illustrate potential water savings for a new residential development and existing well users.
- Chapter 8 – Information needed for a water court-approved augmentation plan to demonstrate that rainwater harvesting can be implemented without injuring other water rights.
- Chapter 9 – Summary of conclusions and recommendations.
- Chapter 10 – Bibliography and work cited.

Precipitation management¹ provides many benefits: 1) maximizes use of a sustainable water source, 2) reduces or delays construction of water infrastructure, 3) improves storm water quality to receiving streams, and 4) saves energy that does not have to be used to treat and transport that water. This study was conducted at a feasibility level. The goal was to investigate the pairing of one specific component of precipitation management (use of cisterns) with outdoor water demand management in northwest Douglas County to a level that allows others to decide whether they are interested in pursuing this concept as a conservation alternative. Although this study focuses on the water supply needs in northwest Douglas County, the methodologies presented herein are applicable throughout the county and to a large extent, throughout the state. Depending on the specific water supply situation, there may be other opportunities for pairing rainwater harvesting and outdoor water demand management (or utilizing one without the other) than identified in this study. The information presented here provides concepts and a toolbox of algorithms that can be used to quantify the benefits of rainwater harvesting and outdoor demand management when conducting water supply studies.

1.1 BACKGROUND

1.1.1 Study Area

With a focus on identifying sustainable and renewable water supplies, water supply planning in Douglas County, Colorado is shifting from being based on how much a given water source will cost to its long-term availability. The availability of local water supplies and water supply requirements within Douglas County is dependent on the specific location (**Attachment B**). The study area is generally bounded on the north by Chatfield Reservoir, Plum Creek on the east, the town of Sedalia on the south, and the foothills on the west (**Figure 1**). This area generally encompasses the water supply area referred to by the County as Margin A. In Margin A, deep aquifer well owners have experienced drops in groundwater levels and the County now requires new developments in this area to obtain renewable water supplies. The County defines renewable water as “water that is annually recharged through the hydrologic cycle, such as streams, and alluvial aquifers associated with streams so that the water supply is sustainable over time” (Douglas County, 2005).

Prior to this study, the focus on obtaining renewable water supplies for Douglas County has been in the area of acquiring senior irrigation water rights or filing for new surface water rights, both within Douglas County and from other areas of the State. The rainwater harvesting concept presented in this study offers an innovative alternative to this traditional approach.

¹ The term ‘precipitation management’ is used interchangeably throughout this report with ‘rainwater harvesting’, which includes the capture of precipitation that falls as both rain and snow.

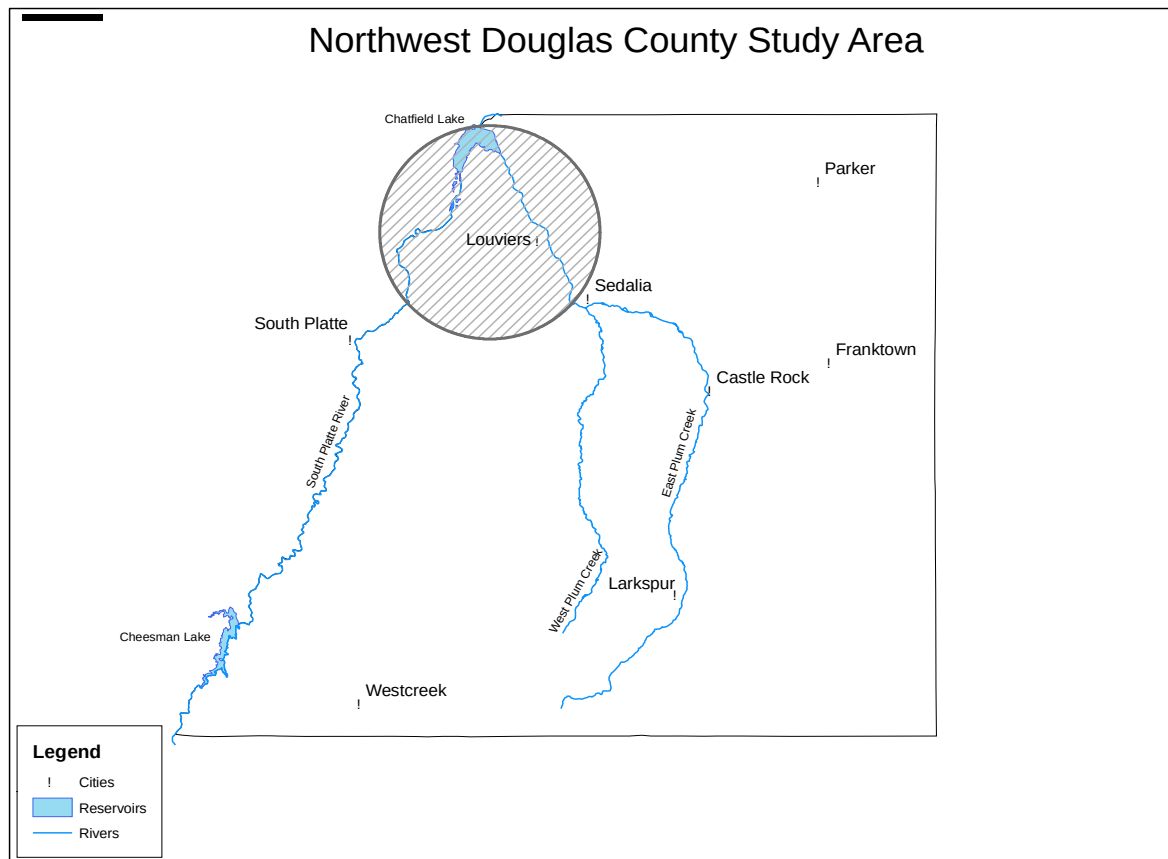


Figure 1. Northwest Douglas County Study Area

1.1.2 Rainwater Harvesting

Precipitation management through rainwater harvesting is an overlooked renewable water supply alternative for Douglas County. It is practiced in various forms in numerous other arid and semiarid states surrounding Colorado. It is the capture and temporary storage of precipitation for beneficial uses; in the case of this study, landscape irrigation. Rainwater harvesting represents a growing understanding of a “water conservation ethic” and progress towards more sustainable development. Over one-thousand years ago, ancient Americans living in the arid conditions of what is now Mesa Verde National Park collected and stored rainwater. Appreciating that we still live in an arid or semiarid climate, contemporary Americans recognize that conserving rainwater for landscape irrigation offers a number of benefits.

In Colorado, rainwater harvesting has been overlooked as a water supply resource for existing developments primarily for two reasons: 1) historically, relatively abundant and low-cost alternative water supplies have been available, and 2) current law requires 100 percent replacement of any precipitation captured, thereby requiring the user to find an equal amount of replacement water. However, existing literature shows that a portion of the precipitation that falls over an undeveloped site *never* reaches the stream system through surface water or groundwater return flows because it is consumed by native vegetation. This implies that for new developments, senior water rights could

be protected by replacing *only the portion of precipitation that did* historically reach the stream system. If an undeveloped site is later developed, the portion of the precipitation falling over the site that *did not* historically reach the stream could be leveraged in innovative ways to help meet the water supply needs for the newly developed site, without injuring senior water rights, and while also reducing the amount of water to be acquired, changed, and/or imported to Douglas County.

For the purposes of this study, a distinction is made between new developments and existing developments. The potential water savings may not be the same for existing developments because runoff from impervious surfaces within the existing development may have become part of the historical supply to streams and aquifers. Junior water rights filed subsequent to the existing development are entitled to the conditions of the streams and aquifers at the time of the appropriation, which may include the increased runoff from the development.

1.1.3 Outdoor Water Demand Management

Under the Section 9 Goals of the Douglas County 2020 Comprehensive Master Plan (Douglas County, 2001), water conservation management is encouraged to help prolong the life of the groundwater resources. The implementation strategy includes developing, adopting, and applying county-wide water conservation standards to all land use and development activities. Douglas County states that water conservation standards should include: 1) low water demand landscaping, 2) efficient irrigation systems, 3) water reuse systems, and 4) low water use plumbing fixtures.

Existing literature shows that landscape irrigation demands can be significantly reduced through simple management practices including reduced irrigated areas, use of water efficient landscaping, and improving irrigation system efficiencies. Pairing these outdoor water demand management practices with rainwater harvesting can provide an innovative water supply alternative for Douglas County.

1.2 STUDY PROCESS

The study consisted of two major components: precipitation management through rainwater harvesting and outdoor water demand management. Leonard Rice Engineers, Inc. took the engineering lead on the precipitation management portion of the study, with legal support from Ryley, Carlock and Applewhite. Meurer and Associates, Inc. took the engineering lead on outdoor water demand management portion of the study. All three firms (study team) worked in cooperation to apply the findings to examples and develop conclusions and recommendations. Guidance and valuable feedback during the study was provided through an Advisory Committee and Peer Review Committee (see **Attachment C** for committee charters). The study team met with both committees for an initial kick-off meeting, and at approximately 50%, 80%, and 95% completion of the study. An additional work session with the Peer Review Committee was held to discuss technical issues. The Advisory Committee provided valuable insight from a variety of perspectives based on the entities represented, while the Peer Review Committee provided technical feedback and recommendations on the scientific portion of the study.

This study considers precipitation management through rainwater harvesting and outdoor water demand management practices individually as stand alone concepts, and then explores the potential

of combining the two under the following scenarios: a) new residential development, b) an existing residence which relies on groundwater, and c) an existing commercial occupancy which relies on groundwater. **Figure 2** illustrates the study components and inter-relationships.

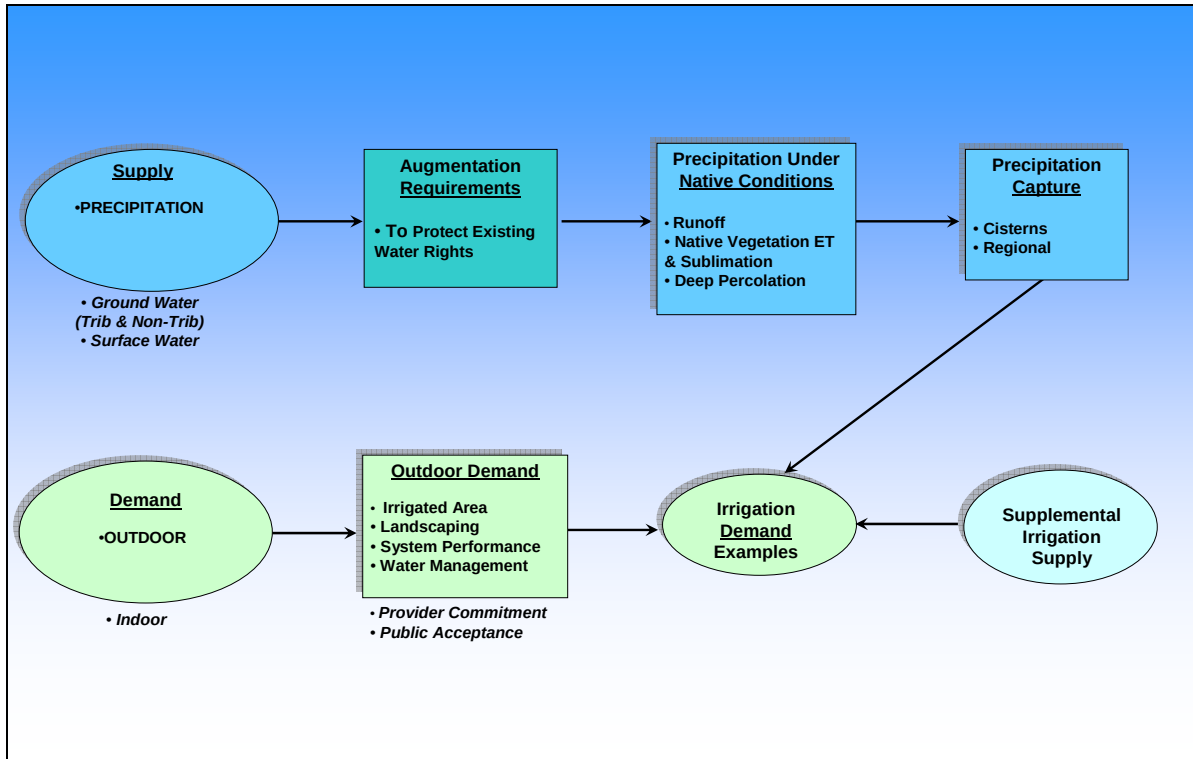


Figure 2. Study Flow Diagram

Following an initial Kick-Off Meeting with the Advisory and Peer Review Committees, the study team conducted an extensive literature review to answer the following basic questions:

- How much water could be captured and made available for other beneficial uses?
- What are the water quality benefits from use of precipitation?
- What is the current water law on augmentation requirements through rainwater harvesting?
- What portion of the precipitation historically returned to the stream system (i.e., what is the water demand of native vegetation)?
- What opportunities exist to reduce landscape irrigation demands?
- What portion of the landscape irrigation demand could be satisfied with the captured water?

Study team preliminary findings were presented at the 1st Milestone Meeting (approximately 50% completion) with the Advisory and Peer Review Committees, along with initial recommendations for scientific algorithms to quantify the following:

1. Water budget components of precipitation falling over an undeveloped site (surface water runoff, consumptive use by native vegetation, deep percolation) to determine the amounts that historically *did* and *did not* reach the stream system.
2. Physical supply available from rooftop capture of precipitation.
3. Irrigation demands for different types of landscape vegetation and application methods.

Details of the proposed methodology and algorithms for the water budget components of precipitation and precipitation capture were discussed in further detail at a follow-up meeting with the Peer Review Committee. A memo providing detailed responses to questions raised regarding sensitivity of results was distributed following the Peer Review Committee meeting.

Advisory and Peer Review Committee comments were taken under consideration and the study team refined the recommended algorithms and then applied them in an example using a new residential development to illustrate the potential water supply from rainwater harvesting and the range of water savings from various combinations of outdoor water demand management measures. These results were presented at the 2nd Milestone Meeting (approximately 80% completion).

A draft report was prepared and submitted to both the Advisory and Peer Review Committees for review and comment. A Third Milestone Meeting (approximately 95% completion) was held to take comments and suggestions for the final report.

1.3 ISSUES RAISED BY THE COMMITTEES TO BE ADDRESSED IN THE FUTURE

Through the study review process, the Advisory and Peer Review Committees raised several questions that were not within this grant study. These questions primarily fall into the categories of provider commitment and public acceptance. While the scope of this study focused on quantifying the potential water savings through precipitation and outdoor water demand management, the study team recognizes that provider commitment and public acceptance are critical components to the successful implementation of any management strategy (further discussion, including several suggestions provided by the committees, are provided in Section 5.1.7 of this report). And while results from this study show that rainwater harvesting and outdoor water demand management offer a potential savings in water and costs associated with providing water, there is also a cost associated with implementing these management practices. Defining the entire system costs was beyond the scope of this study.

This study offers scientific evidence and estimates of the potential water savings so that water providers and users can decide whether they are ready to consider these practices as a holistic approach to sustainable water management in northwest Douglas County and other parts of the state.

2.0 BENEFITS OF PRECIPITATION AS AN ON-SITE WATER SUPPLY

As shown in Figure 2, the first component of the holistic approach to water management examines the benefits of using precipitation as an on-site water supply.

2.1 BENEFITS FROM USING PRECIPITATION AS A SUPPLY FOR OUTDOOR DEMANDS

Conserving precipitation for landscape irrigation offers a number of potential benefits:

- Reducing consumption of potable water for non-potable uses results in less water supply acquisitions (leaving more water in the source stream or aquifer), reduces the amount of storage infrastructure, and reduces energy costs to treat and distribute potable water.
- Reducing peak summer water treatment demands may help utilities delay expansion of treatment and distribution facilities and lower peak electrical energy demands associated with pumping throughout distribution systems.
- Reducing untreated flow to storm drains, improve water quality, and delay the need to upgrade drainage infrastructure and sanitary sewers (described further in Section 2.2).
- With low to nonexistent concentrations of dissolved salts, planted landscapes thrive with rainwater irrigation.

As water and energy resources become increasingly scarce, the practice of rainwater harvesting is becoming more prevalent. It is estimated that over one-half million people in the U.S. and its Territories use some type of rainwater collection system for indoor and/or outdoor purposes (Krishna, 2003). Neighboring states including Arizona, Texas, and New Mexico all allow, and even encourage through financial incentives, rainwater collection and use. In 2003, Santa Fe County, New Mexico adopted an ordinance *requiring* rainwater collection and use for landscaping associated with all new developments (Santa Fe County, 2003). The ordinance requires commercial developments to capture all roof drainage into cisterns and residential development to collect roof drainage from a minimum of 85% of the roof area. Several other western states, including California, Idaho, Montana, and Oregon also allow rainwater collection and reuse.

Rainwater harvesting may also provide a unique opportunity for water users who rely on groundwater. Past practices such as cyclical pumping are being re-evaluated and revised to protect the aquifer while still providing adequate water. Continuous pumping at lower flow rates requires installing storage tanks. Rainwater harvesting could utilize this common infrastructure and supplement a dwindling resource.

2.1.1 WATER QUALITY BENEFITS ASSOCIATED WITH RAINWATER HARVESTING

By maintaining and using precipitation on site, sustainable water practices also provide water quality benefits. Sustainable water management must consider not only the quantity of water available, but also the quality and the protection of stream systems.

In the New Development Planning chapter of the Urban Drainage and Flood Control District (UDFCD) Criteria Manual Volume 3 – Best Management Practices (BMPs), a four-step process is recommended for selecting structural BMPs in newly developed and redeveloped urban areas (UDFCD, 1999). The first step involves minimizing directly connected impervious areas (MDCIA) to route runoff over grassy areas to slow down runoff and promote infiltration. Traditional land development practices promote runoff from rooftops and other impervious areas to curb and gutter stormwater collection systems (**Figures 3A and 3B**). The Criteria Manual discusses alternatives where runoff from rooftops should be directed to landscaped areas, infiltration areas, grassed buffer strips, and grass swales, effectively minimizing the directly connected impervious area (MDCIA).

Benefits from MDCIA include reduced runoff volumes and rates, improved stormwater quality through pollutant removal during the infiltration process, and lower drainage infrastructure costs. These benefits are beyond those obtained through current stormwater detention/retention requirements. However, even with standard MDCIA techniques, some pollutants inevitably pass through to the stream. Not all of the runoff can be absorbed into the ground, and the excess runoff continues as overland flow to the storm sewer system, carrying both particulate and soluble pollutant loads. UDFCD Volume 3 recognizes this, and notes that the effectiveness of pollutant removal for both the use of grass buffers (for sheet flow) and grass swales (for shallow concentrated flow) is only low to moderate.

Rainwater harvesting systems allow the removal of additional pollutants, including nitrogen and phosphorus, above and beyond levels achievable through the use of standard MDCIA techniques. Stormwater runoff from roofs is collected during storm events, and then released to landscaped areas, similar to grass buffers, only when needed to meet landscape irrigation demands (**Figure 3C**). Thus, there is very little excess runoff leaving the site carrying pollutants to surface waters. Also, because the stormwater is applied only at the rate needed for plant growth, there is little excess infiltration water leaving the site and carrying soluble pollutant loads to surface or groundwater sources. Rainwater harvesting offers an innovative extension of a BMP already encouraged by the Urban Drainage and Flood Control District in Colorado.

The Chatfield Reservoir Control Regulation, which regulates phosphorus contributions to Chatfield Reservoir (Water Quality Control Regulation No. 73), seeks to control phosphorous levels for controlling algae and dissolved oxygen levels in the reservoir, and to protect the reservoir's beneficial uses such as aquatic life, recreation, etc. (CDPHE, 2006). Members, including Douglas County, must implement non-point source control programs with a goal of reducing non-point source phosphorus to meet the allocated amount for the watershed. Precipitation management through rainwater harvesting is consistent with the Chatfield Reservoir Control Regulation, and would be an advantageous next step to implementing new non-point source control programs.

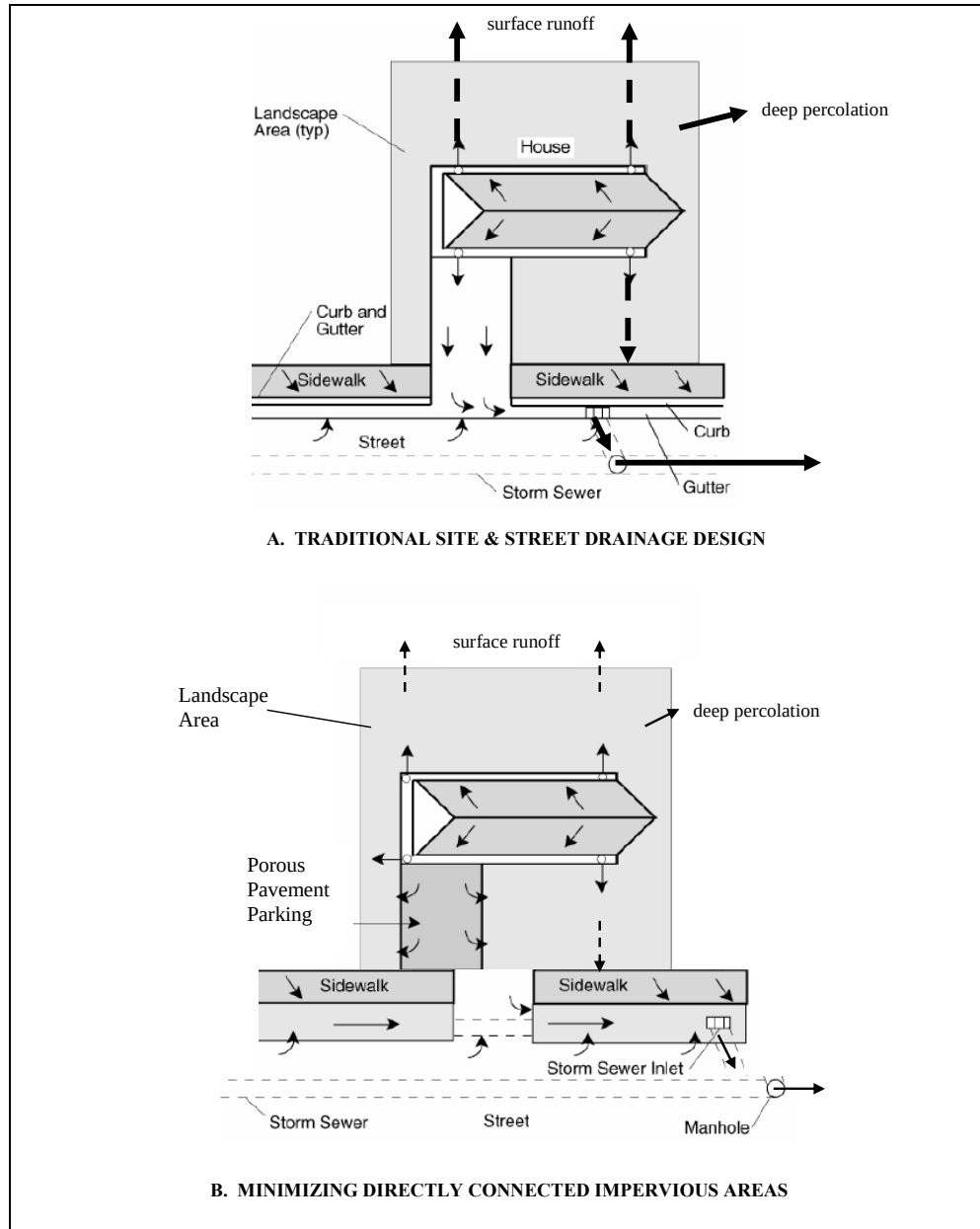


Figure 3. Additional Benefits of Using Cisterns for Rainwater Harvesting
(figure adapted from UDFCD Volume 3 Criteria Manual Figure ND-2).

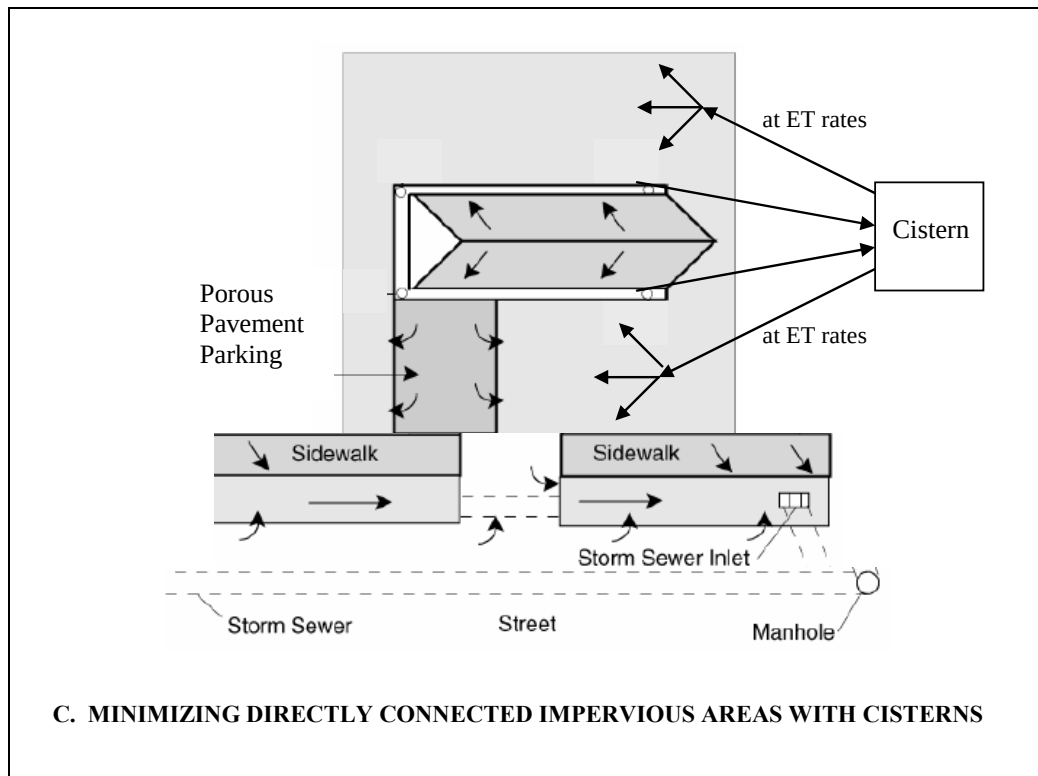


Figure 3 (cont'd). Additional Benefits of Using Cisterns for Rainwater Harvesting
(figure adapted from UDFCD Volume 3 Criteria Manual Figure ND-2).

Precipitation management through rainwater harvesting is also consistent with Douglas County stormwater management requirements. Minimum Control Measure #5, Post-Construction Stormwater Management in New Development and Redevelopment (PCSM), which is part of Douglas County's State-issued Stormwater Discharge Permit, describes requirements for water quality BMPs at newly developed sites. The county requires that, to the maximum extent practicable, stormwater must be controlled and the discharge of pollutants must be reduced. The County also recognizes in its Grading, Erosion, and Sediment Control (GESC) Manual that there will be new advances in the development of erosion and sediment control BMPs that may prove effective, or even out-perform currently accepted controls, and the County allows the use of alternative or innovative BMPs as pilot programs. Precipitation management through rainwater harvesting goes above and beyond standard non-point source control measures for stormwater quality.

3.0 LEGAL RIGHT TO USE PRECIPITATION

Water rights in Colorado are obtained under the doctrine of prior appropriation or "first in time, first in right," which requires that the quantities of water allotted to earlier, more senior rights must be protected. All water that falls as precipitation is assumed to ultimately contribute to flows in the stream, and is deemed to be part and parcel of the water that existing water rights are entitled to use in accordance with their decreed priorities. Intercepting precipitation that would have otherwise

migrated to groundwater or surface water might interfere with the full allocation of existing water rights.

One of the primary purposes of this study is to identify the potential of precipitation as a water supply, including a recommended methodology to quantify the renewable/sustainable yield, and to quantify the augmentation requirements to protect existing water rights. Current Colorado law requires 100% of any precipitation captured out-of-priority for later beneficial use to be replaced to the stream system in like time, place, and amount. However, there are two statutory exceptions that expressly recognize that not all precipitation is a supply to existing water rights: C.R.S. §37-84-117(5) concerning on-stream reservoir evaporation, and C.R.S. §37-80-120(5) and C.R.S. §37-92-305(12)(a) concerning gravel pit pond evaporation. These statutes allow “credit” to be taken against the amount of water that would otherwise need to be provided to offset evaporation from the exposure of groundwater based on the portion of the precipitation that did not historically reach the stream system, due to consumption by native vegetation through evapotranspiration (ET).²

A procedure for estimating the ET credit is outlined in the Division of Water Resources’ General Guidelines for Substitute Water Supply Plans for Sand and Gravel Pits Submitted to the State Engineer Pursuant to Senate Bill 89-120 & Senate Bill 93-260. As stated in the Guidelines, the Division of Water Resources generally accepts an ET Credit of 70% of the total precipitation for each month for non-irrigated native sites with a deep water table and without phreatophytes or subirrigation. The 70% is based on an effective precipitation calculation that suggests 70% of the total precipitation was historically effective at meeting consumptive use demands of native vegetation, and therefore *did not* return to the stream system. The Guidelines specify that higher ET credits must be supported by appropriate engineering documentation; according to the Division of Water Resources higher ET credits have been accepted in the past (Wolfe, 2006).

In contrast, in a series of court cases, summaries of which are contained in **Appendix A**, several would-be water rights appropriators attempted to obtain water rights by reducing or eliminating vegetation that consumed water. These appropriators argued that by eliminating such vegetation, additional water was made available to the river system that had not previously been available, and that they should get to use that water without regard to meeting the demands of senior appropriators. In each case, the Colorado Supreme Court rejected the attempted appropriations, but in doing so, has recognized, “No one on any river would be adverse to a schematic and integrated system of developing this kind of water supply with control and balancing considerations. But to create such a scheme is the work of the legislature . . .” *Southeastern Colo. Water Conservancy Dist. V. Shelton Farms, Inc.*, 187 Colo. 181, 192, 529 P.2d 1321, 1327 (1974); see also *R.J.A., Inc. v. Water Users Ass’n of Dist. No. 6*, 690 P.2d 823, 829 (Colo. 1984) and *State Engineer v. Castle Meadows, Inc.* 856 P.2d 496(1993). Before built-in controls and balances can be struck, an algorithm is needed that can be used to reliably calculate the amount of water potentially available from rainwater harvesting without injuring other water rights.

While Colorado’s current law requires replacement (e.g., augmentation) of 100% of captured precipitation, the portion of the precipitation falling over a native site that was consumed by ET from

² As described under the Colorado Division of Water Resources Policy 2004-3, evapotranspiration (ET) credit is defined as “ET Credit as utilized in the policy is equal to the sum of ET Credit from eradicated phreatophytes and ET Credit from effective precipitation on natural vegetation.”

native vegetation and sublimation (loss of water through evaporation of snow) was not historically available to senior water rights. **Figure 4** depicts a comparison between augmentation requirements under current law versus actual conditions, which is that only the portion of the precipitation that historically returned to the stream system would need to be augmented in order to protect other water rights.

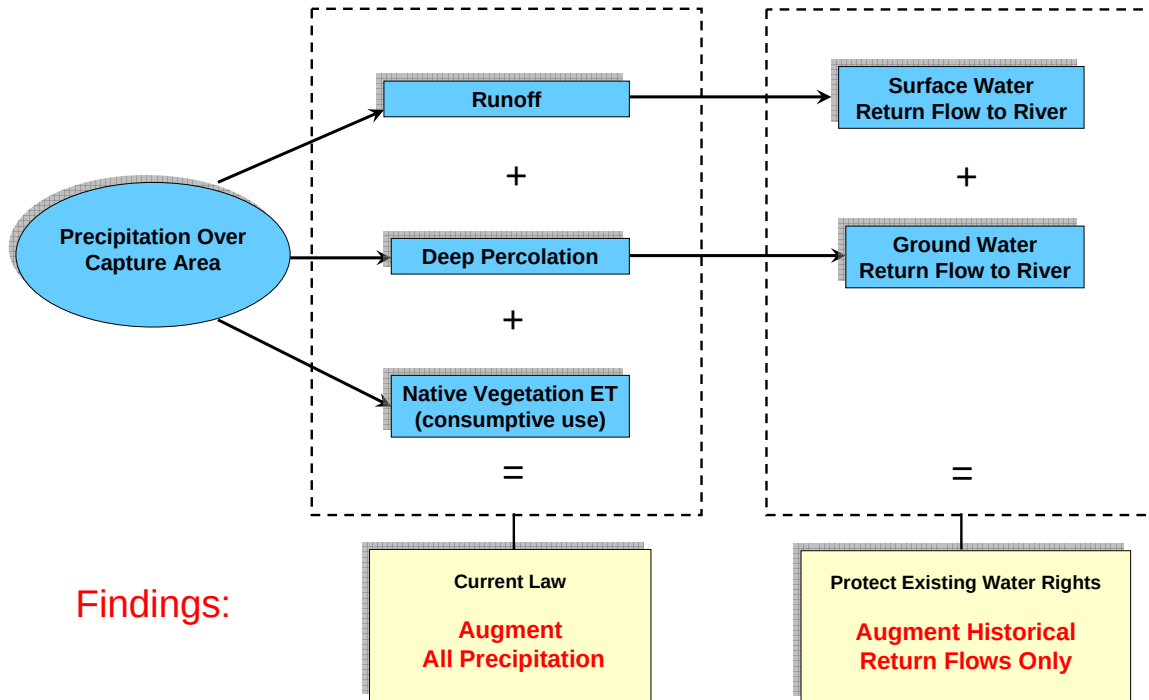


Figure 4. Components of Legal Versus Physical Augmentation Requirements to Protect Other Water Rights

While most scientists and engineers agree that there is a component of the total precipitation that did not historically reach the stream system and therefore could be used in new ways without injuring other water rights, an algorithm is needed to quantify that amount.

From this point forward the study focuses on the scientific methods we recommend to quantify the precipitation return flows from undeveloped areas that need to be augmented to protect existing water rights if captured and used as a new water supply.

4.0 PRECIPITATION WATER BUDGET UNDER PRE-DEVELOPED CONDITIONS

The Douglas County 2020 Comprehensive Master Plan (2001) indicates that less than 1 percent of the annual precipitation actually recharges the Denver Basin bedrock aquifers and that most of the precipitation is lost through evaporation, transpiration, and runoff. It also says that to a limited extent, the Denver Basin aquifers are indirectly recharged from water seepage through overlying soil or aquifers, but that direct recharge only occurs where the aquifer meets the surface stream.

A water budget can be used to quantify the portion of precipitation that was historically part of the physical supply to existing water rights when those water rights were appropriated. Of the total precipitation that falls on undeveloped lands, a portion runs off the land as surface water runoff, a portion is used to satisfy native vegetation evapotranspiration (ET) and sublimation requirements, and the remainder deep percolates to the groundwater aquifer (i.e., groundwater recharge) or is held in storage in the soil moisture zone for later use. This relationship is shown in equation 1 below.

$$\text{Total Precipitation} = \text{Runoff} + \text{Native Vegetation ET \& Sublimation} + \text{Deep Percolation} + \text{Change in Soil Moisture} \quad (1)$$

The following factors affect the balance between surface water runoff, native vegetation ET/sublimation, and groundwater recharge:

- The precipitation amount, frequency, duration and intensity,
- Other climate data such as humidity and solar radiation,
- Topography and soil characteristics,
- Type of vegetation,
- Depth to groundwater, and
- Land management practices.

A literature review was conducted to identify generally accepted methods for estimating the surface water runoff, native vegetation ET/sublimation, and groundwater recharge associated with precipitation occurring over undeveloped sites. **Figure 5** provides an example of the native vegetation at an undeveloped site (study area) in northwest Douglas County. While on-site field measurements provide the most reliable data, the goal of this research effort was to identify methods that could be used with readily available climate data and physical site property data to make reasonable predictions at a feasibility level. The methods reviewed and selected for this study are described in the sections below.



Figure 5. Undeveloped Site in Northwest Douglas County Depicting Native Vegetation

4.1 PHYSICAL SUPPLY FROM PRECIPITATION IN NORTHWEST DOUGLAS COUNTY

In this section, we address the question of: “*What is the sustainable yield of precipitation in the study area of northwest Douglas County?*” The State Climatologist was interviewed and we conducted an analysis of readily available climate data from the National Oceanic and Atmospheric Administration (NOAA). We define sustainable yield as the minimum amount of precipitation that can be expected in a given year.

Based on discussions with Mr. Nolan Doeskin (State Climatologist), a rule of thumb that he uses to estimate annual precipitation in a dry year (an event with an expected return period of 50 to 100 years) is that the dry-year total is approximately 50% of the long-term average. Mr. Doeskin also said there may be isolated areas in Colorado where the dry-year total precipitation is closer to 30% to 40% of the long-term average.

Readily available NOAA records were reviewed and the historical averages for fourteen NOAA climate stations located in and adjacent to Douglas County are shown below in **Figure 6**. The Kassler station, a long-term climate station, was selected to represent precipitation in northwest Douglas County. A summary of monthly precipitation records for the readily available period of 1950 through 2004 is provided in **Appendix B**. The annual precipitation at the Kassler station ranges from 10.68 inches to 28.11 inches, with an average of 17.52 inches per year (**Figure 7**). Based on the lowest recorded amount for the period 1950 through 2004, the estimated “sustainable” yield from precipitation in northwest Douglas County is over 10 inches.

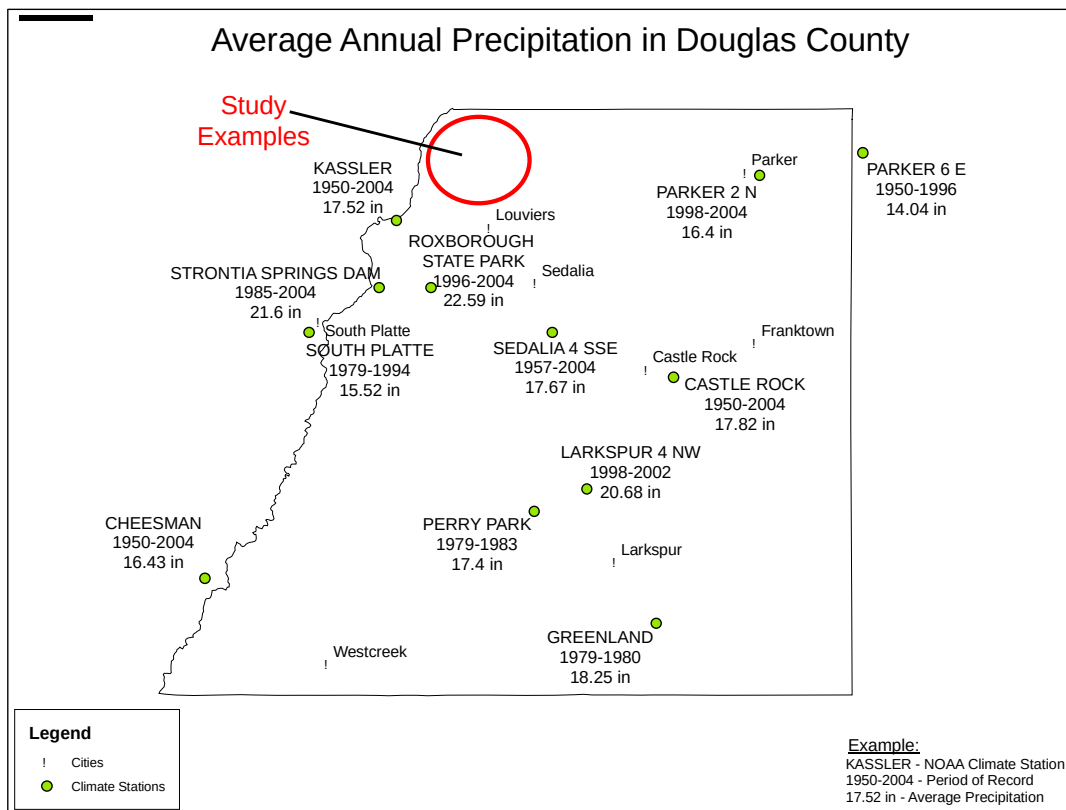


Figure 6. Historical Average Annual Total Precipitation in Douglas County

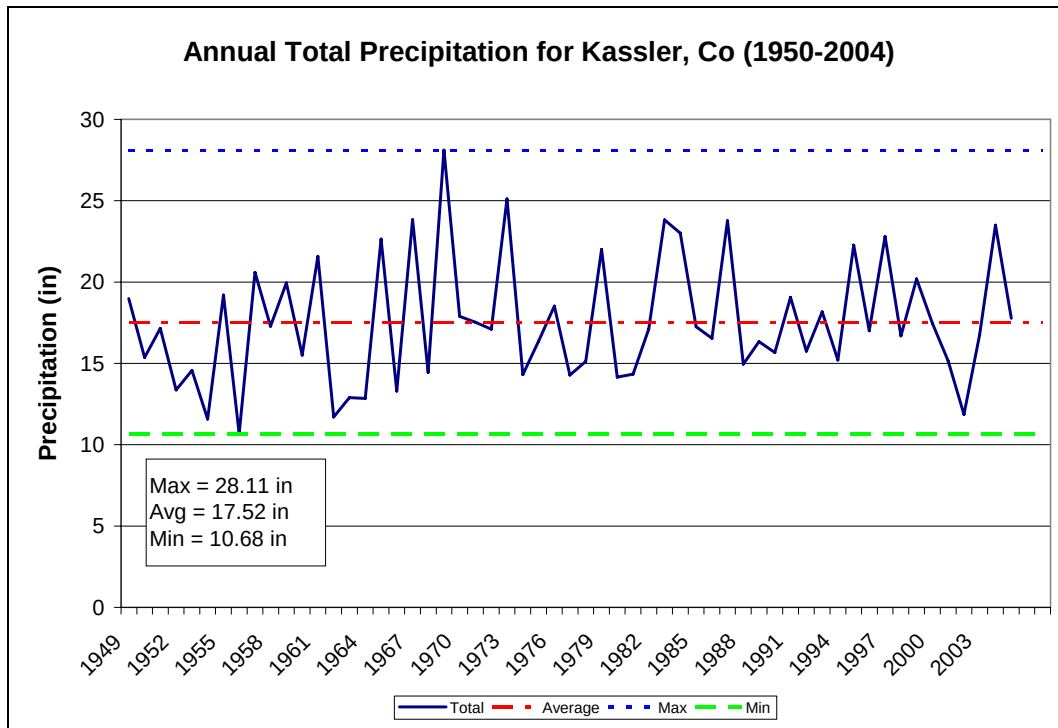


Figure 7. Annual Total Precipitation in Douglas County

In addition to analyzing the annual variation in precipitation, the variation of daily precipitation events was analyzed and is characterized in **Table 2**. This summary shows that over 88% of the daily events occur as small events (less than 0.5 inches per day). In the following section, we evaluate the threshold amount for which runoff occurs at the study area, which is a function of numerous variables including antecedent moisture condition.

Table 2. Characteristics of Daily Precipitation at the Kassler Climate Station

Precipitation Range (in)	Percent of Days with Precipitation, 1950-2004		
	Entire Period	Growing Season	Non-Growing Season
0.01 – 0.10	48.2%	48.3%	48.0%
0.11 – 0.50	40.1%	38.1%	44.2%
0.51 – 1.00	8.9%	9.9%	6.9%
1.01 – 1.50	1.8%	2.3%	0.6%
1.51 – 2.00	0.6%	0.9%	0.2%
2.01+	0.4%	0.5%	0.1%

4.2 SURFACE WATER RUNOFF

Surface water runoff can be estimated using volume-based methods or event-based methods. Event driven (e.g., 15-minute interval) methods provide peak flow rate estimates and are often used in site development applications to design stormwater infrastructure. A member of the Peer Review Committee indicated that the event-based methods are more accurate because they consider storm

intensity. However, based on our research of the Rational Method and the Colorado Urban Hydrograph Procedure (CUHP) event-based methods and discussions with UDFCD, other members of the Peer Review Committee, and other water resources experts, we concluded that for the purpose of this feasibility study, a simpler volume-based method such as the Soil Conservation Service (SCS) Curve Number Method provides sufficient information to estimate daily runoff from an undeveloped site.

The SCS Curve Number Method was developed in the 1950s and modified in the 1960s by a USDA-SCS scientist for determining the portion of total precipitation that becomes surface water runoff in ungaged watersheds. The equation was developed to predict how land use changes affect watershed runoff, usually in the context of problems caused by large precipitation events, but its use has been broadened to include general watershed modeling. The SCS Curve Number Method is based on the potential of the soil to absorb moisture. Based on field observations, runoff from a field or farm was related to watershed storage capacity (S) which was in turn related to a soil curve number. Curve numbers were developed as a function of soil type, land use, and antecedent moisture content (AMC).

The SCS Curve Number methodology is documented in the National Engineering Handbook Volume 4 (USDA, 1985) and is shown in equations 2 and 3 below:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad (2)$$

$$\text{for } P \geq I_a \quad \text{where} \quad I_a = 0.2S \quad (3)$$

Where:

Q = total daily runoff volume

P = total daily precipitation volume

S = potential maximum retention = $(1000/CN) - 10$

I_a = initial abstraction

CN = Curve Number (function of land use description, soil group classification, and antecedent moisture condition)

The following sources were used to develop input data for the SCS Curve Number Method that represents conditions at the example site in northwest Douglas County:

- Raw (unfilled) total daily precipitation data from the NOAA Kassler climate station.
- SCS Soil Types selected from the Water Features (K1) Report of SSURGO Soil data from the Castle Rock Area, Colorado report (approximately 50% Class B – shallow loess, sandy loam and 50% Class C – clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay).
- AMC I (dry), II (average), and III (wet soils) selected based on previous 5-day total precipitation.

- Dormant versus growing season based on growing season for grass pasture at Kassler climate station (typically around April 1 through October 31).
- Curve Number selected using the SCS recommended number for “Pasture or Range” under the “Fair” Hydrologic Condition (versus Poor or Good).
- Curve Number adjusted for AMC by linearly interpolating between values provided by SCS.

A spreadsheet model was developed to estimate runoff on a daily basis for the period of 1950 through 2004, incorporating the above algorithms and representative site data for northwest Douglas County. The results show that for the study area in northwest Douglas County, it takes up to 0.1 inches of precipitation before any runoff occurs under wet soil conditions (AMC = III) and up to 1.5 inches of precipitation before any runoff occurs under dry soil conditions (AMC = I). Referring back to Table 2, almost 50% of precipitation events produce no runoff.

Application of the SCS Curve Number Methodology shows that for the period of 1950 through 2004, the average annual runoff is equivalent to 2% of the annual precipitation. A summary of monthly runoff values for the period of 1950 through 2004 is provided in Appendix B. The maximum runoff in a wet year (1969) was 12% and the minimum runoff in a dry year (1956) was 0%. This means that on average, only 2% of the annual precipitation historically returned to the stream system via surface water return flows.

During times of no runoff, the observed stream flows can be the result of many sources, including delayed returns from precipitation that previously percolated into the local geology and reaches the stream in a delayed pattern as groundwater returns, reservoir releases, wastewater treatment plant discharges, deep aquifer groundwater returns from individual septic systems, and return flows from outdoor water uses.

The runoff analysis findings are consistent with other studies we reviewed in the literature research. A study performed for the Denver Water Board (Walter et. Al, 1990) on formerly irrigated mountain meadows in South Park attributed a maximum of 1% to 3% of the total precipitation to runoff. A study performed in the Turkey Creek Watershed of Jefferson County (Bossong et. Al, 2003) considered surface water flow from both the forested site and meadow sites near Conifer to be zero.

A sensitivity analysis of the soil types and land use conditions used for this study was conducted, based on questions raised by the Peer Review Committee. While the runoff estimates are sensitive to the soil types and the land use conditions, the results show that the soil properties and land use characteristics used for the examples in this study do not significantly increase or decrease the runoff analysis estimates.

4.3 NATIVE VEGETATION EVAPOTRANSPIRATION (ET) AND SUBLIMATION

Precipitation falling on undeveloped sites is consumed during the growing season (typically April through October at this location) by native vegetation evapotranspiration processes and is lost through evaporation and sublimation processes during the non-growing season.

4.3.1 Growing Season

Far more research has been conducted on the consumptive use of precipitation by irrigated agricultural crops and irrigated landscape than native vegetation. The “default” ET Credit of 70% that DWR accepts for gravel pit applications was based on using the Soil Conservation Service methodology for calculating effective precipitation, as outlined in Technical Release 21 (USDA, 1970). This is the most common approach for estimating effective precipitation in water rights transfers. With this method, effective precipitation is estimated as a function of the total monthly precipitation, the estimated crop evapotranspiration (i.e., consumptive use), and the net irrigation application depth. The method was developed for use on irrigated lands and is based on a full water supply. On native lands, where the water supply is limited to the precipitation, the effectiveness of the precipitation increases because it is the only supply available to meet the native vegetation demand.

The methods that are commonly used to estimate ET or consumptive use on irrigated lands rely on crop coefficients that represent specific crop types. Based on our literature review and discussions with the Peer Review Committee and other water resources experts, we concluded that for the purpose of this study, the ET from native vegetation during the growing season (typically April through October at this location) could be approximated using the potential consumptive use of pasture grass. The modified Blaney-Criddle method was used, with an elevation adjustment, to estimate the potential consumptive use of pasture grass. The following sources were used to develop input data for the modified Blaney-Criddle procedure that represent conditions at the example site in northwest Douglas County:

- Raw (unfilled) monthly temperature, precipitation, and frost date data from the NOAA Kassler climate station,
- Crop coefficients for pasture grass published in Soil Conservation Service Technical Release-21,
- SSURGO Soil data from the Castle Rock Area, Colorado report were used to estimate field capacity,
- Root depth for grass pasture was estimated to be 3.3 ft (Jensen et. Al., 1990).

The full potential consumptive use (PCU) of grass pasture, under an unlimited water supply condition, was computed on a monthly basis. Consumptive use of precipitation by native vegetation ET was then computed by 1) estimating the monthly supply available from precipitation as the total monthly precipitation reduced by the portion of precipitation estimated as runoff (using the SCS Curve Number Method as described in the previous section), and 2) comparing the available supply from precipitation to the PCU of grass pasture. Available precipitation in excess of native vegetation ET demands was used to fill a soil moisture reservoir; likewise, when available, water was extracted from the soil moisture reservoir in months native ET demands were not fully met by precipitation. A summary of the monthly total precipitation, runoff, PCU of grass pasture, soil moisture reservoir storage, and native ET met is provided in **Appendix C**. Annual results of the analysis are presented in **Figure 8**. On the average, the precipitation was able to meet approximately half of the PCU associated with pasture grass (an average of 1.2 acre-feet per acre as opposed to the pasture grass potential consumptive use of 2.7 acre-feet per acre). The results show that for the

period of 1950 through 2004, the growing season ET averaged 1.2 acre-feet per acre, which is 81% of the average annual precipitation.

The ET findings are consistent with other studies we reviewed in the literature research. Using the 1950 through 2004 study period, the average annual PCU for buffalo grass, a native grass used in landscaping applications, at the same location is estimated to be 1.2 acre-feet per year. This supports the notion that native grasses have adapted to the locally available precipitation. A study performed for the Denver Water Board (Walter et. Al, 1990) on formerly irrigated mountain meadows in South Park showed 97% to 99% of the May through September (1962-1986) precipitation was effective at meeting crop demands. The study performed in the Turkey Creek Watershed of Jefferson County (Bossong et. Al, 2003) showed on average 83% of precipitation was consumed at the forest site and essentially 100% at the meadow site.

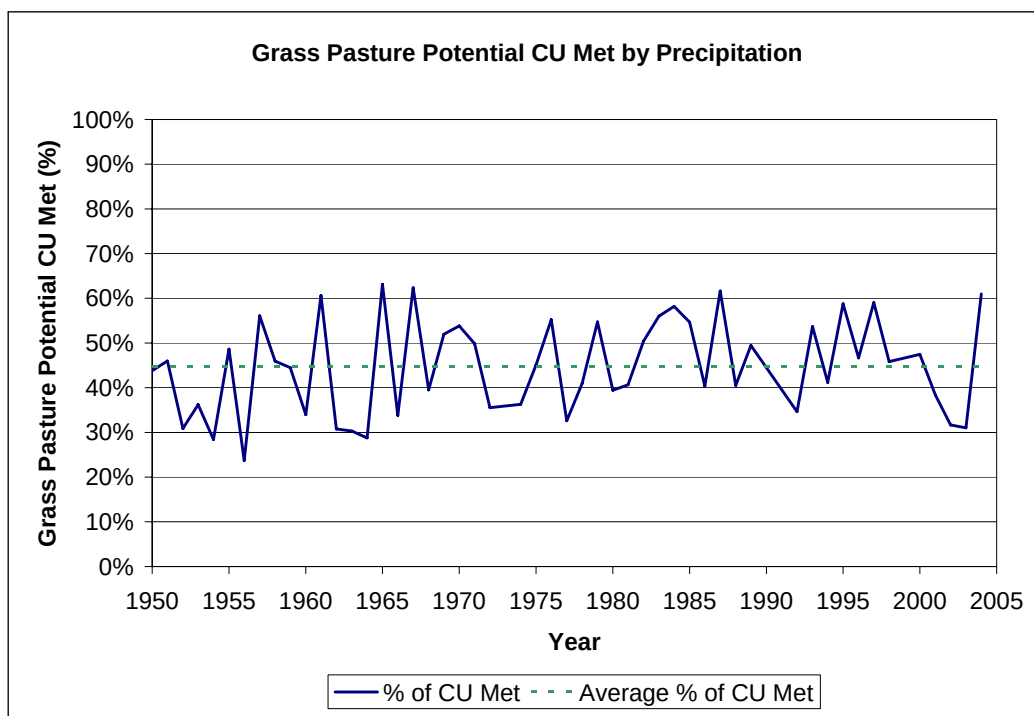


Figure 8. Pasture Grass Potential Consumptive Use Met by Precipitation

4.3.2 Non-Growing Season

In addition to growing season consumption, precipitation can be lost to the stream system during the non-growing season by evaporation and sublimation. Even less research has been conducted in this area. However, based on discussions with the Peer Review Committee and other water resources experts, the results from a study conducted in Akron, Colorado have been used by other water resources professionals for water rights related work in Colorado. Based on data collected during twelve winter seasons from 1965 through 1979, the measured snowmelt intake efficiency on ungrazed native grass pasture averaged 38% (Greb, 1980). The results from the Akron study were applied in this study to estimate the evaporation and sublimation during the non-growing season. Up to 38% of the total monthly precipitation was made available to recharge the soil moisture reservoir;

the remainder was considered to be either runoff, evaporate, or sublimate. If the soil moisture reservoir was full, excess recharge amounts were passed through as deep percolation to the underlying aquifer. The results show that for the period of 1950 through 2004, the annual non-growing season losses to evaporation and sublimation averaged 0.24 acre-feet per acre, which is 16% of the average annual precipitation.

The combined growing season and non-growing season results show that for the period of 1950 through 2004, the average ET and sublimation is equivalent to 97% of the total precipitation. The maximum ET and sublimation in a wet year (1969) was 85% and the minimum ET in a dry year (1956) was 100%.

4.4 DEEP PERCOLATION

Deep percolation is that amount of total precipitation that infiltrates the soil and is not evapotranspired or held in the soil moisture reservoir. It is often estimated using the water balance approach shown in equation 4:

$$\text{Monthly Deep Percolation} = \text{Total Precipitation} - \text{Runoff} - \text{Native Vegetation ET/Sublimation} \quad (4)$$

The water balance approach shows that for the period of 1950 through 2004, the average deep percolation is equivalent to 1% of the total precipitation. The maximum ET and sublimation in a wet year (1969) was 3% and the minimum runoff in a dry year (1956) was 0%. This means that on average, only 1% of the annual precipitation historically returned to the stream system via groundwater return flows.

The deep percolation findings are consistent with other studies conducted in Colorado. Under the Rio Grande Decision Support System, Wilson et. Al (2000) recommended a value of 3 percent total groundwater recharge from precipitation be used to represent non-irrigated lands. This recommendation was based on other studies that showed a range of 0 to 4 percent recharge from precipitation over non-irrigated (i.e., undeveloped) lands.

4.4.1 Delayed Groundwater Return Flows

For an augmentation plan to successfully protect existing water rights, it is important to define the amount, timing, and location of the return flows. Depending on the location and local geology, groundwater recharge from deep percolation can take much longer to reach the stream system than surface water return flows. Several methods have been applied in Colorado to approximate the delay time; selection of the appropriate method depends on the location being evaluated. For example, if the undeveloped lands are overlying saturated alluvium, the Glover Method may be an appropriate option for estimating the lag time between when the deep percolation first occurs and when the associated water reaches the stream. In more complex groundwater situations located outside stream alluviums, it may be necessary to use a program known as MODFLOW, a three-dimensional groundwater simulation model, to estimate the lag time. For the study area in northwest Douglas County, the undeveloped lands are believed to overlies unsaturated alluvium. In this case, until sufficient deep percolation return flows accumulate and establish a water table, it may take an indefinite amount of time for the deep percolation to reach the stream system. This could be

confirmed using a MODFLOW model. For the feasibility level of this study, to be conservative with respect to protecting the stream system and other water rights under this type of situation, an alternative to developing a detailed groundwater model is to assume there is an alluvium through which water moves toward the stream and consider the groundwater return flows to be at steady state condition with a uniform return flow pattern, as described below in equation 5. This is something that should be evaluated on a site-specific basis.

$$\text{Monthly Stream Return Flow} = \frac{\text{Annual Deep Percolation (previous year)}}{12} \quad (5)$$

4.5 AUGMENTATION REQUIREMENTS FOR RAINWATER HARVESTING

Under current law, 100% of any precipitation captured and put to use must to be replaced (i.e., augmented). From a scientific perspective, this legal requirement may apply to existing developments where runoff from impervious areas has become part of the physical water supply for existing water rights. However, the science shows that for undeveloped areas, only the portion of the precipitation that historically returned to the stream system as surface runoff or delayed groundwater returns from deep percolation would need to be augmented in order to protect the yield relied upon by existing water rights. The remaining portion that did not historically return to the stream system represents an innovative new water supply alternative for new developments.

The runoff and water budget analysis shows that for the period of 1950 through 2004, the average annual return flow to the stream was 3% (2% from runoff and 1% from deep percolation). The maximum return flow to the stream in a wet year (1969) was 15% (12% from runoff and 3% from deep percolation) and the minimum return flow in a dry year (1956) was 0%. This means that for previously undeveloped areas, on average, only 3% of the annual precipitation historically returned to the stream system via surface and groundwater return flows.

Under current law, for every acre-foot of precipitation captured, one acre-foot of replacement water must be acquired and returned to the stream. However, our scientific literature review shows that for new developments, the average leverage potential from rainwater harvesting is on the order of 28 fold. In other words, for every acre-foot of replacement water available, one could capture and use 28 acre-feet of precipitation without injury to existing water rights.

To better understand the potential supply from rainwater harvesting and its augmentation requirements, we applied the algorithms described in Sections 4.1 through 4.4 to an example development site with 1,000 new residences, each with a rooftop surface area of 1,500 square feet. Prior to development, the historical average annual precipitation of 17.5 inches that fell over the roof areas was equivalent to 50 acre-feet. On average, only 2 acre-feet (3%) returned to the stream system via surface and groundwater return flows. The difference of 48 acre-feet was consumed by native vegetation and never reached the stream system. However, current law requires the full 50 acre-feet to be replaced through an augmentation plan. **Figure 9** depicts the potential savings in augmentation water under current law versus the physical requirement to protect existing water rights under dry (minimum replacement), average, and wet (maximum replacement) year conditions.

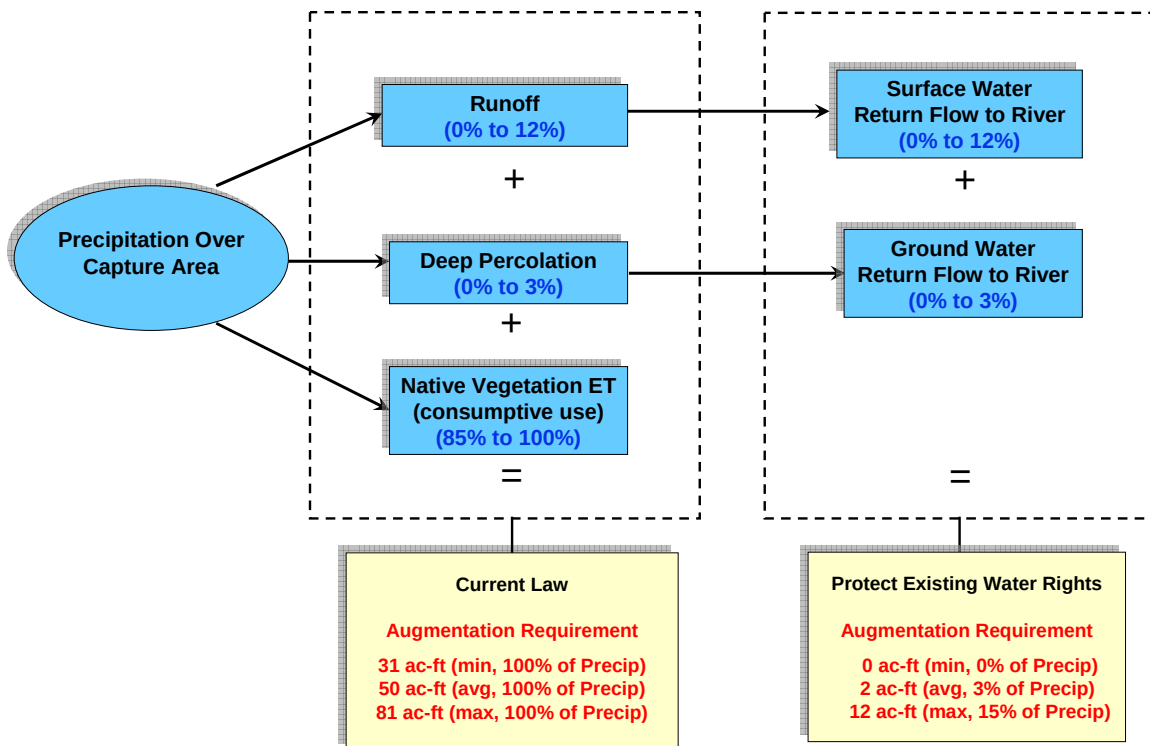


Figure 9. Legal Versus Physical Augmentation Requirement Estimates at Example Site

5.0 OUTDOOR WATER DEMAND CONSERVATION

As shown in Figure 2, the second component of the holistic approach to water management focuses on outdoor water demands and how water efficient landscaping and irrigation practices can be used to reduce outdoor demands. Outdoor water use conservation includes well-known concepts such as soil analysis, appropriate plant selection, and use of practical turf areas. It can also extend to the design of the landscaped area itself. The micro-topography of a landscaped area can enhance the flow of irrigation water through the use of subtle grade changes, guided swales, terraces, and shallow infiltration impoundments. Irrigation system efficiency can be maximized through the use of properly designed and located sprinklers, micro-irrigation (also known as drip irrigation), hand watering, and appropriate watering intervals. Water savings can be identified and quantified through proactive (coordinated) irrigation system audits followed by recommended improvements.

5.1 COMPONENTS OF OUTDOOR WATER DEMAND

There are a multitude of factors that affect outdoor water demands. The literary review and interviews performed for this study identified five main factors that combine to encompass a holistic approach to outdoor water demand. The factors are:

1. Irrigated area,
2. Landscaping,
3. System performance,

4. Water management, and
5. Provider commitment and public acceptance.

The first four factors are combined as coefficients in an outdoor water demand calculation algorithm to derive the total outdoor water demand based on the water user's design choices. While the primary focus of the study is for residential use, this algorithm can be applied to any outdoor water demand situation. The fifth factor is more subjective coefficient, but can significantly impact the outdoor water demand.

5.1.1 Irrigated Area

The irrigated area for landscaping is represented by the amount of turf and plantings that will be installed and maintained. A typical lot can be divided into four areas:

- Impervious area (building footprint, walkways, driveway, and deck),
- Irrigated turf area,
- Irrigated planting area, and
- Non-irrigated area.

The impervious area includes the building foot print, walkways, driveway, and deck. Based on Urban Drainage Flood Control District (UDFCD) runoff criteria (UDFCD, 2001), 50% of a two-story 3,000 square foot house (1,500 square foot rooftop) lot is impervious and will not have planting or turf. The remaining 50% of the property is divided between turf, plantings, and non-irrigated areas. A 3,000 square foot house size and related impervious area was used for the study.

Using the UDFCD criteria, the amount of impervious area is dependent on the lot size. An analysis of the existing developments in northwest Douglas County identifies a typical density of five dwelling units per acre. The developments reviewed for the lot analysis and calculations of their average units per acre are identified in **Appendix D**.

Using five dwelling units per acre with a 20% reduction for roads results in a lot size of 6,970 square feet. Applying the UDFCD criteria results in 50% available for landscaping, or 3,485 square feet. The irrigated portion of the lot is divided between turf, plantings, and non-irrigated areas. The turf and planting areas are described in the Landscaping Section 5.1.2 of this report. The non-irrigated area can also include impervious areas such as decorative rock, decking or non-irrigated plantings. The use of this space is dependent on the preference of the property owner.

5.1.2 Landscaping

Landscaping is divided between turf and planting areas. The landscaping system includes the largest number of combinations to obtain water efficiency, given the large number of turf and planting opportunities. The choice of landscaping is only one factor that must be considered to create water efficiency. The landscaping design and maintenance also significantly impact the water efficiency.

To calculate the water demand associated with a particular type of landscaping, a reference crop is used to establish the baseline evapotranspiration (ET). ET is a combination of water transpired from the plantings and turf and evaporated from the soil and plant surfaces (ASAE, 1998). This reference

value is then multiplied by a turf or planting coefficient to calculate the water demand for a particular type of turf or planting. The landscape water use calculation is identified in equations 6 and 7.

$$\text{Turf Demand} = \text{Reference ET} \times \text{Turf Coefficient} \quad (6)$$

$$\text{Planting Demand} = \text{Reference ET} \times \text{Planting Coefficient} \quad (7)$$

Reference ET

Reference ET was calculated using the ASCE Standardized Penman-Monteith method, using a tall reference crop (alfalfa). However, the turf and plant coefficients were developed for use with short cool season grasses. Based on his experience along the front-range of Colorado, Mr. Brent Mecham of the Northern Colorado Water Conservancy District (Mecham, 2006) indicated that the reference ET calculated with the tall reference crop can be multiplied by an adjustment factor of 0.8 to reasonably approximate the reference ET for a short cool season grass ($ET_{\text{ref, short crop}} = 0.8 \times ET_{\text{ref, tall crop}}$).

The ASCE Standardized Penman-Monteith method requires daily minimum and maximum air temperature, dewpoint temperature, solar radiation, vapor pressure, and wind speed. While daily minimum and maximum air temperature data were available from the Kassler climate station, data representing the other variables were not readily available in Douglas County. The examples for this study used filled daily dewpoint temperature, solar radiation, vapor pressure, and wind speeds from the Fort Lupton CoAgMet climate station, the closest location available through the State of Colorado's Decision Support System.

Turf and Planting Coefficients

The choices of landscaping (plantings and turf) are virtually limitless because they can be mixed and matched. A survey completed by Green Industries of Colorado (GreenCO) and Colorado State University (GreenCO, 2004) divided the landscape choices by estimated water usage, as a percentage of the reference ET and plant type (**Appendix E**). **Tables 3** and **4** identify the water usage categories, percent of water use compared to reference ET, and landscape choices.

Table 3. Landscape Water Usage Categories

Estimated Water Usage	Percentage of Reference ET
Very Low	<25%
Low	25-50%
Medium	50-75%
High	>75%

Table 4. Landscape Choices

1	Annual
2	Perennial
3	Tree
4	Vine
5	Ground Cover
6	Shrub
7	Turf

For this study, the landscaping was divided into turf and plantings which include all of the non-turf options shown in Table 4. **Table 5** describes the type of landscaping and the percent of ET based on the reference ET. The turf coefficients are based on the water demand for the specific plant. The planting choices represent an average of the total planting area. A planting area that has a native water use may include high, medium, low, or very low plant choices, but the average of the total planting area equals 30% of the reference ET.

Table 5. Turf and Planting Coefficients

Turf Coefficient		Planting Coefficient	
Description	% Reference ET	Description	% Reference ET
Bluegrass	90%	Traditional	70%
Fescue	70%	Moderate	50%
Buffalograss	50%	Native	30%

The basic premise for the turf and plant coefficients is that the landscaping is well maintained, as represented by routine watering, mowing, trimming, and fertilizing. The percentages identified in the tables represent the amount of water required to keep the desired “look” of the landscaping.

The following are additional factors affecting the turf and planting coefficients:

- The planting coefficients assume a water demand for mature planting and account for the varied densities of plantings.
- Planting in a turf zone is assumed to be watered by the turf, such as a tree that shades the grass. The grass will need less water because of the tree, but it is assumed that the tree will use the water saved from the turf.
- The affects of the microclimate of the turf and planting are included in the coefficients. The microclimate includes the location of the landscaping such as the side of the structure, amount of daily sun, and wind protection.

5.1.3 System Performance

The system performance coefficient is a combination of the installed irrigation system application method and its installation and operations method (equation 8). These two sub-coefficients cover the Irrigation Association’s ranking system for irrigation system performance (Mecham, 2004).

$$\text{System Performance} = \text{Application Method Efficiency} \times \text{Installation \& Operations Method Adjustment} \quad (8)$$

Application Method

The application method is divided into three types of irrigation systems. The efficiency of each of the systems is identified in **Table 6** below. An application method can be applied to turf and planting areas separately or the same method can be applied to both.

Table 6. Application Method Efficiencies

Irrigation System	Efficiency
Spray	75%
Rotor	80%
Subsurface Drip	95%

The operational life of the irrigation systems identified in Table 6 are similar and dependent on the quality of the materials, installation, and maintenance of the systems. The cost of installation can vary widely between the systems, depending on the chosen irrigation system. In general, drip systems are more cost effective than spray or rotor systems in areas that are less than 12 feet wide, but can be cost effective in a large open area in new installations. Further review of the operational life and installation costs for the irrigation systems should be addressed in a pilot program.

Installation & Operations Method

Once the landscape and irrigation systems are installed, they must be operated and maintained properly. These two guidelines are the critical factors for water efficiency. Without them, the best-designed system will ultimately become a water waster. The installation and operations of the landscaping and application method affects the ET of the landscaping and the efficiency of the application method. **Table 7** provides factors that can be used to adjust the application method efficiency for the specific installation and operations method. The factors provide an evaluation of the application method based on the optimum efficiency identified in Table 6. The ranking represents an indication of the quality of the irrigation system such as area covered by the sprinkler heads, quality of the components, system design, system installation, long-term maintenance of the system (Mecham, 2004), soil type and preparation, fertilization, and care methods (e.g., mowing and trimming). The values provided in Tables 8 and 9 were developed from the Irrigation Association rating system of sprinkler system efficiency (Mecham, 2004).

Table 7. Installation & Operations Method Adjustments

Description	Installation & Operations Method Adjustment
Excellent	100%
Good	80%
Poor	60%

5.1.4 Water Management

The water management coefficient accounts for the amount of effective precipitation that is used to reduce the outdoor demand from the irrigation system over the irrigation season. The water management factor is calculated by multiplying effective precipitation by the technology used to adjust the application method, as identified in equation 9.

$$\text{Water Management} = \frac{\text{Effective Precipitation} \times \text{Technology Adjustment}}{\text{Adjustment}} \quad (9)$$

Effective Precipitation

The effective precipitation is the portion of the total precipitation that falls on the irrigated area during the growing season which is effective at reducing the irrigation water requirement (irrigation water requirement = outdoor water demand – effective precipitation). The SCS effective precipitation method outlined in Technical Release 21 (USDA, 1970) method was used to calculate the effective precipitation (previously described in Section 4.3.1)

Irrigation System Technology

The use of technology allows the effective precipitation that falls on the landscaping to be accounted for in the water demand. Without technology, the study's assumption is that a typical user will not adjust their irrigation application method to account for rainfall on a regular basis. **Table 8** identifies the type of technology used and the percentage of effective precipitation that can be used to reduce the outdoor water demand.

Table 8. Technology Affects on Effective Precipitation

Technology Type	Technology Adjustment Factor
Active	80%
Passive	40%
No Technology	0%

The use of new technology can help to improve a new or existing irrigation system. The research shows the use of technology that can adjust the amount of water applied to the landscaping based on its water needs. Typically, landscaping requires less water in the spring and fall with the most water demand occurring during the summer. The technology used to adjust the amount of water applied is classified into passive, active, and no technology subcategories. The portion of the effective rainfall applied for each technology (technology adjustment factor) is identified in Table 8.

The percentages applied are based on information from several articles and interviews (Aquacraft Inc., 2003; DeOreo et. Al, 1997; Mecham, 2006). If technology is used to reduce the outdoor water demand, it should be installed and programmed by a knowledgeable technician to maximize the water savings. The percentages in Table 8 assume installation by a knowledgeable technician.

Passive technology typically uses historical water demand data to set a watering amount during the season. This technology cannot automatically adjust for changes in weather patterns, such as a drought or rainfall. It adjusts the amount of watering by typical average demand, such as monthly, over the irrigation season. The system operator must manually adjust the amount of water applied for events outside the limits of the average event. This could lead to over watering so only a portion of the effective rainfall is credited for use of this type of technology. Single-family residential units typically only use a passive controller like a preprogrammed average ET controller or rain stop controller.

Active technology can automatically adjust the amount of water delivered to the landscaping with changing weather patterns. This is typically done with a soil moisture sensor, rain gauge, and/or a connection to a weather monitoring station that tells the controller how much rainfall has occurred. The active technology removes the human interface in the system, which can lead to efficient water use. However, there is still some inefficiency in the technology so a full credit for the effective precipitation was not given. Per Mr. Brent Mecham of Northern Colorado Water Conservancy District, currently large parks are the typical user of active controllers like weather radio data and soil moisture sensors.

The use of no technology can be either hand watering or a traditional irrigation system controller. A traditional controller allows for the setting of watering dates (e.g., every other day), but does not adjust for the seasonal variation of the landscaping demands over the course of the irrigation season. A user can manually set this by reducing the water time per irrigated zone to achieve a passive controller status. However, it was assumed that an average irrigator will not adjust their controller over the irrigation season, so no credit was given for no-technology use.

5.1.5 Water Demand Calculation Algorithm

The irrigated area, landscaping, system performance, and water management components described above can be combined to calculate a total annual outdoor water demand. The total outdoor water demand (equation 10) is the sum of the turf demand (equation 11) and the planting demand (equation 12).

$$\text{Outdoor Water Demand} = \text{Turf Demand} + \text{Planting Demand} \quad (10)$$

$$\text{Turf Demand} = \frac{[(\text{Ref ET} \times \text{Turf Coeff}) - \text{Water Management}]}{\text{System Performance}} \times \text{Irr Acres} \quad (11)$$

$$\text{Planting Demand} = \frac{[(\text{Ref ET} \times \text{Planting Coeff}) - \text{Water Management}]}{\text{System Performance}} \times \text{Irr Acres} \quad (12)$$

There are multiple combinations of examples that can be developed by using these outdoor water demand coefficients. **Table 9** summarizes the coefficients as identified in the report.

Table 9. Outdoor Water Demand Coefficient Summary

Irrigated Area (5 Units per Acre)		Landscaping		System Performance		Water Management
Turf (Square Feet)	Landscape (Square Feet)	Turf (% of Ref ET)	Plantings (% of Ref ET)	Application Method Efficiency	Installation & Operations Method Adjustment	Technology Adjustment for Effective Precipitation
0 to 3,500	0 to 3,500	Bluegrass 90%	Traditional 70%	Spray 75%	Excellent 100%	Active 80%
		Fescue 70%	Moderate 50%	Rotor 80%	Good 80%	Passive 40%
		Buffalograss 50%	Native 30%	Drip 95%	Poor 60%	None 0%

Using the components, an outdoor water demand can be calculated. The example provided in **Table 10** below is for a traditional landscape outdoor water demand representative of northwest Douglas County.

Table 10. Traditional Landscape Outdoor Water Demand Scenario

	Coefficient	Sub Coefficient	Coefficient Description
1	Irrigated Area	Turf Irrigated Area	2,000 square feet
		Planting Irrigated Area	1,500 square feet
2	Landscaping	Turf Coefficient	Bluegrass with Reference ET of 90%
		Planting Coefficient	Traditional with Reference ET of 70%
3	System Performance	Application Method Efficiency	Spray with an efficiency of 75%
		Installation & Operations Method Adjustment	Good with an efficiency of 80%
4	Water Management	Technology Adjustment	None used

The parameters used in the traditional landscape example result in a total annual outdoor water demand of 0.35 acre-feet per year per residence or approximately 32 gallons per square foot per year. This is a conservative criteria that provides a planning number for water providers to determine an outdoor water demand. The City of Boulder and Colorado State University (CSU) have calculated lower water demands, in the range of 20 gallons per square foot per year. A detailed calculation of the water demand example can be found in **Appendix F**.

5.1.6 Sensitivity Analysis

A sensitivity analysis of the four coefficients of the outdoor water demand was performed based on the traditional landscape outdoor water demand described above. The analysis varied an individual coefficient from the scenario identified in Table 10, while the remaining coefficients were held constant. The sensitivity analysis and results are generally stated below and identified in **Appendix G**. Below is a summary of the water savings by coefficient (note that the savings are not necessarily directly additive). The effectiveness of the components is listed below from most effective to least.

1. Irrigated Area – A 57% water savings is obtained when the combined turf and planting areas are reduced from 3,500 square feet to 1,500 square feet.
2. System Performance – A 52% water savings is obtained when the application method (spray, rotor, subsurface drip) and operations method is varied. The savings is highly dependent on the operations method practiced (excellent, good, poor).
3. Water Management – A 34% water savings is obtained when water management is implemented to utilize the effective precipitation via active irrigation controller technology.
4. Landscape – A 34% water savings is obtained when the landscaping choices are changed to lower water demand landscaping. An example is from bluegrass turf and traditional plantings to fescue turf and native plantings. The buffalograss and native plantings option was not chosen because research indicated that this landscape option is not the most desirable from the homeowner.

5.1.7 Provider Commitment and Public Acceptance

The calculation of the total outdoor water demand is academic in nature and adjusts for the water user by using the coefficients and algorithms. However, this equation must be filtered through the subjective factor of the water provider's commitment and public acceptance. These two factors have a major influence on the final water demand and are highly variable. The following two sections provide insight and points to consider when evaluating a provider's commitment and the public's acceptance of outdoor water demand conservation.

Provider Commitment

The information, education, and resources supplied to the customers from the water provider will affect how much water can be saved. These guidelines serve as a connection point between the customer and the water provider. Points to consider for water providers are identified below.

Information and Education

1. Water budget calculations
2. Approved water saving landscaping and irrigation equipment
3. Water savings seminars
4. Demonstration gardens
5. Frequent communication - mailings and/or handouts

Resources

1. Tiered water rates
2. Individual irrigation meters
3. Water resources staffing
4. System design support (landscape design specifications)
5. Real time water usage data
6. Water system inspections (new and existing systems)
7. Water conservation incentives
8. Subsidies for water efficiency

Public Acceptance

Public acceptance of water conservation measures may be the most difficult factor to track and implement. It will require a paradigm shift by the residents of northwest Douglas County and the Colorado Front Range. The public can use the information, education, and resources provided by the water provider as guidelines when they perform their design, operations, and maintenance on their landscape and irrigation systems. There is a willingness of the public to implement water savings methods as identified in public opinion surveys.

- Residents support additional water-saving actions, including conservation education, ensuring all new development has adequate water and limits on new lawns (Ciruli Associates, 2006).
- Residents will invest in water conservation and supply programs and projects (Ciruli Associates, 2006).
- 97% of homeowners rate their landscaping as a somewhat important aspect of their home (GreenCO, 2003).
- 51% of homeowners said they would be very likely to make changes to their landscaping to conserve water (GreenCO, 2003).
- 86% of homeowners said that they would be somewhat or much more likely to make water conservation changes if rebates were offered (GreenCO, 2003).

5.1.8 Summary of Outdoor Water Demand Components

Significant outdoor water demand savings can be realized by choosing greater water conserving coefficients of the Water Demand Calculation Algorithm. A sensitivity analysis of each individual coefficient identified water savings from the traditional northwest Douglas County outdoor water demands. The four coefficients used in the algorithm and their individual water savings from the traditional Douglas County water demand scenario are:

1. Irrigated Area – 57% water savings
2. System Performance – 52% water savings
3. Water Management – 34% water savings
4. Landscaping – 34% water savings

A fifth factor that is not included in the algorithm which has a significant impact on water savings. This highly variable coefficient is:

5. Provider Commitment and Public Acceptance

The coefficients must all be combined to provide a real picture the total outdoor water demand.

5.2 OUTDOOR WATER DEMAND SCENARIOS

There are many variables and options for calculating the outdoor water demand using the Outdoor Water Demand Calculation Algorithms. This study considers three scenarios to describe the outdoor water demand for a typical residence located in northwest Douglas County. The Douglas County Total Water Demand base scenario is provided in the next section to compare the algorithm to Douglas County's current minimum water supply standard.

5.2.1 Douglas County Total Water Demand

Douglas County has a total (combined indoor and outdoor) water demand requirement of 0.75 acre-feet per year for a residential unit (Douglas County, 2005). Assuming 0.30 acre-feet per year of the water is used for indoor water demand then the outside water demand is 0.45 acre-feet per year. The traditional water demand scenario and the Water Demand Calculation Algorithm (equation 10) calculated a lot density of 3.8 residential units per acre (**Appendix H**). The density of 5.0 units per acre used in this study provides a lower water usage per lot (0.35 acre-feet per year outdoor water demand) using the traditional water demand scenario and the Water Demand Calculation Algorithm.

The total water demand, consisting of indoor water demand and outdoor water demand, varies among water providers. Denver Water uses a total water demand of 0.46 acre-feet per year, Castle Pines North Metropolitan District uses a total water demand of 0.40 acre-feet per year, the Town of Castle Rock uses a total water demand of 0.55 acre-feet per year, and the Centennial Water and Sanitation District uses a total water demand of 0.50 acre-feet per year. By comparison, the total water demand used in this study is 0.65 acre-feet per year, which is still a conservative planning number compared to other nearby communities.

5.2.2 Water Use Scenarios

Three examples were used to define the outdoor water demand for the typical northwest Douglas County lot. The examples were chosen based on an acceptable look of the landscaping to the public. The examples start with a traditional landscape that can be found along the Front Range. This includes bluegrass and traditional plantings with a spray irrigation system. A detail for this scenario and all of the examples can be found in **Appendix I**. The moderate scenario uses fescue turf that has a lower water demand than bluegrass and plantings that are classified as moderate and has a portion of the potential landscaped area as non-irrigated area. The water wise scenario uses fescue turf and native plantings with an increase in non-irrigated area. The term "water wise" is used by several groups such as the Colorado Water Wise Council, Colorado State University, and others to describe different conservation techniques, typically related to outdoor water use. For the purposes of this study, water wise encompasses a publicly acceptable outdoor water demand conservation scenario. It does not incorporate the lowest possible water using landscape and irrigation systems, but a practical application of the outdoor water demand practices discussed above. The total outdoor water demand for the three scenarios and Douglas County Outdoor Water Demand is summarized in **Table 11**. The percentage of water savings from the Douglas County scenario and traditional scenario are summarized below. The percentage savings to both scenarios is presented, since the lot density varies from the Douglas County scenario (3.8 units per acre) and the other three scenarios (5.0 units per acre).

Table 11. Summary of Outdoor Water Demand Scenarios

Water Use Scenario	Outdoor Water Demand (acre-feet per year)	Savings from Douglas County Scenario	Saving from Traditional Scenario
Douglas County	0.45	0%	NA
Traditional	0.35	22%	0%
Moderate	0.16	64%	53%
Water Wise	0.08	82%	76%

The outdoor water demands calculated from the Water Demand Calculation Algorithm represent planning numbers, which may vary between providers and may change the percent savings between the Water Use Scenarios.

6.0 RAINWATER HARVESTING

The amount of precipitation that can physically be captured and put to use depends on the amount and timing of the precipitation, the amount and timing of the demand, and the system storage capacity.

6.1 SYSTEM COMPONENTS

Water harvesting systems are typically characterized as either simple or complex (**Figure 10**). Simple systems distribute precipitation immediately to landscaped areas whereas complex systems store some or all of the precipitation in a container for later use. Complex systems are more expensive to construct and maintain, but yield higher water savings.

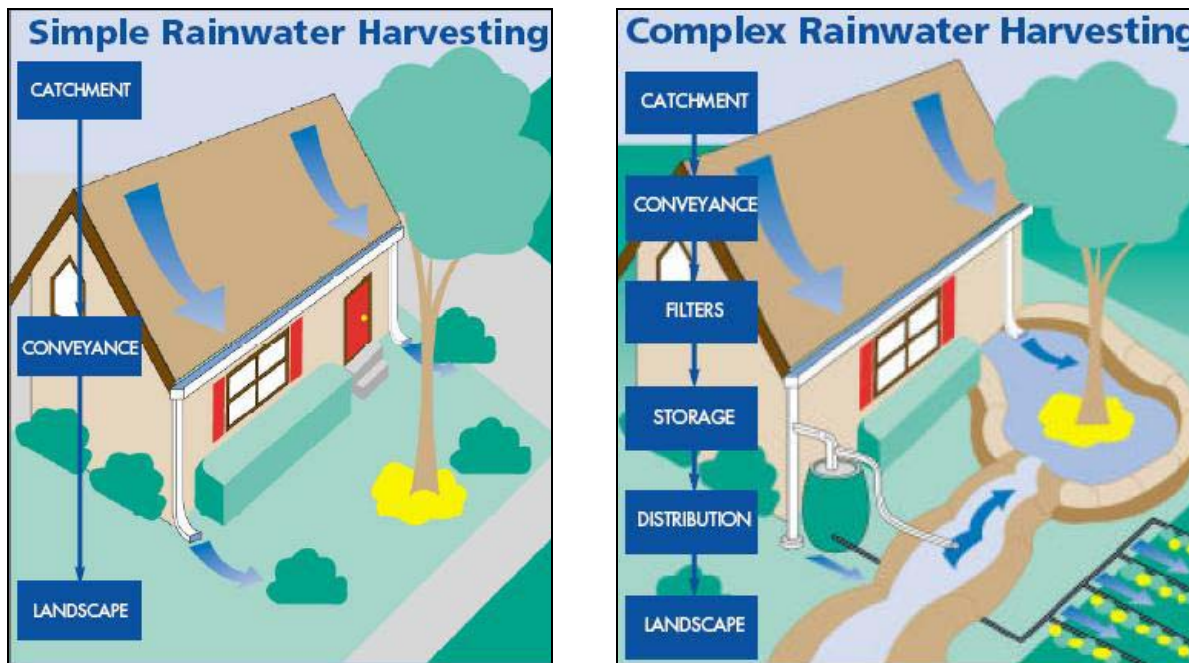


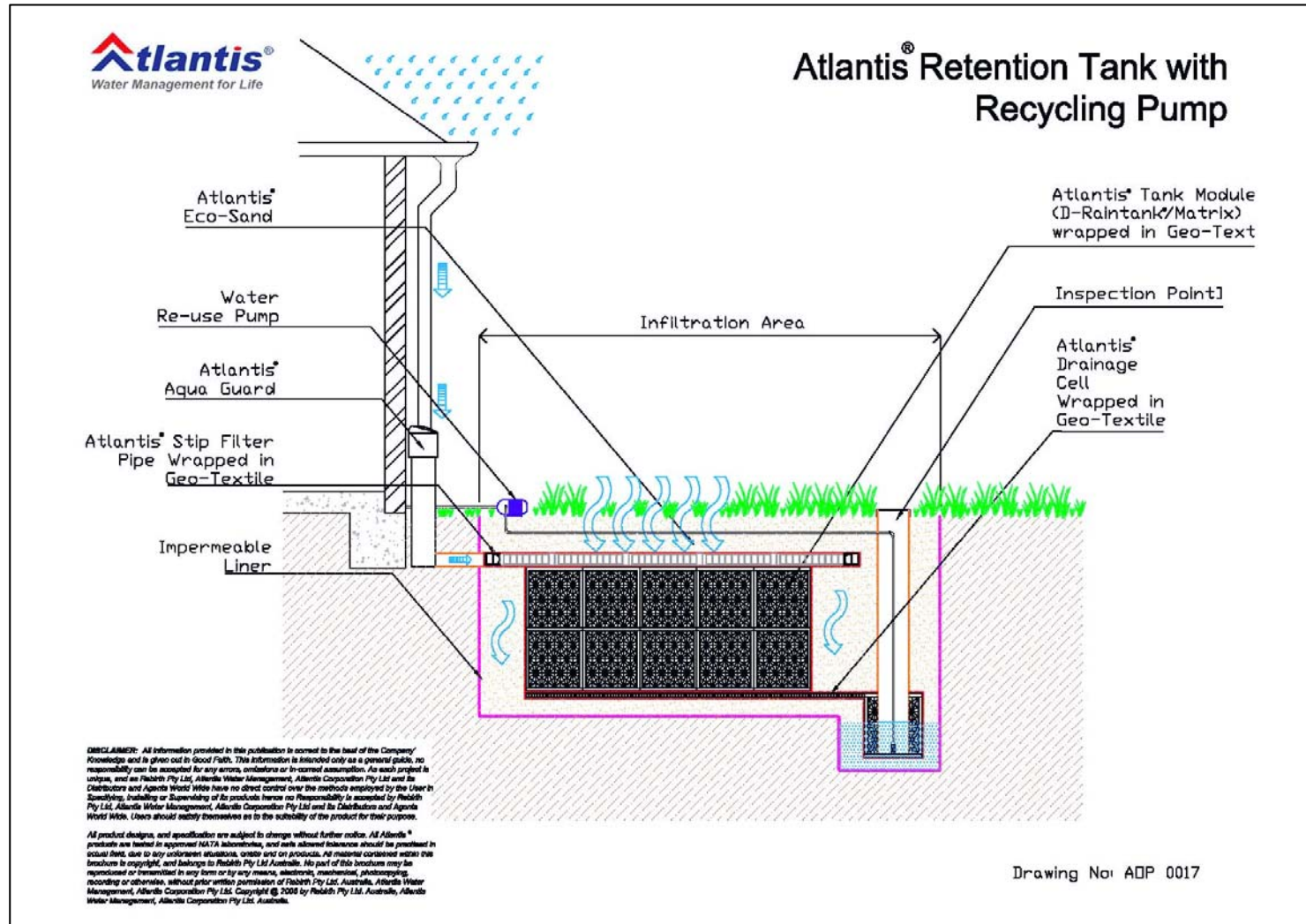
Figure 10. Components of Simple and Complex Systems
(figures taken from *A Waterwise Guide to Rainwater Harvesting*,
New Mexico Office of the State Engineer).

A simple system can be limited to a catchment area (e.g., roof), conveyance system (e.g., gutters), and bermed landscaped holding area. The basic components of a complex system include:

- catchment area (e.g., roofs),
- conveyance (e.g., gutters and downspouts),
- filters (e.g., gutter leaf screen, first flush roof washing system, or additional filtration for a drip irrigation system),
- storage (e.g., rain barrels, cisterns),
- distribution system (e.g., water faucet, valve, water lines, electric pump), and
- landscape area.

In addition to gutter leaf screens and first flush devices that prevent large items from entering the storage tank, complex system designs may include liners and sand filter traps that help maintain good water quality (**Figure 11**).

Figure 11. Atlantis Cistern System



(figure taken from Atlantis Corp website; <http://www.atlantiscorp.com.au/drawings/downloads15> (Re Use Tank.pdf).

This study focuses on the use of local (residential) cisterns to capture precipitation in a holistic approach to sustainable water management. In certain situations, other capture approaches such as regional cisterns, regional infiltration ponds, or modified detention/retention facilities may be more advantageous from a management, maintenance, and/or cost perspective. Some of these alternative approaches are being implemented in other states, such as the Daybreak Community in Salt Lake City, Utah. Evaluation of alternative approaches may be necessary to find the best system for a given project, depending on the precipitation timing, irrigation demand, storage capacity, and economics of the proposed project. Regardless of the capture mechanism, the concepts from this study can be used to further evaluate incorporating precipitation management through rainwater harvesting into particular water supply scenarios.

6.2 SYSTEM SIZING

Cistern sizing depends on the amount and timing of the supply and the demand. The supply is a function of the precipitation, the catchment (e.g., roof) area, and the catchment material. For this study, where the demand is associated with landscape irrigation, the demand is a function of the amount of landscaped area, planting density and grouping, type of landscape, and irrigation practices.

The literature suggests using a water budget approach for system sizing where the monthly supply is compared to the monthly demand (City of Albuquerque, 1995; Cunliffe, 1998; Texas Water Development Board, 2005). Most of the literature recommends using average monthly precipitation to estimate the supply, as shown in equation 13 below.

$$\text{Supply} = \frac{\text{Precipitation}}{(\text{ft})} \times \frac{\text{Roof Area}}{(\text{ft}^2)} \times \frac{\text{Collection Efficiency}}{(\%)} \quad (13)$$

The collection efficiency represents losses due to wetting the roof, filling the roof washer, gutter overshoot and spilling from the gutters during heavy downpours, and water that cannot be collected because the storage tank is already full. Composite roofs can have an approximate 10 percent loss due to inefficient flow or evaporation (Krishna, 2005). Efficiencies were cited in other publications ranging from 75 percent to 95 percent, depending on the system design and capacity; an average of 85 percent was used for the examples in this study.

The demand can be estimated using the formulas outlined in the previous section. The closer the supply and demand match, in terms of amount and timing, the smaller the storage capacity needed. For a given supply situation, a larger demand typically requires a smaller storage capacity (water is pulled out of storage faster, therefore making capacity available when the supply occurs). This relationship is illustrated by the set of curves shown in **Figure 12**.

Cistern sizing ultimately comes down to an economic decision: whether to install a larger, more costly cistern to capture the maximum possible amount or to install a smaller, less expensive cistern and capture only a portion of the available precipitation. This decision will be driven in part by the particular water supply situation and whether other cost-effective water supply options are available. A range of storage solutions are shown in Figure 12 for a typical residence with a 1,500 square foot capture area and an 85% capture efficiency. In this case, a 5,000 gallon cistern results in around

10,000 to 16,000 gallons of precipitation captured (depending on the landscape demand and the rate at which precipitation is withdrawn from storage) over an average season, almost 85% of the total precipitation. A 5,000 -gallon cistern is approximately equivalent in area to a one-car garage (12 feet by 30 feet at 4 feet deep).

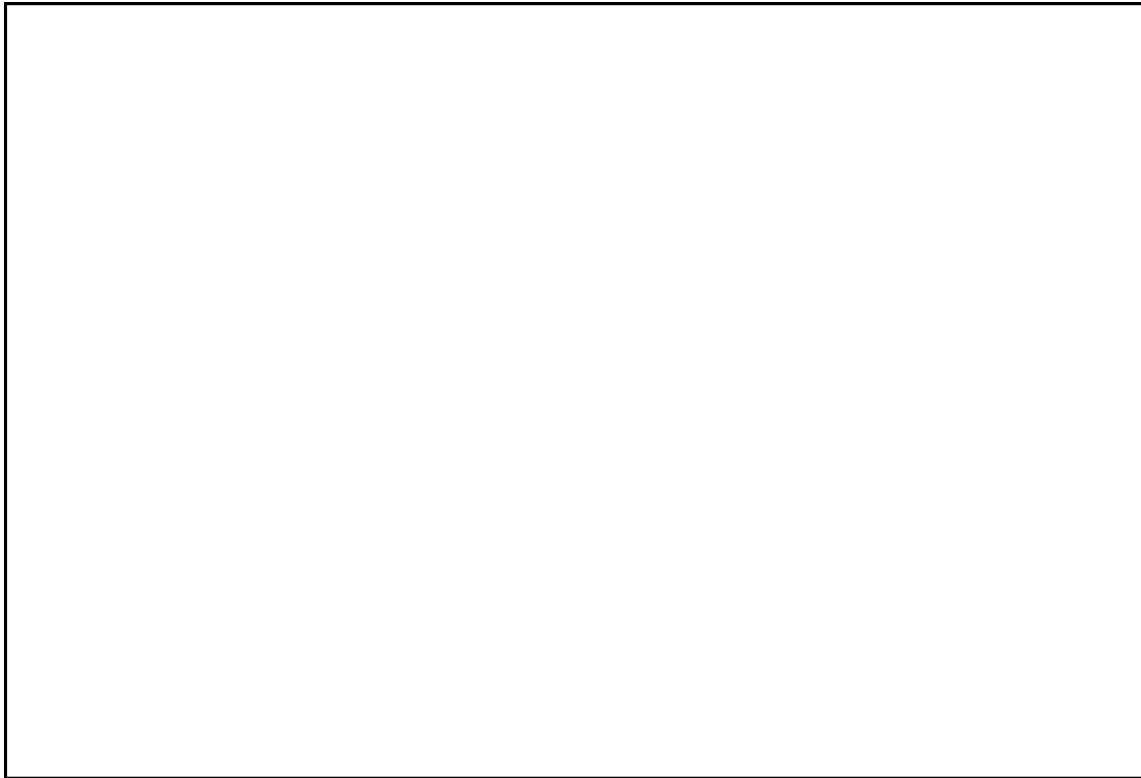


Figure 12. Cistern Sizing Alternatives

6.3 SYSTEM COSTS

Costs to install rainwater harvesting systems depend on the type of system, degree of filtration, and distance between the storage container and the place of use. The storage vessel is typically the most expensive component in the system.

Krishna indicates the total costs generally range from \$5,000 to \$8,000 including the gutters, cistern, pump, and treatment system (Krishna, 2004). More specific cost information from Krishna (2005) includes:

- Storage tank costs depend on the size and material, ranging from \$0.50 per gallon for large fiberglass tanks to \$4.00 per gallon for welded steel tanks.
- Gutters range from \$0.30 per foot for do-it-yourself installations to professionally installed gutters ranging from \$3.50 to \$12 per foot, including materials and installation.
- Roof washer costs range from \$50 to over \$800.

- Pumps needed for drip irrigation systems range from around \$400 to over \$1,000 for combined high-end pump and pressure tanks.
- Filtration, also important for drip irrigation systems, costs around \$50 per filter. Filter cartridges have to be replaced regularly.

Based on communication with AquaHarvest (2006), there is an economy of scale in storage tank costs:

- @ 1,000 gallon capacity ~ \$5.50 to \$6.50 per gallon,
- @ 5,000 gallon capacity ~ \$2.00 to \$2.40 per gallon,
- @ 10,000 gallon capacity (e.g., regional storage) ~ \$1.00 to \$1.75 per gallon.

AquaHarvest is currently installing these systems in the Rancho Viejo development outside of Santa Fe, New Mexico (**Figure 13**). The storage tanks have an average life of around 30 years, while the pumping equipment has a life of approximately 5 years. A detailed cost/benefit analysis was not included in this study. As previously mentioned, the cistern size will most likely be dictated by an economic decision based on an individual's situation, in terms of alternative supplies. If the cistern provides the only source of water (e.g., wells going dry), then a larger cistern may be well worth the additional capital cost. Further, the water supply provided by rainwater harvesting may serve to offset other project costs such as reduced water rights acquisitions, fewer wells for pumping, and reduced system sizing.



Figure 13. Cistern Installation

7.0 COMBINING RAINWATER HARVESTING WITH OUTDOOR WATER DEMAND MANAGEMENT

In this chapter, we investigate precipitation as a water supply for outdoor water demands and the different augmentation requirements for existing and new development examples. The relationship between the amount of precipitation captured and the landscape demand is illustrated, on a conceptual basis, in **Figure 14**. In Colorado, precipitation typically peaks in early to mid spring while landscape demands peak later in the summer.

If the outdoor water demand is managed such that the total outdoor water demand is less than or equal to the supply from precipitation, cisterns or alternative storage options could be used to simply capture the precipitation when it is available and re-time the storage releases to match the demands. Alternatively, if the outdoor water demand exceeds the captured precipitation, then some amount of supplemental irrigation water may still be needed, as depicted in Figure 14. In this case, the captured precipitation reduces the amount of supplemental supply that would otherwise be needed.

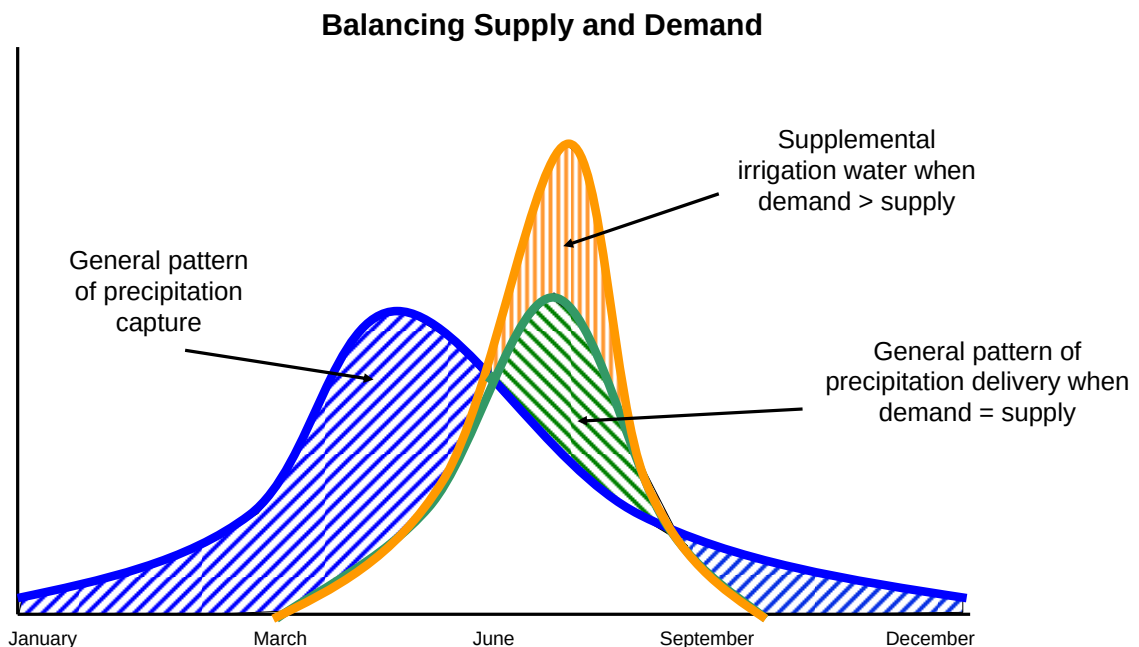


Figure 14. Concepts of Balancing Supply and Demand

To show how rainwater harvesting and outdoor water demand management practices can be paired to provide a holistic approach to sustainable water management in Douglas County, three general examples were considered:

- New Residential Development – precipitation collected from rooftops only,
- Existing Domestic Well Users – precipitation collected from rooftops only,
- Existing Commercial Non-Tributary Well User – precipitation collected from rooftops and other impervious areas.

Using the algorithms presented in Chapters 5 and 6, monthly water budgets were developed to compute the supply from precipitation, and outdoor water demands for landscaping irrigation. The algorithms presented in Chapter 4 were then used to estimate augmentation requirements under each scenario. A study period of 1993 through 2003, representing average, wet, and dry conditions, was selected. Precipitation data from the Kassler NOAA climate station were used to estimate the supply from precipitation. Outdoor water demands were estimated using temperature and frost dates from the Kassler NOAA climate station and wind speeds, vapor pressure, and solar radiation data from the Ft. Lupton CoAgMet climate station, the closest CoAgMet climate station with this type of data. The results provided below are based on these monthly water budget analyses.

7.1 NEW RESIDENTIAL DEVELOPMENT

The benefits of pairing rainwater harvesting with traditional, moderate, and water wise conservation scenarios, as identified in Section 5.2.2, for a new residential development were considered (**Table 12**). For this example, a 1,500 square foot roof capture area with a 5,000-gallon cistern and 85% capture efficiency was considered. Irrigated areas and associated outdoor water demands for traditional landscaping, moderate conservation, and water wise conservation were based on information presented in Chapter 6. An example of the calculations under a moderate conservation scenario are provided in Appendix I.

**Table 12. Precipitation and Outdoor Water Demand Management
with New Residential Development**

One Single Family Residential Equivalent (SFE)								
Demand Scenario	Irrigated Area	Outdoor Water Demand		Cistern Supply ^(a)		Supplemental Irrigation Supply	Supply From Precipitation	Savings from Traditional Landscaping
	(Sq. Feet)	(Acre-Feet)	(Gallons)	(Acre-Feet)	(Gallons)	(Acre-Feet)	(%)	(%)
	[1]	[2]	[3]	[4]	[5]	[6]	[7] ^(d)	[8] ^(d)
Traditional Landscaping	3,500	0.347 ^(c)	113,000	0	0	0.347	0%	---
Traditional Landscaping & Cisterns ^(b)	3,500	0.347	113,000	0.042	13,800	0.305	12%	12%
Moderate Conservation	2,500	0.164	53,600	0	0	0.164	0%	53%
Moderate Conservation & Cisterns ^(b)	2,500	0.164	53,600	0.042	13,800	0.122	26%	65%
Water Wise	1,500	0.082	26,600	0	0	0.082	0%	76%
Water Wise & Cisterns ^(b)	1,500	0.082	26,600	0.041	13,200	0.041	50%	88%
(a) Cistern supply varies depending on timing of precipitation supply and irrigation demand. (b) 5,000 gallon cistern (c) The Traditional Landscaping scenario equates to 32 gallons per square foot per year water demand, which is higher than the 20 gallons per square foot per year identified in other outdoor water demands studies by The City of Boulder and Colorado State University. (d) A lower Traditional Landscaping water demand will increase the percentage of supply identified in column 7 and reduce the savings identified in column 8.								

As previously mentioned, this study considers rainwater harvesting and outdoor water demand management practices individually as stand alone concepts, and then explores the added benefit of combining the two. For the new residential example described above, the average annual water savings are as follows:

- Outdoor water demand management practices alone, as compared to traditional landscaping practices, can produce an average water savings of approximately 53% (0.183 acre-feet per SFE) and 76% (0.265 acre-feet per SFE) under moderate conservation and water wise practices, respectively (Table 12, columns 2 and 8).
- Rainwater harvesting has the potential of supplying approximately 0.04 acre-feet or 12% of the traditional landscape demand, approximately 26% of moderate conservation demand, and approximately 50% of the demand with water wise practices (Table 12, column 7).
- Combining outdoor water management with rainwater harvesting, as compared to traditional landscaping water demand without cisterns (0.35 acre-feet per year), has potential potable water savings of 65% (0.23 acre-feet per year) for the moderate conservation scenario, and 88% (0.31 acre-feet per year) for the water wise scenario (Table 12, column 8).

Precipitation and outdoor water demand management offer an opportunity for substantial water savings, particularly when considered on a larger scale. For example, the numbers provided in Table 12 could be incorporated with Douglas County growth projections to estimate the full potential savings if rainwater harvesting and outdoor water demand management were incorporated in all new developments throughout Douglas County.

To illustrate potential savings on a larger scale, the same examples presented in Table 12 are shown in Table 13. For a new development of 1,000 homes, without precipitation or outdoor water demand management, the new development would require approximately 350 acre-feet to meet average outdoor demands with traditional landscaping (column 2). Adding rainwater harvesting could provide 40 acre-feet of supply, reducing the demand to 310 acre-feet (columns 2 and 4). Even without the rainwater harvesting component, water savings are estimated to be approximately 190 acre-feet with moderate conservation and 310 acre-feet with water wise practices (column 4).

Pairing rainwater harvesting and moderate landscape conservation, the same development that required 350 acre-feet of supply with traditional demands would require only 120 acre-feet with moderate conservation and only 40 acre-feet with water wise practices (column 2). For these examples, the cost savings in water supply acquired for outdoor demands are estimated to be approximately \$5.1 million and \$6.8 million, respectively (column 6).

**Table 13. Precipitation and Outdoor Water Demand
Management on a Development Scale**

1,000 Single Family Residential Equivalents (SFE)						
Demand Scenario	Outdoor Water Supply Required ^(a)		Water Rights Cost ^(c,d)	Savings from Traditional Landscape (1,000 SFE's)		
	1 SFE	1,000 SFE's				
	(Acre-Feet)	(Acre-Feet)	(\$ Millions)	(Acre-Feet)	(%)	(\$ Millions)
	[1]	[2]	[3]	[4] ^(f)	[5] ^(f)	[6] ^(f)
Traditional Landscaping	0.35 ^(e)	350	\$7.70	0	---	\$0.00
Traditional Landscaping & Cisterns ^(b)	0.31	310	\$6.80	40	12%	\$0.90
Moderate Conservation	0.16	160	\$3.50	190	53%	\$4.20
Moderate Conservation & Cisterns ^(b)	0.12	120	\$2.60	230	65%	\$5.10
Water Wise	0.08	80	\$1.80	270	76%	\$5.90
Water Wise & Cisterns ^(b)	0.04	40	\$0.90	310	88%	\$6.80
(a) Cistern supply varies depending on timing of precipitation supply and outdoor water demand. (b) 5,000 gallon cistern (c) Cost based on \$15,000 to acquire and \$7,000 for storage to provide a firm yield of water at a total cost of \$22,000 per acre-foot. (d) Includes cost for augmentation that protects downstream water rights per this study. (e) The Traditional Landscaping scenario equates to 32 gallons per square foot per year water demand, which is higher than the 20 gallons per square foot per year identified in other outdoor water demands studies by The City of Boulder and Colorado State University. (f) A lower Traditional Landscaping water demand will reduce the savings identified in columns 4, 5, and 6.						

7.1.1 Augmentation Requirements for New Residential Development

Under current law, 100% of the precipitation captured would need to be augmented (returned to the stream), as presented in Sections 3 and 4. However, our scientific literature review shows that on average, only 3% of precipitation falling over undeveloped areas returns to the stream. Therefore, an average of 97% of the historical precipitation could be used in a rainwater harvesting system without injuring other water rights.

Due to inefficiencies in capturing precipitation, we estimated that on average, only 85% of the water falling over the roof area would be captured with cisterns. If 97% of the historical precipitation can be used without injuring other water rights but only 85% can be captured with cisterns, it is possible that all of the captured water could be used without injuring other water rights.

What happens to the other 15% of the precipitation that is not captured? A portion may return to the stream system or it may be consumed by rooftop evaporation and other losses. To be conservative to the stream system and other existing water rights, we are recommending augmentation requirements

be based on a percentage of the total precipitation that fell over the rooftop areas rather than the 85% that was actually captured and used.

As previously described in Section 4.4, prior to development, the historical average annual precipitation of 17.5 inches that fell over a development of 1,000 homes with 1,500 square foot rooftops was equivalent to 50 acre-feet. On average, only 2 acre-feet (3%) returned to the stream system via surface and groundwater return flows. The difference of 48 acre-feet was consumed by native vegetation and never returned to the stream system. Therefore, we estimate the average annual augmentation requirement from this development should be 2 acre-feet per year in order to protect existing water rights. However, current law requires the full 50 acre-feet to be replaced.

7.2 EXISTING DOMESTIC WELL USERS

7.2.1 Non-Tributary

With the exception of a 2% relinquishment to the stream system, non-tributary water is fully consumable. When the wastewater from indoor uses is treated with an individual sewage disposal system, it is typically estimated to be only 10% consumptive, with the remaining 90% returning to the stream system. The portion that is not consumed and not relinquished can be used as a reusable “credit” to offset stream depletions associated with other uses. Note that outdoor uses are not typically considered to be 100% consumptive and therefore also result in a return flow credit. However, for simplicity, the example provided for this study considers reusable credits associated with indoor uses only.

The benefits of adding rainwater harvesting to an existing domestic non-tributary well user with traditional landscaping were considered. For this example, a 1,500 square foot roof area with a 5,000-gallon cistern and maximum 85% capture efficiency was considered. The associated demands are shown below in **Table 14**. With 10% consumption and 2% relinquishment, this well user would have a reusable credit of 88% or approximately 86,000 gallons. This credit far exceeds the amount captured with the cistern as well as the total amount that historically fell over the 1,500 square foot roof area. There are sufficient return flow credits associated with the indoor use of non-tributary water to offset the augmentation requirement, even if 100% of the water falling over the capture area had to be replaced. Even with current Colorado water law, rainwater harvesting could be a viable option for domestic non-tributary well users. Rainwater harvesting is in alignment with the goals outlined in the Douglas County 2020 Comprehensive Master Plan and under this example, would save an average of 13,800 gallons per year pumping. Pairing rainwater harvesting with outdoor water demand management would have even greater potential of reducing pumping.

Table 14. Augmentation Requirements for a Domestic Non-Tributary Well User (Gallons per Year)

Outdoor Use	
Outdoor Demand	113,000
Average Precipitation	16,000
Precipitation Captured (max 85%)	13,800
Supplemental Supply	99,200
Indoor Use Credits	
Indoor Demand (0.3 AF)	97,800
Reusable Credits (88%)	86,064
Augmentation Requirement (Current Law)	
Depletions (100% of Precip)	16,000
Return Flow Credits (88%)	86,064
Augmentation Requirement	0

7.2.2 Tributary

Douglas County residents relying on or seeking a water supply from a tributary aquifer likely have or may be able to apply for an “exempt” well permit. According the Colorado Department of Water Resources, exempt well permits for Household Use Only Wells are issued for ordinary household uses in one single family dwelling on tracts of land that are less than 35 acres. These permits do not allow for any outdoor water use or livestock watering. Generally, this type of permit is issued to individuals in a rural setting who own a lot in a subdivision that was created prior to June 1, 1972. These types of users are likely located in the foothills on the west side of Douglas County.

For these specific water users, rainwater harvesting could provide a physical water supply for outdoor uses, as well as a potential supply for fire storage. To legally divert, store, and use the precipitation would require an augmentation plan. Currently, the Upper South Platte Water Conservancy District has applied for a “blanket” augmentation plan (Case No. 02CW389) to cover these types of small depletions for users within its boundaries such as the foothills area of Douglas County. The algorithms presented in this report could serve as the basis for determining the augmentation requirements. **Table 15** compares estimated augmentation requirements for a domestic tributary well user under current law versus replacements needed to protect existing water rights.

Table 15. Augmentation Requirements for a Domestic Tributary Well User (Gallons per Year)

Augmentation Requirement	Current Law (100% of Precip)	Protect Existing Water Rights
Depletions	16,000	480

7.3 EXISTING COMMERCIAL NON-TRIBUTARY WELL USER

Irrigated and impervious acreage and water use information associated with the Castle Pines North administration building were used to consider the benefits of adding rainwater harvesting to an existing commercial non-tributary well user with traditional landscaping. While the administration building may actually be more representative of a public facility than a true commercial user (due to a slightly higher irrigated area to impervious area ratio), it is sufficient for demonstrating the concept of capturing precipitation from both a rooftop and other impervious areas.

As previously mentioned, with the exception of a 2% relinquishment to the aquifer, non-tributary water is fully consumable. With commercial users, the wastewater from indoor uses is typically treated at a central wastewater treatment plant. In this case, the indoor use is typically considered to be only 5% consumptive, with the remaining 95% returning to the stream system. The portion that is not consumed can be used as a reusable “credit” to offset stream depletions associated with other uses. As with the domestic example provided above, return flow credits associated with outdoor uses were not considered for this example.

The following estimates were used for this example:

- Cistern capacity of 70,000 gallons with an maximum 85% capture efficiency,
- Impervious capture area of 0.60 acres (including rooftop, parking lot, and sidewalks),
- Irrigated area of 0.586 acres (92% bluegrass, 8% traditional plantings), and
- Traditional landscaping application efficiencies.

Under these conditions, this commercial well user would have an average outdoor demand of approximately 540,000 gallons per year (**Table 16**). It is estimated that rainwater harvesting with cisterns could supply approximately 237,400 gallons (44%) of this demand. Note that the amount of precipitation that historically fell over the impervious areas is approximately 286,700 gallons, but with a maximum capture efficiency of 85% and cistern capacity of 70,000 gallons, only 237,400 gallons are captured.

The indoor demand for this user is estimated to be 48,000 gallons per year. With 5% consumption and 2% relinquishment, this well user would have a reusable credit of approximately 44,640 gallons. In this case, the available credit is less than the amount captured with the cistern. While rainwater harvesting would save an average of 237,400 gallons per year pumping, it would result in a net augmentation requirement of approximately 242,060 gallons from indoor uses under current law. It is likely that under a more typical commercial use, where the irrigated area to impervious area ratio is lower, the results of this analysis would be more similar to the case of the domestic non-tributary well user where the reusable return flow credits would exceed the augmentation requirements even under current law.

Table 16. Augmentation Requirements for a Commercial Non-Tributary Well User (Gallons per Year)

Outdoor Use	
Outdoor Demand	540,000
Average Precipitation	286,700
Precipitation Capture (max 85%)	237,400
Supplemental Supply	302,600
Indoor Use Credits	
Indoor Demand	48,000
Return Flow Credits (93%)	44,640
Augmentation Requirement (Current Law)	
Depletions (100% of Precip)	286,700
Reusable Credits	44,640
Augmentation Requirement	242,060

8.0 AUGMENTATION PLANS

8.1 CURRENT AUGMENTATION REQUIREMENTS

A plan for augmentation is statutorily defined as “a detailed program . . . to increase the supply of water available for beneficial use in a division or portion thereof by the development of new or alternate means or points of diversion, by a pooling of water resources, by water exchange projects, by providing substitute supplies of water, by the development of new sources of water, or by any other appropriate means. *‘Plan for Augmentation’ does not include the salvage of tributary waters by the eradication of phreatophytes, nor does it include the use of tributary water collected from land surfaces that have been made impermeable, thereby increasing the runoff but not adding to the existing supply of tributary water.*” C.R.S. § 37-92-103(9). Because no credit is allowed for the eradication of phreatophytes or the collection of precipitation off impermeable surfaces, such as rooftops, all rainwater or snowmelt collected is considered to be tributary to the stream and must be replaced with another source of water.

In the 1,000-unit new home development example discussed above, an augmentation plan for rooftop capture of precipitation with subsequent storage in cisterns and application to beneficial use would require the following elements:

- Appropriation of new, conditional water right that would represent the diversion of water through capture of precipitation;
- Identification of structures to be augmented, i.e., structures capturing precipitation;
- Measurement and/or calculation of all precipitation captured;
- Identification of sufficient water to be used to replace presumed depletions to the stream such as non-tributary groundwater return flows, reservoir releases, or the addition to the stream of changed surface water rights;

- Timing analysis of when precipitation would reach stream and protective term and condition mimicking timing;
- Calculation of lawn irrigation return flows generated by irrigating with water collected in cisterns in order to offset augmentation requirements. NOTE: if an applicant did not want to undertake this analysis, or wanted to do so later, 100% of captured precipitation would have to be replaced;
- Accounting forms acceptable to Division Engineer to track augmentation requirements; and
- A way to curtail or shut off precipitation capture mechanisms if adequate replacement not being made.

Despite water quality and storm water management benefits, under today's law, there is no incentive to invest in precipitation harvesting and management, which require additional infrastructure, because water supply requirements are not reduced.

8.2 AUGMENTATION REQUIREMENTS IF COLORADO ALLOWED USE OF RAINWATER HARVESTING

For augmentation plans involving the capture and beneficial use of precipitation to function as an actual component of the water supply, changes in the law are necessary. Ultimately, water users meeting certain criteria established by the legislature to maintain a system of balance and control would need to be allowed to:

- Capture precipitation from impermeable surfaces for storage and later use,
- Quantify how much of that precipitation had never historically reached the stream because it had been consumed by native vegetation or sublimation, and
- Reduce their augmentation requirement by that historical ET amount.

Many of the elements of an augmentation plan that allowed credit for historic water consumption by native plants would be similar to those outlined above in Section 8.1. However, in addition to those elements outlined above, an applicant would have to quantify the percentage of precipitation consumed by vegetation, and therefore not available to the stream, versus the percentage of precipitation that did accrue to the stream via surface flows and/or groundwater flows. An applicant for an augmentation plan involving precipitation harvesting would also have to provide evidence of the timing of the augmentation requirements.

Besides the additional elements of proof involved, the main difference between an augmentation plan under current legal standards and an augmentation plan that allowed an applicant to calculate and take credit for actual, historic patterns of precipitation accrual to streams, is that the later enables the water user to utilize on-site precipitation as a real component of their water supply system. Water users, pursuant to balancing and control standards established by the legislature, would be able to capture and use rain or snowfall on-site, thereby reducing the amount of water they would otherwise need to acquire and introduce to that same site.

9.0 STUDY CONCLUSIONS AND RECOMMENDATIONS

This study investigates a holistic approach to balancing sustainable/renewable water supplies with outdoor water demands in the design of water supply systems in the study area of northwest Douglas County. The study was conducted at a feasibility level, investigating the pairing of one specific component of rainwater harvesting (use of cisterns) with outdoor water demand management.

While rainwater harvesting is being practiced and encouraged in Colorado's neighboring states, it presents unique challenges in Colorado due, in part, to Colorado's water law. Through conducting a detailed literature review and applying generally accepted algorithms, the results from this study show that the limitations currently posed by Colorado's water law on use of precipitation are overly conservative with respect to protecting the stream system for existing water rights.

Combining rainwater harvesting with outdoor water demand management provides the greatest potential for saving water, however, the results from this study are presented such that the recommended algorithms and findings related to each practice can be utilized to investigate benefits associated with either practice individually or paired together. These concepts can be used to find innovative solutions under various water supply situations. Although this study focuses on the water supply needs in northwest Douglas County, the methodologies presented herein are applicable throughout the county and to much extent, throughout the state.

9.1 STUDY CONCLUSIONS

9.1.1 Precipitation as a Potential Water Supply

- The annual precipitation in northwest Douglas County ranges from 10.68 inches to 28.11 inches, with an average of 17.5 inches per year.
- Based on the lowest record amount for the period 1950 through 2004, the estimated "sustainable" yield from precipitation in northwest Douglas County is over 10 inches.

9.1.2 Legal Right to Use Precipitation

- Current law in Colorado requires 100% of any precipitation captured for later use to be replaced to the stream system in quantity, time, and place.
- There are two statutory exceptions (for streambed reservoirs and gravel pit ponds) which allow "credit" to be taken for the portion of the precipitation that did not historically reach the stream system, due to evapotranspiration (ET) and sublimation.
- For the two statutory exceptions, the Division of Water Resources generally accepts an ET credit of 70% of the total precipitation and will accept higher ET credits when supported by appropriate engineering documentation.
- For rainwater harvesting to become a viable component of water supply planning, legislation would need to be enacted defining the circumstances under which precipitation capture, including appropriate credit for historic patterns of native vegetation ET, could be implemented, taking into consideration adequate balancing and control mechanisms to protect other valuable state resources.

9.1.3 Precipitation Water Budget under Pre-Developed Conditions

To expand the ability to use ET Credits beyond the two statutory exceptions (for streambed reservoirs and gravel pit ponds), an algorithm is needed to quantify the portion of the total precipitation that falls over an undeveloped site but does not reach the stream system, and therefore could be used in new ways without injuring existing water rights).

- Of the total precipitation that falls on undeveloped lands, a portion runs off the land as surface water runoff, a portion is used to satisfy native vegetation ET and sublimation requirements, and the remainder deep percolates to the groundwater aquifer (i.e., groundwater recharge). This relationship is described by the following equation:

$$\text{Total Precipitation} = \text{Runoff} + \text{Native Vegetation ET \& Sublimation} + \text{Deep Percolation} + \text{Change in Soil Moisture} \quad (1)$$

- Research was conducted of various scientific methods to calculate variables in equation (1). We conclude that application of the following equations reasonably reflects the destination of precipitation on undeveloped lands.

Runoff – The Soil Conservation Service (SCS) Curve Number Method was selected to estimate daily runoff from an undeveloped site.

- Application of the SCS Curve Number methodology for the study area shows that for the period of 1950 through 2004, the average annual runoff is equivalent to 2% of the annual precipitation (0.03 acre-feet per acre). The maximum runoff in a wet year (1969) was 12% (0.28 acre-feet per acre) and the minimum runoff in a dry year (1956) was 0%.

Native Vegetation ET & Sublimation – During the growing season, the modified Blaney-Criddle method, with an elevation adjustment, was selected to estimate the monthly ET from native vegetation (based on potential consumptive use of pasture grass). During the non-growing season, up to 38% of the total monthly precipitation was made available to recharge the soil moisture reservoir; the remainder was considered to be runoff, evaporation, or sublimation.

- The combined growing season and non-growing season study area results show that for the period of 1950 through 2004, the average ET and sublimation is equivalent to 97% of the total precipitation (1.4 acre-feet per acre). The maximum ET and sublimation in a wet year (1969) was 85% (2.0 acre-feet per acre) and the minimum ET and sublimation in a dry year (1956) was 100% (0.89 acre-feet per acre).

Deep Percolation – A monthly water balance approach was used to estimate deep percolation as total precipitation less the sum of runoff and native vegetation ET and sublimation.

- Study area results show that for the period 1950 through 2004, the average deep percolation is equivalent to 1% of the total precipitation (0.01 acre-feet per acre). The maximum deep percolation in a wet year (1969) was 3% (0.07 acre-feet per acre) and the minimum deep percolation in a dry year (1956) was 0%.
- To maintain the water supply that existing water rights have relied upon, if precipitation is captured and used, the historical runoff and deep percolation amounts would need to be

replaced in quantity, time, and place. The runoff and water budget analysis shows that for the period of 1950 through 2004, the average annual return flow to the stream was 3% (2% from runoff and 1% from deep percolation). The maximum return flow to the stream in a wet year (1969) was 15% (12% from runoff and 3% from deep percolation) and the minimum return flow in a dry year (1956) was 0%. This means that for previously undeveloped areas within the study area of northwest Douglas County, on average, only 3% of the annual precipitation historically returned to the stream system via surface water and groundwater return flows.

- We conclude that current law is very conservative in protecting existing water supplies: for every acre-foot of precipitation captured, one acre-foot of replacement water must be acquired and returned to the stream. Our scientific literature review shows that for new developments, where runoff from impervious areas is not already part of the water supply to existing water rights, the average leverage potential of rainwater harvesting is on the order of 28 fold. In other words, for every acre-foot of replacement water available, one could capture and use 28 acre-feet of precipitation on the average without injury to the water supply of existing water rights.

9.1.4 Outdoor Water Demand Management

- There are a multitude of factors that affect outdoor water demands. The literary review and interviews identified five main coefficients that combine to evaluate a holistic approach to outdoor water demand: 1) irrigated area, 2) landscaping, 3) system performance, 4) water management, and 5) provider commitment and public acceptance. These factors are combined into an algorithm as defined by equations 10, 11, and 12, to calculate the total outdoor water demand.

$$\text{Outdoor Water Demand} = \text{Turf Demand} + \text{Planting Demand} \quad (10)$$

$$\text{Turf Demand} = \frac{[(\text{Ref ET} \times \text{Turf Coeff}) - \text{Water Management}]}{\text{System Performance}} \times \text{Irr Acres} \quad (11)$$

$$\text{Planting Demand} = \frac{[(\text{Ref ET} \times \text{Planting Coeff}) - \text{Water Management}]}{\text{System Performance}} \times \text{Irr Acres} \quad (12)$$

- Reducing the irrigated area of landscaping (turf and plants) can save 57% of the outdoor water demand of a traditional northwest Douglas County water demand.
- Changing turf and plantings to more water conservative options can reduce outdoor water demand by 34% while still maintaining the “look” of a traditional outdoor water demand lot.
- Irrigation system performance, like installing a subsurface drip irrigation system and maintaining it in excellent condition, can save 52% more water than a spray irrigation system that is poorly maintained.
- Using water controlling technology allows for water management savings of 34% over a standard irrigation controller.

- Provider commitment and public acceptance is the filter the other water management coefficients must pass through before true water savings can be realized. The report presents several areas to consider when analyzing the effectiveness of the provider's commitment and the public's acceptance.
- Using Douglas County total water demand criteria and a traditional landscaping plan, a lot density of 3.8 units per acre is achieved.

9.1.5 Rainwater Harvesting

This study focuses on the use of local (residential) cisterns to store and regulate precipitation to meet outdoor demands. In certain situations, other storage options such as regional cisterns, regional infiltration ponds, or modified detention/retention facilities may prove to be more advantageous from a management, maintenance, and cost perspective.

- **Water Quality** – Gutter leaf screens, first flush devices, cistern liners, and sand filter traps can be incorporated with cisterns to maintain good water quality.
- **Capture Efficiency** – Precipitation capture efficiencies were cited ranging from 75 percent to 95 percent, depending on the system design and capacity; an average of 85 percent was used for the examples in this study.
- **Cistern Sizing** – The literature suggests using a water budget approach for system sizing, where the monthly supply is compared to the monthly demand. Ultimately, sizing comes down to an economic decision: whether to install a larger, more costly cistern to capture the maximum possible amount or to install a smaller, less expensive cistern and capture only a portion of the available precipitation.
 - For a typical residence with a 1,500 square foot capture area and an 85% capture efficiency, a 5,000-gallon cistern results in around 10,000 to 16,000 gallons of precipitation captured (depending on the landscape demand and the rate at which precipitation is withdrawn from storage) over an average season, almost 85% of the total precipitation.
- **Costs** – Costs to install rainwater harvesting systems depend on the type of system, degree of filtration, and distance between the storage container and the place of use.
 - The storage vessel is typically the most expensive component in the system. Research indicates a 1,000-gallon capacity cistern costs around \$5.50 to \$6.50 per gallon installed, while a 5,000-gallon capacity cistern costs around \$2.00 to \$2.40 per gallon.
- **Useful Life** – The storage tanks have an average life of around 30 years, while the pumping equipment has a life of approximately 5 years.

9.1.6 Combining Rainwater Harvesting with Outdoor Water Demand Management

Potential water savings from implementing rainwater harvesting and outdoor water demand management were considered for new residential users and existing well users.

New Residential – The base residential outdoor water demand was estimated at 0.35 acre-feet per year for a traditional landscaped yard, and precipitation capture was based on a 1,500 square foot roof capture area with a 5,000-gallon cistern. The outdoor water demand may vary based on the local water provider's criteria. Potential water savings from implementing rainwater harvesting and outdoor water demand management for moderate and water wise conservation scenarios are summarized below:

- Outdoor water demand management practices alone, as compared to traditional landscaping practices, can produce an average savings in water of approximately 53% (0.19 acre-feet per residence) under a moderate conservation scenario and 76% (0.27 acre-feet per residence) for a water wise scenario.
- Rainwater harvesting has the potential of supplying approximately 12% (0.04 acre-feet per residence) of the traditional landscaping demand, approximately 26% of a moderate conservation scenario demand, and approximately 50% of a water wise scenario demand.
- Combining outdoor water management with rainwater harvesting, as compared to traditional landscaping demand without cisterns (0.35 acre-feet per year), has potential potable water savings of 65% (0.23 acre-feet per year) for a moderate conservation scenario and 88% (0.31 acre-feet per year) for a water wise conservation scenarios.
- The study example shows traditional landscape demands are on the order of 0.35 acre-feet per residence – a water supply of 350 acre-feet is needed for a 1,000-home development. Based on an estimated total cost to purchase water rights and provide regulatory storage at \$22,000 per acre-foot, implementation of rainwater harvesting and outdoor water demand management to a 1,000-home development represents the following savings in water supply acquisitions:
 - A moderate conservation scenario requires approximately 120 acre-feet, a 230 acre-foot savings, which represents about \$5.1 million dollars in savings.
 - A water wise scenario requires approximately 40 acre-feet, a 310 acre-foot savings, which represents about \$6.8 million dollars in savings.

Existing Well Users – Results of implementing rainwater harvesting and outdoor water demand management to existing well users show the following:

- For well users in areas determined to be non-tributary, every gallon of precipitation captured and used for outdoor landscape irrigation is one less gallon pumped from the non-tributary aquifer. For a typical single family home with a 1,500 square foot roof capture area and a 5,000-gallon cistern, this represents about 13,800 gallons per year savings. For 1,000 wells, this represents about 42 acre-feet per year less pumping.
- Even under current Colorado law, rainwater harvesting could be a viable option for non-tributary well users because of reusable return flow credits from indoor uses. Typical return flow credits from indoor use are estimated to average 86,000 gallons per year, while

augmentation requirements for rainwater harvesting would approximate 16,000 gallons per year under current law.

- For domestic exempt well users currently limited to indoor use only, rainwater harvesting represents a potential water supply for fire storage and outdoor water uses. An augmentation plan would be required to replace captured precipitation; either 100% under current law (16,000 gallons/year), or something far less if precipitation ET credits were allowed (approximately 500 gallons/year).

9.1.7 Augmentation Plans

- Under current law, it is possible for a water user to capture precipitation for beneficial use. However, 100% of the precipitation captured would have to be replaced to the stream. This full replacement requirement makes utilizing precipitation capture impracticable in most situations, with the possible exception of non-tributary well users.
- If legislation was passed that allowed, in certain circumstances, the capture of precipitation, the calculation of the amount of such precipitation that had historically accrued to the stream, and for credit to be assigned for that amount of precipitation that did not historically accrue to the stream, rainwater harvesting could become a viable component of sustainable water supply planning, particularly in areas such as Douglas County where renewable surface supplies are very limited.

9.2 RECOMMENDATIONS

1. We recommend that statutory law be crafted to allow precipitation capture and use with augmentation requirements based on maintaining the amount, timing, and location of historical runoff and deep percolation, which is the water supply for existing water rights. The law would require a water court application for an augmentation plan to provide a forum to allow existing water right owners to evaluate the details of the augmentation plan and impose terms and conditions to protect the historical yield of their water rights.
 - Colorado's current law is constraining the ability of its citizens to use available water resources in the state by requiring 100% of captured precipitation to be augmented, even though studies show a large percent does not contribute to the stream or aquifer system.
 - Colorado currently has two statutory laws that recognize not all precipitation contributes to stream flows and allows the use of historically consumed precipitation by native vegetation to offset evaporation augmentation requirements for streambed reservoirs and gravel pit ponds.
2. We recommend the water budget algorithms presented in Chapter 4 be the basis for determining the augmentation requirements for a water court application to capture and use precipitation, where:
 - Total daily precipitation is based on the nearest active representative climate station.
 - Runoff is determined on a daily basis using the SCS Curve Number Method.

- Native vegetation ET and sublimation is determined on a monthly basis, using the Modified Blaney-Criddle Method for the growing season and findings from the Greb study for the non-growing season.
- Deep percolation is determined on a monthly basis as the residual in the water balance equation: $\text{Deep Percolation} = \text{Total Precipitation} - \text{Runoff} - \text{Native Vegetation ET/Sublimation}$.
- Delayed ground water return flows are determined using an appropriate groundwater model such as the Glover Method for alluvial areas with a groundwater table and MODFLOW for areas outside the stream alluvium.

Other more detailed methods may also be appropriate where data are available.

3. Policy makers may want to consider first authorizing a pilot project to verify and/or calibrate the calculated results from the recommended algorithms above. The pilot project could be used to work out many of the detail issues that may arise in a water court application to use rainwater harvesting. Variables such as rainfall intensity versus runoff and winter consumption are two potentially contentious issues that may be raised in a water court application. A pilot project would also provide an opportunity to evaluate how cisterns or other rainwater collection systems are constructed and operated.
4. We recommend Douglas County and other counties/municipalities consider approval of the algorithms in Chapter 5 for computing outdoor water demands, under various water conservation alternatives, in determining water supply requirements for new developments. For Douglas County, we recommend this be an approved methodology in the appeal process to using the standard minimum of 0.75 acre-feet per year per residence.
 - Decision makers at the County may want to first consider authorizing a pilot project be conducted to verify and/or calibrate the calculated results from the recommended algorithm in Chapter 5.
 - Alternatively, a safety factor, such as 10% to 20%, could be applied to calculated outdoor water demands, with residential data collected to verify and/or calibrate the calculated results from the recommended algorithm for future developments.

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Appendix A – Summary of Previous Case Law

Southeastern Colorado Water Conservancy Dist. v. Shelton Farms, Inc., 529 P.2d 1321 (1974)

Facts

Shelton owned about five hundred acres of land on the Arkansas River. He cleared two land areas of phreatophytes and filled in a third marshy area; by doing this he claimed that approximately four hundred and forty-two acre-feet of water per year was now available for beneficial use. Shelton's plan was to use the water salvaged from phreatophyte eradication to augment his water rights for eight previously decreed wells. The lower court awarded Shelton 181.72 acre-feet of water, free from the call of the river in recognition of his activities that saved water that otherwise would have been taken from the river by the plants or evaporation.

The companion appellee to this case, Colorado-New Mexico Land, Co., Inc., received a similar award of 181 acre-feet of water free from the call of the river. The facts in this case differ only because there was no plan for augmentation.

Appellees claimed their actions provided maximum utilization of water, protected vested water rights, and encouraged conservation and waste reduction. They also argued that their actions did not injure any other water rights because the water they claimed was unavailable for use anyway.

Objectors asserted the decrees violated Colorado's appropriation doctrine of "first in time, first in right." Further, existing case law in Colorado limits the doctrine of 'free from call' to waters which are truly developed and were never part of the river system.

Holdings

- In Colorado, one who adds to an existing water supply is entitled to a decree affirming the use of such water. Strong evidence is required to prove the addition of the water. The court distinguishes between "developed" and "salvaged" water. The former is new water not previously part of the river system, that is, it is imported or nontributary water. The latter is tributary water made available for beneficial use through elimination of waste. Only developed water can be made the basis of a right independent of the priority system.
- Court agreed with objectors and ruled that the waters salvaged by the removal of phreatophytes were subject to call by prior appropriators. The phreatophytes were water thieves (they grew up after the most senior water rights were appropriated and had been stealing water from the river for decades) and the thirsty men cannot step into their shoes.
- Can't substitute priority doctrine with lack of injury doctrine.
- Court acknowledges this is a legislative issue. **"No one on any river would be adverse to a schematic and integrated system of developing this kind of water supply with control and balancing considerations. But to create such a scheme is the work of the legislature..."** (1327)

1975 Statutory Amendment

In 1975, shortly after *Shelton Farms*, the General Assembly revised the definition of "plan for augmentation" to affirm that neither the salvage of tributary waters by eradicating phreatophytes nor the increase of runoff by making land surfaces impermeable provides an increased supply of water that may be utilized to support a plan for augmentation. C.R.S. §37-92-103(9).

R.J.A. v. Water Users Ass'n of Dist No.6, 690 P.2d 823 (1984)

Facts

R.J.A. operates a summer resort business on property south of Estes Park, CO. The land originally included a twenty-seven-acre peat moss marsh which was approximately three thousand years old and comprised the headwaters of Tahosa Creek.

R.J.A. removed the peat moss, drained the marsh and converted it to a meadow. RJA then sought a developed water right outside of the priority system based on reducing the consumptive use of water formerly lost to evaporation in the marsh. R.J.A. argued that because peat bog pre-existed all water rights, there was not a water "thief" issue as there was in *Shelton*.

Holdings

- Lower Court's ruling denying claim for a water right was upheld.
- Reduction of consumptive use of tributary water cannot provide basis for a water right that is independent of the system of priorities on the stream.
- Court comes to same conclusion reached under *Shelton Farms*: that under prior case law no person has been granted a water right free from the call of the river for water which has always been tributary to a stream.
- Emphasis on environmental balancing: "the waters of Colorado belong to the people, but so does the land. There must be a balancing effect, and the elements of water and land must be used in harmony to the maximum feasible use of both."
- **Court reemphasized a legislative scheme that provides control and balance:** "The water rights sought here are based upon alterations of long existing physical characteristics of the land. Alteration of natural conditions and vegetation in order to save water carries with it the potential for adverse effects on soil and bank stabilization, soil productivity, wildlife habitat, fisheries production, water quality, watershed protection and the hydrologic cycle. Whether to recognize such rights, and thus to encourage innovative ways of reducing historical consumptive uses by modifying conditions found in nature, is a question fraught with important public policy considerations. As such, the question is especially suited for resolution through the legislative process." (828).

Giffen v. State, 690 P.2d 1244 (1984)

Facts

The applicant sought approval from the water court for a plan for augmentation that included a proposed developed water right. The applicant based his claim to a developed water right on a proposal to reduce water lost to the atmosphere by replacing trees on his property with less water-consumptive grasses. He again relied upon “old” vegetation to eliminate the water thief argument. The applicant’s plan would have resulted in a net gain to the stream, so there was no injury to other water rights. The water court granted the objectors’ motion for summary judgment and denied the applicant’s request.

Holdings

- For reasons given in *R.J.A., Inc.*, reduction of consumptive use of tributary water cannot provide the basis for a water right that is independent of the system of priorities. Such reductions cannot be considered “development of new sources of water” as part of a plan for augmentation pursuant to C.R.S. § 37-92-103(9).
- Contrary to applicant’s assertion, the water saved is clearly tributary ground water under the relevant statutes. Tributary ground water consists of “that water in the unconsolidated alluvial aquifer of sand, gravel, and any other sedimentary materials, and all other waters [under the surface] hydraulically connected thereto which can influence the rate or direction of movement of the water in that alluvial aquifer or natural stream.” C.R.S. § 37-92-103(11).
- Applicant’s argument that trees are not phreatophytes and that the legislature impliedly condoned removal of non-phreatophytes failed (court concluded that the legislature did not provide that a reduction in a consumptive use of tributary water by the removal of non-phreatophytic vegetation could have been a basis for a developed water right outside of the priority system).

State Engineer v. Castle Meadows, Inc., 856 P.2d 496 (1993)

Facts

The issue in these consolidated cases was whether other water rights will be injured by post-withdrawal stream depletions that will result from the applicants’ pumping of not nontributary Denver aquifer groundwater. Castle Meadows obtained a decree in April of 1987, enabling it to make annual withdrawals of 2,990 acre-feet of not nontributary groundwater through its Denver aquifer wells provided Castle Meadows obtained judicial approval of an augmentation plan ensuring replacement of four percent of the amounts withdrawn annually pursuant to C.R.S. §37-90-137(9)(c).

In October of 1986, Castle Meadows filed an application in the district court seeking approval of such a plan. The district court determined the plan was sufficient and in December of 1988, entered a final judgment and decree entitling Castle Meadows to withdraw 2,990 acre-feet of Denver aquifer groundwater annually. However, this augmentation plan extended only to those years that water is actually pumped from the wells. Although, the court found that Castle Meadows withdrawals will have some continuing depletive effect on the tributary stream system after one hundred years, it did not require that water be replaced after withdrawals from the wells cease.

The State Engineer appealed contending that Castle Meadows' plan for augmentation did not satisfy §37-90-137 because it requires compensation be made for depletions accruing to a stream after ground water withdrawals cease. The case was remanded to consider whether pumping will cause injury. The water court found there would be post pumping depletions to the stream, but that those depletions would not be injurious because they would be offset by increased runoff attributable to urbanization (i.e., more impermeable surfaces and different plants).

Similarly, in the second case, Castle Pines sought an augmentation plan to replace depletions associated with pumping not nontributary Denver basin groundwater. The water court found that post-pumping depletions would be offset of the amounts of increased runoff attributable to urbanization. Thus, Castle Pines was not required to augment the stream system after withdrawals cease and it would satisfy its statutory obligation by replacing four percent of its annual withdrawals during the years in which water is withdrawn through the wells.

Applicants did not dispute that statute prevents use of runoff as a source of supply water for an augmentation plan. Rather, applicants say it was a factor in determining the overall impact of their pumping. The runoff was likened to a return flow that reduces the consumptive use of the withdrawn water and must be taken into account in assessing whether senior water rights will be injured.

Holdings

- Court said district court erred when it considered urban runoff as a factor in making determination that applicants need not include means of compensating for post-withdrawal stream depletions.
- It would contravene the purpose of the 1975 amendment to §37-92-103(9) to allow stream depletions to be offset by these anticipated increases in runoff with the result of circumventing the applicant's obligations to compensate holders of water rights for injuries that would otherwise occur.
- In C.R.S. § 37-92-102(1)(a), the legislature declared it is the policy of this state to integrate the appropriation, use, and administration of underground water tributary to a stream with the use of surface water in such a way as to maximize the beneficial use of all of the waters of this state. However, case law and the General Assembly have recognized that the countervailing interest of protection of vested rights must be given effect. Therefore, the goal of maximizing the use of our waters must sometimes yield to that interest and be implemented to ensure that water resources are utilized in harmony with the protection of other valuable state resources.
- Emphasis on legislative amendment of §37-92-103(9) prohibiting the removal of phreatophytes from constituting an augmentation plan. The fact that this amendment also prevents runoff water collected from land surfaces that have been made impermeable from serving as a source of augmentation means the legislature intended the analogous result of removing the incentive for persons to attempt to increase water supplies by replacing natural land conditions with impermeable surfaces.

Appendix B.1 – Monthly Precipitation Records for Kassler NOAA Climate Station (1950 through 2004)

Time Series Identifier = 4452.NOAA.Precip.Month
 Description = KASSLER
 Data source = NOAA
 Data type = Precip
 Data interval = Month
 Data units = IN
 Period = 1950-01 to 2004-12
 Orig./Avail. period = 1948-08 to 2006-03

Comments:

Station and time series information from HydroBase determined at time of query:

Time series identifier = 4452.NOAA.Precip.Month
 Description = KASSLER
 Data source = NOAA
 Data type = Precip
 Data interval = Month
 Data units = IN
 HydroBase query period = Query All
 HydroBase available period = 1948 to 2006
 Located in water div, district = 1, 8
 Located in county, state = JEFFERSON, CO
 Located in HUC = 10190002
 Latitude, longitude = 39.483334, -105.099998
 Drainage area = NA
 Non-natural contributing area = NA
 Elevation = 5586.94 FT

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1950	0.91	0.95	0.80	3.46	4.08	1.12	0.83	0.35	0.84	0.32	1.60	0.11	15.37
1951	0.84	1.25	1.82	1.43	2.10	1.81	2.49	1.90	0.69	1.66	1.02	0.14	17.15
1952	0.00	0.47	1.77	3.49	3.84	0.04	0.93	0.92	0.18	0.09	1.18	0.45	13.36
1953	0.47	1.16	1.51	1.86	2.92	1.16	2.08	0.94	0.10	0.35	0.51	1.51	14.57
1954	0.35	0.50	1.03	0.95	1.12	0.25	2.76	1.19	1.82	0.14	0.89	0.58	11.58
1955	0.22	1.02	1.25	1.27	6.27	1.45	2.48	3.35	0.89	0.46	0.36	0.18	19.20
1956	0.44	0.93	0.99	0.95	2.03	0.35	1.36	1.60	0.00	0.58	0.89	0.56	10.68
1957	0.40	0.58	0.96	4.10	5.46	2.28	1.47	0.89	0.93	2.22	1.14	0.16	20.59
1958	0.69	0.69	1.59	2.29	3.19	1.94	2.86	0.85	1.54	0.56	0.68	0.40	17.28
1959	1.35	1.01	2.81	1.89	3.10	1.39	0.60	0.93	2.66	2.93	0.71	0.56	19.94
1960	0.59	2.57	0.83	1.48	2.70	0.55	0.53	0.38	0.50	3.33	0.40	1.66	15.52
1961	0.27	1.15	2.01	1.23	3.41	1.46	2.66	1.73	5.15	0.84	1.41	0.26	21.58
1962	1.17	1.00	0.62	2.82	0.73	1.97	0.94	0.64	0.59	0.05	0.92	0.26	11.71
1963	0.72	0.36	1.24	0.04	0.97	2.71	0.51	2.39	1.59	0.66	0.74	0.97	12.90
1964	0.36	1.36	1.78	0.93	2.33	1.26	0.49	1.68	0.87	0.13	0.99	0.67	12.85
1965	0.85	1.18	2.00	2.30	1.27	4.05	3.94	2.61	2.95	0.42	0.43	0.64	22.64
1966	0.30	1.27	0.57	1.54	0.62	1.65	1.84	1.09	1.67	1.95	0.67	0.12	13.29

1967	0.72	0.65	0.58	3.70	4.22	4.06	2.45	1.32	1.56	1.91	1.25	1.41	23.83
1968	0.48	1.28	1.00	2.45	1.66	0.32	1.44	1.61	1.02	1.47	1.23	0.49	14.45
1969	0.31	0.36	1.47	0.64	9.64	3.51	1.76	1.64	0.25	6.49	1.04	1.00	28.11
1970	0.28	0.12	3.26	1.38	1.82	2.37	1.76	0.42	2.59	1.54	2.33	0.03	17.90
1971	0.39	1.45	0.90	4.56	2.76	0.79	1.07	0.82	3.31	0.67	0.43	0.38	17.53
1972	0.76	0.74	0.92	1.92	1.92	1.97	1.20	1.86	0.79	0.41	3.48	1.14	17.11
1973	1.44	0.13	2.23	4.23	7.96	0.39	1.57	0.10	3.12	1.31	0.63	2.00	25.11
1974	1.46	1.07	1.28	1.87	0.24	1.86	0.83	0.33	1.38	1.95	1.13	0.91	14.31
1975	0.42	0.61	0.82	1.70	3.38	2.46	0.82	1.87	1.09	0.73	2.31	0.15	16.36
1976	0.53	0.09	1.63	1.56	1.19	1.15	5.05	1.87	2.90	1.57	0.22	0.76	18.52
1977	0.15	0.51	0.71	2.66	0.58	1.68	4.31	1.75	0.07	0.60	0.88	0.38	14.28
1978	0.32	0.56	1.94	2.46	4.22	0.98	0.46	0.21	0.38	1.80	0.38	1.40	15.11
1979	0.84	0.39	3.27	1.91	4.45	2.72	0.66	2.75	0.63	1.39	1.79	1.20	22.00
1980	0.54	0.40	1.44	2.06	3.65	0.00	2.01	1.57	1.23	0.17	1.04	0.04	14.15
1981	0.02	0.59	2.25	0.72	3.55	0.84	1.81	1.13	0.58	1.51	0.49	0.85	14.34
1982	0.30	0.32	0.54	0.56	3.77	2.06	1.06	3.44	2.38	1.26	0.38	1.05	17.12
1983	0.19	0.17	5.64	2.30	3.60	3.82	2.21	1.48	0.22	0.08	3.24	0.87	23.82
1984	0.28	1.18	2.17	2.61	0.82	0.79	2.53	4.86	0.91	5.98	0.54	0.34	23.01
1985	0.52	0.87	1.06	2.70	1.56	1.54	2.37	0.62	2.87	0.44	1.98	0.72	17.25
1986	0.32	0.66	0.80	3.39	2.70	1.60	0.52	0.37	0.70	2.24	1.81	1.43	16.54
1987	1.65	1.80	1.39	1.52	4.85	2.51	0.90	2.29	0.31	1.99	2.43	2.14	23.78
1988	0.35	0.77	1.15	1.10	3.80	1.23	0.88	2.52	1.41	0.07	0.62	1.05	14.95
1989	0.75	0.47	0.74	1.49	2.92	2.92	1.50	1.10	2.19	1.24	0.05	0.97	16.34
1990	0.52	0.38	3.12	1.63	1.65	0.53	2.71	1.13	1.45	0.97	1.40	0.17	15.66
1991	0.77	0.10	0.37	1.58	3.76	2.86	2.74	1.81	0.71	0.99	3.37	0.00	19.06
1992	0.97	0.02	3.35	0.52	1.82	1.61	0.87	3.22	0.05	0.25	1.98	1.08	15.74
1993	0.34	0.77	1.20	2.71	2.20	2.13	0.56	1.01	2.68	2.77	1.44	0.36	18.17
1994	0.42	0.70	2.06	2.57	1.79	2.06	0.76	0.45	1.23	1.06	1.69	0.42	15.21
1995	0.39	0.61	1.99	4.73	5.50	2.70	0.72	1.40	2.69	0.50	0.87	0.16	22.26
1996	1.17	0.20	1.66	1.22	3.32	1.01	0.80	2.08	3.67	0.76	0.87	0.24	17.00
1997	0.37	1.30	0.69	3.77	0.74	2.21	1.59	3.35	2.82	3.27	1.53	1.16	22.80
1998	0.36	0.07	2.70	3.29	0.61	1.67	2.75	1.61	0.52	0.99	1.46	0.66	16.69
1999	0.35	0.32	0.44	6.10	2.79	1.15	1.54	3.88	0.90	0.77	0.48	1.48	20.20
2000	0.80	0.21	1.78	1.49	3.27	1.44	1.04	3.02	2.48	0.52	0.96	0.45	17.46
2001	0.38	0.74	0.64	1.46	3.88	1.21	0.99	2.21	1.66	0.23	1.12	0.64	15.16
2002	0.69	0.13	1.00	0.10	1.79	1.38	3.07	0.75	1.27	1.30	0.31	0.07	11.86
2003	0.18	1.16	7.52	1.38	1.06	1.94	0.41	1.20	0.44	0.36	0.44	0.67	16.76
2004	0.80	1.09	1.01	4.64	1.07	5.54	1.65	2.64	0.86	1.66	1.91	0.63	23.50

Notes:

Years shown are calendar years.

Annual values and statistics are computed only on non-missing data.

NC indicates that a value is not computed because of missing data or the data value itself is missing.

Appendix B.2 – Monthly Runoff Estimates in Inches, Summarized from Daily Runoff Analysis

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1950	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1953	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.80	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.85
1956	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.16	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.09	0.00	0.00	0.13
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.06
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.03	0.00	0.00	0.00	0.00	0.15
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03
1967	0.00	0.00	0.00	0.30	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.36
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	3.30	0.00	0.00	0.00	0.00	0.02	0.09	0.00	3.41
1970	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.01	0.00	0.06
1971	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.10
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04
1973	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.26
1977	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	1.05
1978	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
1979	0.00	0.00	0.08	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.16
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.08
1983	0.00	0.00	0.98	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.03	0.00	1.03
1984	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.07
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.19	0.39
1988	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.11
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.30
1992	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
1996	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.26
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.18
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	3.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.97
2004	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.04	0.00	0.00	0.00	0.00	0.14

Appendix C – Summary of Monthly Water Budget Under Pre-Developed Conditions

Total Precipitation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	10.6	14.8	31.6	39.5	52.7	34.3	30.6	30.8	27.0	24.7	21.8	12.9	331.5
Min Year	1956	8.4	17.8	18.9	18.2	38.8	6.7	26.0	30.6	0.0	11.1	17.0	10.7	204.3
Max Year	1969	5.9	6.9	28.1	12.2	184.4	67.1	33.7	31.4	4.8	124.2	19.9	19.1	537.8
Runoff	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.0	0.0	1.9	0.3	1.7	0.1	0.5	0.1	0.1	0.2	0.1	0.1	5.2
Min Year	1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max Year	1969	0.0	0.0	0.0	0.0	63.2	0.0	0.0	0.0	0.0	0.4	1.7	0.0	65.3
Potential Native Vegetation CU	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.0	0.0	0.0	37.9	78.1	117.4	147.3	126.9	81.0	41.6	0.0	0.0	630.2
Min Year	1956	0.0	0.0	0.0	43.8	95.3	147.6	146.5	127.4	94.6	55.3	0.0	0.0	710.5
Max Year	1969	0.0	0.0	0.0	53.5	86.5	95.0	151.7	136.4	90.4	15.4	0.0	0.0	629.0
Actual Native Vegetation CU	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.0	0.0	0.0	35.9	66.3	55.6	35.0	30.8	26.3	18.9	0.0	0.0	268.8
Min Year	1956	0.0	0.0	0.0	39.3	38.8	6.7	26.0	30.6	0.0	11.1	0.0	0.0	152.5
Max Year	1969	0.0	0.0	0.0	40.3	86.5	95.0	40.5	31.4	4.8	15.4	0.0	0.0	313.9
Winter Evaporation/Sublimation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	6.6	9.2	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	7.9	54.7
Min Year	1956	5.2	11.0	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	6.6	45.2
Max Year	1969	3.7	4.3	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	11.9	47.9
Unlagged Deep Percolation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.0	0.1	0.6	0.6	1.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.7
Min Year	1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max Year	1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	7.6	7.3	15.6
Augmentation Requirement =														
Runoff + Lagged Deep Percolation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.2	0.2	2.2	0.5	2.0	0.3	0.8	0.3	0.3	0.4	0.4	0.3	7.9
Min Year	1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max Year	1969	1.3	1.3	1.3	1.3	64.5	1.3	1.3	1.3	1.3	1.7	3.0	1.3	80.9
Change in Soil Moisture	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	4.01	5.53	11.38	2.63	-16.42	-21.37	-4.96	0.00	0.67	5.61	8.14	4.77	0.00
Min Year	1956	3.20	6.76	7.20	-21.08	0.00	0.00	0.00	0.00	0.00	0.00	6.47	4.07	6.62
Max Year	1969	2.25	2.62	10.69	-28.06	34.69	-27.89	-6.80	0.00	0.00	107.58	0.00	0.00	95.07

Notes: 230 acres = 1,000 (sq-ft) / 43,560 (sq-ft/acre) * 10,000 single family homes
All Values in Acre-Feet
Change in Soil Moisture = 0 for overall period; individual years may vary

Appendix D – Irrigated Area Calculation

D.1 Lot Size Review

This appendix includes development information for the Highlands Ranch, Roxborough Park, Roxborough Village, and The Meadows from the Douglas County demographer, Ms. Nancy Gedeon. These communities are all located in the northwest portion of Douglas County. The communities' density serve as a way to bound the lot density of 5 units per acre used for the study area. A summary of the densities are below.

Table D.1 – Community Density

Community	Density (units per acre)
Highlands Ranch	5.39
Roxborough Park	2.91
Roxborough Village	5.79
The Meadows	6.61

D.2 Irrigated Area Calculation

The lot area calculation for the study lot size of 5 units per area is included in this appendix. The lot area is calculated as a gross area and a net area. The net area is gross lot area reduced by 20% for roads. The calculation also calculates the irrigated area of the lot assuming 50% of the net lot area is available for landscaping.

Appendix E – Landscape Water Usage Estimates

E.1 Landscape Estimate Water Usage

Attached is the cover sheet and Appendix E from Green Industry Best Management Practices, May 2004. Appendix E provides a water usage estimate for plants based on a survey from horticulturists from around the Rocky Mountain Region. The landscape is divided into plant type and water usage. The categories for the landscape and water usage are summarized below.

Table E.1 – Planting Water Usage

Estimated Water Usage	Percentage of Reference ET
Very Low	<25%
Low	25-50%
Medium	50-75%
High	>75%

Table E.2 – Landscape Choices

1	Annual
2	Perennial
3	Tree
4	Vine
5	Ground Cover
6	Shrub
7	Turf

Appendix F – Water Demand Calculation

F.1 Water Demand Calculation

The water coefficients identified in Section 5.1 are summarized on the attached calculation. The base scenario for the Water Demand Calculation Algorithm is included to calculate the total water demand of 0.35 acre-feet per year for the base scenario. The coefficients for the base scenario and the algorithm equation are below.

Table F.1 – Traditional Landscape Outdoor Water Demand Scenario

	Coefficient	Sub Coefficient	Coefficient Description
1	Irrigated Area	Turf Irrigated Area	2,000 square feet
		Planting Irrigated Area	1,500 square feet
2	Landscaping	Turf	Bluegrass with Reference ET of 90%
		Planting	Traditional with Reference ET of 70%
3	System Performance	Application Method	Spray with an efficiency of 75%
		Operations Method	Good with an efficiency of 80%
4	Water Management	Technology	None used

F.2 Water Demand Calculation Algorithm

$$\text{Total Landscape Demand} = \text{Turf Demand} + \text{Plantings Demand}$$

$$\text{Turf Demand} = \frac{[(\text{Reference ET X Turf Coefficient}) - \text{Water Management}]}{\text{System Performance}}$$

$$\text{Planting Demand} = \frac{[(\text{Reference ET X Planting Coefficient}) - \text{Water Management}]}{\text{System Performance}}$$

Appendix G – Water Demand Sensitivity Analysis

G.1 Sensitivity Analysis of Water Demand Coefficients

This appendix identifies the sensitivity analysis for the water demand coefficients. The base scenario presented in Appendix C is used for the starting point of the analysis. An individual coefficient was varied while the remaining coefficients were held constant. Below is a summary of the water savings by coefficient.

Irrigated Area – A 57% reduction in water demand, from 0.35 acre-feet per year (ac-ft/yr) to 0.15 ac-ft/yr, when the landscape area was reduced. The turf area ranged from 2,000 square feet (sf) to 1,000 sf. The planting area ranged from 1,500 sf to 500 sf.

Landscaping – A 34% reduction in water demand, from 0.35 ac-ft/yr to 0.23 ac-ft/yr, when the landscape choices were reduced from bluegrass turf and traditional plantings to fescue turf and native plantings. The turf choices were bluegrass, fescue, and buffalograss. The planting categories were traditional, moderate, and native water usage. A 48% reduction in water demand is obtained from bluegrass turf and traditional plantings to buffalograss turf and native plantings. There is some question on whether this options would be marketable, so it was not considered.

System Performance – A 52% reduction in the water demand, from 0.46 ac-ft/yr to 0.22 ac-ft/yr, when the water application method was varied using spray, rotor, and subsurface drip irrigation. The water usage was highly influenced by the efficiency of the operation and maintenance excellent, good, or poor of the irrigation system.

Water Management – A 34% reduction in the water demand, from 0.35 ac-ft/yr to 0.23 ac-ft/yr, when the water management was used to adjust the water supply for the effective precipitation. Technology is used to adjust the watering cycles of the irrigation system using active, passive, or no technology.

Appendix H – Douglas County Water Demand Calculation

H.1 Douglas County Base Scenario

The attached slide and calculation (Attachment H) determine the outdoor water demand and lot size using the Douglas County water demand criteria of 0.75 acre-feet per year and the Water Demand Calculation Algorithm.

Appendix I.1 – Water Use Scenarios

I.1 Water Use Scenarios

The attached slide and calculations (Attachment I) determine the outdoor water demand using the Water Demand Calculation Algorithm.

Appendix I.2 – Moderate Conservation Example for New Residential Development

Total Precipitation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	1.4	1.6	5.7	7.5	7.0	4.9	3.7	5.5	5.3	3.3	2.9	1.6	50.5
Dry Year	2002	2.0	0.4	2.9	0.3	5.1	4.0	8.8	2.2	3.6	3.7	0.9	0.2	34.0
Wet Year	1999	1.0	0.9	1.3	17.5	8.0	3.3	4.4	11.1	2.6	2.2	1.4	4.2	58.0
Precipitation Captured	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	1.2	1.4	4.2	6.4	6.0	4.2	3.2	4.6	4.5	2.8	2.5	1.4	42.3
Dry Year	2002	1.7	0.3	2.4	0.2	4.4	3.4	7.5	1.8	3.1	3.2	0.8	0.2	28.9
Wet Year	1999	0.9	0.8	1.1	14.9	6.8	2.8	3.8	9.5	2.2	1.9	1.2	3.6	49.3
Total Landscape Demand	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.0	0.0	0.0	19.3	22.2	28.2	31.3	26.1	20.9	16.4	0.0	0.0	164.4
Dry Year	2002	0.0	0.0	0.0	25.6	21.9	30.7	30.9	25.9	20.3	13.7	0.0	0.0	169.0
Wet Year	1999	0.0	0.0	0.0	14.5	22.4	26.5	28.8	22.2	17.2	16.1	0.0	0.0	147.7
Total Landscape Demand Met by Precipitation	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.0	0.0	0.0	14.0	7.4	5.3	3.2	4.7	4.6	2.2	0.0	0.0	41.4
Dry Year	2002	0.0	0.0	0.0	9.0	4.4	3.4	7.5	1.8	3.1	2.8	0.0	0.0	31.9
Wet Year	1999	0.0	0.0	0.0	14.5	15.1	2.8	3.1	10.1	2.2	1.9	0.0	0.0	49.7
Deficit Needing to be Made Up	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Study Period Average	Average	0.0	0.0	0.0	5.3	14.8	22.8	28.1	21.5	16.3	14.2	0.0	0.0	123.0
Dry Year	2002	0.0	0.0	0.0	16.7	17.5	27.3	23.4	24.1	17.2	10.9	0.0	0.0	137.1
Wet Year	1999	0.0	0.0	0.0	0.0	7.3	23.7	25.7	12.1	15.0	14.3	0.0	0.0	98.0

Notes: Moderate - 1500 sf of Low Maintenance Grass and 1000 sf of Low Maintenance Landscaping - 1,000 single family homes
All Values in Acre-Feet

ATTACHMENT A

CWCB GRANT PROPOSAL

Dominion Water and Sanitation District
1546 Cole Boulevard, Suite 227
Golden, CO 80401

January 27, 2005

Ms. Genoveva McCaig
Section Chief
Conservation and Drought Planning Section
Colorado Water Conservation Board
1313 Sherman Street, 7th Floor
Denver, CO 80203

Re: Water Efficiency Grant Program Application:
Dominion Water and Sanitation District/Castle Pines North
Metropolitan District/Douglas County

Dear Ms. McCaig:

Pursuant to C.R.S. § 37-60-126 creating a grant program for certain water conservation and drought mitigation planning activities, Dominion Water and Sanitation District (Dominion) and Castle Pines North Metropolitan District, each located in Douglas County, Colorado, and Douglas County submit this innovative HB05 1254 Water Efficiency Grant Program Application. It is intended to substitute for the earlier application submitted to this office on December 28, 2005. Specific details of these three organizations are found in Attachment A of this submittal. Dominion, Castle Pines North, and Douglas County believe that the outcome of this study and the implementation of a total water management approach will be of unique benefit not only to existing well users of Douglas County and related existing residential and commercial development, but also to new planned development.

Dominion, Castle Pines North, and Douglas County are committed to promoting sustainable development coupled with the efficient use of water resources in Douglas County. Dominion, Castle Pines North, and Douglas County are supported in this effort by a number of other organizations and governmental entities. As part of their overarching philosophy, the Districts and the County would like to pursue three potential water saving strategies to minimize outside water usage: 1) water efficient landscape plantings; 2) irrigation system efficiency audits; and 3) precipitation management. The outline of this project is found in Attachment B of this submittal.

Dominion, Castle Pines North, and Douglas County are seeking a \$47,500.00 matching grant to achieve these purposes for a twelve-month period. The matching funds from Dominion, Castle Pines North, and Douglas County will take the form of direct funds for outside engineering and other professional consultants, in-kind contributions of staff time, and in-kind contributions of facilities with a combined value exceeding \$47,500.00. Other supporting

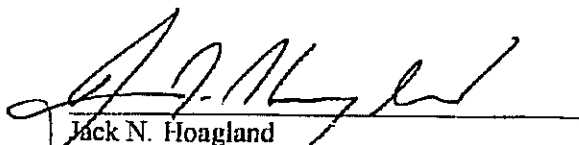
entities and organizations may provide additional funding for the study, which will be noted in the report.

The study results and findings will be subject to a two-part review process: 1) review by a panel of stakeholders representing agricultural water users, municipal and special district water suppliers, and elected and appointed local government officials; 2) a peer review process by staff of the Water Conservation Board and the Division of Water Resources.

We understand that under HB05 1254, the covered entity applying for a Water Efficiency Grant should have a locally adopted Water Conservation Plan with defined goals in the Plan that are in accordance with C.R.S. § 37-60-126. We request that you approve this grant application conditional to Castle Pines North Metropolitan District submitting a Water Conservation Plan to CWCB for review. Upon receiving this conditional approval, we will begin early phases of this study. However, we will not submit invoices until all conditions of the approval have been satisfied.

As previously referenced, specific application information is appended to this document. On behalf of Dominion Water and Sanitation District, Castle Pines North Metropolitan District, and Douglas County, we look forward to working with you and the staff of the Colorado Water Conservation Board on this important project.

Sincerely,



Jack N. Hoagland
For Dominion Water and Sanitation District,
Its President

Mark Shively
President, Board of Directors
Castle Pines North Metropolitan District

Peter Italiano
Director of Planning
Douglas County

Cc: Carolyn F. Burr, Ryley Carlock & Applewhite
Carmine J. Iadarola, AquaSan Network
Shayne M. Madsen, McKenna Long & Aldridge

Gordon Meurer, Meurer & Associates
Greg Roush, Leonard Rice Engineers, Inc.

Attachment A
HB05 1254 Water Efficiency Grant Program Application Submittal

Name and Contact Information of Joint Applicants Seeking Grant

Dominion Water and Sanitation District
1546 Cole Boulevard
Lakewood, CO 80401
Contact: Harold R. Smethills
303.202.6800
hsmethil@ix.netcom.com

Castle Pines North Metropolitan District (covered entity for grant administration)
Contact: Jim McGrady
7404 Yorkshire Drive
Castle Rock, CO 80108
Contact: Jim McGrady
303.688.8550
jmcgrady@cpnmd.org

Douglas County
100 Third Street, Suite 220
Castle Rock, Colorado
Contact: Peter Italiano
303.660.7460

Organizations Responsible for Performing the Project

The study will be conducted by Leonard Rice Engineers, Inc. (LRE) and Meurer & Associates, two Denver-area engineering firms. LRE will concentrate on refining evapotranspiration data while Meurer will focus on the infrastructure required for rainwater conservation. Both firms will make extensive use of existing research and data. LRE will be responsible for developing the water balance algorithms and sample augmentation plans as well as summarizing the study for the Colorado Water Conservation Board.

Leonard Rice Engineers, Inc.
2000 Clay Street, Suite 300
Denver, CO 80211
Attention: Greg Roush
303.455.9589
roush@lrcwe.com

Meurer & Associates
143 Union Boulevard, Suite 600
Lakewood, CO 80228
Attention: Gordon C. Meurer
303.985.8738
gmeurer@meurer.com

Water Delivery Information

Dominion Water and Sanitation District

Dominion Water and Sanitation District is a Title 32 Special District authorized to provide water and wastewater services to other water districts and municipalities in northern Douglas County. As the only Douglas County-based regional wholesale water district, Dominion is committed to providing water and wastewater services in the most environmentally sustainable manner possible.

Current projections suggest that Dominion will provide over 3,000 acre-feet to planned development, as well as to its neighbors the existing single-family home well users in northwest Douglas County. The existing well users are drawing from heavily stressed aquifers, a non-renewable resource. Dominion is at the forefront of the effort to provide renewable water for Douglas County, a need indicated by both the County's Master Plan and the recent South Metro Water Supply study.

It is Dominion's intent that all planned new development include conservation measures such as suitable landscaping, water-efficient fixtures, innovative stormwater management techniques, and other practices such as those planned for evaluation by this study. Dominion believes that rainwater management techniques may prove to provide a unique benefit to existing well users as well as to new development.

Castle Pines North Metropolitan District

The Castle Pines North Metropolitan District (District) is planning to develop a Water Conservation Plan (Plan). The Plan will be developed in accordance with the recommendations outlined in the Colorado Water Conservation Board's (CWCB) Water Conservation Plan Development Guidance Document.

The following information is taken from an Amendment to an application for grant monies offered by the CWCB for the development of a Conservation Plan (the Characterization of the Water System).

1.0 Characterization of the Water System

1.1 Historical water demands

Historical demand data are not available. These data were lost when the District changed their billing system in 2004. Historical annual demands were estimated with well production data, as presented in the grant application and in this document.

1.2 Calculations/equations/variables used to determine demands

Per capita water demands have been refined in response to CWCB's request. The refined estimates presented in this Amendment include residential, school employees, commercial employees, and traffic (customers from outside the service area using commercial services). The District conducted a survey finding that employment population in 2005 totaled 458 people. Assuming a traffic flow of 100 people, the total employment and traffic population was 558

people in 2005. Historical employment and traffic values were estimated by multiplying the estimated fraction of development in each year by the 2005 employment/traffic population (Table 1).

There is an average of 2.88 people per household in Douglas County (U.S. Census Bureau, February 2006). The number of people living in the service area was determined by multiplying 2.88 by the number of houses built in given year. These data are provided in Table 1 of the grant application.

Table 1. Estimated population for commercial, schools, and customer traffic

Year	Level of Development	Employee and Traffic Population
1998	Two schools	125
1999	Two schools	125
2000	One third of 2005 commercial development and two schools	267
2001	Two thirds of 2005 commercial development and two schools	440
2002	All of 2005 commercial development and two schools	498
2003	All of 2005 commercial development and three schools	558
2004	All of 2005 commercial development and three schools	558
2005	All of 2005 commercial development and three schools	558

Figure 1 shows the estimated per capita water demands for calendar years 1998 through 2005. As shown in the equation below, per capita demands were estimated by dividing potable system water demands (i.e., total well production minus water used by the Ridge Golf Course) by the total population. The total population includes employment in the school and commercial sector, traffic, and residents.

$$\text{Per capita demands} = \frac{\text{Total annual well production} - (\text{Annual golf course irrigation well production})}{\text{Total population}}$$

Figure 2 provides further explanation of the District's water production. Annual water production may be partitioned into reuse on the Ridge Golf Course, well production for the Ridge Golf Course, and well production for the remainder of the service area. The Ridge Golf Course usage is not incorporated into the per capita demands.

Figure 1. Per Capita Water Demands

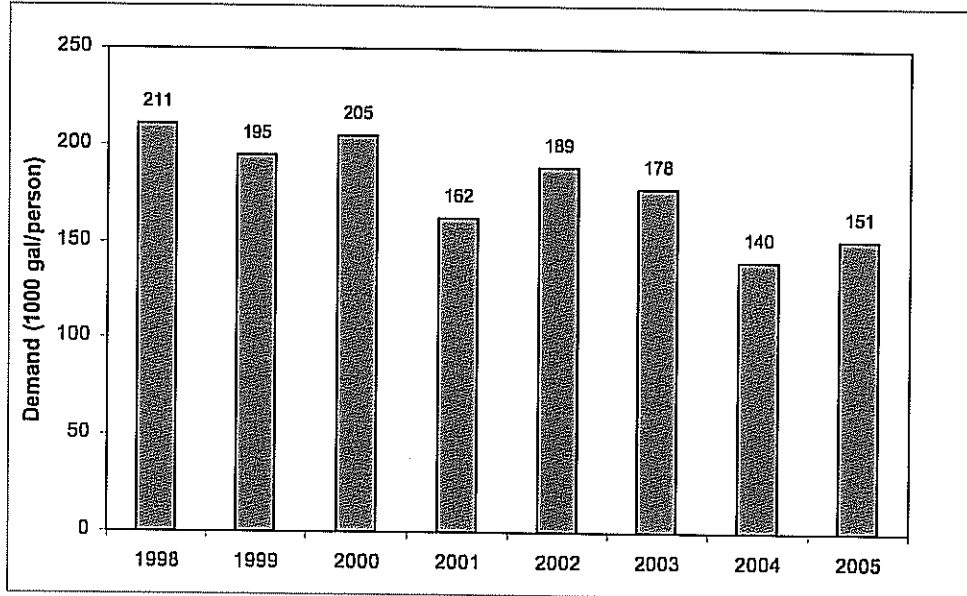
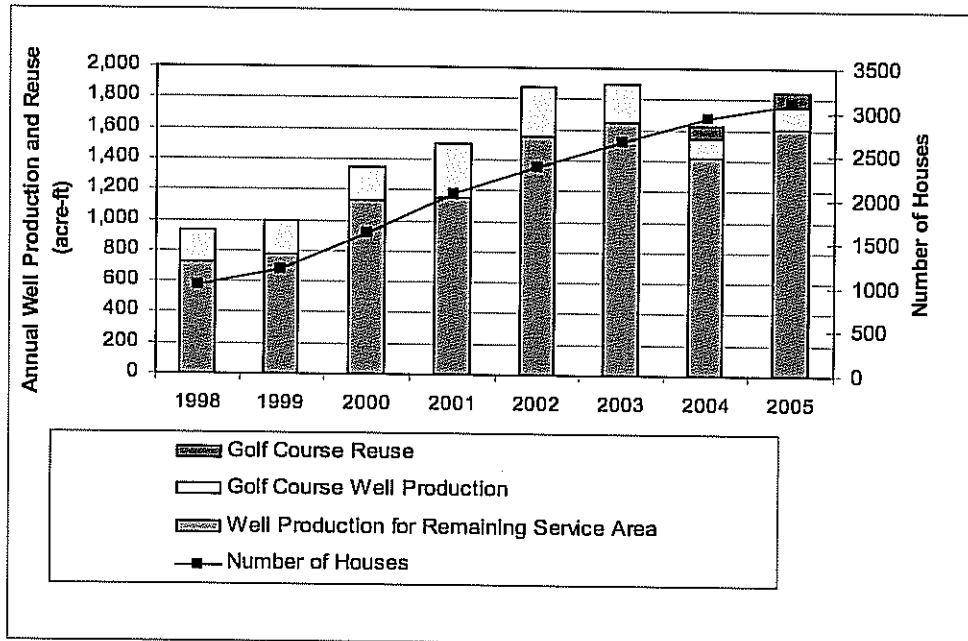


Figure 2. Annual Water Production



1.3 Water Use by Customer Type

As previously discussed, historical billing data are not available to differentiate historical water use by customer type. However, some 2003 metered data are available through a study conducted on 2003 water demands by Jehn Water Consultants, Inc. Table 2 provides 2003 water demands per customer type and Figure 3 shows the percentage of 2003 water demands using values from that study.

Table 2. Water Use by Customer in 2003

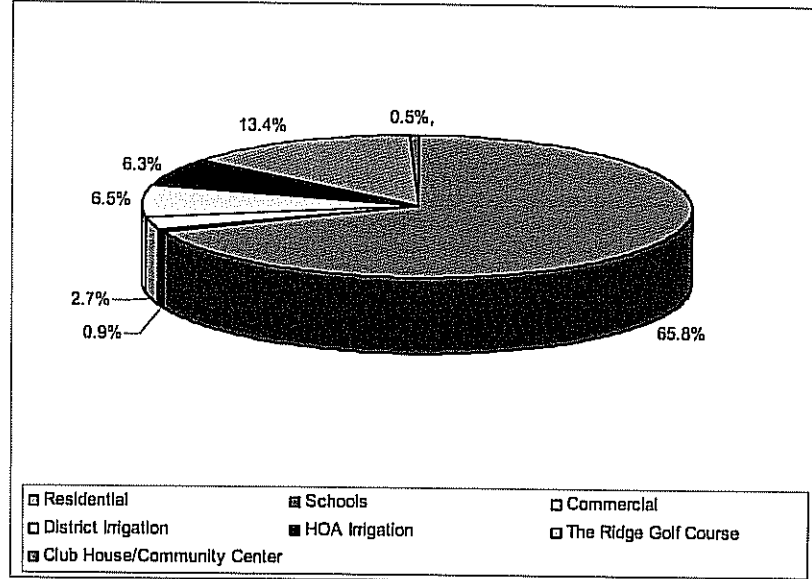
Type of Water Use	Demand (acre-ft)	Calculations
Residential	1,248	Difference of well production and all other water uses
Schools	16	Product of number of schools, students, and water usage/student/year
Commercial	52	Metered
District Irrigation	123	Metered
HOA Irrigation	119	Metered
The Ridge Golf Course	254	Metered
Club House/Community Center	9	Sum of water usage by 3 residential pools, 7 clubhouse pools including showers, and use of community center – Results of 2003 Demand Study by Jehn Water Consultants, Inc

Total Demand = 1,821 AFY

Assumed unaccounted water of 4% = 76 AFY

Total = 1,897 AFY

Figure 3. Water Demands in 2003



1.4 Rebates

The District began to provide rebates for a variety of retrofits in 2003. Water savings for the low flow toilets, low usage washers, and irrigation clocks are indicated in Table 3.

Table 3 Water Savings of Retrofits

Retrofit	Rebate	2003		2004		2005		Average Savings from 2003-2005 (1000 gal/yr)	Calculations	Assumptions
		Number Rebates	Savings (1000 gal/yr)	Number Rebates	Savings (1000 gal/yr)	Number Rebates	Savings (1000 gal/yr)			
Low Flow Toilets	\$100	3	30	3	60	12	180		Average flush/person/day x Average people per home x (gal/flush of toilets prior to 1993 - gal/flush of toilets post 1993) = gal saved/home/day	Average flush/person/day = 5 Average people per home = 2.88 Toilet prior to 1993 = 3.5 gal/flush Toilet post 1993 = 1.6 gal/flush
Low Usage Washers	\$125	7	38	56	344	17	437	273	Average washes/week/household x (gal/wash of average washer - gal/wash of low usage washer) = gal saved/week	Low Usage Washer = 25 gal/wash Average Washer = 40 gal/wash Average 7 washes per week
Irrigation Clock	\$75	13	137	15	294	10	399	277	Assumed savings (gpcd) x number of people per household = gal saved/day	Savings of 10 gpcd Average people per home = 2.88

*These are preliminary data. Changes in these data may occur as assumptions are refined.

1.5 Billing System

Prior to 2004, the District used a fixed fee plus a four tiered increasing block rate structure where after a specified amount of water use is exceeded, the rate per thousand gallons increases.

A new system was implemented in 2004. This system also incorporates a four tiered inclining block rate structure and includes a water budget for each customer based upon actual lot size. Water budgets have been calculated for each customer type based on a reasonable amount of usage needed to meet both indoor and outdoor needs. The water rate (unit price per thousand gallons) a customer pays remains fixed until usage exceeds the budget. As shown in Table 4 the increase in unit price depends on the percentage by which each customer exceeds their budget. The District has approved a 12% rate hike in the 2005 rates shown below. These will be implemented on April 1, 2006.

Table 4 2005 Rate Structure for the New Water Rate System

Level	Percentage Exceedence	Cost/Thousand Gallons
1	Within Budget Amount	\$2.50
2	100.01% - 120%	\$3.25
3	120.01% - 140%	\$4.00
4	Over 140.01%	\$7.00

The water budget for each customer depends on customer type and lot size. Budgets for commercial customers that do not have any outdoor landscaping only account for indoor use, whereas budgets for residential homes assume an indoor usage of 9,000 gal/month and also account for landscape irrigation during the summer months (May - October). The total monthly budget is the sum of the indoor use and outdoor irrigation.

In order to calculate the budget for outdoor irrigation, the District assumes 27 inches of water (17 gal/square foot/yr) is adequate to maintain green lawns during the irrigation season. This value is multiplied by a percentage of the lot size that is assumed to be irrigated to determine the quantity of water needed for irrigation. Table 5 lists the assumptions made to calculate water budgets for a variety of customers.

Table 5 Water Budget Assumptions

Type	Indoor	Outdoor
Single family homes less than 1.25 acres	9,000 gal/year	50% of lot is irrigated
Single family homes greater than 1.25 acres	9,000 gal/year	25% of lot is irrigated
Outdoor Commercial	n/a	85% of lot is irrigated
HOA open space	n/a	85% of lot is irrigated
Indoor/outdoor commercial	Meter reading	85% of lot is irrigated
Indoor Commercial	Meter reading	n/a

1.6 Water Conservation Public Education Campaign

In 2004, the District implemented a coordinated effort to educate its customers on their water supply, water rates, and the importance of water conservation. A variety of media/venues are used to distribute information to customers. These include:

- *Newsletters* – Five newsletters have been distributed to customers since May 2004. Typically, one third or more of each newsletter has focused on conservation. Topics such as the Rebate Program, explanation of the water rate structure and water bills, xeriscaping, and efficient outdoor water rips have been covered.
- *Bill inserts* – Four bill inserts have been distributed to customers since 1994. These inserts have provided information on rate increases, the Integrated Water Resources Plan, and on stormwater.
- *Website* – Castle Pines North has a website providing information on water, parks, finances, board members, and a variety of other information. Information on water focuses on water supply and infrastructure, water rates and budget, water quality, conservation, sewer, and storm drain. See www.cpnmd.org/
- *Email distribution list* - Includes almost 80 percent of District customers and is used to notify the public about upcoming events (e.g., public meetings), programs, and other District news.

The District has held several public meetings in 2003 and 2004 to discuss groundwater supplies. The District believes that public meetings are an important venue of communication.

Douglas County

The vision of Douglas County's citizens is embodied in the Douglas County 2020 Comprehensive Master Plan (CMP), the keystone to the County's growth management program. The CMP encourages development of renewable resources and implementing conservation practices.

The Douglas County Planning Division facilitates implementation of the CMP through review of land use applications, which are presented to the Board of County Commissioners as the decision-making body. The vision of the CMP is further expressed in policy and regulatory documents, including the Parks & Trails Plan, Transportation Plan, and Subdivision and Zoning Resolutions.

Project Description

See Attachment B.

Attachment B

Sustainable Development in Colorado – Water Efficient Landscaping, Irrigation System Efficiency, and Precipitation Management: Matching Grant Study Proposal

Introduction

Douglas County residents' primary water supply is the Denver Basin Aquifers, a series of deep groundwater reserves located below the County. Although Denver Basin groundwater is currently considered an ample source of water, as demand increases in the future and supplies become depleted, it will become more difficult and costly to produce sufficient water to meet growing demands. Already, some individual well users located in northwestern portions of the County are witnessing dramatic drops in the water table and reduced production rates.

Some water providers in the area have already taken measures to preserve groundwater, but additional efforts are needed to meet future demands. Three strategies that hold great potential for saving water and promoting ecologically aware use of existing resources include 1) water efficient landscaping, 2) improved irrigation system efficiency, and 3) precipitation management. Joint applicants Dominion Water and Sanitation District, Castle Pines North Metropolitan District, and Douglas County hereby submit this proposal for a matching grant of \$47,500.00 to fund what we believe will be an innovative approach toward achieving true sustainability of water supplies in Douglas County. Benefits can accrue to existing well users in rural areas, commercial and residential developments that rely on groundwater, and can be incorporated into new planned developments.

Background

The proposed study intends to combine a review of the existing literature and studies concerning the use of water efficient landscaping and irrigation system efficiencies as applied to the northwest Douglas County area, with an audit of precipitation management utilizing new engineering studies and data, in an effort to review the combination of the three strategies as components of a total water management approach.

Water efficient landscaping includes well-known xeriscaping concepts such as soil analysis, appropriate plant selection, and use of practical turf areas. It can also extend to the design of the landscaped area itself. The micro-topography of a landscaped area can enhance the flow of irrigation water through the use of subtle grade changes, guided swales, terraces, and shallow infiltration impoundments.

Irrigation system efficiency can be maximized through the use of properly designed and located sprinklers, micro-irrigation (also known as drip irrigation), hand watering, and appropriate watering intervals. Water savings can be identified and quantified through proactive irrigation system audits followed by recommended improvements.

Precipitation Management (hereinafter referenced as rainwater conservation) is the capture and temporary storage of precipitation for landscape irrigation and other beneficial uses. It represents a growing understanding of a “water ethic” and progress towards more sustainable development. Over one-thousand years ago, ancient Americans living in the arid conditions of what is now Mesa Verde National Park collected and stored rainwater. Appreciating that we still live in an arid climate, contemporary Americans recognize that conserving rainwater for landscape irrigation offers a number of benefits:

- *Reduce consumption of potable water for non-potable uses* – every gallon of potable water conserved represents savings. Not merely of the water itself, but of the infrastructure required to transport, treat, store, and distribute that water. It also saves the energy invested in every gallon of water to transport and treat it, as well as the chemicals used in the treatment and disinfection processes.
- *Reduce peak summer landscape watering demands* – overall water usage peaks during the summertime; reducing this load helps utilities delay expansion of treatment and distribution facilities. Water usage is inextricably intertwined with energy usage; lowering water demand in the summertime means lowering peak electrical energy demands as well.
- *Rainwater conservation may reduce untreated flow to storm drains and improve water quality* – a properly designed and engineered rainwater collection system may reduce the flow of untreated storm water thereby reducing non-point pollution.
- *Protect streamflow* – a properly designed rainwater conservation system may enhance streamflow by mitigating the high surge flow caused by extreme storm events. The introduction of augmentation water may produce more predictable stream flows.
- *Rainwater is soft (low to nonexistent concentrations of dissolved salts) and thus preferable for most landscape irrigation applications.*
- *Rainwater conservation represents wise use of a scarce resource and is an integral component of the “total water management” approach* – water professionals increasingly recognize that current water and development issues in Colorado require a more regional approach to assure that our limited water resources are administered in the most effective and efficient manner possible. This requires implementing a “total water management” approach – one that considers innovative water resources such as rainwater collection, conjunctive use, groundwater recharge, regional planning, wastewater issues, watershed management, demand-side management via conservation and recycling, actively managing stormwater systems, and most importantly, good stewardship of a vital natural resource.

As water and energy resources become increasingly scarce, the practice of rainwater collection is becoming more popular. It is estimated that over one-half

million people in the U.S. and its Territories use some type of rainwater collection system for indoor and/or outdoor purposes¹. Neighboring states including Arizona, Texas, and New Mexico all allow – and even encourage through financial incentives – rainwater collection and use². Santa Fe County, New Mexico *requires* rainwater collection and use for all new commercial developments, and residential structures exceeding a 2,500 square feet footprint³. Several other western states also allow rainwater collection and use⁴.

Rainwater conservation may also provide a unique opportunity for water users who rely on groundwater. Past practices such as cyclical pumping are being reevaluated and revised to protect the aquifer while still providing adequate water. Continuous pumping at lower flow rates requires installing storage tanks. Rainwater conservation practices could utilize this common infrastructure and supplement a rapidly dwindling resource.

The practice of rainwater conservation does present some potential challenges, including:

- *Variable rainfall* – annual precipitation in Colorado varies both by locale and year. Absolute reliance on precipitation as a water source could lead to shortfalls.
- *Cost* – a well engineered rainwater collection system may entail greater costs for a property owner than simply using potable water with a conventional sprinkler system; operations and maintenance costs may be higher as well.
- *Water quality* – rainwater water quality is typically high. However, the quality of collected and stored rainwater may be subject to degradation. While not intended for human consumption, the public health issues associated with rainwater collection and use must be considered. Rainwater collection and storage systems must be designed and operated to minimize water quality deterioration and the possibility of insect infestation.

In some instances such as Douglas County, the current situation is not a matter of how much a given quantity of source water will cost, but its absolute availability. Surface water obtained from historical sources (e.g., consumptive use credits from agricultural water rights changed to domestic and other uses) to support continued growth in Colorado is simply unavailable in sufficient quantity, quality, or reliability. Groundwater resources are similarly stressed with rapid depletion of regional aquifers. New and innovative water resources must be tapped to meet growing demand, and rainwater

¹ Krishna H, *An Overview of Rainwater Harvesting Systems and Guidelines in the United States*, Proceedings of the First Annual Rainwater Harvesting Conference, 2003.

² Hall P, *Municipal Uses of Stormwater Runoff*, Stormwater p.74, May/June 2005

³ Santa Fe County Ordinance No. 2003-6, http://www.co.santa-fe.nm.us/departments/land_use/water_harvesting/docs/Water_Harvesting_%20Ordinance.pdf

⁴ California, Hawaii, Idaho, Montana, Oregon (roof runoff only), and Washington

conservation represents one of those sources. As urban growth continues, the demand for more water will likely result in additional changes of water rights from agricultural to domestic use. Adopting prudent water efficient landscaping, improving irrigation system efficiencies, and implementing rainwater conservation practices may reduce the need for such changes; this would reduce the ongoing process of drying up productive agricultural lands.

Proposed Study

Under current Colorado law, a property owner does not own the precipitation falling from the sky onto his or her rooftop or driveway. Ownership of the water resource remains in the public domain and utilizing that water for a beneficial use requires obtaining a water right. Water rights are obtained under the doctrine of Prior Appropriation or “first in time, first in right” and the quantities allotted to earlier, more senior rights must be protected. Intercepting rainwater that would have otherwise migrated to groundwater or surface water might interfere with the full allocation of those senior water rights.

Colorado’s doctrine of prior appropriation and current policies means that precipitation cannot be diverted, stored, or put to beneficial use (with landscape irrigation for example) without an augmentation plan to replace the depletions associated with the diversion. Therein lays the crux of the proposed study – to demonstrate the feasibility and sustainability of rainwater conservation without injuring existing water rights within the framework of existing Colorado law.

Rainwater collection and use could be practiced in Colorado by:

- Accurately determining the consumptive use of rainfall by evaporation and native vegetation and thus quantifying the return flow to streams and aquifers from rainfall;
- Calculating an algorithm to define the net depletion/accretion to the river under a rainwater conservation scenario; and
- Identifying the entity responsible for providing any shortfalls to the river via an approved augmentation plan.

This approach ensures that collecting and using rainwater for immediate and local irrigation purposes does not harm any existing water rights. The process also uses a familiar and well-understood mechanism in the form of an approved augmentation plan. The water balance algorithm will produce practical and defensible estimates of consumptive use and return flows, and allow development of an augmentation plan. Finally, this course acknowledges that there are other stakeholders in the water rights arena.

Sound public policy must be supported by sound science. In this case, sound science means defining the influence of rainwater conservation on evapotranspiration, water transport, and water storage, and thus the ability to quantify the impacts of this practice.

This science can be accomplished via a well-designed, peer-reviewed rainwater conservation study.

The study proposes to evaluate potential water savings from under three different conservation scenarios:

1. Use of efficient landscaping, improved irrigation system efficiencies, and implementing rainwater conservation practices in new residential developments for individual and common area irrigation,
2. Retrofitting a cistern to an existing home which currently uses groundwater (domestic exempt groundwater well users) to supplement stressed groundwater resources, and
3. Retrofitting an existing commercial occupancy (supplied by groundwater) with catchments to provide common area irrigation.

The study will essentially examine the water balance under each scenario and compare it to the water balance of that same scenario with conservation practices. The net differential will then allow an augmentation plan to be structured to cover all depletions associated with rainwater conservation practices. The following figure graphically illustrates that process and this study.

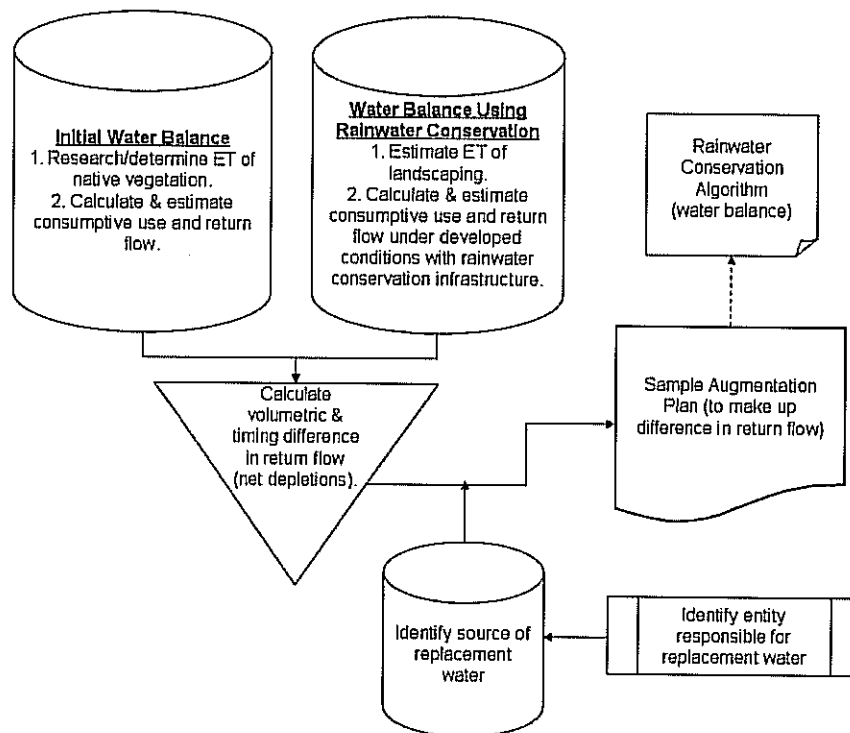


Figure 1 – Conceptual Project Model

Thus the scope of the study will be limited to 1) new development in an unincorporated area of northwest Douglas County, 2) existing residential groundwater users in unincorporated areas of northwest Douglas County, and 3) an existing commercial building (supplied by groundwater) in a developed area of northwest Douglas County. This project represents a sound, conservative approach to evaluating a new and innovative use of an existing water resource for the people of the state of Colorado.

Task 1. Determine Method for Estimating Evapotranspiration of Native Vegetation

The first step in quantifying the impacts of rainwater conservation on existing water rights will be determining the evapotranspiration (ET) of native vegetation in a selected area. ET is the consumptive use of water and includes evaporation of water from land (and water) surfaces and transpiration by vegetation⁵. Determining an appropriate method of estimating ET depends on the type of vegetation, time of year, and soil type. For larger areas of native vegetation, this can be exceptionally difficult due to inadequate information about the types, density, and vigor of naturally-occurring species⁶. Far more research has been conducted about the needs and resultant ET of irrigated agricultural crops.

ET can be determined either by measurement or calculations. Among the physical measuring methods used are soil water depletion, using lysimeters or tanks, water balance (typically used in larger areas), or some combination of methods⁷. A number of additional analytical methods are also used to calculate ET⁸.

A significant body of extant research exists that has not been mined or applied to the issue of rainwater conservation in Colorado. This project proposes to develop a valid and scientifically defensible method of estimating native vegetation ET by conducting an extensive review of the existing literature including peer-reviewed and agency publications. The project team will make extensive use of existing research and data from resources such as the State of Colorado Decision Support System and the Colorado Water Resources Research Institute affiliated with Colorado State University. Using existing research and data sources, recommendations will be made for the estimation of the ET of native vegetation and landscaping in northwest Douglas County.

Task 2. Identify Rainwater Conservation Infrastructure Requirements

Although technical innovations and novel rainwater conservation applications continue to be developed, the basic physical and operational tenets of this favorable practice are relatively mature. This portion of the study will describe the physical infrastructure required for rainwater conservation on both a macro (large commercial developments)

⁵ American Society of Civil Engineers (ASCE), *Evapotranspiration and Irrigation Water Requirements*, ASCE Publications, 1990

⁶ Johns, EL ed., *Water Use by Naturally Occurring Vegetation Including an Annotated Bibliography*, American Society of Civil Engineers, 1989.

⁷ ASCE, *op. cit.*

⁸ *Ibid*

and micro (individual single-family homes or individual commercial buildings) scale. Using conventional civil engineering calculations (often originating in stormwater management designs), the volume of water collected by the rainwater conservation system will be determined. This effort will also include an economic evaluation that will allow a true “cost” of the process to be determined.

Then, the study will model the application of this conserved rainwater for turf and landscape irrigation. However, maximizing the efficiency of any rainwater conservation approach will extend beyond the physical components of the collection and distribution system to the design of the landscaped area itself. The micro-topography of the landscaped area can enhance the flow of both stormwater and collected rainwater through the use of subtle grade changes, guided swales, terraces, and shallow infiltration impoundments. Landscaping design should also incorporate well-known xeriscaping concepts including soil analysis, appropriate plant selection, and practical turf areas. Actual irrigation efficiency can be maximized through the use of properly designed and located sprinklers, micro-irrigation (also known as drip irrigation), hand watering, and appropriate watering intervals.

A high-level reconnaissance and review of available data and methodologies for innovative stormwater management techniques intended to improve the quality of run-off into surface water bodies will also be conducted.

This task will describe the physical infrastructure required for rainwater conservation on both a macro (large commercial developments) and micro (individual single-family homes or individual commercial buildings) scale. Key factors will be 1) general design concepts, 2) potential capture efficiencies, and 3) economic considerations.

Task 3. Define Initial Water Balances

Given a certain location – how much precipitation actually migrates to groundwater or reaches a stream as inflow of tributary groundwater? That quantity will be established by the amount of rainfall, the site’s proximity to the surface water or groundwater, type of soil, and duration of rainfall event (*i.e.*, does rain occur uniformly throughout the year or is the location subject to infrequent storms).

By applying conventional and well understood techniques that are acceptable under current Colorado water law, the amount of return flow (the non-consumptive fraction of rainwater that ultimately returns to a river after having been applied to beneficial use) can be determined under initial conditions as defined in the three scenarios. This will define the water balance under existing conditions with no development and no rainwater conservation.

Task 4. Define Water Balance Using Conservation Practices

What is the water balance of a site using water efficient landscaping, increased irrigation system efficiency, rainwater conservation practices? Similar to the process used to

calculate the water balance under the native vegetation scenario, a water balance for developed areas employing rainwater conservation will be determined.

Task 5. Quantify Potential Water Savings from Conservation Practices

Potential water savings from implementing efficient landscaping, improving irrigation system efficiencies, and implementing rainwater conservation practices will be approximated.

Task 6. Quantify Differences in Return Flows

The next phase of the project will quantify the differences in water balances between the native vegetation scenario and that of a development using rainwater conservation. Specifically, the study will identify any differences in time, place, quantity, and quality of return flows. This will allow a replacement volume to be calculated as well as identifying the nature and timing of the substitute supply.

Task 7. Develop Sample Augmentation Plan

The final work phase of the project will result in the development of a sample augmentation plan that will identify the structures, diversions, beneficial uses, timing, and amount of depletions to be replaced, along with how and when the replacement water will be supplied, and how the augmentation plan will be operated⁹. From this plan, an algorithm can be extracted that could be applied to future applications of rainwater conservation throughout Colorado. The plan would also identify potential entities and means of providing replacement water.

Task 8. Prepare Project Report

The ET data, water balances under each scenario, infrastructure requirements, economic evaluation, potential water savings under conservation scenarios, and sample augmentation plan outline will be summarized in a public report that will allow sound policy to be developed for Colorado. Written progress reports will be provided to the Peer Review Committee at approximately 50% and 95% completion of the study. A final report, incorporating comments from the Peer Review Committee will be the ultimate work product for this study project.

Task 9. Project Management

Components of project management will include tracking work accomplished, maintaining budget and schedule, regularly reporting the status of work activities, and promote communication between all parties contributing to this study.

An additional component of a successful study will be the inclusion of a two-part review process: 1) review by a Project Advisory Committee consisting of individuals who will

⁹ Colorado Foundation for Water Education, *Colorado Water Law*, 2003

provide valuable insight and recommendations throughout the life of the project, and 2) review by a Peer Review Committee of staff from the Colorado Water Conservation Board and the Division of Water Resources. Committee members represent stakeholders with a variety of perspectives; however all are vitally concerned with Colorado water issues. Regular communication and feedback from both Committees will be important, particularly at project milestones. We anticipate three meetings with each committee including project kickoff and at approximately 50% and 95% completion of the study.

The project schedule for the proposed study is provided in **Table 1** below. The estimated project costs for this study are \$95,000.00 as detailed below in **Table 2**. Funding will be provided from the sources described in **Table 3** below.

Summary

Rainwater conservation – the temporary storage and use of rainwater for irrigation purposes – offers both benefits as well as challenges. However, given the stresses on existing surface water and groundwater sources in Colorado and throughout the arid west, the benefits seemingly outweigh the potential shortcomings. Rainwater conserved represents 1) an innovative water source, 2) water infrastructure that does not have to be constructed, and 3) energy that does not have to be used to treat and transport that water.

The technical challenges of rainwater conservation are straightforward; the majority of required technology and infrastructure exists and can be employed with few or no modifications. The challenge lies with applying rainwater conservation practices within existing Colorado water law and its doctrine of Prior Appropriation. It is achieving the recognition that this approach represents sound public policy and wise use of an increasingly scarce resource, while at the same time recognizing that the legal imperative of existing Colorado water law, and senior water rights extending back to the 19th Century, must be respected.

Table 1

Project Schedule - Water Efficient Landscaping, Irrigation System Efficiency, and Precipitation Management Study																																	
	March					April					May					June					July					August							
	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27								
Project Start	3/15																																
PHASE 1 (Tasks 1 through 4)																																	
Task 1																																	
Literature Review: ET of Native Vegetation and Landscaping																																	
Task 2																																	
Rainwater Conservation Infrastructure Requirements																																	
Task 3 and Task 4																																	
Evaluate Water Balances																																	
**Submit Interim Progress Report (50%)	6/15																																
PHASE 2 (Tasks 5 through 8)																																	
Task 5																																	
Potential Water Savings Using Conservation Practices																																	
Task 6																																	
Quantify Differences in Return Flows																																	
Task 7																																	
Develop Sample Augmentation Plan																																	
Task 8																																	
Project Report																																	
PROJECT MANAGEMENT																																	
Task 9																																	
Project Management - Phase 1																																	
Project Management - Phase 2																																	
**Submit Draft Report (95%)	7/24																																
Review Draft Report																																	
CWCB and Peer Review Committee																																	
**Submit Final Report	8/21																																

Table 2

Project Estimate – Water Efficient Landscaping, Irrigation System Efficiency, and Precipitation Management Study			
Task	Total	Joint Applicants	CWCB Matching Grant *
Phase 1 – Tasks 1 through 4			
Task 1 – Literature Review: ET of Native Vegetation and Landscaping	\$17,000.00	\$17,000.00	
Task 2 – Rainwater Conservation Infrastructure Requirements	\$17,000.00	\$17,000.00	
Task 3 and Task 4 – Evaluate Water Balances	\$2,500.00	\$2,500.00	
Phase 2 – Tasks 5 through 8			
Task 5 – Potential Water Savings Using Conservation Practices	\$3,500.00		\$3,500.00
Task 6 – Quantify Differences in Return Flows	\$4,000.00		\$4,000.00
Task 7 – Develop Sample Augmentation Plan	\$9,500.00		\$9,500.00
Task 8 – Project Report	\$19,500.00		\$19,500.00
Project Management			
Task 9A – Project Management, Phase 1	\$11,000.00	\$11,000.00	
Task 9B – Project Management, Phase 2	\$11,000.00		\$11,000.00
Total	\$95,000.00	\$47,500.00	\$47,500.00

* All invoices to CWCB will show 10% of total billed retained by CWCB, which will be requested in writing at the end of the project upon final completion and approval.

Table 3

Funding Sources for Water Efficient Landscaping, Irrigation System Efficiency, and Precipitation Management Study	
Organization	Direct Funds
Joint Applicants: Dominion Water & Sanitation District/ Castle Pines North Metropolitan District/ Douglas County *	\$47,500
Colorado Water Conservation Board	\$47,500 matching grant
Totals	\$95,000
See attached letters showing breakdown of joint-applicants funding contributions: Dominion Water & Sanitation District - \$37,000 Castle Pines North Metropolitan District - \$5,000 Douglas County - \$5,000 Plum Valley Heights HOA - \$500	

ATTACHMENT B

DOUGLAS COUNTY ZONING RESOLUTION
SECTION 18A
WATER SUPPLY-OVERLAY DISTRICT

SECTION 18A WATER SUPPLY - OVERLAY DISTRICT (Amended 4/27/05)

1801A Intent

To ensure that development in all areas of Douglas County provides for a water supply that is sufficient in terms of quantity, quality, and dependability. [§ 30-28-133 (3)(d), C.R.S.]

In order to accomplish the intent, this section includes methods and provisions for:

- delineating the various water supply areas of the County;
- aligning the water supply standards with statutory provisions;
- restricting the dependence on nonrenewable water sources;
- encumbering groundwater through the use of restrictive covenants;
- verifying water rights and adjudication of these rights;
- identifying minimum water supply standards;
- identifying the land-use process affected by these standards; and
- providing an appeal process to prove water-supply sufficiency.

Compliance with the following water-supply standards permits a presumption that a proposed water supply meets the standards set forth in these regulations. Any landowner unable to comply with these water-supply standards may appeal to the Board to prove a sufficient water supply, as set forth in Section 1809A. (Amended 3/13/02)

1802A Applicability

The Water Supply - Overlay District shall be applied as a supplemental regulation to those set forth in the underlying zoning district and to all applications submitted pursuant to the following regulations:

1802A.01 Douglas County Zoning Resolution:

- Rezoning
- Use By Special Review

1802A.02 Douglas County Subdivision Resolution:

- Sketch Plan (Amended 8/25/99)
- Preliminary Plan
- Final Plat
- Minor Development - *Single-Family, Multifamily and Nonresidential*

1802A.03 Douglas County Building Code

- Building Permit

1802A.04 County Review of Special District Applications

All of the restrictions and requirements set forth in other applicable regulations remain in full force and effect. In the case of overlapping or conflicting requirements, the most restrictive provision shall apply.

1803A Boundaries

The Water Supply - Overlay District encompasses the entire area of Douglas County. The District is divided into zones identified as Pike/Rampart, Margin A, Margin B and the Central Basin, as depicted on the Water Supply - Overlay District Map, Figure 18A, attached hereto and incorporated herein with this reference.

- 1803A.01 When a proposed land use overlies 2 or more of the water supply zones, the water supply shall comply with the requirements of the zone from which the water is supplied.
- 1803A.02 When a water supply is proposed to be obtained from multiple water supply zones, the regulations for each zone shall apply based upon the proportionate land area within each zone and the land's corresponding water availability. *(Amended 4/12/00)*

These zones will be periodically reviewed by the County, as new data are available, and boundaries adjusted, as needed, to meet changing aquifer conditions.

1804A Minimum Water-Supply Standards

The following minimum water standards are required unless amended through the appeal process, or when an existing special district providing the water supply has its own standards:

- 1804A.01 Residential:
- | | |
|----------------------------------|------------------------------|
| ER, RR, LRR, A-1 zone districts: | 1 acre-foot/year/residence |
| All other zone districts: | .75 acre-foot/year/residence |
- 1804A.02 Irrigated lawn/garden or golf course: 2.50 ac.-ft./year/acre
- 1804A.03 Commercial/office/industrial: .75 ac.ft./yr. per 6,695-sq. ft. of bldg. space
- 1804A.04 Other uses: Sufficient water supply for the proposed uses, based on the estimate of the proposed usage and analysis by the County.

1805A Pike/Rampart – Water-Supply Zone

A renewable water supply is required for land uses proposed within Pike/Rampart, except for issuance of a building permit only. The following methods of providing a water supply are allowed, in compliance with the standards set forth below:

1805A.01 Existing District

When service is proposed by an existing district, the applicant shall obtain a letter from the district stating its ability to serve, the amount of water available, and the feasibility of extending service. A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.]

If the existing district must expand its service boundary in order to serve the proposed development, the district expansion must be completed prior to recordation of the first final plat for the development.

1805A.02 Extraterritorial District

When service is proposed by an extraterritorial district, either directly or through another district, the applicant, in coordination with the extraterritorial district, shall demonstrate through a water supply plan, that definite provision has been made for a water supply that is sufficient in terms of quantity, quality, and dependability. [§ 30-28-133 (3)(d), C.R.S.] Approval of the water supply plan shall be based upon review of the following:

- 1805A.02.1 An attorney's opinion letter shall be provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, sufficient adjudicated water rights and a copy of the court decree adjudicating the water rights.
- 1805A.02.2 An adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan. *An adjudicated Augmentation Plan shall be submitted prior to the scheduling of a public meeting or public hearing for the application.*
- 1805A.02.3 The available water rights are sufficient based on the minimum water supply standards (Sec. 1804A).
- 1805A.02.4 The applicant, in coordination with the extraterritorial district, has demonstrated that the water rights can be used for the proposed use(s).
- 1805A.02.5 The reliability of the water right has been analyzed and is deemed sufficient by the County based on its priority date within the Colorado System of Water Rights Administration and the additional volume that can be extracted from this water right.
- 1805A.02.6 The water storage capacity is deemed sufficient by the County to ensure that no water supply shortages will occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.
- 1805A.02.7 Delivery of the water supply to the development is deemed adequate and feasible by the County.
- 1805A.02.8 The applicant has provided a letter from the extraterritorial district stating its commitment and ability to serve the proposed development.

1805A.03 New Special District

The organization of a new special district to provide water service is authorized by § 32-1-201, *et seq.* C.R.S. The BCC is authorized by § 32-1-203 C.R.S., to review and approve the service plan.

A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.] Approval shall be based on compliance with the following service and facility standards: [§ 32-1-203(2.5)(b), C.R.S.]

- 1805A.03.1 The proposed water supply for any district proposed to be located within Pike/Rampart shall be obtained from renewable water rights;

AND/OR

from beneath land located in the Central Basin that has been zoned as Open Space Conservation District, or is subject to a perpetual open space conservation easement, in accordance with the standards in section 1808A.03.

A copy of the conservation easement shall be submitted to the Planning Division, and shall contain provisions which restrict the uses of the land to substantially the same uses and level of development as are permitted on land zoned as Open Space Conservation District, as determined by the Director. A copy of the declaration of restrictive covenants shall be provided, as required.

- 1805A.03.2 An attorney's opinion letter has been provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, adjudicated renewable water rights along with a copy of the court decree adjudicating the renewable water rights.

- 1805A.03.3 The water rights are sufficient based on the minimum water-supply standards (Sec. 1804A).

- 1805A.03.4 The applicant has demonstrated that the water rights can be used for the proposed use(s).

- 1805A.03.5 The reliability of the water right has been analyzed based on its priority date within the Colorado System of Water Rights Administration and the volume that can be extracted from this water right has been quantified.

- 1805A.03.6 The proposed water-storage capacity has been identified to ensure that no water-supply shortages occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.

- 1805A.03.7 The water delivery system has been identified and the system feasibility has been assessed.

- 1805A.04 Renewable Water – Surface Water Supply

When service is proposed by renewable tributary water rights the following standards shall apply:

- 1805A.04.1 An attorney's opinion letter shall be provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, adjudicated renewable water rights and a copy of the court decree adjudicating the renewable water rights.
- 1805A.04.2 The water rights are sufficient based on the minimum water-supply standards (Sec. 1804A).
- 1805A.04.3 The applicant has demonstrated that the water rights can be used for the proposed use(s).
- 1805A.04.4 The reliability of the water right is deemed sufficient, by the County, based upon its priority date within the Colorado System of Water Rights Administration and the volume that can be extracted from this water right.
- 1805A.04.5 The water storage capacity is deemed sufficient, by the County to ensure that no water supply shortages will occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.
- 1805A.04.6 Delivery of the water supply to the development is deemed adequate by the County.

1805A.05 Renewable Water - Groundwater from Granitic/Metamorphic Fractures

A well in the granitic/metamorphic fractures may only be allowed as the source of water, when required for issuance of a building permit, for a principal or accessory use currently allowed by zoning on a legally created parcel as follows:

- 1805A.05.1 The landowner must submit evidence of a well test as follows:

A minimum 4-hour, constant-discharge test that would require the well to be pumped at a constant rate commensurate with the ability of the aquifer to yield not less than 1 gpm, with water level measurements being made throughout the duration of the test. To conduct an acceptable well test, the pump shall be valved to maintain a constant rate, a calibrated flow meter used to measure flow, and a means to obtain water levels from the pumped well provided. The well test results must be signed by a licensed water well contractor, or professional geologist or engineer;

OR

- 1805A.05.2 a statement signed by a licensed well contractor that the average yield

of the well is greater than 10 gpm after 4 hours of airlifting.

- 1805A.05.3 If the water flow is less than 1 gpm, the applicant shall install a cistern in compliance with the Douglas County plumbing code, as amended. Further, if the water flow of the well is not sufficient to fill the cistern, as required by the plumbing code, the landowner shall submit an agreement with a water provider for the balance of the water, in a form acceptable to the County.

1806A Margin A – Water Supply Zone

A renewable water supply is required for land uses proposed within Margin A, except for issuance of a building permit only. The following methods of providing a renewable water supply are allowed in compliance with the standards set forth below:

1806A.01 Existing District

When service is proposed by an existing district, the applicant shall obtain a letter from the district stating its ability to serve, the amount of water available, and the feasibility of extending service. A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.]

If the existing district must expand its service boundary in order to serve the proposed development, the district expansion must be completed prior to recordation of the first final plat for the proposed development.

1806A.02 Extraterritorial District

When service is proposed by an extraterritorial district, either directly or through another district, the applicant, in coordination with the extraterritorial district, shall demonstrate through a water supply plan, that definite provision has been made for a water supply that is sufficient in terms of quantity, quality, and dependability. [§ 30-28-133 (3)(d), C.R.S.] Approval of the water supply plan shall be based upon review of the following:

- 1806A.02.1 An attorney's opinion letter shall be provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, sufficient adjudicated water rights and a copy of the court decree adjudicating the water rights.
- 1806A.02.2 An adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan. *An adjudicated Augmentation Plan shall be submitted prior to the scheduling of a public meeting or public hearing for the application.*
- 1806A.02.3 The available water rights are sufficient based on the minimum water supply standards (Sec. 1804A).
- 1806A.02.4 The applicant, in coordination with the extraterritorial district, has demonstrated that the water rights can be used for the proposed use(s).

- 1806A.02.5 The reliability of the water right has been analyzed and is deemed sufficient by the County based on its priority date within the Colorado System of Water Rights Administration and the additional volume that can be extracted from this water right.
- 1806A.02.6 The water storage capacity is deemed sufficient by the County to ensure that no water supply shortages will occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.
- 1806A.02.7 Delivery of the water supply to the development is deemed adequate and feasible by the County.
- 1806A.02.8 The applicant has provided a letter from the extraterritorial district stating its commitment and ability to serve the proposed development.

1806A.03 New Special District

The organization of a new special district to provide water service is authorized by § 32-1-201, *et seq.* C.R.S. The BCC is authorized by § 32-1-203 C.R.S., to review and approve the service plan.

A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.] Approval shall be based on compliance with the following service and facility standards: [§ 32-1-203(2.5)(b), C.R.S.]

- 1806A.03.1 The proposed water supply for any special district proposed to be located within Margin A shall be obtained from renewable water rights;
AND/OR
from beneath land located in the Central Basin or Margin B that has been zoned as Open Space Conservation District, or is subject to a perpetual open space conservation easement, in accordance with the Denver Basin aquifer standards in section 1808A.03 or section 1807A.03 respectively.

A copy of the conservation easement shall be submitted to the Planning Division, and shall contain provisions which restrict the uses of the land to substantially the same uses and level of development as are permitted on land zoned as Open Space Conservation District, as determined by the Director. A copy of the declaration of restrictive covenants shall be provided, as required.

- 1806A.03.2 An attorney's opinion letter shall be provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, adjudicated renewable water rights and a copy of the court decree adjudicating the renewable water rights.

- 1806A.03.3 The water rights are sufficient based on the minimum water-supply standards (*Sec. 1804A*)
- 1806A.03.4 The applicant has demonstrated that the water rights can be used for the proposed use(s).
- 1806A.03.5 The reliability of the water right has been analyzed based on its priority date within the Colorado System of Water Rights Administration and the volume that can be extracted from this water right has been quantified.
- 1806A.03.6 The proposed water-storage capacity has been identified to ensure that no water-supply shortages occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.
- 1806A.03.7 The water delivery system has been identified and the system feasibility has been assessed.

1806A.04 Renewable Water

When service is proposed by renewable tributary water rights the following standards shall apply:

- 1806A.04.1 An attorney's opinion letter shall be provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, adjudicated renewable water rights and a copy of the court decree adjudicating the renewable water rights.
- 1806A.04.2 The water rights are sufficient based on the minimum water-supply standards (*Sec. 1804A*).
- 1806A.04.3 The applicant has demonstrated that the water rights can be used for the proposed use(s).
- 1806A.04.4 The reliability of the water right is deemed sufficient, by the County, based on its priority date within the Colorado System of Water Rights Administration and the volume that can be extracted from this water right.
- 1806A.04.5 The water storage capacity is deemed sufficient by the County to ensure that no water supply shortages will occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.

1806A.04.6 Delivery of the water supply to the development is deemed adequate by the County.

1806A.05 Nonrenewable Water - Denver Basin Aquifers or Dakota Sandstone Formation

A groundwater well may only be allowed as the source of water, when required for issuance of a building permit, for a principal or accessory use currently allowed by zoning on a legally created parcel as follows:

1806A.05.1 The landowner must submit evidence of a well test as follows:

A minimum 4-hour, constant-discharge test that would require the well to be pumped at a constant rate commensurate with the ability of the aquifer to yield not less than 1 gpm, with water level measurements being made throughout the duration of the test. To conduct an acceptable well test, the pump shall be valved to maintain a constant rate, a calibrated flow meter used to measure flow, and a means to obtain water levels from the pumped well provided. The well test results must be signed by a licensed water well contractor, or professional geologist or engineer;

OR

1806A.05.2 a statement signed by a licensed well contractor that the average yield of the well is greater than 10 gpm after 4 hours of airlifting.

1806A.05.3 If the water flow is less than 1 gpm, the applicant shall install a cistern in compliance with the Douglas County plumbing code, as amended. Further, if the water flow of the well is not sufficient to fill the cistern, as required by the plumbing code, the landowner shall submit an agreement with a water provider for the balance of the water, in a form acceptable to the County.

1807A Margin B – Water Supply Zone

The following methods of providing a water supply are allowed for land uses proposed within Margin B, in compliance with the standards set forth below:

1807A.01 Existing District

When service is proposed by an existing district, the applicant shall obtain a letter from the district stating its ability to serve, the amount of water available, and feasibility of extending service. A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.]

If the existing district must expand its service boundary in order to serve the proposed development, the district expansion must be completed prior to recordation of the first final plat for the proposed development.

1807A.02 Extraterritorial District

When service is proposed by an extraterritorial district, either directly or through another district, the applicant, in coordination with the extraterritorial district, shall demonstrate through a water supply plan, that definite provision has been made for a water supply that is sufficient in terms of quantity, quality, and dependability. [§ 30-28-133 (3)(d), C.R.S.] Approval of the water supply plan shall be based upon review of the following:

- 1807A.02.1 An attorney's opinion letter shall be provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, sufficient adjudicated water rights and a copy of the court decree adjudicating the water rights.
- 1807A.02.2 An adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan. *An adjudicated Augmentation Plan shall be submitted prior to the scheduling of a public meeting or public hearing for the application.*
- 1807A.02.3 The available water rights are sufficient based on the minimum water supply standards (Sec. 1804A).
- 1807A.02.4 The applicant, in coordination with the extraterritorial district, has demonstrated that the water rights can be used for the proposed use(s).
- 1807A.02.5 The reliability of the water right has been analyzed and is deemed sufficient by the County based on its priority date within the Colorado System of Water Rights Administration and the additional volume that can be extracted from this water right.
- 1807A.02.6 The water storage capacity is deemed sufficient by the County to ensure that no water supply shortages will occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.
- 1807A.02.7 Delivery of the water supply to the development is deemed adequate and feasible by the County.
- 1807A.02.8 The applicant has provided a letter from the extraterritorial district stating its commitment and ability to serve the proposed development.

1807A.03 New Special District

The organization of a new special district to provide water service is authorized by § 32-1-201, *et seq.* C.R.S. The BCC is authorized by § 32-1-203 C.R.S., to review and approve the service plan.

A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.] Approval shall be based on compliance with the following service and facility standards: [§ 32-1-203(2.5)(b), C.R.S.]

- 1807A.03.1 the proposed water supply for any special district proposed to rely on Denver Basin aquifers may be obtained from the Denver Basin aquifers underlying the subject land;

AND/OR

from beneath land located in the Central Basin or Margin B that has been zoned as Open Space Conservation District, or is subject to a perpetual open space conservation easement, in accordance with the Denver Basin aquifer standards in section 1808A.04 or 1807A.04 respectively.

A copy of the conservation easement shall be submitted to the Planning Division, and shall contain provisions which restrict the uses of the land to substantially the same uses and level of development as are permitted on land zoned as Open Space Conservation District, as determined by the Director. A copy of the declaration of restrictive covenants shall be provided, as required.

- 1807A.03.2 An attorney's opinion letter has been provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, all Denver Basin aquifers present beneath the subject land and a copy of the court decree adjudicating those water rights, if those water rights have been adjudicated;
- 1807A.03.3 An adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan. *An adjudicated Augmentation Plan shall be submitted prior to the scheduling of a public meeting or public hearing for the application.*
- 1807A.03.4 The water rights are sufficient based on the minimum water-supply standards (Sec. 1804A)
- 1807A.03.5 the water in all Denver Basin aquifers shall be reserved in perpetuity, for the benefit of future landowners within the proposed development, pursuant to a declaration of restrictive covenants in a form prescribed by the County;
- 1807A.03.6 the total annual demand of water proposed for the subject land, in accordance with the minimum water standards (Sec. 1804A), shall not exceed 50 percent of the total annual appropriable water supply contained within the Denver Basin aquifers underlying the subject land;
- 1807A.03.7 Service Plan Provisions

- (1) The proposed service plan shall include a well-field analysis that demonstrates that such wells will not adversely impact existing water rights on adjoining lands, consistent with the provisions in § 37-90-137(4)(c), C.R.S., as amended.
- (2) The proposed service plan shall require the district to install an acceptable water level measuring device in all new district wells to measure and record water levels on a monthly basis, whether the water level obtained is a static or pumping water level, and provide for an annual report of such data to Douglas County.

1807A.04 Denver Basin Aquifers

When the water supply is proposed from the Denver Basin aquifers, the following standards shall apply:

- 1807A.04.1 an attorney's opinion letter shall be submitted stating ownership, by the applicant of, or an executed contract granting rights to the applicant for, all Denver Basin aquifers present beneath the subject land and a copy of the court decree adjudicating those water rights, if those water rights have been adjudicated;
- 1807A.04.2 an adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan; *An adjudicated Augmentation Plan, if not available prior to the hearings, may be required as a condition of approval.*
- 1807A.04.3 the water in all Denver Basin aquifers shall be reserved in perpetuity, for the benefit of future landowners within the proposed development, pursuant to a declaration of restrictive covenants in a form prescribed by the County;
- 1807A.04.4 the total annual demand of water proposed for the subject land, in accordance with, the minimum water standards (*Sec. 1804A*), shall not exceed 50 percent of the total annual appropriable water supply contained within the Denver Basin aquifers underlying the subject land; and
- 1807A.04.5 for residential lots less than 35 acres in size well-site envelopes shall be established at least 600 feet from any other well on or off site for wells located in the same aquifer.
- 1807A.04.6 When the landowner does not own rights to all of the Denver Basin aquifers, a groundwater well may be allowed as the source of water as required for issuance of a building permit, for a principal or accessory use currently allowed by zoning, on a legally created parcel.

1808A Central Basin – Water Supply Zone

The following methods of providing a water supply are allowed for land uses proposed within the Central Basin area, in compliance with the standards set forth below:

1808A.01 Existing District

When service is proposed by an existing district, the applicant shall obtain a letter from the district stating its ability to serve, the amount of water available, and feasibility of extending service. A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.]

If the existing district must expand its service boundary in order to serve the proposed development, the district expansion must be completed prior to recordation of the first final plat for the proposed development.

1808A.02 Extraterritorial District

When service is proposed by an extraterritorial district, either directly or through another district, the applicant, in coordination with the extraterritorial district, shall demonstrate through a water supply plan, that definite provision has been made for a water supply that is sufficient in terms of quantity, quality, and dependability. [§ 30-28-133 (3)(d), C.R.S.] Approval of the water supply plan shall be based upon review of the following:

- 1808A.02.1 An attorney's opinion letter shall be provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, sufficient adjudicated water rights and a copy of the court decree adjudicating the water rights.
- 1808A.02.2 An adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan. *An adjudicated Augmentation Plan shall be submitted prior to the scheduling of a public meeting or public hearing for the application.*
- 1808A.02.3 The available water rights are sufficient based on the minimum water supply standards (Sec. 1804A).
- 1808A.02.4 The applicant, in coordination with the extraterritorial district, has demonstrated that the water rights can be used for the proposed use(s).
- 1808A.02.5 The reliability of the water right has been analyzed and is deemed sufficient by the County based on its priority date within the Colorado System of Water Rights Administration and the additional volume that can be extracted from this water right.
- 1808A.02.6 The water storage capacity is deemed sufficient by the County to ensure that no water supply shortages will occur due to variations in the hydrologic cycle. At a minimum, storage capacity sufficient to provide 1-year of additional carryover storage, on an average annual

basis, beyond that necessary to meet all demands under all anticipated hydrologic conditions will be required.

1808A.02.7 Delivery of the water supply to the development is deemed adequate and feasible by the County.

1808A.02.8 The applicant has provided a letter from the extraterritorial district stating its commitment and ability to serve the proposed development.

1808A.03 New Special District

The organization of a new special district to provide water service is authorized by § 32-1-201, *et seq.* C.R.S. The BCC is authorized by § 32-1-203 C.R.S., to review and approve the service plan.

A water supply sufficient in terms of quantity, quality, and dependability shall be required. [§ 30-28-133 (3)(d), C.R.S.] Approval shall be based on compliance with the following service and facility standards: [§ 32-1-203(2.5)(b), C.R.S.]

1808A.03.1 The proposed water supply for any special district proposed to rely on Denver Basin aquifers may be obtained from the Denver Basin aquifers underlying the subject land;

AND/OR

from beneath land located in the Central Basin that has been zoned as Open Space Conservation District, or is subject to a perpetual open space conservation easement, in accordance with the Denver Basin aquifer standards in section 1808A.04.

A copy of the conservation easement shall be submitted to the Planning Division, and shall contain provisions which restrict the uses of the land to substantially the same uses and level of development as are permitted on land zoned as Open Space Conservation District, as determined by the Director. A copy of the declaration of restrictive covenants shall be provided, as required.

1808A.03.2 An attorney's opinion letter has been provided stating ownership by the applicant of, or an executed contract granting rights to the applicant for, all Denver Basin aquifers present beneath the subject land and a copy of the court decree adjudicating those water rights, if those water rights have been adjudicated;

1808A.03.3 An adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan. *An adjudicated augmentation plan shall be submitted prior to the scheduling of a public meeting or public hearing for the application.*

1808A.03.4 The applicant has demonstrated that the water rights can be used for the proposed use(s).

- 1808A.03.5 The water rights are sufficient based on the minimum water-supply standards. (Sec. 1804A)
- 1808A.03.6 The water in all Denver Basin aquifers shall be reserved in perpetuity, for the benefit of future landowners within the proposed development, pursuant to a declaration of restrictive covenants in a form prescribed by the County.
- 1808A.03.7 The total annual demand of water proposed for the subject land, in accordance with, the minimum water standards (Sec. 1804A), shall not exceed 100 percent of the total annual appropriable water supply contained within the Denver Basin aquifers underlying the subject land.
- 1808A.03.8 Service Plan Provisions
- (1) The proposed service plan shall include a well-field analysis that demonstrates that such wells will not adversely impact existing water rights on adjoining lands, consistent with the provisions in § 37-90-137(4)(c), C.R.S., as amended.
 - (2) The proposed service plan shall require the district to install an acceptable water level measuring device in all new district wells to measure and record water levels on a monthly basis, whether the water level obtained is a static or pumping water level, and provide for an annual report of such data to Douglas County.

1808A.04 Denver Basin Aquifers

The water supply may be provided from the Denver Basin aquifers, in compliance with the following:

- 1808A.04.1 An attorney's opinion letter stating ownership by the applicant of, or an executed contract granting rights to the applicant for, all Denver Basin aquifers present beneath the subject land and a copy of the court decree adjudicating those water rights, if those water rights have been adjudicated;
- 1808A.04.2 An adjudicated Augmentation Plan shall be provided, if required by the Colorado State Engineer, and a copy of the court decree adjudicating the Augmentation Plan. *An adjudicated Augmentation Plan, if not available prior to the hearings, may be required as a condition of approval.*
- 1808A.04.3 The water in all Denver Basin aquifers shall be reserved in perpetuity, for the benefit of future landowners within the proposed development, pursuant to a declaration of restrictive covenants in a form prescribed by the County.
- 1808A.04.4 The total annual demand of water proposed for the subject land, in accordance with the minimum water-supply standards (Sec. 1804A),

shall not exceed 100 percent of the total annual appropriable water supply contained within the Denver Basin aquifers underlying the subject land.

1808A.04.5 When the landowner does not own rights to all the Denver Basin aquifers, a groundwater well may be allowed as the source of water as required for issuance of a building permit, for a principal or accessory use currently allowed by zoning, on a legally created parcel.

1809A Appeal Process

An appeal to the water supply standards is allowed as follows:

1809A.01 The applicant shall discuss the appeal informally with planning staff to discuss the procedures and submittal requirements.

1809A.02 The applicant shall submit an explanation in narrative form explaining the appeal and attach any information including site-specific data, for the Board to consider.

1809A.03 The following analysis will be required for appeals to Margins A/B:

1809A.03.1 A static analysis to include an evaluation of the volume of the appropriable water supply for the proposed development.

1809A.03.2 A dynamic analysis that evaluates whether the appropriable water supply is sustainable for 100 years, including:

- (1) site-specific aquifer hydraulic characteristics
- (2) simulation of the current and future pumping effects from all pumping centers in the Denver Basin, using currently accepted estimates of present and future pumping volumes in the Basin
- (3) simulation of pumping of the applicant's proposed wells to evaluate if, under these pumping conditions, the applicant's wells can satisfy the Minimum 100-year Useful Life
- (4) simulation of the hydraulic control that is exerted by pumping of other wells in the confined portion of the aquifers - This will require simulation of the layering effects in the aquifers.
- (5) simulation of the elevation differences within each aquifer, *e.g., the bowl-shaped nature of the Basin*

1809A.03.3 A well-field analysis to evaluate impacts on neighboring wells using information gained from the dynamic analysis.

1809A.04 Upon receipt of the narrative and attached documents, staff shall submit this information for review by the County's water consultant and any other referral agencies deemed relevant by staff. Staff shall schedule the

appeal before the Planning Commission and Board for public hearings and notify the applicant of the meeting dates and times.

- 1809A.05 The applicant is responsible for posting notice on the subject land in accordance with the public notice requirements set forth in Section 1810A, herein.
- 1809A.06 At a public hearing, the Planning Commission shall evaluate the application, based on the technical data, the water consultants' opinions, site-specific data, the water-supply standards, the staff report, and public testimony, and shall make a recommendation to the Board to approve, conditionally approve, or deny the appeal. The Planning Commission's comments shall be based on the evidence presented.
- 1809A.07 At a public hearing, the Board shall evaluate the application based on the technical data, the water consultants' comments, site-specific data, the water-supply standards, the staff report, the Planning Commission's recommendation, and public testimony and shall approve, conditionally approve, table for further study, or deny the appeal. The Board's decision shall be based on the evidence presented.

1810A Public Notice Requirements - Appeal

In calculating the required time period for posting and publishing a notice of a public hearing, the day of publishing or posting shall be counted in the total number of days required. The day of the hearing shall not be counted toward the total number of days required for the notification period.

The degree of accuracy required for the information contained in these public notices shall be that of substantial compliance with the provisions of this section. Substantial compliance for these public notices shall be determined by the Planning Commission and the Board of County Commissioners for their respective public hearings. *(Amended 3/28/01)*

1810A.01 PUBLISHED NOTICE

At least 14 days prior to the Planning Commission hearing and 14 days prior to the Board hearing, the applicant shall:

- publish a notice in at least one publication of a daily or a weekly legal newspaper of general circulation, printed or published in whole or in part in Douglas County; and
- provide a publisher's affidavit of said published notice to the Planning Division at least 7 days prior to the hearing. The notice shall read:

**NOTICE OF PUBLIC HEARING BEFORE THE
(PLANNING COMMISSION OR BOARD OF COUNTY COMMISSIONERS)**

A public hearing will be held on *(date)*, at *(time)*, in the Commissioners' Hearing Room, 100 Third Street, Castle Rock, CO, for an appeal concerning water regulations in the Douglas County Zoning Resolution for the property located at approximately *(distance and direction from nearest major intersection)*. For more information call Douglas County Planning, 303-660-7460.

File #/Name:

When concurrent notice has been approved by staff, the notice shall read:

**NOTICE OF PUBLIC HEARINGS BEFORE THE
PLANNING COMMISSION AND BOARD OF COUNTY COMMISSIONERS**

A public hearing will be held before the Planning Commission on *(date)*, at *(time)*, and before the Board of County Commissioners on *(date)*, at *(time)*, in the Commissioners' Hearing Room, 100 Third Street, Castle Rock, CO, for an appeal concerning water regulations in the Douglas County Zoning Resolution for the property located at approximately *(distance and direction from nearest major intersection)*. For more information call Douglas County Planning, 303-660-7460.

File #/Name:

1810A.02 POSTED NOTICE

At least 14 days prior to the Planning Commission hearing and 14 days prior to the Board hearing, the applicant shall post a notice on the property that is the subject of the appeal. The sign posting shall consist of at least 1 sign facing each abutting public or private street open for travel, within 10 feet of the lot line abutting such street, placed on posts at least 4 feet above ground level. In the event the staff planner determines a sign cannot be placed abutting such street and be visible from such street or that there is no abutting public or private street open for travel, the staff planner may require an alternate location for a sign. Each sign shall measure not less than 3' by 4'. Letter size shall be a minimum of three inches high. The notice shall read:

**NOTICE OF PUBLIC HEARING BEFORE THE
(PLANNING COMMISSION OR BOARD OF COUNTY COMMISSIONERS)**

This land shall be considered for an appeal concerning water regulations in the Douglas County Zoning Resolution. The public hearing is on *(date)*, at *(time)*, in the Commissioners' Hearing Room, 100 Third Street, Castle Rock, CO. For more information call Douglas County Planning, 303-660-7460.

File #/Name:

When concurrent notice has been approved by staff the notice shall read:

**NOTICE OF PUBLIC HEARINGS BEFORE THE
PLANNING COMMISSION AND BOARD OF COUNTY COMMISSIONERS**

This land shall be considered for an appeal concerning water regulations in the Douglas County Zoning Resolution before the Planning Commission on *(date)*, at *(time)*, and before the Board of County Commissioners on *(date)*, at *(time)*, in the Commissioners' Hearing Room, 100 Third Street, Castle Rock, CO. For more information call Douglas County Planning, 303-660-7460.
File #/Name:

1811A Definitions

- 1811A.01 Appropriable Water Supply: The volume of water in storage in the Denver Basin aquifers beneath a parcel of land, exclusive of prior appropriated rights. The volume of appropriable water in storage is calculated based on overlying land area, aquifer saturated thickness, and the specific yield of the aquifer. Under Colorado law, 1/100th of the appropriable water in storage can be extracted on an annual basis from each Denver Basin aquifer.
- 1811A.02 Augmentation Plan: If a tributary or not-nontributary water right is sought to be appropriated, it is incumbent upon the applicant for these water rights to demonstrate non-injury to existing, vested senior water rights. If such analysis indicates that there is the potential for injury to existing vested senior water rights, an augmentation plan must be adjudicated in Water Court which defines the uses of the water sought in the appropriation, defines the extent of the injury that will occur due to this appropriation, and presents a plan that will fully mitigate injury to all existing vested senior water rights.
- 1811A.03 Colorado System of Water Rights Administration: Colorado operates under a “first in time, first in right” water rights administration for tributary waters of the state. This means that the most senior tributary water rights are wholly satisfied first, prior to any junior water rights diverting. If there is insufficient water to meet the water demands of all of the water rights, some water rights will be deemed “out of priority”, and will not be allowed to divert any water until sufficient supply is available for all rights senior to that right.
- 1811A.04 Denver Basin: A large groundwater basin of sedimentary rock formations containing 4 principal aquifers, the Dawson, Denver, Arapahoe and Laramie-Fox Hills. This water basin extends from Greeley on the north to Colorado Springs on the south, Limon on the east to the foothills on the west. Groundwater contained within the Denver Basin aquifers is considered to be either nontributary or not-nontributary water under the Colorado Water Rights System.

- 1811A.04.1 Central Basin: The area comprising most of the eastern half of Douglas County that is underlain by the Denver Basin. This is the area of the Denver Basin where the four principal aquifers are present and where the aquifers are located at, or near, the base of the bowl-shaped Denver Basin. Due to the presence of the four principal aquifers and the relative location in the Central Basin, water supplies developed in this zone can provide the Minimum 100-Year Useful Life.
- 1811A.04.2 Margin B: An area west of the Central Basin of the Denver Basin, where aquifer elevations are comparable in relation to the Central Basin of the Denver Basin. Water supply availability in this zone may not provide a Minimum 100-Year Useful Life.
- 1811A.04.3 Margin A: An area west of Margin B of the Denver Basin, which is characterized by the westernmost extent of the Denver Basin. Due to the outcrop of the Denver Basin in this area and the relative elevation of the Denver Basin aquifers compared to the remainder of the Basin, water supplies in this zone may not provide a Minimum 100-Year Useful Life.
- 1811A.05 Dynamic Analysis: Water supply availability and reliability evaluation required if a land use applicant wishes to use Denver Basin water in Margin A or more than 50 percent of the water supply availability in Margin B, as estimated from the static analysis. This analysis requires the use of a model that accurately simulates the geologic and hydrogeologic characteristics of the Denver Basin and how aquifer parameters and water levels will change over time. A dynamic analysis can evaluate long-term water supply availability and reliability because it simulates actual conditions and how they likely will change in the future, rather than assuming constant values for all time, as in the static analysis. This analysis is typically completed using a numerical groundwater model.
- 1811A.06 Existing District: A special district currently offering water service, organized or validated pursuant to the Special District Act, § 32-1-101, *et seq.*, C.R.S., with a service plan or statement of purposes approved by Douglas County prior to August 12, 1998.
- 1811A.07 Extraterritorial District: A special district currently offering water service, organized or validated pursuant to the Special District Act, § 32-1-101, *et seq.*, C.R.S., with a service plan or statement of purposes approved by an entity other than Douglas County.
- 1811A.08 Dakota Sandstone Formation: An area of the County that is depicted on the Water Supply - Overlay District Map in the area between the Pike/Rampart and the Denver Basin. This area consists of older sedimentary formations that generally underlie the Denver Basin aquifers but are uplifted to the surface in this area and are characterized by pronounced hogback and red sandstone features. Water supplies

obtainable from these older sedimentary formations are quite limited and closely resemble the water availability of Margin Area A of the Denver Basin. Therefore, this area is considered part of Margin Area A for the purposes of the regulations set forth in the Water Supply - Overlay District.

- 1811A.09 Minimum 100-Year Useful Life: A water supply that will reliably provide water for a minimum time frame of 100 years. The County policy to determine useful life requires a showing from both a static and dynamic basis that a proposed water supply will be viable for a minimum 100-year period. The static analysis would include evaluation of the volume of water that is appropriable for the proposed development. The dynamic analysis would evaluate whether the appropriable water supply is sustainable for 100 years, giving consideration to the location within the Basin, as well as impacts caused by both current and future pumping by others in the Basin.
- 1811A.10 New Special District: A special district offering water service, organized pursuant to the Special District Act, § 32-1-101, *et seq.*, C.R.S., with a service plan approved by Douglas County after August 12, 1998.
- 1811A.11 Non-Renewable Water: Water that is not annually recharged through the hydrologic cycle, and development of the water resource relies upon drawing water principally from storage in the aquifer. This is also referred to as a finite water supply.
- 1811A.12 Nonresidential Equivalent: The quantity of water necessary for light industrial or office uses which corresponds to the residential standard of .75 acre-foot per year. The nonresidential equivalent is equal to .75 acre-foot per year required for each 6,695 square feet of building space.
- 1811A.13 Nontributary Water: Waters of the Denver Basin that, when pumped, *will not*, within 100 years, affect the flow of any natural stream by greater than one-tenth of one percent of the annual pumping volume. This is a non-renewable water supply.
- 1811A.14 Not-Nontributary Water: Waters of the Denver Basin that, when pumped, *will*, within 100 years, affect the flow of a natural stream by greater than one-tenth of one percent of the annual pumping volume. Because the pumping of not-nontributary water will cause an impact to the surface stream system, an adjudicated plan for augmentation is required prior to the use of not-nontributary groundwater from the Denver Basin aquifers. This is a non-renewable water supply.
- 1811A.15 Pike/Rampart: The western portion of Douglas County that is characterized by the uplifted granitic mountains west of the Dakota Sandstone Formation and the Denver Basin. Water supplies in this zone are primarily through fractures in the granitic and metamorphic rock. While this water is renewable, due to the relatively low permeability of

these fractures, water supply availability is relatively limited in the Pike/Rampart.

1811A.16 Renewable Water: Water that is annually recharged through the hydrologic cycle, such as streams, and alluvial aquifers associated with streams so that the water supply is sustainable over time.

1811A.17 Static Analysis: Water supply availability evaluation required for proposed land uses that plan to use Denver Basin water in Margin B or in the Central Basin. This analysis is based on assumed constant values for the land area, aquifer specific yield and aquifer-saturated thickness. Aquifer specific yield and saturated thickness values are obtained from the Denver Basin Rules, promulgated by the Colorado State Engineer's Office, or, when available, from a decree from the Water Court.

Annual water supply availability is calculated by static analysis as: land area available for appropriation X aquifer specific yield X aquifer saturated thickness) 100 years. A static analysis cannot evaluate the long-term reliability of a water supply.

1811A.18 Tributary Water: Water contained within the surface stream systems, or in groundwater that is hydraulically connected to the stream system. Tributary waters are considered waters of the state, are available for appropriation through the Colorado Water Rights System, and are subject to the Colorado System of Water Rights Administration. Tributary Water rights are based on the priority of the rights to the extent that they can be relied upon as a water supply and meet the minimum water supply criteria, herein. This is a renewable water supply.

1811A.19 Water Supply: The legal and physical delivery of water service that is sufficient in terms of quantity, quality, and dependability for proposed development.

1811A.20 Water Supply Plan: Documentation provided to Douglas County in support of a land-use application which details:

(a) the water demands of the proposed development as specified in 1804A;

(b) the source(s) of water to be used to meet the development demand;

(c) the water-supply delivery system, including the structures to be used for the diversion or extraction of the water, the conveyance system, and the required storage facilities;

(d) demonstration of the reliability of the water supply, both from a physical and legal supply perspective, and including all losses associated with the delivery and storage system to be used;

(e) proof that the water supply is owned and can be used by the applicants for the purposes intended in the application;

- (f) proof that all necessary decrees, permits, and any other legal requirements are in place that allow the legal use of the water supply;
- (g) the timing of the development demands through the buildout of the project.

1811A.21 Well-Field Analysis: Evaluation required with proposed land-uses that plan to use Denver Basin water in Margin B or the Central Basin, to assess whether a new proposed well field associated with the proposed land use will create water level change impacts such that neighboring wells, either on or off the subject property, will have their ability to produce their water rights impaired. A change in water level at an adjacent well is not, in and of itself, considered to be an impact. This analysis is typically completed using an analytical ground water model.

Figure 9.5

WATER SUPPLY ZONES

DOUGLAS COUNTY, COLORADO

LEGEND

- | | |
|---|--|
|  | CENTRAL BASIN - DENVER FORMATION |
|  | MARGIN A - DENVER FORMATION |
|  | MARGIN A - DAKOTA SANDSTONE FORMATION |
|  | MARGIN B - DENVER FORMATION |
|  | PIKE/RAMPART - PRIVATE HOLDINGS - GRANITIC FORMATION |
|  | PIKE NATIONAL FOREST - GRANITIC FORMATION |
|  | INCORPORATED AREAS |
|  | WESTERN EDGE OF DENVER BASIN |
|  | EASTERN EDGE OF GRANITIC FORMATION |
|  | TOWNSHIP LINES |
|  | STREAMS |

DISCLAIMER:

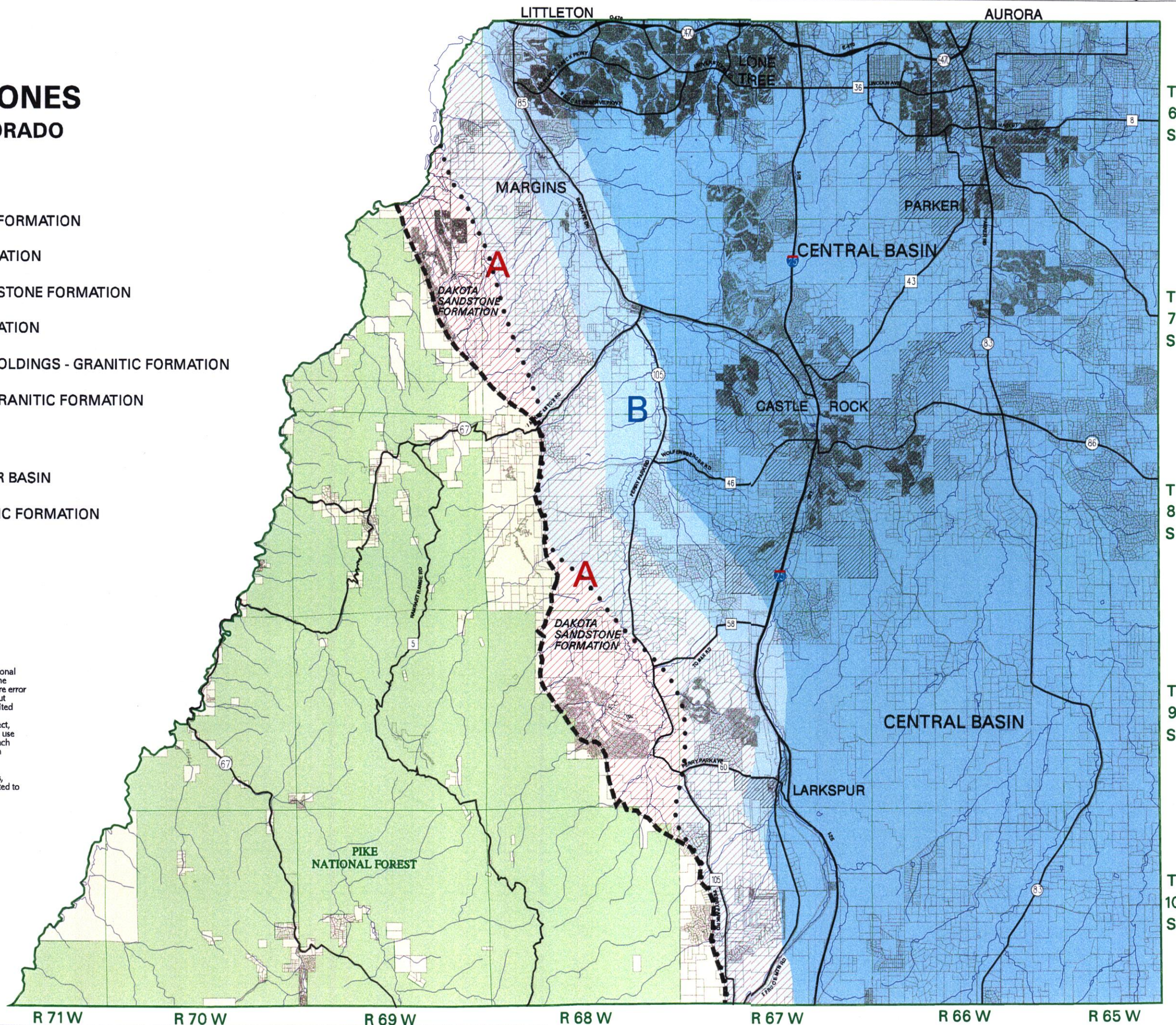
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One inch on the map equals 3 miles on the ground



May 2001



ATTACHMENT C

ADVISORY COMMITTEE AND
PEER REVIEW COMMITTEE CHARTERS

Sustainable Development in Colorado – Total Water Management Approach for Outdoor Water Uses

CWCB Conservation Grant Study for Dominion, CPN, and Douglas County

ADVISORY COMMITTEE

Charter: The Advisory Committee will provide its technical expertise and a non-technical review and assessment of policy implications of the study.

Purpose/Goals:

1. Offer non-technical perspectives and technical expertise.
2. Assist Study Team in identifying existing research for inclusion in the literature review.
3. Provide insight on policy directives or changes to state and local requirements.
4. Identify key next steps for study.
5. Develop framework for post-study implementation.

Period: Commencing May 1, 2006 with expected completion by mid-September 2006.

Members:

- Co-Chairs
 - Ronda Sandquist – Attorney, Jackson Kelly
 - Amy Conklin – Littleton City Council
- Committee Participants
 - Andrew Appell – Denver Water Planning Division
 - Joe Porter – Design Workshop
 - Mike Gilsdorf – Arapahoe Acres Nursery, Chatfield East HOA
 - Nicole Adams – Thunderbird Water & Sanitation Dist
 - Jeff Watson – Douglas County
 - Jim McGrady - Castle Pines North Metropolitan District
 - Dave Merritt - Colorado River Water Conservation District Representative
 - Paul Lander – City of Boulder
 - Kevin Lusk – Colorado Springs Utilities

Communication:

Three meetings will be held.

Interim work products will be provided to the members of the Advisory Committee via e-mail, and the Committee will provide comments back to the Study Team via e-mail. The Study Team will work with the Advisory Committee Co-Chairs to determine whether, and how, to

incorporate the comments. The substance of interim discussions will be shared with all committee members and interested parties. Every couple of weeks, the Study Team will distribute to the members of the Committee, via e-mail, a summary of the comments it has received. The Study Team will indicate how the comment(s) has been incorporated into the study or work product, or will state the reason it has not been incorporated.

Further updates and comments can be discussed at the meetings. One of The Advisory Committee Co-Chairs will conduct the meetings to assure the agendas are covered in the allotted time. The Advisory Committee Chair will prepare meeting summaries and email them to the Committee members and Study Team following the meeting.

The Study Team will consider all feedback provided by the Committee as the Study budget, schedule, and scope allow; a brief follow-up email will be used to update Committee members on changes as a result of feedback.

Meeting Agendas:

Project Kickoff –Advisory Committee members will provide (1) initial input on the study goals and objections and (2) identify existing studies or materials that may be relevant for review by the Study Team during the literature review process.

Agenda issues for subsequent meetings will be drawn from the previous meeting (unresolved or completed issues) and major issues identified in interim e-mails and discussions.

Sustainable Development in Colorado – Total Water Management Approach for Outdoor Water Uses

CWCB Conservation Grant Study for Dominion, CPN, and Douglas County

PEER REVIEW COMMITTEE

Charter: The Peer Review Committee is established by the Colorado Water Conservation Board to assure quality control and fulfillment of the study grant objectives. The Peer Review Committee is responsible for the primary technical review of the study findings and evaluation of the application of those findings and scientific applications used throughout the study.

Purpose/Goals:

1. Provide quality control by assuring sound scientific bases for the study and defensible scientific applications or assumptions.
2. Offer technical perspectives and expertise.
3. Assist Study Team in identifying existing research for inclusion in the literature review.
4. Assure that the recommended algorithms for estimating water savings through conservation efforts are based on the best available data and methods.
5. Review final written product for accuracy and its usefulness for future implementation of study findings.

Period: Commencing May 1, 2006 with an expected completion by mid-September 2006.

Members:

- Rod Kuharich – Colorado Water Conservation Board
- Veva McCaig – Colorado Water Conservation Board
- Jack Byers – Division of Water Resources
- Dick Wolfe – Division of Water Resources
- (not yet designated) – Colorado Water Quality Control Division

Communication:

Three meetings will be held.

Interim work products will be provided to the members of the Peer Review Committee via e-mail, and the Committee will provide comments. The substance of interim discussions will be shared with all committee members and interested parties.

Every couple of weeks, The Study Team will summarize the comments it receives and will describe how those comments will be addressed by the study.

Additional comments can be discussed at the meetings.

The Study Team will prepare meeting summaries and email them to the Committee members following the meeting. The Study Team will consider all feedback provided by the Committee subject to limitations of the Study budget and schedule.

Brief follow-up emails will update Committee members on changes as a result of feedback.

Meeting Agendas:

Project Kickoff –Committee members will provide (1) initial input on the study goals and process and (2) identify studies or materials that may be relevant for review by the Study Team during the literature review process.

Agenda issues for subsequent meetings will be drawn from the previous meeting (unresolved or completed issues) and major issues identified in interim e-mails and discussions.

ATTACHMENT D

IRRIGATED AREA CALCULATION DOCUMENTS
(FOR APPENDIX D)

Appendix A.1.1 NW Douglas County Densities

From: Nancy Gedeon [NGedeon@douglas.co.us]
Sent: Friday, October 06, 2006 2:40 PM
To: cdouglass@meurer.com
Cc: Robert Barton
Subject: NW Douglas County Densities

Attachments: NW area urban densities - final.xls

Chris,

The attached file contains the residential densities of Highlands Ranch, Roxborough Park and Village, and The Meadows. The dwelling units per acre are calculated by total planned units (number at build-out), by total platted units, and by total units built as of 1-1-06 (CO'd units).

I also distinguished between acres of residential land versus total acres in the subdivision. Because The Meadows are in the Town of Castle Rock, we do not keep totals of the plats or COs, so those fields are incomplete.

Please contact me if you have any questions or need further information.

Nancy
x4370

Nancy Gedeon
Demographic Technician
Community Development Department
Douglas County
303-660-7460

Northwest Douglas County Residential Densities

CURRENT AS OF 01/01/2006

SUBDIVISION	DWELLING UNITS						
	TOTAL ZONED UNITS	PLAT SF UNITS	PLAT MF UNITS	TOTAL PLAT UNITS	SF CO'S	MF CO'S	TOTAL CO'S
HIGHLANDS RANCH	36,700	26,136	6,644	32,780	25,297	5,672	30,969
ROXBOROUGH PARK	2,868	974	405	1,379	794	64	858
ROXBOROUGH VILLAGE	2,748	1,976	-	1,976	1,969	-	1,969
MEADOWS THE	13,796						

ACRES			
S.F. ACRES	M.F. ACRES	TOTAL RESID ACRES	TOTAL ZONED ACRES
5,946	861	6,807	21,806
		985	2,464
		475	696
1,552	535	2,087	3,555

DWELLING UNITS PER ACRE					
AT BUILD-OUT		2006 CO'd UNITS		PLATTED UNITS	
TOTAL ACRES	RESID ACRES	TOTAL ACRES	RESID ACRES	TOTAL ACRES	RESID ACRES
1.68	5.39	1.42	4.55	1.50	4.82
1.16	2.91	0.35	0.87	0.56	1.40
3.95	5.79	2.83	4.15	2.84	4.16
3.88	6.61				

KEY

SF: Single Family residential

MF: Multi-Family residential

PLAT: Subdivided land

CO: Certificate of Occupancy

Appendix A.2

Lot Area Calculations

	1 acre =	43,560 square feet
Gross Lot Area	5 units/acre =	8,712 square feet
Net Lot Area	20% reduction for roads	6,970 square feet
Impervious Area	50% of Net Lot Area	3,485 square feet
Area Available for Irrigation	50% of Net Lot Area	3,485 square feet

ATTACHMENT E

LANDSCAPE WATER USAGE DOCUMENTS
(FOR APPENDIX E)

Green Industry
Best Management Practices (BMPs)
for the Conservation and Protection
of Water Resources in Colorado

Prepared for

The Green Industries of Colorado (GreenCO)
5290 E. Yale Circle, Suite 204
Denver, CO 80222

Prepared by

Wright Water Engineers, Inc.
2490 West 26th Avenue, Suite 100A
Denver, CO 80211

With support from:

The Colorado Water Conservation Board

Headwaters Consulting, LLC

Colorado Department of Public Health and Environment
Water Quality Control Division

(under a grant from the U.S. Environmental Protection Agency)



2ND RELEASE, MAY 2004

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Green Industry Best Management Practices (BMPs) for the Conservation and Protection of Water Resources in Colorado

Prepared for

The Green Industries of Colorado (GreenCO)
5290 E. Yale Circle, Suite 204
Denver, CO 80222

Prepared by

Wright Water Engineers, Inc.
2490 West 26th Avenue, Suite 100A
Denver, CO 80211

With support from

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Second Release, May 2004

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May 2004

Dear GreenCO Member,

The following manual, "Green Industry Best Management Practices (BMPs) for the Conservation and Protection of Water Resources in Colorado" describes conservation practices for the Green Industry in Colorado. As a whole, GreenCO is dedicated to the conservation and preservation of all Colorado's precious resources which contribute to Colorado's natural environment and beauty. Since 1996, the Green Industries of Colorado (GreenCO) has been working with a diverse set of industry experts and partners to develop a water conservation and water quality protection program for its nine member associations. In May 2002, the first release of the BMP manual was developed and distributed to the green industry through the support of GreenCO, Wright Water Engineers, Inc., Colorado Water Conservation Board (CWCB), and Headwaters Consulting, LLC.

Coincidentally, following the initial release of the manual, the Green Industry was hit-hard by drought restrictions during 2002 and 2003. The drought has been a wake-up call for Green Industry professionals and communities alike, emphasizing that water conservation must become a way of life in Colorado, all the time, not just during a drought. In order to promote this reality to the Green Industry professionals and to provide increased training regarding water conservation practices, GreenCO decided to take the BMPs to the next level by revising the manual. A training course was also developed to accompany the manual.

The revisions were based on lessons learned from the drought experiences during 2002 and 2003. Key practices which were added include herbaceous plant care and water budgeting. The manual will continue to be updated periodically to remain current with the state-of-the-art practices for water conservation and water quality protection. If periodic updates are necessary, the GreenCO website will reflect the latest updates.

Although the BMP manual is copyrighted by GreenCO, it is our intent that this information be distributed widely amongst Green Industry professionals, municipalities, water districts, and others concerned with wise water use landscapes. Green Industry professionals should use this manual as general guidance with the recognition that some environmentally sensitive or drought-stricken areas may require modification of some practices.

Whether you're a Green Industry professional, homeowner, commercial property manager, or homebuilder, we hope you find this manual useful. If you have any questions, please contact GreenCO's Project Manager, Brenda O'Brien (brenda.obrien@comcast.net).

Sincerely,
GreenCO Board Members

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Appendix A: Basic Erosion and Sediment Control Practices

Appendix B: Permanent Stormwater BMPs

Appendix C: Summary of Potentially Applicable Regulations

Appendix D: Water Budget Calculator

Appendix E: Plant Water Requirement Estimates (Results of GreenCO/Colorado State University 2004 Crop Coefficient (Kc) Survey)

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Development of the manual and its initial release was made possible through the Colorado Water Conservation Board, which provided funding for the manual in keeping with its goals of conserving, developing, protecting and managing Colorado's water for present and future generations. The Colorado Department of Public Health and Environment Water Quality Control Division provided funding for the revision and second release of the manual.

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Kristen Sirovatka, ALCC
Paul Thomas, Wenk Associates
Keith Williamson, Little Valley Wholesale Nursery, CNA

In keeping with GreenCO's desire not to "reinvent the wheel" when high-quality information on relevant BMPs was already in existence, the following written materials were relied upon heavily and may have been partially reproduced or adapted into this manual:

- Colorado State University Cooperative Extension. 2004. Planttalk Colorado Web site: www.ext.colostate.edu/ptlk.
- Colorado State University Cooperative Extension. 2004. Gardening On-line Web site: www.coloradogardening.com.
- Denver Water. 2004. Denver Water Conservation and Xeriscape Web sites: http://www.denverwater.org/cons_xeriscape/cons_xeriscapeframe.html. Also Denver Water brochures. (Particularly with regard to information related to Xeriscape, a term copyrighted by Denver Water in 1981.)
- Irrigation Association Water Management Committee. 2001. *Turf and Landscape Irrigation Best Management Practices*. Falls Church, VA: Irrigation Association. Also see www.irrigation.org.
- Panter, K.L., S.E. Newman, and R.M. Waskom. 1998. *Pollution Prevention in Colorado Greenhouses*. XCM-206 (www.ext.colostate.edu/pubs/garden/xcm206.pdf). Ft. Collins, CO: Colorado State University Cooperative Extension.
- Urban Drainage and Flood Control District. 1999. *Urban Storm Drainage Criteria Manual, Volume 3, Stormwater Best Management Practices*. Denver, CO: UDFCD.
- Urban Drainage and Flood Control District. 2001. *Urban Storm Drainage Criteria Manual, Volume 2*. Denver, CO: UDFCD.

- Wright Water Engineers and Denver Regional Council of Governments. 1996. *Guidelines for Water Quality Enhancement at Golf Courses Through the Use of Best Management Practices*. Denver, CO: DRCOG.

Purpose and Limitations

The purpose of this manual is to consolidate and improve upon Green Industry Best Management Practices (BMPs) for the conservation of water resources and protection of water quality. These BMPs include a variety of design, installation, maintenance, grower and retail practices relevant to the Green Industry and the public that they serve. This document is an initial building block for the Green Industry to use in further developing common industry-wide standards.

This manual should be used to enhance the professional qualifications and judgement of the Green Industry—it is not a regulatory document. Green Industry professionals should use this manual as general guidance with the recognition that some environmentally sensitive or drought-stricken areas may require modification of these practices. This document is not a design manual; instead, it provides overviews of key BMPs and directs the user to relevant design and certification manuals, where appropriate.

As technological and horticultural advances occur, this manual will need to be updated periodically to remain current with the state-of-the-art practices for water conservation and water quality protection. For the most recent version of this manual, please refer to the GreenCO Web site (www.greenco.org) or the Colorado Water Conservation Board Web site (www.cwcb.state.co.us).

Background

The Green Industries of Colorado (GreenCO) is an umbrella trade organization representing the common interests of nine landscape-related trades:

- Associated Landscape Contractors of Colorado (ALCC)
- Colorado Chapter of the American Society of Landscape Architects (ASLA)
- Colorado Association of Lawn Care Professionals (CALCP)
- Colorado Greenhouse Growers Association (CGGA)
- Colorado Nursery Association (CNA)
- Garden Centers of Colorado (GCC)
- International Society of Arboriculture/Rocky Mountain Chapter (ISA/RMC)
- Rocky Mountain Sod Growers Association (RMSGGA)
- Wholesale Florists of Colorado (WFC)

GreenCO members represent diverse interests including sod growers, landscape architects, greenhouse growers, nurseries, retailers, contractors, lawn care professionals, arborists and florists. Each of GreenCO's members has in common an economic dependence on built landscapes.

In 1996, GreenCO began working to help the Green Industry develop an understanding and strategy to respond to challenges posed to the industry by potential water shortages related to either population growth or drought. Representatives from GreenCO's nine trade associations worked with diverse partners including Colorado State University Cooperative Extension, the Colorado WaterWise Council, Denver Water and the Colorado Water Resources Research Institute. GreenCO worked proactively to support water conservation and quality goals without specific regulatory pressure.

Looking to the future, GreenCO recognizes that the economic health of the industry and the health of the state's water resources are inextricably linked. Its water-related goals are to:

- Realize significant, measurable improvements in water quality and conservation statewide through improved and efficient landscape practices.
- Ensure the future health and competitiveness of the Green Industry in Colorado in the face of new standards and regulations.
- Provide improved water management tools and resources for GreenCO member businesses and their customers.

To realize these goals, GreenCO identified the development of industry-wide BMPs as a first step toward getting its “house in order” by compiling and improving industry-wide standards for tools and technologies that support water conservation and quality.

Definition of Best Management Practices (BMPs) and Principles

The simplest way to define a BMP for purposes of this manual is a voluntary activity undertaken to reduce water consumption and protect water quality. Appropriateness of the BMPs may vary depending on site-specific and regional conditions. The term BMP has been selected for use in this manual primarily for consistency with other national and international efforts to protect water quality. For example, the U.S. Environmental Protection Agency (EPA), the state of Colorado (including the Nonpoint Source Council and the Water Quality Control Division), regional organizations such as the Denver Regional Council of Governments, local governments, as well as many others, have retained the term BMP in ordinances, regulations and guidance manuals.

Most of the BMPs in this manual are relevant to both water quality and water conservation and are based on these basic principles:

1. Healthy landscapes enhance water quality and the environment. Inclusion of green areas in urban settings helps minimize pollutant-laden runoff to waterbodies and allows precipitation in urban areas to infiltrate into the soil, rather than overload natural drainageways. Landscape features such as grass swales, vegetated buffer strips along waterways, constructed wetlands and other well-vegetated areas are key components of good stormwater management. Well-vegetated areas are particularly important in reducing sediment loading to streams and lakes.
2. Over-irrigation is the leading source of water waste in landscaping. Landscapes (including their irrigation systems) are water-efficient when they are properly designed, installed and maintained according to sound landscaping and water conservation principles. The term "Xeriscape" was copyrighted by Denver Water in 1981 to help make water-conserving landscaping an easily recognized concept based on these seven principles: comprehensively designed landscapes, healthy soil, practical turf areas, proper plant selection and placement, efficient irrigation, mulching and good maintenance.
3. Water budgeting is an effective tool for designing and maintaining water-efficient landscapes during both normal and drought conditions. An outdoor water budget identifies the amount of water needed for healthy landscapes. Comparison of actual water used to the water budget provides a basis for adjusting water usage to reduce water waste.
4. It is easier to prevent or reduce pollution by controlling it at its source, rather than correcting its impacts. For the Green Industry, this means minimizing runoff from landscapes, properly applying and/or minimizing pesticide and fertilizer usage, and minimizing erosion and sediment-laden runoff at landscaping sites.

5. Both improved water quality and water conservation are dependent on behavior changes. Education of both the end user (homeowner/landscape owner) and Green Industry professionals (growers, retail owners, landscape designers, installation and maintenance professionals) is necessary for behavior change to occur. It takes more than a nice manual on a shelf for improved water quality and conservation to happen. BMPs must be integrated into a variety of Green Industry professional training and certification programs and actually put into practice in the field. Both Green Industry businesses and the public must recognize the value of water quality and water conservation, and the consequences of failing to implement these BMPs, in order for behavioral change to occur.

List of BMPs

Hundreds of individual practices have been consolidated into 31 general BMPs described in this document and summarized by industry in Table 1 including:

1. Drought and General Water Conservation Practices for Landscape Management
2. Drought and General Water Conservation Practices for Nurseries, Greenhouses and Growers
3. Education of Employees
4. Education of the Public
5. Herbaceous Plant Care
6. Fertilizer Application
7. Irrigation Efficiency (General Principles)
8. Irrigation System Design
9. Irrigation System Installation
10. Irrigation System Maintenance
11. Landscape Design
12. Landscape Installation and Erosion and Sediment Control
13. Landscape Maintenance
14. Lawn Aeration
15. Lawn Waste Disposal/Composting
16. Mowing

17. Mulching
18. Park, Golf Course and Other Large Landscape Design and Management
19. Pesticide and Herbicide Application
20. Pesticide, Fertilizer and Other Chemical Storage, Handling and Disposal
21. Plant Selection and Placement
22. Production Practices for Nurseries, Greenhouses and Growers
23. Regulatory Awareness and Compliance
24. Retail Practices for Nurseries, Greenhouses and Garden Centers
25. Revegetation of Drainageways
26. Riparian Buffer Preservation
27. Soil Amendment/Ground Preparation
28. Turf Management
29. Water Budgeting
30. Woody Plant Care
31. Xeriscape

Table 1
Summary of GreenCO BMPs by Industry

BMP	BMP Description	Member Industries								
		ASLA	ALCC	CALCP	CGGA	CNA	GCC	ISA	RMSG	WFC
Drought and General Water Conservation Practices for Landscapes	Manage landscapes using the most water-efficient techniques during drought conditions.	X	X	X	X	X	X	X	X	
Drought and General Water Conservation Practices for Nurseries, Greenhouses and Growers	Properly irrigate nursery and greenhouse crops with the minimum amount of water waste during drought conditions.				X	X	X	X	X	
Education of Employees	Educate industry employees on water quality and water conservation practices.	X	X	X	X	X	X	X	X	X
Education of the Public	Model and teach water conservation and water pollution prevention to the general public and consumers of green industry products.	X	X	X	X	X	X	X	X	X
Fertilizer Application	Properly apply fertilizers, based on the specific needs of plants, particularly as identified by appropriate soil or plant tissue tests.		X	X	X	X	X	X	X	
Herbaceous Plant Care	Properly plant and maintain herbaceous plants to maximize plant health and conserve water.	X	X	X	X	X	X	X		
Irrigation Efficiency	Properly design, install and maintain irrigation systems to ensure uniform and efficient distribution of water, thereby conserving water and protecting water resources.	X	X	X	X	X	X	X	X	
Irrigation System Design	Design the irrigation system for the efficient and uniform distribution of water.	X	X	X	X	X	X	X	X	
Irrigation System Installation	Install the irrigation system according to the irrigation design specifications, which should be in accordance with manufacturer's specifications, local code requirements and sound principles of efficient and uniform water distribution.		X	X	X	X	X	X	X	
Irrigation System Maintenance	Maintain the irrigation system for optimum performance, ensuring efficient and uniform distribution of water. Modify the irrigation system as needed to provide supplemental water for maintaining healthy plants without wasting water.		X	X	X	X	X	X	X	
Landscape Design	Plan and design landscaping comprehensively to conserve water and protect water quality.	X	X	X	X	X	X	X	X	
Landscape Installation/Erosion and Sediment Control	Minimize erosion and control sediment leaving the construction site during landscape installation.	X	X	X		X		X	X	
Landscape Maintenance	Practice landscape maintenance appropriate for the site including practices such as pruning, weeding, mulching, fertilization and attention to the irrigation system.		X	X				X	X	
Lawn Aeration	Aerate lawns to reduce thatch, thereby improving nutrient and water uptake, reducing runoff and reducing compaction.		X	X					X	
Lawn Waste Disposal/Composting	Dispose of yard waste to minimize adverse impacts to the environment by keeping waste out of storm drains. Recycle and compost organic materials whenever possible.		X	X	X	X	X	X	X	
Mowing	Mow lawns to the proper height and at the proper frequency to maintain turfgrass health, thereby minimizing the need for pesticide and fertilizer application and reducing water usage.		X	X					X	
Mulching	Use organic mulches to reduce water loss through evaporation, to reduce soil loss due to exposure to wind and runoff, to suppress weeds, and to provide a more uniform soil temperature.		X	X	X	X	X	X		
Park, Golf Course and Other Large Landscape Design and Management	Large landscaped areas such as parks and golf courses should be well designed and properly managed to be an environmental amenity and to minimize runoff to waterbodies.	X	X	X				X	X	
Pesticide and Herbicide Application	Apply pesticides and herbicides at minimal levels in accordance with the label and targeted to specific disease and weed problems.		X	X	X	X	X	X	X	
Pesticide, Fertilizer and Other Chemical Storage, Handling and Disposal	Pesticides, herbicides, fertilizers, fuel and other maintenance chemicals must be properly applied, stored, handled and disposed of to prevent contamination of surface water and groundwater.		X	X	X	X	X	X	X	
Plant Selection and Placement	Select appropriate plants for the site, place plants in appropriate locations and group plants according to similar water needs (i.e., "hydrozoning").	X	X	X	X	X	X	X	X	
Production Practices for Nurseries, Greenhouses and Growers	Nurseries, greenhouses and other growers should implement a variety of source, structural, cultural and managerial controls to minimize pollution of water resources. Irrigation practices that minimize off-site transport of pollutants also typically conserve water.				X	X		X	X	
Regulatory Awareness	A variety of local, state and federal environmental regulations impact landscaping and nursery operations. Green industry professional should be aware of these regulations and comply with their requirements.	X	X	X	X	X	X	X	X	X
Retail Practices for Nurseries, Greenhouses and Garden Centers	Retail businesses should operate in a manner to maintain the health of plants, to conserve water and to promote water conservation and water resource protection to the general public.				X	X	X	X	X	
Revegetation of Drainageways	Establishment of a robust cover of vegetation is critical to the proper functioning of engineered drainage structures such as grass-lined channels, detention basins, retention ponds, and wetlands.	X	X	X				X	X	
Riparian Buffer Zone Preservation	Preserve wide, undisturbed natural riparian areas along streams.	X	X	X				X		
Soil Amendment/Ground Preparation	Evaluate soil and improve, if necessary, to promote efficient water usage and healthy plants.	X	X	X	X	X	X	X	X	
Turf Management	Plan, properly install and maintain practical turf areas.	X	X	X					X	
Water Budgeting	Calculate the water needs of irrigated landscapes based on plant types, land area and irrigation system efficiency. Use the calculated water budget to apply water according to the needs of the plants and manage irrigation.	X	X	X	X	X	X	X	X	
Woody Plant Care	Properly plant and maintain prune or trim trees, shrubs and other woody plants to maximize the plants' health.	X	X	X	X	X	X	X		
Xeriscape	Implement the seven basic landscape principles of Xeriscape: planning and design, soil improvement, zoning of plants, practical turf areas, efficient irrigation, mulching and appropriate maintenance.	X	X	X	X	X	X	X	X	

ASLA = American Society of Landscape Architects
 ALCC = Associated Landscape Contractors of Colorado, Inc.
 CALCP = Colorado Association of Lawn Care Professionals
 CGGA = Colorado Greenhouse Growers Association
 CNA = Colorado Nursery Association
 GCC = Garden Centers of Colorado
 ISA = International Society of Arboriculture
 RMSG = Rocky Mountain Sod Growers Association
 WFC = Wholesale Florists of Colorado

Organization of BMP Descriptions

The BMPs in this manual are listed alphabetically. Each of the BMP descriptions is in the form of a fact sheet including the following information:

- Brief description of the BMP.
- Identification of the BMP's applicability to design, installation, maintenance, grower or operation activities.
- Identification of the BMP's relevance to various GreenCO member industries.
- Basic practice guidelines to follow when implementing the BMP.
- Regional or industry considerations/adaptations.
- Key references for more detailed information.

The discussion of each BMP is limited to several pages with the intention that the BMP sheets can be taken out of this notebook for easy reference and distribution. Because it is expected that users of this manual may focus on individual BMPs rather than the manual in its entirety, there may be redundancy among some BMP descriptions. Efforts have been made to minimize this redundancy by cross-referencing the user to related BMPs.

One important aspect of the BMP descriptions focuses on regional considerations for implementation of the BMP. Because climate and topographic conditions along the Front Range vary considerably from the western slope of Colorado, some practices that work well in one location may not work well in others, or may require special adaptations. Where appropriate, these types of considerations have been identified in the BMP descriptions.

This BMP manual is not intended to serve as a design and specification manual; instead, it compiles and summarizes into one document the key BMPs spread across the nine trades within the Green Industry. For many of the BMPs, entire workbooks and certification manuals are already in place, providing detailed guidance on the practice. In these cases, the "key references" identified in the BMP fact sheets can be obtained for more detailed guidance. A comprehensive list of these references is also provided at the end of this document.

Literature Review

A key component of this project was to identify to the degree to which the Green Industry BMPs have been developed. As a companion to this manual, a notebook of existing publications has been compiled. As a credit to the environmental awareness already present in the Green Industry, the majority of the BMPs included in this manual already have high quality publications, brochures and other materials available from multiple sources. Most of the industry certification manuals also cover many of these BMPs. The challenge to the Green Industry is ensuring that BMPs are implemented more broadly among its individual members. This manual will serve as a key step towards achieving this goal.

In general, the written information on Green Industry water conservation and water quality BMPs was consistent among sources, at least in principle, even if the details of the practice varied somewhat. Given the broad scope of this manual, primary emphasis has been given to communicating the basic principles. Where differing recommendations exist with regard to supporting details for the BMP, the source of the recommendation has been provided with an acknowledgement that recommendations may vary among industry professionals. An example relates to fertilizer application. Most key sources agree on the basic principles that fertilizer application should be timed to the needs of the plants and that fertilizer should not be over-applied. However, significant variation in recommended fertilizer application rates exists among references and member industries. In the case of lawn fertilizer application, a table of recommendations prepared by CSU Cooperative Extension experts was included as reasonable guidance for the industry with an acknowledgement that best professional judgement and site conditions should be taken into consideration.

Some of the key information sources that industry professionals may be interested in obtaining that have been important resources in developing this manual include industry certification manuals, industry web sites, local government ordinances, CSU Cooperative Extension resources, publications developed in other states experiencing water shortages and several other key resources. A few of the most relevant resources from over 200 documents used in development of this manual are listed below.

Industry Certification Manuals

Associated Landscape Contractors of America

- Associated Landscape Contractors of America. 2003. *Landscape Installation Training*. Herndon, VA: ALCA.
- Associated Landscape Contractors of America. 2003. *Landscape Irrigation Training*. Herndon, VA: ALCA.
- Associated Landscape Contractors of America. 2003. *Landscape Maintenance Training*. Herndon, VA: ALCA.

Colorado Nursery Association

- Colorado Nursery Association. 2001. *Colorado Certified Nursery Professionals Manual*. Denver, CO: CNA.

Colorado Greenhouse Growers

- Colorado Greenhouse Growers. 2003. *Colorado Certified Greenhouse Professional Manual*. Denver, CO: CGGA.

International Society of Arboriculture

- International Society of Arboriculture. 1992. *Arborists Certification Study Guide*. Champaign, IL: ISA.
- Britton, John. 1994. *Tree-Pruning Guidelines*. Champaign, IL: ISA.

Industry Web Sites

American Nursery and Landscape Association (ANLA). 2002. Web site: www.anla.org.

American Society of Landscape Architects (ASLA). 2002. Web site: www.asla.org.

Associated Landscape Contractors of Colorado (ALCC). 2002. Web site: www.alcc.com.

Colorado Association of Lawn Care Professionals (CALCP). 2002. Web site: www.gardeningcolorado.com/calcp.

Colorado Nursery Association (CNA). 2002. Web site: www.coloradonurseries.org.

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GreenCO BMPs for the Protection and Conservation of Water Resources in Colorado

Appendix A: Basic Erosion and Sediment Control Practices

Sediment is one of the most prevalent nonpoint source runoff components associated with urban development and construction activities. Similar BMPs are applicable to both stormwater runoff in urban areas and construction site runoff.

Detailed guidance on erosion and sediment control practices can be obtained from the Urban Drainage and Flood Control District (1999) *Storm Drainage Criteria Manual, Volume 3* and the Denver Regional Council of Governments (1998) *Keeping Soil on Site: Construction Best Management Practices*. These practices are designed for use with urban development and other construction activities and they are applicable to all urban areas and construction activities in Colorado. The Colorado Nonpoint Source Task Force also recommends these BMPs. The following discussion provides a general overview of key erosion and sediment control practices.

1. Sediment and Erosion Control Plan

The objective of erosion control is to limit the amount and rate of erosion occurring on disturbed areas. The objective of sediment control is to capture the soil that has been eroded before it leaves the construction site. Despite the use of both erosion control and sediment control measures, it is recognized that some amount of sediment will remain in runoff leaving the construction site.

An erosion and sediment control plan is comprised of three major elements.

- The erosion control measures that will be used to limit erosion of soil from disturbed areas at a construction site;
- The sediment control measures that will be used to limit transport of sediment to off-site properties and downstream receiving waters; and,
- The drainageway protection measures that will be used to protect streams and other drainageways located on the construction site from erosion and sediment damages.

Erosion control planning should occur early in the site development process. The planning process can be divided into five separate steps:

- Gather information on topography, soils, drainage, vegetation and other predominant site features.
- Analyze the information in order to anticipate erosion and sedimentation problems.
- Devise a plan that schedules construction activities and minimizes the amount of erosion created by development.
- Develop an Erosion and Sediment Control Plan which specifies effective erosion and sediment control measures
- Follow the Erosion and Sediment Control Plan and revise it when necessary.

2. *Erosion Control*

The planning for the installation of permanent or temporary soil erosion controls needs to begin in advance of all major soil disturbance activities on the construction site. After construction begins, soil surface stabilization should be applied within 14 days to all disturbed areas that may not be at final grade but will remain dormant (undisturbed) for periods longer than an additional 30 calendar days. Soil surface stabilization protects soil from the erosive forces of raindrop impact, flowing water, and wind. Erosion control practices include surface roughening, mulching, establishment of vegetative cover, and the early application of gravel base on areas to be paved. Stabilization measures to be used should be appropriate for the time of year, site conditions and estimated duration of use.

Surface roughening provides temporary stabilization of disturbed areas from wind and water erosion. It is particularly useful where temporary revegetation cannot be immediately established due to seasonal planting limitations. All disturbed areas must be mulched, or seeded and mulched, within 14 days after final grade is reached on any portion of the site not otherwise permanently stabilized. Areas that will remain in an interim condition for more than one year should be seeded.

A viable vegetative cover should be established within one year on all disturbed areas and soil stockpiles not otherwise permanently stabilized. Vegetation is not considered established until a ground cover is achieved which, in the opinion of the city or county of jurisdiction, is sufficiently mature to control soil erosion and can survive severe weather conditions. Areas to be re-vegetated should have soil conditions capable of supporting vegetation. Over-lot grading will often bring to the surface subsoils that have low nutrient value, little organic matter content, few soil microorganisms, and conditions less conducive to infiltration of precipitation. Under certain conditions, soil amendments and treatments may be necessary to provide an adequate growth medium to sustain vegetation.

Temporary revegetation is required on all disturbed areas having a period of exposure prior to final stabilization of one year or longer. All temporary seeding should be protected with mulch. To provide vegetative cover on disturbed areas not paved or built upon for a period of two years or longer, or for an indeterminate length of time, a perennial grass mix should be planted. Each site will have different characteristics, and a landscape professional should be contacted to determine the most suitable seed mix for a specific site.

Road cuts, road fills, and parking lot areas should be covered with the appropriate aggregate base course on the surfaces to be paved in lieu of mulching. Early application of road base is suitable where a layer of coarse aggregate is specified for final road or parking lot construction. This practice may not be desirable in all instances, and is not needed when final pavement construction will take place within 30 days of grading to final contours. All non-paved portions of road cut, fill, and parking lot areas should be seeded and mulched as soon as possible after final grading has occurred, but in no case later than 14 days after grading has been completed.

3. *Sediment Control*

Sediment control will be site specific and can include vehicle tracking controls; sod buffer strips around the lower perimeter of the land disturbance; sediment barriers, filters, dikes, traps or sediment basins; or a combination of any or all of these measures. Sediment controls must be constructed before land disturbance takes place. Earthen structures such as dams, dikes, and diversions should be mulched within 14 days of installation. Earthen structures that are expected to remain in place for more than one year must be seeded and mulched.

Wherever construction vehicles enter onto paved public roads, provisions must be made to prevent the transport of sediment (mud and dirt) by runoff or by vehicles tracking onto the paved surface. Cut-and-fill slopes must be designed and constructed to minimize erosion. This requires consideration of the length and steepness of the slope, the soil type, up-slope drainage area, groundwater conditions and other applicable factors. Slopes that are found to be eroding excessively will require additional slope stabilization until the problem is corrected. A temporary diversion dike is a horizontal ridge of soil placed perpendicular to the slope and angled slightly to provide drainage along the contour. Temporary diversion dikes can be constructed by excavation of a V-shaped trench or ditch and placement of the fill on the down-slope side of the cut.

The drainage system provided for roads will define to some extent the length and area of individual slope segments within the disturbed area. Sediment can be controlled on slopes that are particularly steep by the use of terracing. During grading, relatively flat sections, or terraces, are created and separated at intervals by steep slope segments. The steep slope segments are prone to erosion, however, and must be stabilized in some manner. Retaining walls, gabions, cribbing, deadman anchors, rock-filled slope mattresses and other types of soil retention systems are available for use. These should be specified in the plan and installed according to manufacturer's instructions.

There are certain instances when runoff must be directed down a slope within the disturbed area. A temporary slope drain can be used to protect these hill-slope areas from scour and additional erosion. A number of alternative designs and materials can be used for a slope drain. Sediment entrapment facilities are necessary to reduce sediment discharges to downstream properties and receiving waters. Sediment entrapment facilities include straw bale barriers, silt fences, sod filter strips, sediment traps and sediment basins. The type of sediment entrapment facility to be used depends on the tributary area, basin slope and slope length of the upstream area.

Straw bales can be placed at the base of a hill-slope to act as a sediment barrier. These are not recommended for use within a swale or channel. Straw bales are temporary in nature and may only perform for a period of weeks or months. Proper installation and maintenance is necessary to ensure their performance. A silt fence is made of a woven synthetic material and acts to filter runoff. Silt fences can be placed as a temporary barrier at the base of a disturbed area but are not recommended for use in a channel or swale.

Vegetated filter strips act to cause deposition of sediment within the area of vegetation. Buffer strips of natural vegetation can be left at the time of site grading, or can be created by using sod. A dense ground cover is necessary or runoff will channelize within the area. A minimum width

of 20 feet is recommended. A sediment trap is a temporary structure that is designed to fill with sediment. A sediment trap can be constructed by either excavating below grade or building an embankment across a swale. Excavated traps are less prone to failure than embankments. No pipe is used at the outlet, as in a sediment basin, and an open-channel spillway must be included in the design. A minimum of 1,800 cubic feet of storage volume must be provided for each tributary acre.

Areas draining more than five acres must be routed through a sediment basin. If the site is to include a stormwater quality or flood detention basin, the permanent detention facility may be used as the temporary sediment basin, provided the outlets are modified upon completion for this purpose. Such permanent detention facilities should be restored to design grades, volumes, and configurations after site development is completed and the project is finalized.

4. *Topsoil Preservation and Reuse*

Topsoil preservation and reuse involves the preservation of a scarce and irreplaceable natural resource. Topsoil is valuable for the establishment and maintenance of protective vegetation and ornamental landscaping. Topsoil is the uppermost, usually darker colored, horizon of a natural soil, possessing the most favorable characteristics for plant growth, including a good supply of organic matter, nutrients, biological activity, and good structure which promotes the infiltration and circulation of water and air and the development of healthy root systems in plants.

At a minimum, topsoil preservation and reuse involves the removal, stockpiling, and re-spreading of the surface with six to eight inches of natural soil. Salvaged topsoil should be stockpiled in an area where it is protected from off-site surface drainage, wind and water erosion, and weed invasion. The stockpile should be located and protected so that unavoidable erosion does not pose a threat to off-site property or water quality. Man-altered landscapes (i.e., fills, cuts, dumps, etc.) may possess surface soils that are inferior to natural soils and undesirable for plant growth. These sites must be individually evaluated for physical and chemical properties that influence plant growth.

Topsoil should be re-spread on sites that are being prepared to receive permanent vegetative stabilization or landscaping. On large areas graded for residential development, topsoil re-spreading should be performed for each individual home site after the basement is excavated and spoils are removed or re-spread. If basement excavation spoils will be hauled away, then topsoil can be re-spread over the entire site after final grading and before home construction.

Topsoil in many parts of Colorado is thin compared to other regions of the United States that have more plentiful rainfall. Yet topsoil is arguably more valuable here, because our subsoils, with their accumulations of clay, low permeability, high pH, and concentrations of salts, tend to be much more hostile to plant growth compared with subsoils of other regions. Our subsoils, even amended with fertilizers and conditioners, cannot be easily transformed into good plant growth media.

Topsoil preservation and reuse has important implications for the conservation of water supplies, as well as for protecting water quality. Water efficient, sustainable landscaping depends on good

soil. Good soil enables efficient irrigation water management. Poor soil produces unhealthy plants and undermines attempts at efficient landscape and irrigation water management.

5. *Drainageway Protection*

At times construction activities must occur adjacent to or within a drainageway. Whenever this occurs, bottom sediments will be disturbed and transported downstream. The movement of sediments resulting from construction activities that take place within any drainageway should be minimized. Temporary facilities can be installed to divert flowing water around sediment-generating construction activities within drainageways.

Limiting construction activities within actively flowing water will significantly reduce sediment movement downstream from these activities. This can be done by using a temporary diversion facility that carries water around construction activities taking place within a waterway. To protect adjacent downstream properties from erosion due to concentrated flows, a stable outlet or channel is necessary. If there is no stable outlet, one may have to be constructed. In lieu of constructing a temporary or permanent outlet to the storm drainageway system, temporary total retention of the runoff from a 24-hour, 100-year storm may be provided. All storm sewer inlets which are made operable during construction must be protected to prevent sediment-laden runoff from entering the conveyance system without first being filtered or otherwise treated to remove sediment.

6. *Material Storage Practices*

Materials are sometimes used at a construction site that present a potential for contamination of stormwater runoff. These include fuel, oil, lubricants, paints, solvents, concrete-curing compounds and other liquid chemicals such as fertilizers, herbicides and pesticides.

Areas at the construction site used for storage of toxic materials and petroleum products should be designed with an enclosure, container, or dike located around the perimeter of the storage area to prevent discharge of these materials in runoff from the construction site. These barriers will also function to contain spilled materials from contact with surface runoff. Areas used for collection and temporary storage of solid or liquid waste should be designed to prevent discharge of these materials in runoff from the construction site. Collection sites should be located away from the storm drainage system. Consideration should be given to covering waste storage areas, fencing these areas, if necessary, to contain windblown materials, and construction of a perimeter dike to exclude runoff.

7. *Underground Utility Construction*

The construction of most underground utility lines should be subject to the following criteria:

- No more than 200 feet of trench is to be opened at one time (local criteria may be more restrictive).
- Where consistent with safety and space considerations, excavated material should be placed on the uphill side of trenches.

- Trench dewatering devices must discharge in a manner that will not adversely affect flowing streams, wetlands, drainage systems, or off-site property.
- Whenever soil erosion from the excavated material has the potential for entering the storm drainage system, storm sewer inlet protection should be provided.

8. *Disposition of Temporary Measures*

All temporary erosion and sediment control measures should be removed and disposed of within 30 days after final site stabilization is achieved, or after the temporary measures are no longer needed, whichever occurs earliest, or as authorized by the city or county of local jurisdiction. For example, a site containing only one building will have temporary erosion control measures removed after building construction is complete and final landscaping is in place. Temporary erosion control measures may be removed from a commercial construction site or residential subdivision only after streets are paved and all areas have achieved final stabilization. Trapped sediment and disturbed soil areas resulting from the disposal of temporary measures must be returned to final plan grades and permanently stabilized to prevent further soil erosion.

9. *Maintenance*

All temporary and permanent erosion and sediment control practices should be maintained and repaired by the owner during the construction phase as needed to assure continued performance of their intended function. Straw bale barriers or silt fences may require periodic replacement and all sediment accumulated behind them must be removed and disposed of properly. Sediment traps and basins will require periodic sediment removal when the design storage level is one-half full. All facilities must be inspected by the owner or owner's representative following each heavy precipitation or snowmelt event that results in runoff.

Appendix B: Permanent Stormwater BMPs

1. Overview

This appendix provides an overview of guidance for the selection and siting of structural best management practices (BMPs) for new development. The guidance is provided within the context of a four-step process that may be followed for new site developments and significant redevelopments. This appendix has been adapted directly from “BMP Planning for New Development and Significant Redevelopment” from Volume 3 of the *Urban Storm Drainage Criteria Manual* (UDFCD 1999).

Detailed descriptions, sizing and design criteria, and design procedures for these BMPs are provided in the chapter titled “Structural Best Management Practices” from Volume 3 of the *Urban Storm Drainage Criteria Manual* (UDFCD 1999).

The selection of BMPs for a development site is intended to be made collaboratively as a result of coordination between the developer and the local jurisdiction. It is recommended that discussions regarding proposed BMPs occur early in each project between the developer’s planner and engineer and municipal staff.

2. Four-Step Process

The following four-step process is recommended for selecting structural BMPs in newly developing and redeveloping urban areas:

- **Step 1. Employ Runoff Reduction Practices.** To reduce runoff peaks and volumes from urbanizing areas, employ a practice generally termed “minimizing directly connected impervious areas” (MDCIA). The principal behind MDCIA is twofold -- to reduce impervious areas and to route runoff from impervious surfaces over grassy areas to slow down runoff and promote infiltration. The benefits are less runoff, less stormwater pollution, and less cost for drainage infrastructure. There are several approaches to reduce the effective imperviousness of a development site:
 - **Reduced Pavement Area.** The use of smaller roadway cross sections is encouraged. Sometimes, creative site layout can reduce the extent of paved areas, thereby saving on initial capital cost of pavement and then saving on pavement maintenance, repair, and replacement over time.
 - **Porous Pavement.** The use of modular block porous pavement or reinforced turf in low-traffic zones such as parking areas and low use service drives such as fire lanes can significantly reduce site imperviousness. This practice can reduce the extent and size of the downstream storm sewers and detention.
 - **Grass Buffers.** Draining impervious areas over grass buffers slows down runoff and encourages infiltration, in effect reducing the impact of the impervious area.

- Grass Swales. The use of grass swales instead of storm sewers, like grass buffers, slows down runoff and promotes infiltration, also reducing effective imperviousness. It also can reduce the size and cost of downstream storm sewers and detention.
- Step 2. Provide Water Quality Capture Volume (WQCV). A fundamental requirement for any site addressing stormwater quality is to provide WQCV. One or more of six types of water quality basins, each draining slowly to provide for long-term settling of sediment particles, may be selected. These six BMPs include:
 - Porous Pavement Detention
 - Porous Landscape Detention
 - Extended Detention Basin
 - Sand Filter Extended Detention Basin
 - Constructed Wetland Basin
 - Retention Pond
- Step 3. Stabilize Drainageways. Drainageway, natural and manmade, erosion can be a major source of sediment and associated constituents, such as phosphorus. Natural drainageways are often subject to bed and bank erosion when urbanizing areas increase the frequency, rate, and volume of runoff. It is important that drainageways adjacent to or traversing development sites be stabilized. One of three basic methods of stabilization may be selected.
 - Constructed Grass, Riprap, or Concrete-Lined Channel. This method of channel stabilization has been in practice for some time; it is described in Volume 2 of the *Urban Storm Drainage Criteria Manual* (UDFCD 2000). The water quality benefit associated with these channels is the reduction of severe bed and bank erosion that can occur in the absence of a stabilized channel. On the other hand, the hard-lined low flow channels that are often used do not offer much in the way of water quality enhancement or wetland habitat. The Urban Drainage and Flood Control District does not recommend the use of riprap or concrete lined flood conveyance channels, but does recommend the use of rock lined low-flow channels.
 - Stabilized Natural Channel. This method of channel stabilization is also addressed in Volume 2 of the *Urban Storm Drainage Criteria Manual*. However, in practice, many natural drainageways in and adjacent to new developments in the Denver area are frequently left in an undisturbed condition. While this may be positive in terms of retaining desirable riparian vegetation and habitat, urban development may cause the channel to become destabilized. When degradation occurs in these drainageways, significant erosion, loss of riparian and aquatic habitat, and elevated levels of sediment and associated pollutants can result. Therefore, it is recommended that some level of stream stabilization always be considered. Small grade control structures sized for a 5-year or larger runoff event are often an effective means of establishing a mild slope for the baseflow channel and arresting stream degradation. Severe bends or cut banks may also need to be stabilized. Such efforts to stabilize a

natural waterway also preserves and promotes natural riparian vegetation which can provide paybacks in terms of enhanced aesthetics, habitat, and water quality.

One additional method of drainageway stabilization gives special attention to stormwater quality and is the constructed wetland channel.

- Step 4. Consider Need for Industrial and Commercial BMPs. If a new development or significant redevelopment activity is planned for an industrial or commercial site, the need for specialized BMPs must be considered. Examples include covering of storage/handling areas and spill containment and control.

3. Other BMPs

The structural BMPs identified above were selected after a comprehensive screening of known structural BMPs with representatives of a number of cities and counties in the Denver metropolitan area, Colorado Department of Transportation, Colorado Water Quality Control Division, industry, homebuilders, and a municipality located outside the Denver metropolitan area. Final selection by this group was based on the review of documentation on potential effectiveness in a semiarid climate, local applicability, maintenance considerations, and cost.

Other BMPs include manufactured devices such as water quality vaults and inlets, infiltration trenches, oil/grease separators, fabric inserts for inlets, and stream buffer setbacks. Some of these BMPs show promise but need further independent research to determine their pollutant removal effectiveness in a semiarid climate and to develop cost-effective design criteria to insure that they are properly designed, constructed, and maintained. As additional BMPs are field tested, and as supporting information becomes available, they may be added to the *Urban Storm Drainage Criteria Manual*.

4. Implementing Step 1. Employ Runoff Reduction Techniques

4.1 Benefits of Reducing Imperviousness

Reducing imperviousness offers the following benefits:

- Increased infiltration and decreased rate and volume of site runoff
- Decreased WQCV and, in turn decreased size of required WQCV facilities
- Decreased 2-year and 5-year peak runoff rates and volumes for downstream conveyance and detention facilities
- Reduced need for irrigation
- Less curb and gutter
- Smaller storm sewer systems

- Decreased pavement
- Decreased runoff rates and volumes further downstream in watershed, especially if MDCIA is used on a widespread basis

4.2 BMPs for Minimizing Effective Imperviousness

Described next are structural BMPs that minimize effective imperviousness.



Grass Buffer (GB)

Uniformly graded and densely vegetated area of turf grass. This BMP requires sheet flow to promote filtration, infiltration, and settling to reduce runoff pollutants.



Grass Swale (GS)

Densely vegetated drainageway with low-pitched side slopes that collects and slowly conveys runoff. Design of longitudinal slope and cross section size forces the flow to be slow and shallow, thereby facilitating sedimentation while limiting erosion.



Modular Block Porous Pavement (MBP)

Modular block porous pavement consists of open void concrete slab units underlain with gravel. The surface voids are filled with sand. This BMP is intended to be used in low traffic areas to accommodate vehicles while facilitating stormwater infiltration near its source. A variation of this BMP is termed stabilized-grass porous pavement, consisting of plastic rings affixed to filter fabric underlain with gravel. The surface voids are filled with sand and grass sod/or seed.

4.3 Applying MDCIA to a Site

Minimizing directly connected impervious area requires a basic change in land development design philosophy. This change seeks to reduce paved areas and directs stormwater runoff to landscaped areas, grass buffer strips, and grass-lined swales to slow down the rate of runoff, reduce runoff volumes, attenuate peak flows, and encourage filtering and infiltration of stormwater. Traditional land development practices do not focus on water quality enhancement. Instead, they promote runoff from rooftops, parking lots, driveways, and roads to quickly flow to a curb and gutter and to a formalized stormwater conveyance system. This practice concentrates runoff quickly, which results in a fast responding system and relatively large peak runoff rates during small storms.

Minimizing DCIAs can be made an integral part of landscape and drainage planning for any development. Roof collection systems can direct flow to landscaped areas, infiltration areas, grassed buffer strips, and to grass swales. Instead of using solid curbing, eliminate curbing or use slotted curbing along with stabilized grass shoulders and swales. Residential driveway runoff can be redirected from flowing directly into the street. Large parking lots can reduce DCIAs by using modular block or stabilized grass porous pavement in less used portions of the lot to encourage local infiltration or storage.

Site slopes should be capable of directing stormwater runoff by gravity in a sheet flow away from buildings, roads, and parking lots toward grass-covered or porous pavement covered areas. The runoff then needs to flow as a sheet over these porous surfaces before it reaches swales, storage, stormwater collection, and stormwater conveyance systems. As a result, in areas of high permeability soils (Hydrologic Soil Class A and B soils), the ground can provide for infiltration of large portions of surface runoff. Where less permeable soils are present, significant runoff losses can also be achieved, while the use of sand trenches with underdrains under grass swales can be used to prevent the nuisance of standing water.

Steep sites with average terrain slopes exceeding 4 percent may not lend themselves well to implementing some aspects of this BMP. Some of the difficulties can be dealt with by using terracing and retaining walls. Nevertheless, most sites with general terrain slopes flatter than 4 percent should be suitable for this BMP; the flatter the better.

Minimizing DCIAs can be implemented in varying degrees. Two general levels associated with minimizing DCIAs have been identified for the purpose of the *Urban Storm Drainage Criteria Manual* and are described below:

- Level 1. The primary intent is to direct the runoff generated by impervious surfaces to flow over grass-covered areas, and to provide sufficient travel time so as to encourage the removal of suspended solids before runoff leaves the site, enters a curb and gutter, or enters another stormwater collection system. Thus, at Level 1, *all* impervious surfaces are made to drain over grass buffer strips before reaching a stormwater conveyance system.
- Level 2. As an adjunct to Level 1, this level replaces street curb and gutter systems with low-velocity grass-lined swales and pervious street shoulders. Conveyance systems and storm sewer inlets will still be needed to collect runoff at downstream intersections and crossings where stormwater flow rates exceed the capacity of the swales. Small culverts will be needed at street crossings and at individual driveways until inlets are provided to convey the flow to a storm sewer.

5. Implementing Step 2. Provide Water Quality Capture Volume (WQCV)

These BMPs are designed to capture and provide treatment for a specific volume of stormwater runoff (about half of the runoff from a 2-year storm). This volume is equivalent to the runoff from an 80th percentile storm, meaning that 80 percent of the most frequently occurring storms are fully captured and treated and larger events are partially treated. Detention periods range from 6- to 40-hours, depending on the type of facility. The primary pollutant removal mechanism consists of physical settling of suspended sediments and associated adsorbed pollutants. Secondary pollutant removal mechanisms include filtering, biological uptake, and adsorption.

The WQCV treatment facilities described herein have been selected because they have demonstrated proven results in the Denver area, are relatively cost-effective and are necessary at any site addressing stormwater quality. Runoff from 100 percent of the impervious surfaces of a site must flow through a properly designed installation of one or more of the six WQCV BMPs that are listed herein. Alternate designs may be considered, but they must have equivalent functional requirements of these six BMPs as to WQCV and drain times.

A brief description of the six types of WQCV facilities follows.



Porous Pavement Detention (PPD)

Porous pavement detention consists of modular block porous pavement that is installed flat and is provided with a 2-inch deep detention zone above its surface to temporarily store the WQCV from the tributary drainage area including its own surface. Runoff infiltrates into the void spaces of the gravel base course through the sand filter and slowly exits through an underdrain.



Porous Landscape Detention (PLD)

Porous landscape detention consists of a low-lying vegetated area underlain by a sand bed with an underdrain. A shallow surcharge zone exists above the porous landscape detention for temporary storage of the WQCV. This BMP allows small amounts of WQCV to be provided on parking lots or adjacent to buildings without requiring the set aside of significant developable land areas.



Extended Detention Basin (EDB)

An extended detention basin is appropriate for larger sites and is designed to totally empty out sometime after stormwater runoff ends. The extended basin uses a much smaller outlet than a flood control detention basin, which extends the emptying time for the more frequently occurring runoff events to facilitate pollutant removal.



Sand Filter Extended Detention Basin (SFB)

A sand filter extended detention basin consists of a sand bed and underdrain system. Above the vegetated sand bed is an extended detention basin sized to capture the WQCV. A sand filter extended detention basin provides pollutant removal through settling and filtering and is generally suited to offline, onsite configurations where there is no base flow and the sediment load is relatively low.



Constructed Wetland Basin (CWB)

A constructed wetland basin is appropriate for large catchments and is a shallow retention pond, which requires a perennial supply of water to permit the growth of rushes, willows, cattails, and reeds. It treats runoff by slowing it down to allow time for settling and biological uptake.



Retention Pond (RP)

A retention pond is appropriate for larger catchments. It has a permanent pool of water that is replaced with stormwater, in part or in total, during storm runoff events. In addition, a temporary extended detention volume is provided above this permanent pool to capture storm runoff and enhance sedimentation. It requires a perennial supply of water to maintain the pool.

Appendix C: Summary of Potentially Applicable Regulations

GreenCO BMPs for Conservation and Protection of Water Resources

Appendix C
Summary of Potentially Applicable Regulations

Potential Regulatory Requirements	Regulation Description	Potential BMP Application	Contact	Contact Number & Website
Local/County/Tribal				
Air Quality Control	Regulations to protect air quality	Soil disturbance/bare ground for extended time causing air pollution, heavy equipment emissions, other emissions	Contacts vary based on location.	
Development/Building Permits	Regulations addressing setbacks and other issues	Landscape and irrigation system planning and installation.		
Floodplain Management	Regulations limiting activities in the floodplain	Landscape and irrigation system planning and installation.		
Land Disturbance	Regulations may address wetlands and wildlife, zoning and setbacks.	Landscape and irrigation system planning and installation.		
Landscape Requirements	Some local governments may have ordinances requiring certain landscaping practices.	Landscape and irrigation system planning and installation.		
Water Quality Control	Regulations may address water quality, pollution prevention, stormwater management and water conservation	Erosion and sediment control due to disturbed soil, organic disposal, chemical disposal.		
Noxious Weed Control	County regulations addressing control of noxious weeds.	Landscape maintenance and installation		
State				www.state.co.us
Colorado Air Quality Control Commission Regulations	Regulations 1-13 to protect air quality	Soil disturbance/bare ground for extended time causing air pollution, heavy equipment emissions, other emissions	Jim Geier	303-692-3100 Main 303-692-3167 Direct James.Geier@state.co.us
Colorado Discharge Permit System Construction Dewatering Permit	Discharge water associated with construction activities	Earthwork, landscape design/installation/maintenance, building construction, irrigation system installation/maintenance	Chris Gates	303-692-3339 Chris.gates@state.co.us
Colorado Discharge Permit System Construction Stormwater Management Permit and Plan	Colorado Water Quality Control Act (25-8-101) et seq. CRS 1973 and the Federal Water Pollution Control Act (33 U.S.C. 1251)	Earthwork, landscape design/installation/maintenance, building construction, irrigation system installation/maintenance	Nathan Moore or Kathy Dolan	303-692-3300 Nathan.moore@state.co.us or Kathy.dolan@state.co.us
Reclaimed Domestic Wastewater Control Regulation	Reclaimed Domestic Wastewater Control Regulation, Regulation 84	Special requirements when using reclaimed wastewater for irrigation. For example, cross-connection control, signage, inspection	Michael Luzzi	303-692-3388 Michael.luzzi@state.co.us
Minimal Wastewater from Industrial Facilities (MINDI)	For facilities discharging wastewater of small volume or over a short time period which are unamenable to control through BMP type technologies. Permission to discharge into conveyances, stormwater systems, or ditches must be obtained.	Greenhouses, nurseries and other landscaping operations requiring minimal discharges	Chris Gates	303-692-3339 Chris.gates@state.co.us
Noxious Weed Control	County regulations addressing control of noxious weeds.	Landscape maintenance and installation	Eric Lane	www.ag.state.co.us/DPI/weedsweed.html
Underground Storage Tank (UST) or Above Ground Storage Tank (AST) Registration	7 CCR 1101-14 effective February 1, 1999 and Colorado Revised Statutes 8-20.5	Earthwork, building construction, landscape design, irrigation system design	Oil Inspectors Section	Colorado State Oil Inspection 303-620-4300 T/EL oil.ells.state.co.us
Colorado Pesticide Applicator's Act	Restricted use of pesticides and pesticide application training	Chemical application in industrial, commercial or agricultural use	Water Quality Control Division	www.cdhhs.state.co.us/wq 303-692-3500 (TEL) 303-692-0390 (FAX)
Colorado Uniform Plumbing Code	Title 12, Article 58, of the Colorado Revised Statutes	Pipe design including irrigation system design, installation and maintenance indoor or outdoor	Colorado Department of Regulatory Agencies	www.dora.state.co.us/plumbing 303-894-2300 (TEL) 303-894-2310 (FAX)
Air Quality Permit for Construction	Colorado Revised Statutes, Article 12, Section 25-12-101	Soil disturbance causing air pollution, heavy equipment emissions, other emissions	Air Quality Control Division	www.cdhhs.state.co.us/ap 303-692-3100 (TEL)
Resource Conservation and Recovery Act of 1976 (RCRA)	40 CFR Parts 260 and 261	Chemical usage, record-keeping, reporting, spill-cleanup and disposal	Hazardous Materials & Waste Management Division	www.cdhhs.state.co.us/hm 303-692-3300 (TEL) 888-569-1831 (Toll-Free) 303-759-5355 (FAX)
Colorado Groundwater Management Act and Groundwater Protection Act	Groundwater quality protection and preservation	Any disturbance that potentially affects groundwater	State Engineer's Office	303-866-3581 (TEL)
Colorado Water Quality Control Commission Regulations	Water quality pollution prevention	Erosion and sediment control due to disturbed soil, chemical disposal, pollution prevention	Water Quality Control Commission	303-692-2023 (TEL)
Section 401 Water Quality Certification	5 CCR 1002-82. Project proponents are responsible for choosing appropriate BMPs and providing operation and maintenance procedure and schedules for their projects that could affect water quality	Projects which require issuance of a Federal Section 404 permit by the USACE also require a Section 401 Certification for projects not covered by a Nationwide or General Permit.	United States Army Corps of Engineers and Water Quality Control Division	Nationwide & Individual Permits 303-979-4120 (TEL) www.cdhhs.state.co.us/wq 303-692-3500 (TEL) 303-692-0390 (FAX)
Minimum Instream Flows	Senate Bill 97 established minimum instream flow requirements for aquatic life protection	Irrigation system planning	Colorado Water Conservation Board	cwcb.state.co.us and dan.mcauliffe@state.co.us
Cultural Resources - State Historic Preservation Officer	State of Colorado Historic Landmarks and Preservation	Land disturbance or building demolition	Colorado Historical Society	303-866-2390 (TEL) 1-800-305-3442 (TOLL FREE)
Wildlife Issues	Impact on migration routes, wintering and calving areas and fisheries	Any disturbance of threatened or endangered species	Colorado Division of Wildlife	Dept. of Natural Resources 303-866-3311 (TEL) Division of Wildlife 303-297-1192 (TEL)
Federal				www.epa.gov
Clean Air Act - Title V	Air pollution prevention, monitoring, reporting, permitting and protection	Soil disturbance causing air pollution, heavy equipment emissions, process off-gases	Check with City, County and State regulations as they may follow more strict and detailed guidelines than federal requirements. Land owned by the federal government follows federal regulations.	
Clean Water Act	Water pollution prevention, monitoring, reporting, permitting and protection	Erosion and sediment control due to disturbed soil, chemical disposal		
Section 404 of the Clean Water Act	Wetland permitting	Projects which require issuance of a Federal Section 404 permit by the United States Army Corps of Engineers		
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	Registration, licensing, approved techniques, human health protection/training/certification, reporting, and permitting	Any activities with/in insect, fungus or rodent eradication for installation, building or maintenance activities		
Federal Emergency Management Agency (FEMA)	Floodplain/floodway/floodfringe determination and design requirements	Design, installation or maintenance activities		
Migratory Bird Treaty Act of 1918	Protection of birds, threatened and endangered species	Areas of disturbance inhabited by migrating species		
Federal Endangered Species Act of 1973	Protection of threatened and endangered species	Areas of disturbance inhabited by threatened or endangered species		
Superfund Amendment and Reauthorization Act of 1986 (SARA)	Includes emergency planning notification, emergency and hazardous chemical inventory, community right-to-know act and toxic chemical releases. County or fire district may have reporting thresholds stricter than the federal and state regulations.	Hazardous chemical treatment, storage, disposal and spill reporting		
Occupational Safety and Health Act (OSHA)	OSHA, 29 CFR 1910.1200, Hazard Communications Standard & Material Safety Data Sheets	Safety practices associated with chemical handling, landscape and irrigation system installation.		

Disclaimer: Additional regulations may be applicable that have not been summarized in this table.

Appendix D: GreenCO Water Budget Calculator

Enter your Data in the White Areas

Name	Enter Customer's name
Acct #	999999
Address	99 Any Lane, My City
Agency	ncwcd



greenco
it's easy being green™

1 Home/Interior Water Consumption Estimate

Enter Number of Residents	1	Persons
Low Flow Plumbing?	Yes	

2 Landscape Water Consumption Estimate

Enter Turf Area	1,000	sq.ft.	Automatic	
Enter Shrubs/Ground cover Area	1,500	sq.ft.	Sprinklers?	Yes
Enter Xeriscape Area	0	sq.ft.		
Or Total Area	0	sq.ft.		OK

3 Total Water Budget

Water Restriction	0	% Target
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* Units in Gallons

		Defaults Are:	Local Average ET (in) [enter if different than default]		Actual Usage*	Base Year Use
		0.00	Jan	0.00	9,520	9,000
		0.00	Feb	0.00	7,850	8,000
		0.00	Mar	0.00	12,690	12,500
		4.00	Apr	4.00	24,700	24,500
		4.95	May	4.95	25,620	25,500
		6.20	Jun	6.20	28,990	29,000
		6.60	Jul	6.60	40,125	40,000
		5.50	Aug	5.50	38,600	39,000
		4.00	Sep	4.00	34,256	34,000
		2.80	Oct	2.80	32,890	33,000
		0.00	Nov	0.00	16,456	12,000
		0.00	Dec	0.00	9,900	9,000

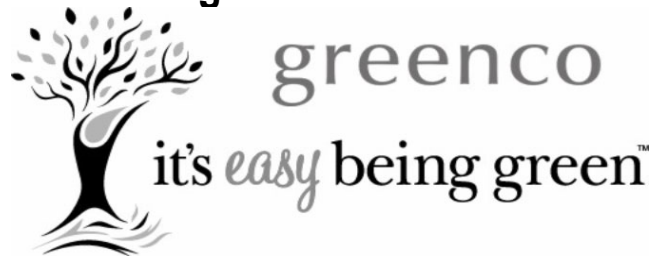
2a. Acres to Sq.Ft. Calculator:		
	Acres	sq.ft.
Enter Acres	2.00	87,120

Home or Single Meter Water Budget Calculator

Data in blue boxes comes from the "Input Table"

Site Info

Name Enter Customer's name
Acct # 999999
Address 99 Any Lane, My City
Agency ncwcd



1 Home/Interior Water Consumption Estimate

Number of Residents Persons
 Low Flow Plumbing?

Gallons Per Home Per Day **55**

2 Landscape Water Consumption Estimate

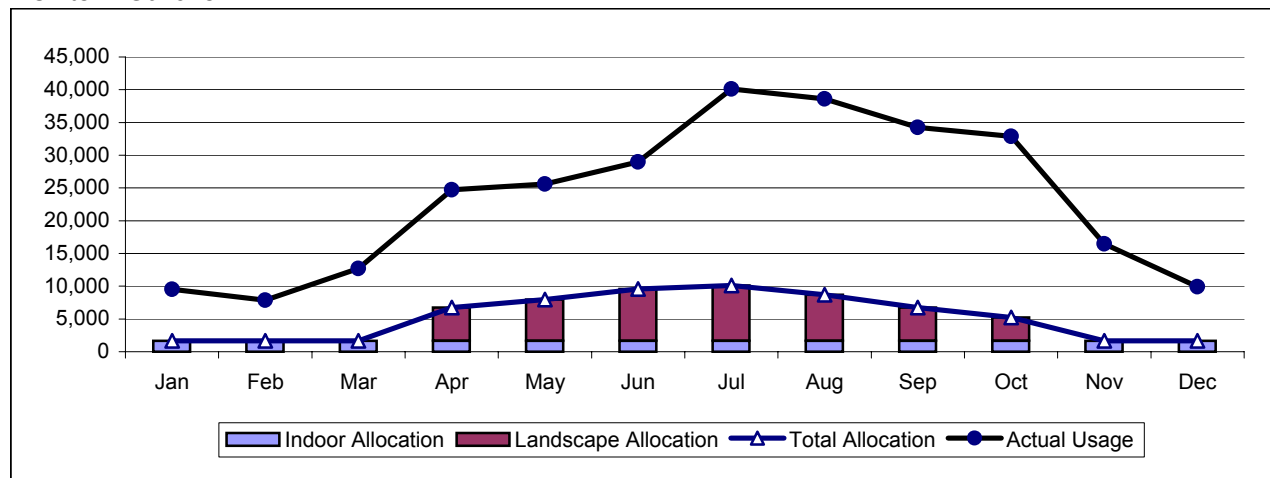
Turf Area sq.ft.
 Shrubs/Ground cover Area sq.ft.
 Xeriscape Area sq.ft.
 Or Total Area sq.ft. OK

Automatic Sprinklers?

3 Total Water Budget

Restriction Budget % Target

* Units in Gallons



Month	Indoor Allocation	Landscape Allocation	Total Allocation	Actual Usage	Savings Potential	Drought Budget	Base Year Use
Jan	1,650	0	1,650	9,520	7,870	1,650	9,000
Feb	1,650	0	1,650	7,850	6,200	1,650	8,000
Mar	1,650	0	1,650	12,690	11,040	1,650	12,500
Apr	1,650	5,115	6,765	24,700	17,935	6,765	24,500
May	1,650	6,330	7,980	25,620	17,640	7,980	25,500
Jun	1,650	7,928	9,578	28,990	19,412	9,578	29,000
Jul	1,650	8,440	10,090	40,125	30,035	10,090	40,000
Aug	1,650	7,033	8,683	38,600	29,917	8,683	39,000
Sep	1,650	5,115	6,765	34,256	27,491	6,765	34,000
Oct	1,650	3,581	5,231	32,890	27,660	5,231	33,000
Nov	1,650	0	1,650	16,456	14,806	1,650	12,000
Dec	1,650	0	1,650	9,900	8,250	1,650	9,000

WATER BUDGET CALCULATOR QUICK GUIDE

DOWNLOAD FILE FROM SITE

Save as (user defined) it stores on customer's hard disk.

INPUT TABLE:

Customer information

Enter as much information as you can (that is for customer's records only)

1 Home/Interior Water Consumption Estimate

- Number of residents:
how many people live at home (or average-year round)
- Low Flow plumbing:
Most likely, your home has Low Flow plumbing when: The majority of your showerheads, kitchen, bathroom and faucet aerators were purchased (or have been retrofitted) after 1992. For toilets, the cut-off year is 1994.

2 Landscape Water Consumption Estimate

- Turf Area:
Measure all your turf (grass) irrigated area and enter the total here.
- Shrubs/Ground cover Area:
Measure all your non-turf (grass) irrigated area and enter the total here.
- Xeriscape Area:
Measure all the areas that are non-turf and have medium to low-water use plants and/or native plants.
- Total area:
If you do not have time to measure all the different parts of your landscape, just enter your total landscape irrigated area.
- Automatic sprinklers?
- 2a. Acres to Sq.Ft. Calculator:
Use this section to convert acres to square feet for large or commercial landscapes.

3 Total Water Budget

- Water Restriction:
If your area has a "conservation goal" or a target percent of water reduction, enter it here. Otherwise, use zero.
- Local Average ET (in):
This is the yearly average Evapotranspiration rate (reference of the amount of water plants need in your area). We use this number, combined with the crop coefficient (Kc) for turf, shrubs/ground cover, and/or xeriscape, to calculate a water budget for every month.
If you know the ET values of your microclimate, you can enter them.

- **Actual usage:**
If you kept all your monthly water bills from your water retailer, you can enter the gallons used every month.
- **Base Year Use:**
This is usually provided to us by your water retailer. It is an average use for an “average home” in your area.

RESULTS TABLE:

All data entered on the Input Table will show up here. The actual budget is calculated at the bottom of the page.

3 Total Water Budget:

- **Indoor Allocation:**
Calculation based on the number of residents and if there are low flow plumbing devices present.
- **Landscape Allocation:**
Calculation based on the local historical ET and the irrigated areas and their square footage.
- **Total Allocation:**
The sum of the calculated indoor and outdoor allocations.
- **Actual Usage:**
Same numbers taken from the Input Table
- **Savings Potential:**
The difference between Total Allocation and Actual Usage. If Actual Usage exceeds Total Allocation, the Savings Potential will be a positive number.
- **Drought Budget:**
Is the total allocation minus the X % entered on the Input Table
- **Base Year Use:**
Same numbers taken from the Input Table. These are usually provided to us by your water retailer. It is an average use for an “average home” in your area.

Appendix E: Plant Water Requirement Estimates (GreenCO/CSU 2004 Crop Coefficient (Kc) Survey)

In response to the extreme drought experienced by Colorado in 2002, GreenCO and Colorado State University initiated a program to document the water needs of landscape plants and to rank each species according to its relative water usage or crop coefficient (Kc). A crop coefficient is the amount of water a species needs compared to a standard crop. For ornamental horticulture this standard crop is cool-season turf, specifically Kentucky bluegrass. The evapotranspiration rate (the combined water loss by transpiration and from evaporation from soil and plant surfaces) for Kentucky bluegrass is known as reference ET, or ET₀. Each species' crop coefficient (Kc) is a percentage of ET₀.

Through a survey of horticulturists from around the region, best professional opinions regarding crop coefficients have been compiled for the common landscape plants of Colorado. The survey was designed with guidance from Dr. Jim Klett of Colorado State University and Tom Ash, Director of Conservation Alliances, Hydropoint Data Systems. Little Valley Wholesale Nursery provided computer support and data compilation. The survey results reflect opinions only; future research at CSU will validate or modify these crop coefficients. The GreenCO website www.greenco.org should be checked for possible changes to this list.

The attached table summarizes the annual estimated irrigation application requirement for each plant based on the categories in Table 1.

Table 1

Estimated Annual Required Irrigation Application

Water Use Category	Percentage of Reference ET (ET₀ = cool season turfgrass)	Approximate Irrigation Requirement for Metro-Denver Front Range Locations¹
High	75 – 100%	15-20 gal/sq. ft.
Medium	50 – 75%	10-14 gal/sq. ft.
Low	25-50%	5-9 gal/sq. ft.
Very Low	0-25%	0-4 gal/sq.ft.

¹Water use estimates will be significantly higher in areas such as Pueblo and Grand Junction and significantly lower in mountainous areas such as Steamboat Springs and Vail.

The results in the spreadsheet are further categorized according to water needs for various regions of Colorado based on elevation, including the East Slope (<6,500 ft), West Slope (6,500 to 8,500 ft), and Mountain Areas (>8,500 ft). The number of survey participants providing an opinion is also listed. Survey instructions specified that participants should not comment on species for which they have no experience.

One of the primary benefits of using ET data is that it enables the user to adjust irrigation rates according to the needs of the plants throughout the growing season. Typically, irrigation application rates are adjusted in terms of inches per week or inches per month. Table 2 provides approximate required application rates at various levels of reference ET in terms of inches per week and inches per month. Actual application rates will be affected by climate conditions.

Table 2

Approximate Weekly Irrigation Application Rates in Inches

	100% ET		75% ET		50% ET		25% ET		0% ET	
Month	Inches/ Month	Inches/ Week	Inches/ Month	Inches/ Week	Inches/ Month	Inches/ Week	Inches/ Month	Inches/ Week	Inches/ Month	Inches/ Week
April	1.00	0.25	0.75	0.17	0.50	0.12	0.25	0.06	0.00	0.00
May	4.25	1.00	3.19	0.72	2.13	0.48	1.06	0.24	0.00	0.00
June	6.50	1.50	4.88	1.13	3.25	0.76	1.63	0.38	0.00	0.00
July	6.50	1.50	4.88	1.11	3.25	0.74	1.63	0.37	0.00	0.00
Aug	5.50	1.25	4.13	0.94	2.75	0.63	1.38	0.31	0.00	0.00
Sept	4.25	1.00	3.19	0.74	2.13	0.49	1.06	0.25	0.00	0.00
Oct	2.00	0.50	1.50	0.34	1.00	0.23	0.50	0.11	0.00	0.00
Total Inches Applied	30.00		22.50		15.00		7.50		0.00	

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual ; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Abeliophyllum distichum	Forsythia, White	S	M	10					M	10
Abies balsamea 'Nana'	Fir, Dwarf Globe Balsam	T	M	17	M	3	M	2	M	22
Abies concolor	Fir, White	T	M	43	M	10	M	12	M	65
Abies fraseri	Fir, Fraser	T	M	16	M	4	M	4	M	24
Abies koreana 'Horstmann's Silberlocke'	Fir, Silver Korean	T	M	7	M	3	M	3	M	13
Abies lasiocarpa	Fir, Subalpine	T	M	19	M	7	M	9	M	35
Acer campestre	Maple, Hedge	T	M	24	L	7	M	5	M	36
Acer ginnala	Maple, Amur	S T	L	45	L	9	L	10	L	64
Acer glabrum	Maple, Rocky Mountain	S	L	29	L	4	L	8	L	41
Acer grandidentatum	Maple, Bigtooth	S T	L	39	L	8	L	6	L	53
Acer griseum	Maple, Paperbark	T	M	19	M	4	M	3	M	26
Acer japonicum 'Aconitifolium'	Maple, Cutleaf Fullmoon	S	H	8	L	2	M	1	M	11
Acer miyabei	Maple, Miyabi	T	M	11	M	3	L	2	M	16
Acer negundo	Box Elder	T	L	34	M	9	L	4	L	47
Acer nigrum 'Greencolumn'	Maple, Greencolumn Black	T	M	9	M	2	M	1	M	12
Acer palmatum	Maple, Japanese	T	M	25	H	3	H	2	H	30
Acer platanoides	Maple, Norway	T	M	36	M	5	M	3	M	44
Acer pseudoplatanus	Maple, Sycamore	T	M	14	M	2	M	1	M	17
Acer rubrum	Maple, Red	T	M	35	M	5	M	3	M	43
Acer saccharinum	Maple, Silver	T	M	40	M	6	M	3	M	49
Acer saccharum	Maple, Sugar	T	M	28	M	4	M	3	M	35
Acer tataricum	Maple, Tatarian	S T	L	38	L	9	L	7	L	54
Acer truncatum	Maple, Shantung	T	M	8	M	2	M	1	M	11
Acer x freemanii	Maple, Freeman	T	M	27	M	5	M	4	M	36
Achillea 'Coronation Gold'	Yarrow, Golden Yellow	P	L	31	L	6	L	4	L	41
Achillea 'Moonshine'	Yarrow, Moonshine	P	L	31	L	7	L	5	L	43
Achillea 'Summer Pastels'	Yarrow, Mixed Pastels	P	L	28	L	6	L	5	L	39
Achillea ageratifolia	Yarrow, Greek	P	L	25	L	5	L	3	L	33
Achillea filipendulina	Yarrow, Tall Yellow	P	L	25	L	6	VL	5	L	36
Achillea lanulosa	Yarrow, Woolly White	P	L	21	L	4	L	3	L	28
Achillea millefolium	Yarrow, Common White	P	L	30	L	7	L	7	L	44
Achillea ptarmica 'The Pearl'	Yarrow, The Pearl	P	L	21	L	4	L	3	L	28
Achillea serbica	Yarrow, Serbian	P	L	21	L	4	L	1	L	26
Achillea tomentosa	Yarrow, Woolly Yellow	P	L	24	L	5	L	3	L	32
Aconitum columbianum	Monkshood, Columbian	P	H	11	M	1	H	1	H	13
Aconitum napellus	Monkshood, Garden	P	M	19	H	3	H	2	H	24
Aconitum x cammarum	Monkshood, Bicolor	P	M	11					M	11
Actinidia arguta	Kiwi, Hardy	P	M	8					M	8
Actinidia kolomikta	Kiwi, Variegated	V	M	10					M	10
Adiantum pedatum	Fern, Western Maidenhair	P	H	11	H	2			H	13
Aegopodium podagraria	Bishop's Weed	GCP	M	26	M	4	M	3	M	33
Aesculus glabra	Buckeye, Ohio	T	M	37	M	5	M	3	M	45
Aesculus hippocastanum	Horsechestnut	T	M	33	M	3	H	2	M	38
Aesculus octandra	Buckeye, Yellow	T	M	19	M	3	L	2	M	24
Aesculus parviflora	Buckeye, Bottlebrush	S	M	14	M	2	H	2	M	18
Aesculus x carnea	Horsechestnut, Red	T	M	23	M	3	M	3	M	29
Aethionema coridifolium	Stonecress, Lebanon	P	L	9	M	3	M	1	L	13
Aethionema grandiflorum	Stonecress, Persian	P	L	11	L	3			L	14
Agapanthus africanus	Lily of the Nile	A	M	14			M	1	M	15
Agastache 'Blue Fortune'	Hyssop, Blue Fortune Anise	P	L	21	L	3	L	1	L	25
Agastache aurantiaca 'Coronado'	Hyssop, Coronado	P	L	30	L	3	L	1	L	34
Agastache barberi	Giant Hummingbird's Mint	P	L	20	L	3	L	1	L	24
Agastache cana	Double Bubblemint	P	L	28	L	4	L	1	L	33
Agastache foeniculum	Hyssop, Anise	P	L	18	L	2	L	1	L	21
Agastache rupestris	Hyssop, Sunset	P	L	31	L	4	L	2	L	37
Ageratum houstonianum	Ageratum	A	M	18	L	3	M	4	M	25
Agropyron cristatum	Crested Wheatgrass	TU	L	20	L	3	L	2	L	25
Agrostis palustris	Bentgrass	TU	H	10			H	1	H	11
Ajania pacifica	Daisy, Pacific	P	L	6	L	1	L	1	L	8
Ajuga genevensis 'Pink Beauty'	Carpet Bugle, Pink Beauty	GC	M	19	M	3	L	2	M	24
Ajuga pyramidalis 'Metallica Crispa'	Carpet Bugle, Pyramid	GC	M	19	M	2			M	21
Ajuga reptans	Carpet Bugle, Green	GC	M	26	M	2	M	2	M	30
Akebia quinata	Chocolate Vine	V	M	7					M	7
Alcea rosea	Hollyhock	P	L	32	L	4	L	3	L	39
Alchemilla alpina	Lady's Mantle, Alpine	P	M	12	L	1	L	1	M	14
Alchemilla erythropoda	Lady's Mantle, Red	P	M	9	M	2			M	11
Alchemilla mollis	Lady's Mantle	P	M	24	M	2	L	1	M	27
Allium cernuum	Nodding Onion	P	L	17	L	1	L	2	L	20
Allium geyeri	Geyer Onion	P	L	10	L	1	M	1	L	12
Allium schoenoprasum	Chives	P	L	25	M	1	M	1	L	27
Alnus glutinosa	Alder, Black	S T	H	28	M	7	M	6	M	41
Alnus rubra	Alder, Red	S	H	9	H	2	H	2	H	13
Alnus tenuifolia	Alder, Thinleaf	S T	M	37	M	8	M	9	M	54
Alyssum montanum 'Mountain Gold'	Basket of Gold, Mountain	P	L	27	L	5	L	3	L	35
Alyssum sp.	Alyssum	A	M	23	L	2	L	4	M	29
Amaranthus spp.	Amaranth	A	L	15	M	2	L	2	L	19
Amelanchier alnifolia	Serviceberry, Saskatoon	S	L	32	L	9	L	8	L	49
Amelanchier canadensis	Serviceberry, Shadblow	S T	L	39	L	9	L	9	L	57
Amelanchier laevis	Serviceberry, Allegheny	S T	M	28	L	4	L	4	L	36
Amelanchier lamarckii	Serviceberry, Lamarck	S T	L	20	L	5	L	5	L	30
Amelanchier stolonifera	Serviceberry, Running	S	L	14	L	4	L	5	L	23
Amelanchier utahensis	Serviceberry, Utah	S	L	18	L	5	L	5	L	28
Amelanchier x grandiflora	Serviceberry, Apple	S T	M	27	L	6	L	5	L	38
Amorpha canescens	Leadplant	S	VL	31	VL	6	VL	1	VL	38
Amorpha fruticosa	False Indigo	S	L	25	L	5	L	4	L	34

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual ; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Amorpha nana	Fragrant False Indigo	S	VL	20	VL	3	VL	2	VL	25
Ampelopsis brevipedunculata	Porcelain Berry Vine	V	M	16	M	1			M	17
Amsonia jonesii	Jones' Bluestar	P	L	12	M	2			L	14
Anacyclus pyrethrum var. depressus	Daisy, Mt. Atlas	P	L	21	L	3	M	1	L	25
Anaphalis margaritacea	Pearly Everlasting	P	L	12	L	3	L	3	L	18
Anchusa spp.	Bugloss	A P	M	17	L	2	L	1	M	20
Andropogon gerardii	Bluestem, Big	P	L	23	L	3	L	1	L	27
Andropogon saccharoides	Bluestem, Silver	P	L	15	L	1	L	1	L	17
Anemone biarmiensis	Anemone, Yellow	P	M	10	M	3	L	2	M	15
Anemone canadensis	Anemone, Meadow	P	M	15	M	3	L	1	M	19
Anemone cylindrica	Thimbleweed	P	M	10	M	3	M	1	M	14
Anemone multifida	Windflower	P	M	15	M	3	M	3	M	21
Anemone sylvestris	Anemone, Snowdrop	P	M	19	L	2	M	1	M	22
Anemone tomentosa 'Robustissima'	Anemone, Grape-leaved	P	M	16	M	2	M	1	M	19
Anemone x hybrida	Anemone, Hybrid	P	M	18	M	2	M	1	M	21
Angelonia spp.	Summer Snapdragon	A	M	9					M	9
Antennaria dioica 'Rubra'	Pussytoes, Pink	P	L	25	VL	3	VL	4	L	32
Antennaria parvifolia	Pussytoes, Dwarf	P	L	24	VL	5	VL	5	VL	34
Anthemis marschalliana	Daisy, Filigree	P	L	8	L	1			L	9
Anthemis tinctoria	Daisy, Marguerite	P	L	18	L	2	L	1	L	21
Antirrhinum majus	Snapdragon	A	M	19	L	4	M	4	M	27
Aquilegia alpina	Columbine, Alpine	P	M	24	M	5	L	4	M	33
Aquilegia bamebyi	Columbine, Barneby's	P	L	15	L	4	M	2	M	21
Aquilegia caerulea	Columbine, Rocky Mountain	P	M	36	M	8	M	8	M	52
Aquilegia canadensis	Columbine, Dwarf Red	P	M	22	M	6	L	4	M	32
Aquilegia chrysantha	Columbine, Yellow	P	L	32	M	7	L	4	L	43
Aquilegia cultivars	Columbine	P	M	27	M	5	M	6	M	38
Aquilegia discolor	Columbine, Spanish	P	M	11	M	3	M	2	M	16
Aquilegia elegantula	Columbine, Dwarf Red	P	M	18	M	3	M	3	M	24
Aquilegia flabellata 'Kurilensis'	Columbine, Compact Pink	P	M	15	M	4	M	2	M	21
Aquilegia formosa	Columbine, Western Red	P	M	15	M	4	M	2	M	21
Aquilegia saximontana	Columbine, Dwarf Blue	P	M	21	M	4	M	3	M	28
Aquilegia vulgaris	Columbine, Garden	P	M	21	M	3	M	4	M	28
Arabis blepharophylla 'Spring Charm'	Rockcress, Spring Charm	P	M	13	L	3	L	2	L	18
Arabis caucasica 'Snowcap'	Rockcress, White Alpine	P	L	19	L	4	L	2	L	25
Arctostaphylos nevadensis	Bearberry, Nevada	GCP S	L	26	L	5	L	2	L	33
Arctostaphylos patula	Manzanita, Greenleaf	S	L	17	L	3	VL	1	L	21
Arctostaphylos uva-ursi	Kinnikinnick	GCP S	L	36	L	8	L	9	L	53
Arenaria montana	Sandwort, Mountain	P	L	14	L	3	L	2	L	19
Argyranthemum	Marguerite Daisy	A	M	14			M	1	M	15
Aristolochia durior	Dutchman's Pipe	V	M	13					M	13
Armeria 'Victor Reiter'	Sea Pinks, Victor Reiter	P	M	12	L	2	M	1	M	15
Armeria maritima	Sea Pinks	P	M	24	M	3	M	1	M	28
Armeria pseudarmeria	Sea Pinks, Wide-leaved	P	M	10	L	2			M	12
Arnica cordifolia	Arnica, Heartleaf	P	M	7	L	2	L	2	M	11
Aronia arbutifolia 'Brilliantissima'	Chokeberry, Brilliant Red	S	M	24	L	4	L	3	M	31
Aronia melanocarpa	Chokeberry, Black	S	L	29	L	5	L	3	L	37
Aronia x prunifolia	Chokeberry, Purple	S	L	17	L	2	L	2	L	21
Artemisia 'Powis Castle'	Sage, Powis Castle	P	L	22	L	6	L	3	L	31
Artemisia abrotanum	Sage, Southernwood	S	L	16	VL	3	VL	3	VL	22
Artemisia absinthium	Sage, Common Wormwood	P	VL	11	VL	2	VL	1	VL	14
Artemisia cana	Sagebrush, Silver	S	VL	26	VL	5	VL	6	VL	37
Artemisia filifolia	Sagebrush, Sand	S	VL	25	VL	6	VL	6	VL	37
Artemisia frigida	Sage, Fringed	P S	VL	34	VL	8	VL	8	VL	50
Artemisia ludoviciana	Sagewort, Prairie	S	VL	19	VL	5	VL	6	VL	30
Artemisia schmidtiana	Sage, Silver Mound	P	L	25	VL	3	VL	2	L	30
Artemisia stelleriana 'Silver Brocade'	Sage, Silver Brocade	P	L	18	L	4	VL	2	L	24
Artemisia tridentata	Sagebrush, Tall Western	S	VL	32	VL	9	VL	9	VL	50
Artemisia tripartita	Sagebrush, Three Parted	S	VL	18	VL	3	VL	3	VL	24
Aruncus dioicus	Goats Beard	P	M	13	L	1			M	14
Arundo donax	Grass, Giant Reed	P	M	10	H	1			M	11
Asclepias incarnata	Milkweed, Swamp	P	M	17	H	1	H	1	M	19
Asclepias speciosa	Milkweed, Showy	P	L	14	L	2	L	2	L	18
Asclepias tuberosa	Gay Butterfly	P	L	23	L	5	L	1	L	29
Aster 'Wood's Purple'	Aster, Wood's Purple	P	M	12	M	3	M	2	M	17
Aster alpinus	Aster, Alpine	P	L	22	L	4	L	1	L	27
Aster bigelovii	Aster, Plains	P	L	14	L	2	M	1	L	17
Aster laevis	Aster, Smooth	P	L	11	L	2	L	2	L	15
Aster novae-angliae	Aster, New England	P	M	21	M	3	M	2	M	26
Aster novi-belgii	Aster, Dwarf Fall	P	M	26	M	5	VL	1	M	32
Aster porteri	Aster, Porter	P	L	11	L	1			L	12
Aster tongolensis 'Wartburg Star'	Aster, Purple	P	M	15	L	2			M	17
Aster x frikartii 'Monch'	Aster, Monch Frikart's	P	M	22	L	3	M	1	M	26
Astilbe chinensis	False Spirea, Chinese	P	H	17	M	3	H	1	H	21
Astilbe x arendsii	False Spirea	P	H	16	M	3	H	1	H	20
Astilbe x japonica	False Spirea	P	H	15	M	3	M	1	H	19
Astilbe x simplicifolia '	False Spirea, Star	P	H	11	M	1	H	1	H	13
Astilbe x thunbergii	False Spirea	P	H	10	H	2	H	1	H	13
Astrantia camiolica	Masterwort, Giant	P	M	5	H	1			M	6
Astrantia major	Masterwort	P	M	8	H	1			M	9
Athyrium filix-femina	Fern, Lady	P	H	12	H	1	H	1	H	14
Athyrium nipponicum 'Pictum'	Fern, Japanese Painted	P	H	14	H	1	M	1	H	16
Atriplex canescens	Saltbush, Four Wing	S	VL	26	VL	7	VL	4	VL	37
Atriplex confertifolia	Saltbush, Spiny	S	VL	18	VL	3	VL	2	VL	23
Atriplex corrugata	Saltbush, Mat	S	VL	14	VL	4	VL	2	VL	20

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Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Atriplex gardneri	Saltbush, Gardner's	S	VL	9	VL	3	VL	2	VL	14
Aubrieta deltoidea 'Purple Gem'	Rockcress, Purple	P	L	18	L	2	L	1	L	21
Aubrieta x cultorum	Rockcress, Hybrid	P	L	11	M	1			L	12
Aurinia saxatilis 'Gold Ball'	Basket-of-Gold Alyssum	P	L	27	L	5	L	3	L	35
Baccharis glutinosa	Seep-Willow	S	L	5	H	1	H	1	M	7
Baccharis pilularis	Coyote Brush	S	L	5	H	1	H	1	M	7
Bacopa spp.	Water Hyssop	A	M	10			M	2	M	12
Baileya multiradiata	Desert Marigold	P	VL	8	L	2	L	1	VL	11
Baptisia australis	False Indigo	P	L	21	L	3	L	2	L	26
Begonia semperflorens	Wax Begonia	A	H	17			H	2	H	19
Belamcanda chinensis	Lily, Blackberry	P	L	14	M	1			L	15
Bellis perennis	Daisy, English	A P	M	10			M	1	M	11
Bellium minus	Daisy, Miniature Mat	P	M	10					M	10
Berberis koreana	Barberry, Korean	S	L	25	L	3	L	2	L	30
Berberis thunbergii	Barberry, Japanese	S	L	36	L	4	L	4	L	44
Berberis x 'Tara'	Barberry, Emerald Carousel	S	L	18	L	3	L	2	L	23
Berberis x gladywensis 'William Penn'	Barberry, William Penn	S	M	14	L	2	M	3	M	19
Berberis x mentorensis	Barberry, Mentor	S	L	26	L	3	L	2	L	31
Bergeria cordifolia	Bergeria, Heart-Leaved	P	M	21	L	2			M	23
Berlandiera lyrata	Chocolate Flower	P	L	20	VL	3	L	1	L	24
Betula 'Crimson Frost'	Birch, Crimson Frost	S T	H	25	H	4	M	4	H	33
Betula fontinalis /occidentalis	Birch, Native River	S T	H	34	M	6	M	6	M	46
Betula jacquemontii	Birch, Himalayan White	S T	H	21	M	3	M	3	H	27
Betula maximowicziana	Birch, Monarch Clump	T	H	12	H	1	H	1	H	14
Betula nigra	Birch, River	T	H	37	H	4	M	3	H	44
Betula papyrifera	Birch, Paper	T	H	35	H	3	M	3	H	41
Betula pendula	Birch, Weeping	T	H	31	H	3	M	3	H	37
Betula platyphylla	Birch, White	T	H	22	H	2	H	2	H	26
Betula x 'Rocky Mountain Splendor'	Birch, Rocky Mt Splendor	T	M	15	M	2	H	3	M	20
Boltonia asteroides	Boltonia	P	M	18	L	2	L	1	M	21
Bouteloua curtipendula	Grass, Side Oats Grama	P	L	15	L	6	L	3	L	24
Bouteloua gracilis	Grass, Blue Grama	P TU	VL	25	VL	5	VL	4	VL	34
Brachycome iberidifolia	Daisy, Swan River	A	M	11			M	2	M	13
Brassica oleracea	Ornamental Cabbage or Kale	A	M	14			M	3	M	17
Bromus inermis	Smooth Brome	TU	L	10	VL	1	M	3	L	14
Browallia speciosa	Bush Violet	A	M	11			H	1	M	12
Brunnera macrophylla	False Forget-Me-Not	P	M	20	L	2	M	1	M	23
Buchloe dactyloides	Buffalograss	TU	VL	28	VL	4	VL	2	VL	34
Buddleja alternifolia	Butterfly Bush, Alternate	S	L	30	L	5	L	2	L	37
Buddleja davidii	Butterfly Bush	S	M	38	L	4	L	2	M	44
Buddleja x weyeriana	Butterfly Bush, Yellow	S	M	12	L	1	L	1	L	14
Buxus microphylla	Boxwood, Littleleaf	S	M	23	M	2	M	1	M	26
Buxus sempervirens	Boxwood, Common	S	M	23	M	3	M	2	M	28
Calamagrostis acutiflora	Grass, Feather Reed	P	L	27	M	6	M	1	L	34
Calamagrostis brachytricha	Grass, Korean Feather Reed	P	L	11	M	3	M	1	L	15
Calandrinia umbellata 'Ruby Tuesday'	Rock Purslane	P	L	6					L	6
Calendula officinalis	Calendula	A	M	19	M	1	L	2	M	22
Calliropa japonica	Beautyberry, Japanese	S	M	11	M	2	M	2	M	15
Callirhoe alcaeoides 'Logan Calhoun'	Prairie Winecups, White	P	L	14	L	1			L	15
Callirhoe involucrata	Prairie Winecups	P	L	30	VL	5	L	1	L	36
Calocedrus decurrens	Cedar, Incense	T	M	7	L	2	L	2	M	11
Calochortus gunnisonii	Mariposa Lily	P	VL	9	VL	1	L	2	L	12
Caltha leptosepala	Marsh Marigold, White	P	H	7	H	2	H	2	H	11
Caltha palustris	Marsh Marigold, Yellow	P	H	8	H	2	H	1	H	11
Calycanthus floridus	Carolina Allspice	S	H	4	H	1	H	1	H	6
Calyophus hartwegii fendleri	Sundrops, Fendler's	P	L	18	VL	6	L	1	L	25
Calyophus serrulatus	Shrubby Evening Primrose	P	L	4					L	4
Campanula carpatica	Harebell, Carpathian	P	M	19	M	3	M	1	M	23
Campanula cochlearifolia	Bluebells, Little	P	M	15	M	3	M	1	M	19
Campanula garganica	Bellflower, Greek	P	M	14	M	3	M	1	M	18
Campanula glomerata	Bellflower, Clustered	P	M	21	M	3	M	1	M	25
Campanula lactiflora	Bellflower, Milky	P	M	10	L	2			M	12
Campanula medium	Canterbury Bells	A P	M	16	M	3	H	2	M	21
Campanula persicifolia	Bellflower, Peach-Leaved	P	M	22	M	3	M	1	M	26
Campanula portenschlagiana	Bellflower, Dalmatian	P	M	16	L	2	M	1	M	19
Campanula poscharskyana	Blue Bells, Adriatic	P	M	18	L	2	M	1	M	21
Campanula punctata 'Cherry Bells'	Bellflower, Cherry Bells	P	M	11	L	1			M	12
Campanula rotundifolia	Harebell, Blue Native	P	L	27	L	5	L	3	L	35
Campsis radicans	Trumpet Vine	P V	L	23					L	23
Campsis x tagliabuana	Trumpet Vine	P V	L	13					L	13
Canna x generalis	Canna	A	H	19	H	1	H	1	H	21
Caragana arborescens	Peashrub, Siberian	S	L	33	VL	8	L	7	L	48
Caragana frutex	Peashrub, Russian	S	L	19	VL	4	L	2	L	25
Caragana maximowicziana	Peashrub, Maximowics	S	VL	12	L	2	L	1	VL	15
Caragana microphylla	Peashrub, Littleleaf	S	VL	12	VL	3	L	1	VL	16
Caragana pygmaea	Peashrub, Pygmy	S	L	22	VL	6	VL	3	L	31
Carex aquatilis	Sedge, Water	P	H	8	H	2	H	1	H	11
Carex buechananii	Sedge, Leatherleaf	P	M	12	M	2			M	14
Carex comans	Sedge, New Zealand Hair	A	M	4					M	4
Carex conica	Sedge, Dwarf	P	M	4	M	1			M	5
Carex elata	Sedge, Tufted	P	M	5	M	1	H	1	M	7
Carex flacca	Sedge, Blue Green	P	M	5					M	5
Carex flagellifera	Sedge, Copperleaf	P	M	4	H	1			M	5
Carex glauca	Sedge, Blue	P	M	4	M	1			M	5
Carex lanuginosa	Sedge, Hairy	P	H	5	H	2	H	1	H	8

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Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Carex morrowii	Sedge, Japanese	P	M	7	H	1			M	8
Carex muskingumensis	Sedge, Palm	P	M	4	H	1			M	5
Carex nebraskensis	Sedge, Nebraska	P	H	5	H	1	H	1	H	7
Carex rostrata	Sedge, Beaked	P	H	4	H	2	H	1	H	7
Carpinus betulus	Hornbeam, European	T	M	21	M	2	M	2	M	25
Carpinus caroliniana	Hornbeam, American	T	M	21	M	3	M	3	M	27
Carpinus japonica	Hornbeam, Japanese	T	M	5	M	1	M	1	M	7
Caryopteris incana	Spirea, Blue Mist	S	L	25	L	5	VL	3	L	33
Caryopteris x clandonensis	Spirea, Blue Mist	S	L	40	L	6	VL	5	L	51
Castilleja integra	Indian Paintbrush, Orange	P	L	20	VL	3	L	2	L	25
Castilleja linariaefolia	Indian Paintbrush, Wyoming	P	L	12	VL	1	L	2	L	15
Castilleja miniata	Indian Paintbrush, Scarlet	P	L	12	VL	1	M	1	L	14
Castilleja rhexifolia	Indian Paintbrush, Rose	P	L	10	VL	1	H	2	L	13
Catalpa ovata	Catalpa, Chinese	T	M	18	L	3	L	3	L	24
Catalpa speciosa	Catalpa, Western	T	L	44	L	6	L	3	L	53
Catananche caerulea	Cupid's Dart	P	L	14			L	1	L	15
Catharanthus roseus	Periwinkle, Madagascar	A	L	14	L	1	L	2	L	17
Ceanothus fendleri	Deerbrush	S	L	13	VL	4	L	5	L	22
Ceanothus gloriosus	Point Reyes Creeper	S	L	4	L	2	L	2	L	8
Ceanothus velutinus	Snowbrush	S	L	8	M	1	M	1	M	10
Cedrus deodora	Cedar, Deodar	T	M	11	M	3	L	2	L	16
Cedrus libani atlantica	Cedar, Blue Atlas	T	M	11	M	1	M	1	M	13
Celastrus scandens	American Bittersweet	S V	L	20	L	3	L	2	L	25
Celosia argentea plumosa	Cockscomb	A	M	19	M	1	L	2	M	22
Celtis laevigata	Sugarberry	T	L	8	L	2	L	2	L	12
Celtis occidentalis	Hackberry, Western	T	L	40	L	7	L	5	L	52
Celtis reticulata	Hackberry, Canyon	S T	L	22	L	4	L	4	L	30
Centaurea cyanus	Bachelor Button	A	L	25	L	3	L	3	L	31
Centaurea dealbata	Bachelor Button, Pink	P	L	15	L	1	L	1	L	17
Centaurea montana	Bachelor Button, Perennial	P	M	23	VL	1	M	1	L	25
Centranthus ruber	Valerian, Red	P	L	29	L	4	L	3	L	36
Cerastium alpinum lanatum	Wooly Cerastium	P	L	4	L	1			L	5
Cerastium arvense	Chickweed, Mouse-ear	P	L	9	L	1	L	1	L	11
Cerastium tomentosum	Snow-In-Summer	P	L	30	VL	4	VL	3	L	37
Ceratostigma plumbaginoides	Plumbago	P	L	21	M	1			L	22
Cercidiphyllum japonicum	Katsura Tree	T	M	11	H	2	H	2	M	15
Cercis canadensis	Redbud, Eastern	S T	M	42	M	7	L	4	M	53
Cercocarpus breviflorus	Mountain Mahogany, Little Flower	S	VL	19	VL	5	VL	4	VL	28
Cercocarpus ledifolius	Mountain Mahogany, Curleaf	S T	VL	40	VL	11	VL	7	VL	58
Cercocarpus montanus	Mountain Mahogany, Common	S T	VL	38	VL	11	VL	9	VL	58
Chaenomeles japonica	Quince, Japanese Flowering	S	M	28	L	4	L	3	L	35
Chaenomeles speciosa	Quince, Flowering	S	M	23	L	3	L	3	L	29
Chaenomeles x superba	Quince, Hybrid Flowering	S	L	15	L	1	L	1	L	17
Chamaebatiaria millefolium	Fernbush	S	VL	25	VL	4	VL	4	VL	33
Chamaecyparis obtusa	Cypress, Hinoki	S	M	13	M	1	M	1	M	15
Chamaecyparis pisifera	Cypress, Japanese False	T	M	10	L	2	L	2	M	14
Chamaemelum nobile	Chamomile	P	L	8	L	1	M	1	L	10
Chamerion angustifolium	Fireweed	P	L	9	L	1	L	3	L	13
Chasmanthium latifolium	Sea Oats, Northern	P	M	16	M	1			M	17
Chilopsis linearis	Desert Willow	S	L	12	VL	3	L	2	L	17
Chionanthus retusus	Fringe Tree, Chinese	S T	M	11	L	3	L	3	M	17
Chionanthus virginicus	Fringe Tree, White	S T	M	19	L	3	M	3	M	25
Chitalpa tashkentensis	Chitalpa	S	L	8	L	2	L	2	L	12
Chrysanthemum x morifolium	Garden Mum	P	M	28	M	3	M	2	M	33
Chrysothamnus nauseosus	Rabbitbrush	S	VL	36	VL	9	VL	5	VL	50
Chrysothamnus viscidiflorus	Rabbitbrush, Sticky	S	VL	24	VL	6	VL	2	VL	32
Cimicifuga racemosa	Black Snakeroot	P	M	16	M	1			M	17
Cimicifuga simplex 'White Pearl'	White Bottlebrush	P	M	10	M	1			M	11
Cladrastis lutea	Yellowwood	T	M	19	M	3			M	25
Clematis alpina	Clematis, Alpine	P V	M	13			M	1	M	14
Clematis columbiana	Clematis, Columbian Virgin's Bow	P V	M	7			M	2	M	9
Clematis cultivars	Clematis	P V	M	29	L	2	M	1	M	32
Clematis hirsutissima	Clematis, Woolly	P	L	10	VL	1	L	2	L	13
Clematis integrifolia	Clematis, Bush	P	M	13			L	1	M	14
Clematis ligusticifolia	Clematis, Western Virgin's Bower	P V	L	17	VL	2	L	3	L	22
Clematis montana rubens	Clematis, Pink Anemone	P V	M	11					M	11
Clematis paniculata	Clematis, Spring	P V	M	16	M	1	M	1	M	18
Clematis pitcheri	Clematis, Purple Leatherflower	P V	M	9					M	9
Clematis tangutica	Clematis, Yellow Lantern	P V	L	16			L	1	L	17
Clematis terniflora	Clematis, Sweet Autumn	P V	L	16	L	1	M	1	L	18
Clematis texensis	Clematis, Scarlet	P	M	9					M	9
Clematis virginiana	Clematis, Virgin's Bower	P V	L	8			H	1	M	9
Clematis viticella	Clematis, Italian	P V	M	9					M	9
Cleome hassleriana	Spiderflower	A	M	15	M	1	H	2	M	18
Cleome serrulata	Rocky Mountain Beeplant	A	L	10	L	1	L	3	L	14
Clethra alnifolia	Summersweet	S	H	8	H	2	H	1	H	11
Coleus spp.	Coleus	A	M	25			M	3	M	28
Colutea arborescens	Bladder Pod	S	L	8	L	2	M	1	L	11
Corvallisaria majalis	Lily-of-the-Valley	GCP	M	25	M	1	M	1	M	27
Coreopsis 'Limerock Ruby'	Coreopsis, Limerock Ruby	P	M	14					M	14
Coreopsis auriculata	Coreopsis, Eared	P	L	20	VL	1			L	21
Coreopsis grandiflora	Coreopsis, Large-flowered	P	L	23	L	2	L	1	L	26
Coreopsis lanceolata	Coreopsis, Lance-leaf	P	L	25	L	3	L	2	L	30
Coreopsis rosea	Coreopsis, Pink	P	M	18	L	2	L	1	M	21
Coreopsis tinctoria	Coreopsis, Plains	A	L	19	L	1	L	2	L	22

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Coreopsis verticillata	Coreopsis, Thread Leaf	P	L	25	L	3	L	1	L	29
Cornus alba	Dogwood, Tatarian	S	M	21	M	2	M	2	M	25
Cornus alternifolia	Dogwood, Pagoda	S T	M	26	M	3	M	2	M	31
Cornus anomum	Dogwood, Silky	S	M	7	H	1	H	1	H	9
Cornus canadensis	Dogwood, Bunchberry	S	M	11	M	2	M	3	M	16
Cornus florida	Dogwood, Flowering	T	H	20	H	3	M	2	M	25
Cornus kousa	Dogwood, Kousa	S T	M	23	H	4	M	3	M	30
Cornus mas	Dogwood, Cornelian Cherry	S T	M	25	M	5	M	3	M	33
Cornus pumila	Dogwood, Dwarf Red Tipped	S	M	12	H	1	H	1	M	14
Cornus racemosa	Dogwood, Gray	S T	M	23	M	5	M	4	M	32
Cornus sericea (stolonifera)	Dogwood, Redosier	S	M	23	M	3	H	4	M	30
Cornus stolonifera 'Kelsey'	Dogwood, Kelsey Dwarf	S	M	28	M	4	M	2	M	34
Cortaderia selloana	Grass, Pampas	P	L	11					L	11
Corylus americana	Filbert, American	T	M	19	M	3	M	3	M	25
Corylus avellana 'Contorta'	Harry Lauder's Walkingstick	S	M	21	M	3	M	2	M	26
Corylus colurna	Filbert, Turkish	T	L	20	M	3	L	3	L	26
Corylus cornuta	Filbert, Beaked	S	M	10	M	2	M	2	M	14
Cosmos bipinnatus	Cosmos	A	L	27	L	1	L	2	L	30
Cotinus coggygria	Smoke Tree	S	M	27	L	4	L	2	M	33
Cotoneaster adpressa praecox	Cotoneaster, Creeping	S	M	13	M	3	L	2	M	18
Cotoneaster apiculatus	Cotoneaster, Cranberry	S	L	33	M	5	L	3	L	41
Cotoneaster congestus	Cotoneaster, Pyrenees	S	L	8	L	1	L	1	L	10
Cotoneaster dammeri	Cotoneaster, Bearberry	S	M	24	M	3	L	2	M	29
Cotoneaster divaricatus	Cotoneaster, Spreading	S	L	27	L	5	L	5	L	37
Cotoneaster glaucophyllus	Cotoneaster, Grey	S	L	10	L	1	L	1	L	12
Cotoneaster horizontalis	Cotoneaster, Rock	S	M	27	L	2	L	2	M	31
Cotoneaster lacteus /parneyi	Cotoneaster, Parney's Red	S	M	10	L	2	L	2	M	14
Cotoneaster lucidus /acutifolius	Cotoneaster, Peking	S	L	33	L	5	L	4	L	42
Cotoneaster multiflorus	Cotoneaster, Many Flowered	S	L	18	L	2	L	2	L	22
Cotoneaster nanshan	Cotoneaster, Creeping	S	L	9	L	1	L	1	L	11
Cowania mexicana	Cliffrose	S	VL	28	VL	5	VL	5	VL	38
Crambe cordifolia	Colewort	P	M	11					M	11
Crataegus 'Skinner Dwarf'	Hawthorn, Skinner Dwarf	T	L	10	L	1	L	1	L	12
Crataegus ambigua	Hawthorn, Russian	S T	L	40	L	8	L	6	L	54
Crataegus arnoldiana	Hawthorn, Arnold	T	M	12	L	2	L	2	L	16
Crataegus chrysoarpa	Hawthorn, Fire Berry	S T	L	13	L	3	L	3	L	19
Crataegus crus-galli	Hawthorn, Cockspur	S T	L	40	L	7	L	5	L	52
Crataegus crus-galli 'Inermis'	Hawthorn, Thornless Cockspur	S T	L	37	L	6	L	5	L	48
Crataegus douglasii	Hawthorn, Douglas	S T	L	23	L	6	L	4	L	33
Crataegus laevigata	Hawthorn, English	T	M	24	L	3	L	3	L	30
Crataegus mollis	Hawthorn, Downy	S T	L	28	L	6	L	4	L	38
Crataegus phaenopyrum	Hawthorn, Washington	S T	L	40	L	7	L	4	L	51
Crataegus punctata	Hawthorn, Thicket	T	L	9	L	1			L	10
Crataegus rivularis	Hawthorn, River	S T	M	16	L	3	L	3	L	22
Crataegus succulenta	Hawthorn, Colorado	S T	L	17	L	3	L	3	L	23
Crataegus x mordenensis	Hawthorn, Morden	T	L	18	L	2	L	2	L	22
Cuphea spp.	Cigar Flower	A	M	7			M	1	M	8
Cupressocyparis leylandii	Cypress, Leyland	T	M	6	L	2	L	2	M	10
Cupressus arizonica	Cypress, Arizona	T	L	12	L	3	L	2	L	17
Cytisus purgans 'Spanish Gold'	Broom, Spanish Gold	S	L	31	VL	3	L	3	L	37
Cytisus scoparius	Broom, Scotch	S	L	23	L	2	L	3	L	28
Cytisus x praecox	Broom, Warminster	S	L	22	L	2	L	1	L	25
Dahlia pinnata	Dahlia	A	M	21			M	2	M	23
Dalea formosa	Indigo Bush	P	L	7					L	7
Dalea purpurea	Clover, Purple Prairie	P	L	14			M	1	L	15
Daphne creorum	Daphne, Rose	S	M	15	L	3	M	3	M	21
Daphne x burkwoodii	Daphne, Burkwood	S	M	31	L	3	M	3	M	37
Dasylium wheeleri	Sotol Yucca	S	L	10	L	2	M	1	L	13
Datura sp.	Angel's Trumpet	A	L	16			M	1	L	17
Davidia involucrata	Dove Tree	T	M	6	M	1	M	1	M	8
Delosperma Mesa Verde	Iceplant, Mesa Verde	P	L	21	L	2	L	2	L	25
Delosperma Table Mountain	Iceplant, Table Mountain	P	L	21	L	2	L	2	L	25
Delosperma cooperi	Iceplant, Purple	P	L	31	L	4	L	2	L	37
Delosperma floribundum 'Starburst'	Iceplant, Starburst	P	L	24	L	3	L	2	L	29
Delosperma nubigenum	Iceplant, Yellow Hardy	P	L	27	L	4	L	2	L	33
Delphinium grandiflorum	Larkspur, Chinese	P	M	21	M	4	L	4	M	29
Delphinium nelsonii	Larkspur, Nelson	P	L	8	M	1	M	1	L	10
Delphinium species	Larkspur,	P	M	18	M	4	M	5	M	27
Delphinium x Pacific Giant	Larkspur, Mixed	P	M	23	M	3	M	4	M	30
Dendranthema weyrichii 'Pink Bomb'	Daisy, Pink Bomb	P	M	8	M	1	M	1	M	10
Dendranthema x rubellum 'Clara Curtis'	Daisy, Rose Pink	P	M	13	M	1	M	1	M	15
Deschampsia cespitosa	Grass, Tufted Hair	P	M	15	M	2	H	2	M	19
Deutzia gracilis	Deutzia, Slender	S	M	10	M	2	M	2	M	14
Dianthus anatolicus	Pinks, Anatolian	P	L	9	L	1	L	2	L	12
Dianthus barbatus	Sweet William	P	M	24	L	2	M	3	M	29
Dianthus caryophyllus	Carnation, Hardy	P	M	18	L	1	L	2	M	21
Dianthus cultivars	Pinks	A P	M	24	L	2	L	3	M	29
Dianthus deltoideus	Pinks, Maiden	P	M	20	L	2	L	2	M	24
Dianthus graniticus	Pinks, Granite	P	M	13	L	2	M	3	M	18
Dianthus gratianopolitanus	Pinks, Pincushion	P	M	17	L	2	L	2	M	21
Dianthus plumarius (lumnitzer)	Pinks, Cottage	P	M	13	L	1	L	2	M	16
Dianthus x chinensis	Border Pink	A	M	17			L	2	M	19
Diascia barberae	Twinspur	A	M	15	L	1			L	16
Diascia integririma 'Coral Canyon'	Twinspur, Coral Canyon	A P	L	26	L	2	L	2	L	30
Dicentra eximia	Bleeding Heart, Fringed	P	M	22	H	2	H	2	M	26

Appendix E
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Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Dicentra formosa	Bleeding Heart, Fringed	P	M	21	M	3	M	4	M	28
Dicentra spectabilis	Bleeding Heart, Old Fashioned	P	M	24	M	3	M	4	M	31
Dictamnus albus	Gas Plant	P	M	6					M	6
Diervilla lonicera	Honeysuckle, Bush	S	L	20	L	4	L	2	L	26
Digitalis 'Mertonensis'	Foxglove, Perennial Pink	P	M	19	M	1	M	1	M	21
Digitalis grandiflora	Foxglove, Perennial Yellow	P	M	19	L	3	M	2	M	24
Digitalis purpurea	Foxglove, Common	P	M	23	M	1	M	2	M	26
Digitalis thapsi	Foxglove, Spanish	P	M	23	M	1	M	1	M	25
Dodecatheon pulchellum	Shooting Star	P	M	14			M	1	M	15
Doronicum grandiflorum	Leopard's Bane	P	M	9	L	1	L	1	M	11
Draba hispanica	Draba, Spanish	P	L	9					L	9
Dracocephalum botryoides	Dragonhead, Evergreen	P	L	5					L	5
Dryopteris dilatata	Fern, Broad Buckler	P	H	8					H	8
Dryopteris erythrosora	Fern, Autumn	P	M	10	M	1			M	11
Dryopteris filix-mas	Fern, Leatherwood Male	P	M	14			M	1	M	15
Dryopteris marginalis	Fern, Leatherwood	P	H	10					H	10
Duchesnea indica	Strawberry, Mock	P	L	18	L	1	L	2	L	21
Dyssodia tenuiloba	Daisy, Dahlberg	A	L	6					L	6
Echinacea angustifolia	Coneflower, Narrow Leaf Purple	P	L	22	L	1	L	1	L	24
Echinacea purpurea	Coneflower, Purple	P	L	35	L	4	M	2	L	41
Echinops ritro	Globe Thistle	P	L	21	L	2	L	1	L	24
Elaeagnus commutata	Silverberry	S	L	19	L	2	L	3	L	24
Elaeagnus umbellata	Autumn Olive	S T	L	22	VL	5	L	4	L	31
Ephedra torreyana	Joint Fir, Torrey	S	VL	16	VL	4	VL	4	VL	24
Ephedra viridis	Mormon Tea	S	VL	22	VL	4	VL	4	VL	30
Epilobium fleischeri	Willowherb, Alpine	P	M	11	L	2	L	2	M	15
Epimedium x cantabrigiense	Bishop's Hat	P	M	9					M	9
Equisetum hyemale	Rush, Scouring	P	H	8			H	1	H	9
Eragrostis trichodes	Grass, Sand Love	P	L	6	L	1			L	7
Erica carnea (herbacea)	Heath, Winter	P	M	5					M	5
Erigeron compositus	Daisy, Cut-Leaf	P	L	17	VL	1	VL	3	L	21
Erigeron divergens	Daisy, Spreading	P	L	9	VL	1	L	1	L	11
Erigeron flagellaris	Daisy, Whiplash	P	L	13	VL	2	L	2	L	17
Erigeron speciosus	Fleabane, Showy	P	L	14	L	1	L	2	L	17
Erigeron subtrinervis	Fleabane, Three-nerved	P	L	9	L	1			L	10
Erigeron vetensis	Daisy, Early Bluetop	P	L	5	L	1			L	6
Eriogonum jamesii	Sulphur Flower, Creamy	P	L	13	L	3	L	4	L	20
Eriogonum umbellatum	Sulphur Flower	P	VL	25	L	4	VL	6	VL	35
Erodium reichardii	Heron's Bill	P	M	8			L	1	M	9
Eryngium alpinum 'Superbum'	Sea Holly	P	L	10	L	1	L	1	L	12
Eryngium amethystinum	Sea Holly, Amethyst	P	L	8	L	1	L	1	L	10
Eryngium planum 'Blaukappe'	Sea Holly, Blue Cap	P	L	11	L	1	L	1	L	13
Eryngium variifolium	Sea Holly, Moroccan	P	L	10	L	1	L	1	L	12
Eryngium yuccifolium	Button-Snakeroot	P	L	11	L	1	L	1	L	13
Erysimum asperum	Wallflower	P	L	14	M	1	L	2	L	17
Erysimum kotschyianum	Wallflower, Alpine	P	M	9	M	1	M	2	M	12
Eschscholzia californica	Poppy, California	P	L	28	VL	3	L	4	L	35
Euonymus alatus	Burning Bush	S	M	33	M	5	M	3	M	41
Euonymus europaeus	Spindle Tree	S T	M	28	M	5	M	3	M	36
Euonymus fortunei 'Coloratus'	Wintercreeper, Purpleleaf	GCP	L	21	L	2	M	1	L	24
Euonymus fortunei	Euonymus	S	M	30	M	4	M	3	M	37
Euonymus kewensis	Euonymus, Kew	GC	M	13	M	1			M	14
Euonymus kiautschovica 'Manhattan'	Euonymus, Manhattan	S	M	28	M	4	M	2	M	34
Eupatorium purpureum	Joe-Pye Weed	P	M	5					M	5
Euphorbia amygdaloides	Spurge, Wood	P	L	13	VL	1	L	1	L	15
Euphorbia polychroma	Spurge, Cushion	P	L	22			L	1	L	23
Eurotia lanata	Winterfat	S	VL	14	VL	5	VL	3	VL	22
Fagus sylvatica	Beech, European	T	M	27	H	3	M	3	M	33
Fallopia japonica compacta	Fleeceflower, Dwarf	P	L	12	VL	1	VL	1	L	14
Fallugia paradoxa	Apache Plume	S	VL	43	VL	6	VL	6	VL	55
Fendlera rupicola	Mockorange, False	S	VL	15	VL	3	VL	3	VL	21
Festuca arundinacea	Tall Fescue	TU	M	17	M	3	M	3	M	23
Festuca glauca	Fescue, Blue	P	L	25	L	3	L	2	L	30
Festuca idahoensis	Fescue, Idaho	P	L	7			M	1	L	8
Festuca ovina	Fescue, Sheep	P TU	L	18	M	3	M	3	L	24
Festuca ovina duriuscula	Hard Fescue	TU	M	8	H	1	H	1	M	10
Festuca rubra	Fescue, Red	TU	M	12	M	2	H	1	M	15
Festuca rubra commutata	Fescue, Chewings	P TU	L	9	H	1	H	1	M	11
Filipendula rubra	Meadowsweet	P	M	13					M	13
Filipendula ulmaria	Meadow Sweet	P	M	10					M	10
Forestiera neomexicana	Privet, New Mexico	S	L	30	VL	5	VL	5	L	40
Forsythia cultivars	Forsythia	S	M	32	M	4	M	3	M	39
Forsythia viridissima 'Broxensis'	Forsythia, Dwarf	S	M	20	M	3	L	2	M	25
Forsythia x intermedia	Forsythia	S	M	26	M	3	M	2	M	31
Fothergilla gardenii	Fothergilla, Dwarf	S	M	12	L	2	L	2	M	16
Fothergilla major	Fothergilla, Large	S	M	10	VL	1	L	2	M	13
Fragaria americana	Strawberry, Wild	GCP	L	21	L	2	L	2	L	25
Fragaria cultivars	Strawberry	GCP	M	22	M	1	M	1	M	24
Fragaria vesca	Strawberry, Runnerless	GCP	M	13			M	1	M	14
Fragaria virginiana glauca	Strawberry, Scarlet	P	L	6			M	1	M	7
Frasera speciosa	Gentian, Green	P	M	4			H	1	M	5
Fraxinus americana	Ash, White	T	M	36	M	4	M	3	M	43
Fraxinus angustifolia 'Raywood'	Ash, Raywood	T	M	8	M	2	M	1	M	11
Fraxinus anomala	Ash, Single-Leaf	S T	L	18	L	4	L	2	L	24
Fraxinus excelsior	Ash, European	T	M	16	M	2	M	1	M	19

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Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Fraxinus latifolia	Ash, Oregon	T	M	6	M	1	M	1	M	8
Fraxinus mandshurica 'Mancana'	Ash, Mancana Manchurian	T	M	20	M	2	M	2	M	24
Fraxinus nigra	Ash, Black	T	M	20	M	3	M	3	M	26
Fraxinus pennsylvanica	Ash, Green	T	M	43	M	5	M	4	M	52
Fraxinus quadrangulata	Ash, Blue	T	M	12	M	2	M	2	M	16
Fraxinus velutina	Ash, Arizona	T	M	10	M	3	L	2	M	15
Gaillardia aristata	Blanket Flower, Native	P	L	31	VL	3	L	2	L	36
Gaillardia x grandiflora	Blanket Flower	P	L	25	VL	1	L	2	L	28
Galium boreale	Northern Bedstraw	P	L	8					L	8
Galium odoratum	Sweet Woodruff	P	M	30	L	2	VL	1	M	33
Gaura lindheimeri	Whirling Butterflies	P	L	28	L	2			L	30
Gazania krebsiana Tanager	Gazania, Orange Hardy	A P	L	19			L	1	L	20
Gazania linearis 'Colorado Gold'	Gazania, Colorado Gold Hardy	P	L	21			L	1	L	22
Gazania rigens	Treasure Flower	A	L	12			L	1	L	13
Genista pilosa 'Vancouver Gold'	Broom, Vancouver Gold	S	L	11	L	1	L	1	L	13
Genista tinctoria 'RoyalGold'	Woadwaxen, Royal Gold	S	L	11	L	2	L	1	L	14
Gentiana affinis	Gentian, Northern Pleated	P	M	11			H	1	M	12
Gentiana cachemirica	Gentian, Himalayan	P	M	6					M	6
Gentiana calycosa	Gentian, Explorer's	P	M	5			L	1	L	6
Gentiana septemfida lagodechiana	Gentian, Crested	P	M	8			H	1	M	9
Geranium caespitosum	Cranesbill, Purple Wild	P	L	15			M	1	L	16
Geranium cinereum 'Ballerina'	Cranesbill, Ballerina Grayleaf	P	M	20			M	1	M	21
Geranium cultivars	Cranesbill	P	M	23	M	1	M	1	M	25
Geranium dalmaticum	Cranesbill, Compact Rose	P	M	13			M	1	M	14
Geranium endressii 'Wargrave Pink'	Cranesbill, Pink	P	M	15	M	1	M	1	M	17
Geranium himalayense	Cranesbill, Lilac	P	M	17			M	1	M	18
Geranium macrorrhizum	Cranesbill, Adriatic	P	L	14	VL	1	L	2	L	17
Geranium maculatum	Geranium, Wild	P	L	16			M	1	M	17
Geranium magniflorum La Veta Lace	Geranium, La Veta Lace	P	M	11					M	11
Geranium platypetalum	Cranesbill, Broad-petaled	P	M	10			M	1	M	11
Geranium psilostemon	Cranesbill, Armenian	P	M	9			M	1	M	10
Geranium sanguineum	Cranesbill, Bloody	P	M	23	L	3	M	1	M	27
Geranium viscosissimum	Geranium, Sticky	P	L	13	L	1	M	1	L	15
Geranium x cantabrigiense	Cranesbill, Cambridge	GCP	L	16	M	1	M	1	M	18
Geranium x magnificum	Cranesbill, Showy	P	M	13	M	1	M	1	M	15
Geranium x oxonianum 'Claridge Druce'	Cranesbill, Lilac Pink	P	M	18	L	2			M	20
Geum chiloense	Avens, Chilean	P	M	17	M	1	L	1	M	19
Geum coccineum 'Borisii'	Avens, Orange	P	M	15			L	1	M	16
Geum triflorum	Avens, Prairie Smoke	P	L	19			L	1	L	22
Ginkgo biloba	Maidenhair Tree	T	M	24	M	3	M	1	M	28
Glechoma hederacea	Ivy, Ground	GCP	M	11			L	1	M	12
Gleditsia triacanthos inermis	Honeylocust, Thornless	T	L	42	L	6	L	3	L	51
Globularia cordifolia	Daisy, Dwarf Globe	GCP	L	12			L	1	L	13
Gomphrene globosa	Globe Amaranth	A	L	15			L	2	L	17
Grindelia squarrosa	Gumweed, Curly-cupped	P	L	7			VL	1	L	8
Gutierrezia sarothrae	Snakeweed	P	VL	12	VL	2	L	1	VL	15
Gymnocarpium dryopteris	Fern, Oak	P	L	1					L	1
Gymnocladus dioica	Kentucky Coffeetree	T	L	38	L	5	L	3	L	46
Gypsophila paniculata	Baby's Breath	P	L	33	M	1	VL	1	L	35
Gypsophila repens	Baby's Breath, Creeping	P	L	24	M	1	L	2	M	27
Hakonechloa macra	Grass, Japanese Forest	P	H	6					H	6
Hamamelis vernalis	Witchhazel, Vernal	S T	M	16	M	3	M	3	M	22
Hamamelis virginiana	Witchhazel, Common	S T	M	18	M	4	M	4	M	26
Haplopappus glutinosus	Golden Star	P	L	8			VL	1	L	9
Hebe albicans	Hebe	P	M	3					M	3
Hedera helix	Ivy, English	V	M	25	L	2	M	1	M	28
Helenium autumnale	Sneezeweed	P	M	17	M	1	L	1	M	19
Helianthemum	Sunrose	P	L	25	M	1	L	1	L	27
Helianthus maximiliana	Sunflower, Maximilian	P	L	27	L	2	VL	1	L	30
Helianthus pumilus	Sunflower, Dwarf	P	L	7					L	7
Helichrysum bracteatum	Strawflower	A	L	11			L	1	L	12
Helichrysum sibthorpii	Everlasting	P	L	5					L	5
Helictotrichon sempervirens	Grass, Blue Avena	P	L	28	L	3	M	1	L	32
Heliopsis helianthoides	False Sunflower	P	M	19			L	1	M	20
Heliotropium arborescens	Heliotrope	A	M	13	M	2	M	1	M	16
Helleborus argutifolius	Hellebore	P	M	14					M	14
Helleborus orientalis	Lenten Rose	P	M	4	M	1			M	5
Hemerocallis	Daylily	P	L	36	L	3	M	3	L	42
Hesperaloe parviflora	Yucca, Red	S	VL	18	VL	3	VL	2	VL	23
Heterotheca horrida	Aster, Golden	P	L	8					L	8
Heterotheca villosa	Aster, Hairy Golden	P	L	12			VL	1	L	13
Heuchera americana	Coral Bells, American	P	M	21			M	1	M	22
Heuchera cultivars	Coral Bells	P	M	27	L	2	M	1	M	30
Heuchera micrantha	Coral Bells, Smallflowered	P	M	19			M	1	M	20
Heuchera sanguinea	Coral Bells	P	M	24	M	1	M	1	M	26
Heuchera x brizoides	Coral Bells, Hybrid	P	M	11					M	11
Heucherella alba	Heucherella, White	P	M	12	M	1			M	13
Hibiscus moscheutos	Rose Mallow	P	M	21					M	21
Hibiscus syriacus	Althea	S	M	29	M	5	M	2	M	36
Hieracium lanatum	Hawkweed, Felted	P	L	8	L	1			L	9
Hierochloa odorata	Grass, Indian Sweet	P	L	5					L	5
Hippophae rhamnoides	Sea Buckthorn	S T	L	28	VL	6	VL	5	L	39
Holodiscus discolor	Ocean-Spray	S	L	15	VL	2	VL	2	L	19
Holodiscus dumosus	Rock Spirea	S	L	23	VL	5	VL	5	L	33
Hosta cultivars	Hosta	P	M	31	L	2	M	1	M	34

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Hosta sieboldiana	Hosta, Sieboldiana	P	M	24	M	1	M	1	M	26
Hosta x fortunei	Hosta, Fortunei	P	M	20			M	1	M	21
Hosta x tardiana 'Halcyon'	Hosta, Halcyon	P	M	15					M	15
Hosta x undulata	Hosta, Wavy	P	M	20	M	1	M	2	M	23
Houttuynia cordata 'Chameleon'	Chameleon Plant	P	M	10					M	10
Humulus lupulus neomexicanus	Hop Vine, Native	P V	L	16	L	1	L	2	L	19
Hydrangea anomala	Hydrangea, Climbing	S	M	14	L	2	L	2	M	18
Hydrangea anomala petiolaris	Hydrangea, Climbing	V	M	11					M	11
Hydrangea arborescens 'Annabelle'	Hydrangea, Annabelle Smooth	S	M	25	M	3	M	2	M	30
Hydrangea macrophylla	Hydrangea, Bigleaf	S	M	13	M	2	M	2	M	17
Hydrangea paniculata	Hydrangea, Panicle	S	M	19	L	2	L	2	M	23
Hydrangea quercifolia	Hydrangea, Oakleaf	S	M	13	L	2	L	2	M	17
Hymenoxys acaulis	Daisy, Angelita	P	L	5			L	1	L	6
Hypericum 'Hidcote'	St. John's Wort, Hidcote	P S	M	27	L	4	L	2	M	33
Hypericum calycinum	St. John's Wort, Mounding	GCP	M	13	M	1			M	14
Hypericum kalmianum	St. John's Wort, Kalm	S	L	16	M	3	L	2	M	21
Hypericum patulum	St. John's Wort, Goldencup	P	M	12	M	1			M	13
Hypericum reptans	St. John's Wort, Creeping	GCP	L	14	M	1			L	15
Hyssopus officinalis	Hyssop	P	L	6					L	6
Iberis gibraltarica	Candytuft, Lilac	GCP	L	13			M	1	L	14
Iberis sempervirens	Candytuft, Evergreen	GCP	L	26	M	1	M	1	L	28
Ilex glabra 'Compacta'	Holly, Compact Inkberry	S	M	10	M	2	M	2	M	14
Ilex x meserveae	Holly, Blue	S	M	19	M	3	M	2	M	24
Ilex x verticillata 'Winter Red'	Holly, Winter Red	S	H	7	M	2	M	2	M	11
Impatiens wallerana	Impatiens	A	H	23	H	1	M	2	H	26
Imperata cylindrica 'Red Baron'	Grass, Japanese Blood	P	M	17					M	17
Incarvillea delavayi	Gloxinia, Hardy	P	M	11					M	11
Ipomea batatas	Sweet Potato Vine	A	M	17			L	1	M	18
Ipomopsis aggregata	Gilia, Scarlet	P	L	17	L	2	L	2	L	21
Ipomopsis candida	Fairy Trumpet, White	P	L	7			L	1	L	8
Iris ensata (kaempferi)	Iris, Japanese	P	M	19	M	1	M	1	M	21
Iris missouriensis	Iris, Western Blue Flag	P	M	21	L	2	L	2	L	25
Iris orientalis	Iris, Yellow Butterfly	P	L	8					L	8
Iris pallida 'Variegata'	Iris, Variegated Sweet	P	L	21			M	1	L	22
Iris pseudacorus	Iris, Yellow Flag	P	M	17			H	1	M	18
Iris setosa arctica	Iris, Dwarf Blue Flag	P	M	14			M	1	M	15
Iris siberica	Iris, Siberian	P	M	27	L	1	L	2	M	30
Iris x germanica	Iris, Bearded	P	L	33	L	1	L	3	L	37
Iris x pumila	Iris, Dwarf Bearded	P	L	19	M	1	M	1	L	21
Itea virginica	Sweetshrub	S	M	7	M	2	M	2	M	11
Jamesia americana	Waxflower	S	L	20	L	5	L	6	L	31
Jasminum fruticans	Jasmine, Evergreen Yellow	P	M	4					M	4
Juglans nigra	Walnut, Black	T	L	35	L	4	L	3	L	42
Juncus balticus	Rush, Baltic	P	H	5			H	1	H	6
Juncus compressus	Rush, Round-fruit	P	H	5			H	1	H	6
Juncus effusus	Rush, Corkscrew	P	H	5			H	1	H	6
Juncus torreyi	Rush, Torrey	P	H	5			H	1	H	6
Juniperus chinensis	Juniper, Chinese	S T	L	39	L	7	L	8	L	54
Juniperus communis	Juniper, Common	S	L	36	L	6	L	8	L	50
Juniperus horizontalis	Juniper, Creeping	S	L	30	L	6	L	5	L	41
Juniperus monosperma	Juniper, One Seed	S T	VL	37	VL	9	VL	9	VL	55
Juniperus procumbens	Juniper, Japanese Garden	S	L	24	L	4	L	3	L	31
Juniperus sabina	Juniper, Savin	S	L	26	L	5	L	5	L	36
Juniperus scopulorum	Juniper, Rocky Mountain	S T	VL	42	VL	9	VL	10	VL	61
Juniperus squamata	Juniper, Flaky	S	L	26	L	4	L	3	L	33
Juniperus utahensis	Juniper, Utah	S T	VL	28	VL	8	VL	6	VL	42
Juniperus virginiana	Juniper, Eastern Red Cedar	T	L	35	L	5	L	5	L	45
Juniperus x media	Juniper, Hybrid Spreading	S	L	16	L	3	L	4	L	23
Kernia japonica 'Pleniflora'	Kernia, Japanese	S	M	10	L	2	L	2	M	14
Knautia macedonica	Knautia, Purple	P	L	16			M	1	L	17
Kniphofia	Torch Lily	P	L	22			L	1	L	23
Koeleruteria paniculata	Golden Rain Tree	T	L	37	L	5	L	3	L	45
Kolkwitzia amabilis	Beauty Bush	S	L	29	L	2	L	2	L	33
Laburnum x watereri	Golden-Chain Tree	T	M	18	H	2	M	1	M	21
Lamiastrum galeobdolon	Yellow archangel	GCP	M	14	M	1	M	1	M	16
Lamium maculatum	Nettle, Spotted	GCP	M	20	M	1	M	1	M	22
Lantana spp.	Lantana	A	L	18			L	2	L	20
Larix decidua	Larch, European	T	M	23	M	3	M	4	M	30
Lathyrus latifolius	Sweet Pea, Perennial	P	L	15			L	1	L	16
Lathyrus odoratus	Sweet Pea, Annual	A	M	19			M	1	M	20
Lavandula angustifolia	Lavender, English	P	L	27	L	2	L	2	L	31
Lavandula dentata	Lavender, French	P	L	16					L	16
Lavandula x intermedia	Lavender, Hybrid	P	L	15					L	15
Lavatera thuringiaca	Shrub Mallow	P	L	20	M	1	M	1	L	22
Leontopodium alpinum	Edelweiss	P	L	13	M	1	L	2	L	16
Lespedeza thurbergii	Japanese Bush-clover	P	L	6					L	6
Leucanthemum x superbum	Daisy, Shasta	P	M	29	M	1	M	2	M	32
Lewisia cotyledon	Bitterroot	P	L	9	L	1	L	2	L	12
Leymus arenarius 'Glaucia'	Grass, Blue Lyme	P	L	8					L	8
Liatis punctata	Gayfeather, Native	P	L	25	L	2	L	2	L	29
Liatis pycnostachya	Gayfeather, Thickspike	P	L	13					L	13
Liatis spicata	Gayfeather, Spike	P	L	26	L	3	L	2	L	31
Ligularia dentata 'Othello'	Groundsel, Golden	P	H	15					H	15
Ligularia przewalskii	Groundsel, Shavalski's	P	H	8					H	8
Ligularia stenocephala 'The Rocket'	Ragwort, The Rocket	P	H	19					H	19

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Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Ligustrum obtusifolium 'Regalianum'	Privet, Regal	S	L	11	L	2	L	2	L	15
Ligustrum vulgare	Privet, Common	S	L	30	L	5	L	3	L	38
Ligustrum x vicaryi	Privet, Golden Vicary	S	M	27	M	4	M	2	M	33
Lilium cultivars	Lily cultivars	P	M	24			M	1	M	25
Limonium latifolium	Sea Lavender, Wide-leaved	P	L	18					L	18
Limonium sinuatum	Statice	A	L	14	L	1	L	1	L	16
Linum flavum	Flax, Yellow	P	L	17	L	1			L	18
Linum perenne	Flax, Blue	P	L	33	VL	3	VL	4	L	40
Liquidambar styraciflua	Sweetgum, American	T	M	14	M	3	L	2	M	19
Liriodendron tulipifera	Tulip Tree	T	M	21	M	2	L	2	M	25
Liriope muscari	Lily Turf	A	M	9			M	1	M	10
Lithospermum incisum	Puccoon, Narrow-leaf	P	L	5					L	5
Lithospermum multiflorum	Puccoon, Many-flowered	P	L	5					L	5
Lobelia cardinalis	Cardinal Flower	P	H	17	L	1			H	18
Lobelia fulgens 'Queen Victoria'	Lobelia, Scarlet	P	M	12					M	12
Lobelia sp.	Lobelia	A	M	20			M	3	M	23
Lobularia maritima	Sweet Alyssum	A	M	16					M	16
Lolium perenne	Perennial Ryegrass	TU	M	12	M	2	H	1	M	15
Lonicera caerulea edulis	Honeysuckle, Bearberry	S	M	11	L	2	L	2	M	15
Lonicera fragrantissima	Honeysuckle, Winter	S	M	8	L	2	L	2	M	12
Lonicera involucrata	Honeysuckle, Twinberry	S	M	19	L	4	L	5	M	28
Lonicera japonica	Honeysuckle, Japanese	S V	L	23	M	3	L	3	L	29
Lonicera korolkowii v. floribunda 'Blue Velvet'	Honeysuckle, Blue Velvet Blueleaf	S	L	24	L	3	L	4	L	31
Lonicera periclymenum	Woodbine, Yellow Flowering	V	M	7					M	7
Lonicera sempervirens 'Magnifica'	Honeysuckle, Scarlet Trumpet	V	M	18	L	1	L	1	M	20
Lonicera syringantha 'Wolfii'	Honeysuckle, Tiny Trumpet	S	M	16	L	2	L	3	M	21
Lonicera tartarica 'Arnold's Red'	Honeysuckle, Arnold's Red Tartaric	S	L	24	L	4	L	4	L	32
Lonicera x 'Honeyrose'	Honeysuckle, Honeyrose	S	M	14	M	3	L	4	M	21
Lonicera x brownii 'Dropmore Scarlet'	Honeysuckle, Dropmore Scarlet Br	V	M	15	L	1	L	1	M	17
Lonicera x heckrotti 'Goldflame'	Honeysuckle, Goldflame	P S V	M	24	L	2	L	2	M	28
Lonicera x xylostoides	Honeysuckle, European Fly	S	L	19	L	4	L	3	L	26
Lunaria annua	Money Plant	A	L	9			L	1	L	10
Lupinus	Lupine	P	M	25	L	2	L	2	M	29
Lupinus argenteus	Lupine, Silvery	P	L	11			L	1	L	12
Lychnis chalcidonica	Maltese Cross	P	M	15	M	1	L	1	M	17
Lychnis coronaria	Rose Campion	P	L	20	M	1	VL	1	L	22
Lysimachia clethroides	Loosestrife, Gooseneck	P	M	13			H	1	M	14
Lysimachia nummularia	Moneywort	P	M	20	H	1	M	1	M	22
Lysimachia punctata	Loosestrife, Yellow	P	M	11			M	1	M	12
Maackia amurensis	Amur Maackia	T	M	20	M	3	L	4	M	27
Machaeranthera bigelovii	Aster, Santa Fe	P	L	9			L	1	L	10
Machaeranthera pattersoni	Aster, Patterson	P	L	7					L	7
Macleaya cordata	Poppy, Plume	P	M	10					M	10
Macleaya microcarpa	Poppy, Plume	P	M	6					M	6
Magnolia grandiflora	Magnolia, Large-flowered	S	M	6	M	1	M	1	M	8
Magnolia kobus	Magnolia, Kobus	S	M	8	M	2	M	1	M	11
Magnolia stellata	Magnolia, Star	S T	M	28	M	6	M	4	M	38
Magnolia virginiana	Magnolia, Sweetbay	S	M	7	M	3	M	2	M	12
Magnolia x loebneri	Magnolia, Loebner	S	M	11	M	1	M	1	M	13
Magnolia x soulangiana	Magnolia, Saucer	S T	M	28	M	6	M	4	M	38
Mahonia aquifolium	Oregon Grape Holly	S	L	34	L	5	L	2	L	41
Mahonia fremonti	Fremont Holly Grape	S	L	18	VL	5	L	2	VL	25
Mahonia repens	Creeping Colorado Holly	GCP S	L	36	L	5	L	5	L	46
Malus crabapple	Crabapple	T	M	41	M	5	L	4	M	50
Malus sylvestris	Apple, Orchard	T	M	27	L	3	L	2	M	32
Malus x zumi 'Calocarpa'	Crab, Zumi	T	M	10	L	2	L	2	M	14
Malva alcea 'Fastigiata'	Hollyhock, Miniature	P	M	16	M	1	L	1	M	18
Marrubium rotundifolium	Horehound, Silvery	GCP	VL	10					VL	10
Matteuccia struthiopteris	Fern, Ostrich	P	H	10			M	1	H	11
Mazus reptans	Mazus	GCP	M	5					M	5
Melampodium leucanthum	Daisy, Blackfoot	P	L	12			VL	1	VL	13
Melinis (Rhynchelytrum) nerviglumis	Grass, Ruby	A	M	10			M	1	M	11
Mentha requienii	Mint, Corsican	P	L	6					L	6
Mentha spicata	Spearmint	P	M	11			M	1	M	12
Mentzelia decapetala	Evening-star	P	VL	9					VL	9
Mertensia lanceolata	Chiming Bells	P	M	8					M	8
Mertensia virginica	Bluebells	P	M	10			H	1	M	11
Metasequoia glyptostroboides	Redwood, Dawn	T	M	14	M	4	M	3	M	21
Microbiota decussata	Cypress, Siberian	S	M	10	L	2	M	3	M	15
Mimulus cardinalis	Monkey Flower, Scarlet	P	H	9					H	9
Mimulus guttatus	Monkey Flower, Yellow	P	H	8			H	2	H	10
Mimulus lewisii	Monkey Flower, Pink	P	M	9			H	1	M	10
Mimulus spp.	Monkey Flower, Annual	A	H	7			H	2	H	9
Mirabilis jalapa	Four O'Clock, Annual	A	L	22	L	1	VL	1	L	24
Mirabilis multiflora	Four-O'Clock, Desert	P	VL	26	VL	3	VL	3	VL	32
Miscanthus floridulus	Grass, Giant Chinese Silver	P	M	12					M	12
Miscanthus sinensis	Grass, Maiden	P	M	26	L	2	M	1	M	29
Molinia caerulea	Grass, Purple Moor	P	M	13	L	1			M	14
Molucella laevis	Bells of Ireland	A	M	9			M	1	M	10
Monarda didyma	Bee-Balm	P	M	28	L	2	L	2	M	32
Monarda fistulosa menthaefolia	Bee-Balm, Native Lavender	P	L	25	L	1	L	2	L	28
Moneses uniflora	One-Flowered Wintergreen	P	M	4			H	2	M	6
Morus alba	Mulberry	T	M	25	M	3	M	3	M	31
Muhlenbergia capillaris	Grass, Muhly	P	L	3			M	1	L	4
Myosotis alpestris	Forget-Me-Not	P	M	18	M	1	M	1	M	20

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Myrica pennsylvanica	Bayberry	S	M	7	L	2	L	2	M	11
Nandina domestica	Bamboo, Heavenly	S	M	20	M	1	M	2	M	23
Nepeta racemosa	Catmint	P	L	18	L	2			L	20
Nepeta x faassenii	Catmint, Faassen's	P	L	24	L	2	VL	1	L	27
Nicotiana spp.	Flowering Tobacco	A	M	21			M	2	M	23
Nierembergia hippomanica	Cup Flower	A	M	8			M	1	M	9
Nolina microcarpa	Grass, Bear	P	L	13			M	1	L	14
Nyssa sylvatica	Sourgum	T	H	11	H	2	M	2	M	15
Ocimum basilicum	Basil	A	M	21			M	2	M	23
Oenothera berlandieri 'Siskiyou'	Primrose, Siskiyou	P	L	19	VL	1	L	1	L	21
Oenothera brachycarpa	Primrose, Leatherleaf	P	L	11	VL	1	M	1	L	13
Oenothera caespitosa	Primrose, White Evening	P	VL	18	VL	4	L	2	VL	24
Oenothera fruticosa glauca	Sundrops	P	L	11	VL	1	M	1	L	13
Oenothera macrocarpa	Primrose, Missouri Evening	P	L	27	VL	2	M	1	L	30
Oenothera speciosa 'Rosea'	Primrose, New Mexico Evening	P	L	22	VL	1	L	1	L	24
Oenothera strigosa	Evening Primrose, Common	P	L	11	VL	1			L	12
Opuntia polyacantha	Cactus, Prickly Pear	P	VL	25	VL	2			VL	27
Origanum lavevatum 'Herrenhausen'	Oregano, Purple	P	L	16					L	16
Origanum vulgare	Oregano, Common	P	L	15	M	1			L	16
Oryzopsis hymenoides	Grass, Indian Rice	P	L	10	VL	1	L	1	L	12
Osteospermum 'Lavender Mist'	Sun Daisy, Lavender Mist	P	L	22	VL	1			L	23
Osteospermum barberiae compactum 'Purple'	Sun Daisy, Purple Mountain	P	L	21	VL	1			L	22
Ostrya virginiana	American Hophornbeam	T	M	16	M	3	M	3	M	22
Oxytropis lambertii	Loco Weed, Lambert's	P	VL	9			L	2	L	11
Pachysandra terminalis	Spurge, Japanese	GCP	M	15	M	2	M	1	M	18
Paeonia lactiflora	Peony	P	M	23	M	1	M	1	M	25
Panicum virgatum	Grass, Switch	P	L	25	L	2	M	1	L	28
Papaver alpinum	Poppy, Alpine	P	M	19	L	2	L	3	L	24
Papaver miyabeianum	Poppy, Japanese Alpine	P	M	10			M	1	M	11
Papaver nudicaule	Poppy, Iceland	P	M	23	L	2	M	3	M	28
Papaver orientale	Poppy, Oriental	P	L	27	L	2	M	3	L	32
Parrotia persica	Persian Parrotia	T	M	7	M	2	L	2	M	11
Parthenocissus quinquefolia	Virginia Creeper	V	L	26	L	3	L	2	L	31
Parthenocissus tricuspidata	Ivy, Boston	P V	M	22	M	1			M	23
Paxistima canbyi	Mountain Lover	P	L	12	L	1	M	2	M	15
Paxistima myrtifolia	Mountain Lover	P	L	7			M	1	L	8
Pedicularis groenlandica	Elephant's Head	P	M	8			H	2	H	10
Pelargonium hybrids	Geranium	A	M	22			M	2	M	24
Pennisetum alopecuroides	Grass, Fountain	P	L	23	L	2			L	25
Pennisetum orientale	Grass, Oriental Fountain	P	L	11	L	1			L	12
Pennisetum setaceum	Grass, Annual Fountain	A	M	21			L	2	M	23
Penstemon 'Elfin Pink'	Penstemon, Pink	P	L	19	VL	1	L	2	L	22
Penstemon 'Hyacinth Flowered'	Penstemon, Hyacinth Flowered	P	M	7					M	7
Penstemon acuminatus	Penstemon, Sand Dune	P	L	7					L	7
Penstemon alpinus	Penstemon, Alpine	P	L	15	L	2	L	2	L	19
Penstemon ambiguus	Penstemon, Sand	P	VL	15	L	2			VL	17
Penstemon angustifolius	Penstemon, Narrowleaf	P	VL	11					VL	11
Penstemon attenuatus	Penstemon, Taper-leaved	P	L	6					L	6
Penstemon barbatus	Penstemon, Scarlet Bugler	P	L	22	VL	3	L	2	L	27
Penstemon caespitosus	Penstemon, Mat	P	L	15	L	3	L	2	L	20
Penstemon cardinalis	Penstemon, Crimson	P	L	11	VL	1	M	1	L	13
Penstemon clutei	Penstemon, Sunset	P	L	11	L	1			L	12
Penstemon cyananthus	Penstemon, Wasatch	P	L	12	L	1			L	13
Penstemon davidsonii	Penstemon, Davidson's	P	L	8					L	8
Penstemon deustus	Penstemon, Hotrock	P	VL	5			VL	1	VL	6
Penstemon digitalis 'HuskerRed'	Penstemon, Husker Red	P	L	29	VL	1	M	1	L	31
Penstemon eatonii	Penstemon, Firecracker	P	L	22	VL	1	M	1	L	24
Penstemon ellipticus	Penstemon, Rockvine	P	VL	3					VL	3
Penstemon fruticosus	Penstemon, Shrubby	P	L	9					L	9
Penstemon glaber	Penstemon, Saw-sepal	P	L	8					L	8
Penstemon gracilis	Penstemon, Slender	P	L	6					L	6
Penstemon grandiflorus	Penstemon, Shell Leaf	P	L	21	VL	1			L	22
Penstemon hirsutus 'Pygmaeus'	Penstemon, Pygmy Purple	P	L	13	L	1	L	2	L	16
Penstemon jamesii	Penstemon, James	P	VL	8	L	1			VL	9
Penstemon linarioides	Penstemon, Blue Mat	P	VL	14			L	1	VL	15
Penstemon neomexicanus	Penstemon, New Mexican Blue	P	L	7					L	7
Penstemon nitidus	Penstemon, Smooth Blue	P	VL	8					VL	8
Penstemon palmeri	Penstemon, Palmer	P	L	17	VL	3			L	20
Penstemon parryi	Penstemon, Parry	P	L	9					L	9
Penstemon pinifolius	Penstemon, Pineleaf	P	L	25	VL	3	L	2	L	30
Penstemon procerus	Penstemon, Small-Flowered	P	L	8	L	1			L	9
Penstemon pseudospectabilis	Penstemon, Desert	P	L	12	L	1			L	13
Penstemon rostriflorus	Bridge's Penstemon	P	L	4					L	4
Penstemon secundiflorus	Penstemon, One-sided	P	L	12					L	12
Penstemon strictus	Penstemon, Rocky Mountain	P	L	27	VL	3	L	3	L	33
Penstemon teucrioides	Penstemon, Grayleaf Creeping	P	L	7					L	7
Penstemon triphyllus	Penstemon, Whorled	P	VL	2					VL	2
Penstemon utahensis	Penstemon, Utah	P	L	8					L	8
Penstemon venustus	Penstemon, Blue Mountain	P	VL	5					VL	5
Penstemon virens	Penstemon, Blue Mist	P	L	15	VL	2	L	2	L	19
Penstemon virgatus asagrayi	Penstemon, Tall	P	VL	7					VL	7
Penstemon whippleanus	Penstemon, Whipple's	P	L	15			L	2	L	17
Penstemon wilcoxii	Penstemon, Wilcox	P	VL	2					VL	2
Penstemon x mexicali	Penstemon, Mexicali Hybrids	P	L	23	VL	2			L	25
Perovskia atriplicifolia	Sage, Russian	S	L	35	VL	6	VL	6	VL	47

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Persicaria affinis	Himalayan Border Jewel	P	L	17	L	1	L	2	L	20
Persicaria virginiana 'Painter's Palette	Border Jewel, Painter's Palette	P	L	9					L	9
Petrophyllum caespitosum	Rock Spirea	P	L	4					L	4
Petunia x hybrida	Petunia	A	M	22	L	1	M	4	M	27
Phacelia campanularia	California Bluebell	A	L	6			L	1	L	7
Phalaris arundinacea	Grass, Ribbon	P	M	17	M	1	M	1	M	19
Philadelphus coronarius	Mockorange, Sweet	S	L	19	L	2	L	3	L	24
Philadelphus lewisii	Mockorange, Lewis	S	L	22	L	5	L	3	L	30
Philadelphus microphyllus	Mockorange, Littleleaf	S	L	20	VL	5	L	3	L	28
Philadelphus x 'Buckley's Quill'	Mockorange, Buckley's Quill	S	M	15	L	3	L	3	M	21
Philadelphus x 'Snowbelle'	Mockorange, Snowbelle	S	M	9	L	2	L	3	L	14
Philadelphus x cymosus 'Bouquet Blanc'	Mockorange, Bouquet Blanc	S	M	14	L	2	L	3	M	19
Philadelphus x virginalis	Mockorange, Virginal	S	M	19	L	4	L	3	M	26
Phlomis cashmeriana	Sage, Himalayan	P	M	11	M	1			M	12
Phlomis russeliana	Sage, Jerusalem	P	L	9			L	1	L	10
Phlox borealis	Phlox, Artic	P	M	4			M	1	M	5
Phlox divaricata	Phlox, Wild Sweet William	P	M	14					M	14
Phlox douglasii	Phlox, Cushion	GCP	L	9			L	1	L	10
Phlox paniculata	Phlox, Garden	P	M	22	M	1	M	1	M	24
Phlox procumbens	Phlox, Creeping	GCP	L	5	M	1	M	1	M	7
Phlox stolonifera	Phlox, Creeping	GCP	M	10					M	10
Phlox subulata	Phlox, Creeping	GCP	L	25	M	2	L	2	L	29
Phyllostachys aurea	Bamboo, Golden	P	M	7					M	7
Phyllostachys aureosulcata	Bamboo, Yellow Groove	P	M	8					M	8
Physocarpus monogynus	Ninebark, Native	S	L	24	VL	5	L	7	L	36
Physocarpus opulifolius	Ninebark	S	L	23	L	5	L	5	L	33
Physostegia virginiana	Obedient Plant	P	M	21			L	1	M	22
Picea abies	Spruce, Norway	S T	M	32	L	6	L	6	M	44
Picea engelmannii	Spruce, Engelmann	T	M	31	L	6	M	9	M	46
Picea glauca 'Conica'	Spruce, Dwarf Alberta	S T	M	35	M	7	M	6	M	48
Picea glauca 'Densata'	Spruce, Black Hills	T	M	29	M	5	M	7	M	41
Picea omorika	Spruce, Serbian	T	M	17	M	3	M	4	M	24
Picea orientalis	Spruce, Oriental	T	M	9	M	2	M	2	M	13
Picea pungens	Spruce, Colorado	S T	M	44	L	7	M	11	M	62
Pieris japonica	Pieris, Japanese	S	H	11	M	2	M	2	M	15
Pieris taiwanensis	Pieris, Taiwan	S	H	6	M	2	M	2	M	10
Pinus aristata	Pine, Bristlecone	S T	L	41	L	8	VL	11	L	60
Pinus bungeana	Pine, Lacebark	T	L	15	M	4	L	4	L	23
Pinus cembra	Pine, Compact Swiss Stone	S	L	15	L	5	L	4	L	24
Pinus contorta latifolia	Pine, Lodgepole	T	L	26	L	7	L	11	L	44
Pinus densiflora	Pine, Tanyosho	S T	L	21	L	6	L	5	L	32
Pinus edulis	Pine, Pinon	T	VL	41	VL	8	VL	8	VL	57
Pinus flexilis	Pine, Limber	T	L	36	L	6	L	10	L	52
Pinus heldreichii (leucodermis)	Pine, Bosnian	S T	L	28	L	6	L	4	L	38
Pinus mugo	Pine, Mugo	S	L	36	L	6	L	6	L	48
Pinus nigra	Pine, Austrian	T	L	40	L	7	L	6	L	53
Pinus parviflora	Pine, Lacebark	T	L	9	L	3	L	3	L	15
Pinus ponderosa	Pine, Ponderosa	T	L	41	L	8	L	10	L	59
Pinus resinosa	Pine, Red	T	M	11	L	2	L	2	M	15
Pinus strobiformis	Pine, Border	T	L	20	L	4	L	4	L	28
Pinus strobus	Pine, Eastern White	T	M	32	L	5	M	4	M	41
Pinus sylvestris	Pine, Scotch	T	L	34	L	7	L	7	L	48
Pinus thunbergii	Pine, Japanese Black	T	L	10	L	4	L	4	L	18
Pinus virginiana 'Wates Golden'	Pine, Wates Golden Virginia Scrub	T	M	5	M	2	M	2	M	9
Platanus occidentalis	Sycamore	T	M	22	M	4	M	3	M	29
Platanus x acerifolia	Planetree, London	T	M	16	M	6	M	3	M	25
Platycladus orientalis 'Aurea Nana'	Arborvitae, Dwarf Golden Oriental	S	M	16	M	3	M	2	M	21
Platycodon grandiflorus	Balloon Flower	P	M	23	M	1	M	1	M	25
Plectranthus argentatus	Silver Dollar Plant	A	L	10			VL	1	L	11
Poa praetensis	Bluegrass	TU	H	25	H	2		2	H	29
Polemonium caeruleum	Jacob's Ladder	P	M	15	M	1	M	1	M	17
Polemonium carneum	Jacob's Ladder, Salmon	P	M	6					M	6
Polemonium reptans	Jacob's Ladder, Creeping	P	M	7					M	7
Polemonium viscosum	Sky Pilot	P	L	5			M	1	L	6
Polygonum aubertii	Vine, Silver Lace	P V	L	22	L	2	L	2	L	26
Polystichum polyblepharum	Fern, Tassle	P	H	6					H	6
Polystichum setiferum	Fern, English Hedge	P	H	7					H	7
Populus alba	Poplar, Silver	T	M	27	M	6	L	4	M	37
Populus angustifolia	Cottonwood, Narrowleaf	T	M	42	M	7	M	8	M	57
Populus balsamifera	Poplar, Balsam	T	M	14	H	3	H	3	H	20
Populus deltoides 'Siouxland'	Cottonwood, Siouxland	T	M	38	M	8	M	4	M	50
Populus fremontii	Cottonwood, Fremont	T	M	26	M	6	M	4	M	36
Populus nigra	Poplar, Lombardy Black	T	H	16	H	6	H	2	H	24
Populus sargentii	Cottonwood, Plains	T	M	40	M	7	M	4	M	51
Populus tremuloides	Aspen	T	M	45	M	8	M	11	M	64
Populus x acuminata	Cottonwood, Lanceleaf	T	M	35	M	8	M	6	M	49
Populus x canescens	Cottonwood, Gray	T	M	16	M	5	M	4	M	25
Portulaca grandiflora	Moss Rose, Portulaca	A	L	21	VL	1	L	3	L	25
Potentilla (Drymocallis) fissa	Cinquefoil, Leafy	P	L	8			L	1	L	9
Potentilla atrosanguinea	Cinquefoil, Red	P	L	15	M	1	L	1	L	17
Potentilla fruticosa	Potentilla, Shrub	S	L	36	L	6	L	8	L	50
Potentilla hippiana	Cinquefoil, Wooly	P	L	14	L	1	VL	1	L	16
Potentilla nepalensis 'Miss Willmott'	Cinquefoil, Miss Willmott	P	M	20	M	1	L	1	M	22
Potentilla neumanniana	Cinquefoil, Creeping	GCP	L	13	L	1	L	2	L	16
Potentilla nevadensis	Cinquefoil, Native Silvery	GCP	L	18	L	2	L	2	L	22

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Potentilla pensylvanica	Cinquefoil, Prairie	P	L	9					L	9
Potentilla species	Cinquefoil, Creeping	GCP S	L	25					L	34
Potentilla thurberi	Cinquefoil, Silver	P	L	5					L	5
Primula 'Colossea'	Primrose, Hardy English	P	M	11					M	11
Primula denticulata	Primrose, Drumstick	P	M	12					M	12
Primula elatior	Primrose, Oxlip	P	M	9					M	9
Primula parryi	Primrose, Rocky Mountain	P	H	8					H	12
Primula veris	Primrose, Cowslip	P	M	8					M	8
Primula vulgaris	Primrose, English	P	M	12					M	12
Prinsepia sinensis	Prinsepia, Cherry	S	M	4					M	6
Prunella grandiflora	Self-Heal	P	M	8					M	8
Prunella laciniata	Lacy Self-Heal	P	L	14					L	17
Prunus americana	Plum, American	S T	L	41					L	56
Prunus armeniaca	Apricot	T	M	28					M	39
Prunus avium	Cherry, Sweet	T	M	25					M	34
Prunus besseyi	Cherry, Western Sand	S	L	36					L	47
Prunus cerasifera	Plum, Cherry	T	M	30					M	40
Prunus cerasus	Cherry, Sour	T	M	23					M	29
Prunus fruticosa	Cherry, European Dwarf	S	M	11					L	15
Prunus glandulosa 'Rosea Plena'	Almond, Pink Flowering	S	M	23					M	28
Prunus maackii	Chokecherry, Amur	T	M	30					M	38
Prunus maritima	Plum, Beach	T	M	6					M	8
Prunus nigra 'Princess Kay'	Plum, Princess Kay Canadian	T	M	28					M	35
Prunus padus	Mayday Tree	T	M	28					M	38
Prunus pensylvanica saximontana	Cherry, Pin	S	M	11					M	13
Prunus pesica	Peach	T	M	23					M	29
Prunus sargentii	Cherry, Sargent	T	M	14					M	20
Prunus serrulata 'Kwanzan'	Cherry, Kwanzan Japanese Flower	T	M	15					M	21
Prunus subhirtella 'Pendula'	Cherry, Weeping Spring	T	M	13					M	18
Prunus tenella	Almond, Dwarf Russian	S	L	14					L	21
Prunus tomentosa	Cherry, Nanking	S	L	29					L	36
Prunus triloba	Rose Tree of China	S	M	17					M	23
Prunus virginiana 'Shubert'	Chokecherry, Canada Red	S T	M	42					L	58
Prunus virginiana melanocarpa	Chokecherry	S	L	32					L	44
Prunus x 'Snow Fountains'	Cherry, Weeping White	S	M	10					M	14
Prunus x americana 'Toka'	Plum, Toka	T	M	16					M	23
Prunus x cistena	Plum, Purple-Leaf	S T	M	38					M	51
Prunus x domestica 'Stanley'	Plum, Stanley Prune	T	M	19					M	23
Pseudotsuga menziesii	Fir, Douglas	S T	M	35					M	51
Psilostrophe tagetina	New Mexico Paper Flower	P	VL	11					VL	13
Ptelea trifoliata	Ash, Wafer	T	L	27					L	36
Pulmonaria 'Roy Davidson'	Bethlehem Sage, Roy Davidson'	P	M	14					M	14
Pulmonaria rubra 'Redstart'	Lungwort, Redstart	P	M	11					M	12
Pulmonaria saccharata	Bethlehem Sage	P	M	13					M	13
Pulsatilla patens	Pasqueflower, Lavender	P	L	13					L	15
Pulsatilla vulgaris	Pasqueflower, European	P	L	18					L	23
Purshia tridentata	Bitterbrush Antelope	S	VL	22					VL	32
Pyracantha angustifolia	Firethorn, Narrowleaf	S	M	19					L	24
Pyracantha coccinea	Firethorn, Scarlet	S	L	22					L	28
Pyrus calleryana	Pear, Ornamental	T	M	32					M	38
Pyrus communis	Pear, Orchard	T	M	18					M	26
Pyrus fauriei	Pear, Korean Wild Pear	T	L	11					L	19
Pyrus ussuriensis	Pear, Ussurian	T	L	24					L	35
Quercus acutissima	Oak, Sawtooth	T	M	12					M	17
Quercus alba	Oak, White	T	M	25					M	32
Quercus bicolor	Oak, Swamp White	T	L	31					L	39
Quercus coccinea	Oak, Scarlet	T	M	23					M	29
Quercus ellipsoidalis	Oak, Northern Pin	T	M	17					M	23
Quercus gambelii	Oak, Gambel	S T	L	42					VL	57
Quercus imbricaria	Oak, Shingle	T	M	15					M	18
Quercus macrocarpa	Oak, Bur	T	L	39					L	49
Quercus muehlenbergii	Oak, Chinkapin	T	L	16					L	21
Quercus palustris	Oak, Pin	T	M	24					M	29
Quercus phellos	Oak, Willow	T	M	13					M	17
Quercus prinus	Oak, Chestnut	T	M	13					M	18
Quercus robur	Oak, English	T	M	30					M	38
Quercus rubra	Oak, Northern Red	T	M	30					M	38
Quercus shumardi	Oak, Shumard Oak	T	M	21					L	26
Quercus turbinella	Oak, Shrub Liveoak	S	VL	13					VL	17
Quercus undulata	Oak, Wavyleaf	T	L	16					L	20
Ranunculus gramineus	Buttercup, European	P	M	9					M	10
Ranunculus repens	Creeping Buttercup	P	M	15					M	16
Ratibida columnifera	Coneflower, Prairie	P	L	26					VL	31
Rhamnus catharticus	Buckthorn, Common	S	L	29					L	34
Rhamnus frangula 'Asplenifolius'	Buckthorn, Glossy Cutleaf	S	M	19					L	26
Rhamnus frangula 'Columnaris'	Buckthorn, Tall Hedge	S	L	26					L	33
Rhamnus saxatile	Buckthorn, Rock	S	L	10					L	14
Rhamnus smithii	Buckthorn, Smith's Alder	S	L	16					L	23
Rheum rhabarbarum	Rhubarb	P	M	20					M	21
Rhododendron	Rhododendron	S	H	19					H	25
Rhus aromatica	Sumac, Fragrant	S	L	24					L	33
Rhus glabra	Sumac, Smooth	S	L	28					L	38
Rhus lanceolata	Sumac, Flameleaf	S	L	8					L	15
Rhus microphylla	Sumac, Little Leaf Desert	S	VL	12					VL	19
Rhus trilobata	Sumac, Three-Leaf	S	VL	33					VL	46

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Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

			East Slope			West Slope				
Botanic Name	Common Name	Plant Type	Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Rhus typhina	Sumac, Staghorn	S	L	28	L	6	L	4	L	38
Ribes alpinum	Currant, Alpine	S	L	33	L	7	L	6	L	46
Ribes aureum	Currant, Yellow Flowering	S	L	26	L	6	L	6	L	38
Ribes cereum	Currant, Squaw	S	L	22	L	6	L	7	L	35
Ribes hirtellum 'Pixwell'	Gooseberry, Pixwell	S	L	20	L	5	L	6	L	31
Ribes inerme	Gooseberry, Whitestem	S	L	10	L	5	L	6	L	21
Ribes leptanthum	Currant, Black	S	L	12	L	3	L	4	L	19
Ribes nigrum	Currant, Black	S	L	9	L	3	L	3	L	15
Ribes odoratum	Currant, Clove	S	L	19	L	5	L	4	L	28
Ribes sanguineum	Currant, Red Flowering	S	L	7	L	1	L	1	L	9
Ribes silvestre 'Red Lake'	Currant, Red Lake	S	L	19	L	3	L	4	L	26
Ribes uva-crispa 'Red Jacket'	Gooseberry, Red Jacket	S	L	14	L	3	L	3	L	20
Ricinus communis	Castor Bean	A	M	9					M	9
Robinia neomexicana	Locust, New Mexico	S T	L	35	VL	9	VL	5	L	49
Robinia pseudoacacia	Locust, Black	T	L	35	L	6	L	4	L	45
Rosa	Rose, Shrub	S	M	21	L	3	L	4	M	28
Rosa foetida 'Bicolor'	Rose, Austrian Copper	S	L	23	L	4	L	4	L	31
Rosa foetida 'Persiana'	Rose, Persian Yellow	S	L	21	L	4	L	4	L	29
Rosa glauca	Rose, Red-Leaved	S	L	22	L	4	L	5	L	31
Rosa pomifera	Rose, Apple	S	L	9	L	3	L	3	L	15
Rosa rugosa	Rose, Rugosa	S	L	23	L	3	L	5	L	31
Rosa woodsii	Rose, Native Pink	S	L	25	L	4	L	5	L	34
Rosa xanthina hugonis	Rose, Yellow Shrub	S	L	16	L	3	L	3	L	22
Rosmarinus officinalis	Rosemary	A P	L	16			L	1	L	17
Rosularia globularifolia	Rosularia, Roundleaf	P	L	5					L	5
Rubus deliciosus	Boulder Raspberry	S	L	28	L	4	L	6	L	38
Rubus idaeus	Raspberry	S	M	16	L	1	L	2	M	19
Rubus odoratus	Raspberry, Purple-flowering	S	L	12	L	2	L	2	L	16
Rubus parviflorus	Thimbleberry	S	M	15	L	4	L	5	L	24
Rudbeckia fulgida	Black-Eyed Susan	P	L	28	L	2	L	1	L	31
Rudbeckia hirta	Black-Eyed Susan	P	M	25	L	2	M	2	M	29
Rudbeckia laciniata 'Double Gold'	Black Eyed Susan, Double Gold	P	M	18			H	1	M	19
Saccharum ravennae	Grass, Plume	P	M	13					M	13
Sagina subulata	Pearlwort	GCP	M	10			M	1	M	11
Sagittaria latifolia	Arrowhead, Broadleaf	P	H	8			H	1	H	9
Salix 'Prairie Cascade'	Willow, Prairie Cascade Weeping	T	H	25	H	3	H	2	H	30
Salix alba 'Tristis'	Willow, Golden Weeping	S T	H	32	H	6	M	4	H	42
Salix alba vitellina	Willow, Russian Golden	S T	H	23	M	5	M	6	H	34
Salix amygdaloides	Willow, Peach Leaf	S T	M	26	M	6	M	7	M	39
Salix arenaria	Willow, Silver Creeping	S	M	11	M	3	M	3	M	17
Salix bebbiana	Willow, Bebb's	S	M	9	M	2	M	3	M	14
Salix caprea	Willow, Goat	S	H	10	H	1	H	1	H	12
Salix discolor	Willow, Pussy	S	H	21	H	3	M	3	H	27
Salix drummondiana	Willow, Drummond	S	H	8	M	2	M	3	M	13
Salix exigua	Willow, Coyote	S	M	19	M	3	H	4	M	26
Salix fragilis	Willow, Crack	S	H	10	M	3	H	4	H	17
Salix geyeriana	Willow, Geyer's	S	H	8	M	2	M	3	M	13
Salix integra 'Hakuro Nishiki'	Willow, Dappled	S	H	11	H	2	H	2	H	15
Salix irrorata	Willow, Blue Stem	S	M	20	M	3	M	5	M	28
Salix lutea ligulifolia	Willow, Strapleaf Yellow	S	M	9	M	2	M	2	M	13
Salix matsudana 'Umbraculifera'	Willow, Globe	S T	H	29	H	6	M	3	H	38
Salix monticola	Willow, Yellow Mountain	S	H	11	M	4	M	5	M	20
Salix pentandra	Willow, Laurel Leaf	T	H	16	M	3	M	2	M	21
Salix purpurea	Willow, Basket	S	H	18	M	4	M	3	M	25
Salix repens	Willow, Creeping	S	M	13	M	3	M	3	M	19
Salix scouleriana	Willow, Scoulers	S	M	7	M	2	M	2	M	11
Salix x sepulcralis chrysocoma	Willow, Niobe Weeping	T	H	17	M	3	M	2	H	22
Salvia argentea	Salvia, Silver	P	L	18	L	2	L	2	L	22
Salvia azurea grandiflora	Salvia, Blue	P	L	15	L	2			L	17
Salvia farinacea	Mealycup sage	A	M	10			L	1	M	11
Salvia greggii	Sage, Autumn	P	L	15	L	1			L	16
Salvia jurisicii	Salvia, Cutleaf	P	L	13					L	13
Salvia leucantha	Sage, Mexican Bush	P	L	7					L	7
Salvia lyrata	Sage, Lyre-leaf	P	L	5					L	5
Salvia microphylla	Salvia, Red Baby	P	L	8					L	8
Salvia nemorosa	Salvia, Blue	P	L	19	L	2	M	1	L	22
Salvia officinalis	Sage, Garden	P	L	21	L	2			L	23
Salvia pitcheri	Sage, Pitcher	P	L	9					L	9
Salvia sclarea	Clary Sage	A P	L	21	VL	1	M	1	L	23
Salvia splendens	Scarlet Salvia	A	M	11			L	2	M	13
Salvia superba	Salvia, Hybrid	P	L	13			M	1	L	14
Sambucus canadensis	Elder, American	S	M	26	M	5	M	5	M	36
Sambucus nigra 'Marginata'	Elder, Variegated	S	M	16	M	3	M	4	M	23
Sambucus pubens	Elder, Native Red Berried	S	M	18	L	4	L	6	M	28
Sambucus racemosa	Elder, European Red	S	M	15	M	4	M	4	M	23
Santolina chamaecyparissus	Lavender Cotton	P	L	24	L	2	VL	1	L	27
Santolina rosmarinifolia	Lavender Cotton, Green	P	L	18	VL	1	VL	1	L	20
Sanvitalia procumbens	Creeping Zinnia	A	L	11			L	2	L	13
Sapindus drummondii	Soapberry, Western	S T	L	8	L	3	L	2	L	13
Saponaria ocyroides	Rock Soapwort	P	L	20	L	2	M	1	L	23
Saxifraga oppositifolia 'Purple Robe'	Saxifrage, Purple Robe	P	M	12	M	1	H	2	M	15
Saxifraga x arendsii	Saxifrage, Rose Mound	P	M	10			H	1	M	11
Scabiosa caucasica	Pincushion Flower	P	M	19	M	1	L	1	M	21
Scabiosa columbaria	Pincushion Flower	P	L	16			L	1	L	17
Scabiosa lucida	Pincushion Flower, Dwarf	P	L	15	M	1	L	1	L	17

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Scabiosa ochroleuca	Pincushion, Yellow	P	L	12					L	12
Scaevola aemula	Fan Flower	A	M	11			M	2	M	13
Schizachyrium scoparium	Bluestem, Little	P	L	22	VL	3	L	2	L	27
Schizophragma hydrangeoides	Vine, Japanese Hydrangea	P	M	4					M	4
Schoenoplectus lacustris	Bulrush, Common	P	H	6					H	6
Schoenoplectus validus	Bulrush, Softstem Great	P	H	6					H	6
Scirpus acutus	Bulrush, Hardstem	P	H	7			H	1	H	8
Scirpus americanus	Bulrush, Three-square	P	H	7			H	1	H	8
Scirpus microcarpus	Bulrush, Small-fruited	P	H	7			H	1	H	8
Scutellaria alpina 'Arcobaleno'	Skull Cap, Rainbow	P	M	8			M	1	M	9
Scutellaria resinosa	Skull Cap, Prairie	P	L	8					L	8
Sedum 'Autumn Joy'	Stonecrop, Autumn Joy	P	L	28	L	1	L	1	L	30
Sedum 'Blue Spruce'	Stonecrop, Blue Creeping	GCP	L	14	L	2	L	2	L	18
Sedum 'Robustum'	Stonecrop, Red-leaf Showy	P	L	11			L	1	L	12
Sedum 'Vera Jameson'	Stonecrop, Vera Jameson	P	L	17	L	1	M	1	L	19
Sedum acre evergreen	Stonecrop, Goldmoss-Utah	GCP	L	16	L	2	VL	3	L	21
Sedum hybridum	Stonecrop, Oak-leaf	GCP	L	12	VL	1	L	2	L	15
Sedum kamschatcicum	Stonecrop, Russian	P	L	13	L	1	VL	1	L	15
Sedum lanceolatum	Stonecrop, Native	P	VL	11			VL	2	VL	13
Sedum populifolium	Stonecrop, Herbacious	P	L	8					L	8
Sedum sieboldii 'October Daphne'	Stonecrop, October Daphne	P	L	8					L	8
Sedum spectabile 'Indian Chief'	Stonecrop, Russet Showy	P	L	15	L	1	L	1	L	17
Sedum spurium	Stonecrop, Two-row	GCP	L	17	L	2	VL	2	L	21
Sempervivum species	Hens and Chicks	GCP	VL	32	VL	4	L	4	VL	40
Senecio cineraria	Dusty Miller	A	L	22	L	1	L	2	L	25
Senecio longilobus	Groundsel, Threadleaf	P	L	8			L	1	L	9
Senecio spartioides	Groundsel, Broom	P	L	5			L	1	L	6
Sequoiadendron giganteum	Giant Sequoia	T	M	10	M	2	L	2	M	14
Shepherdia argentea	Buffaloberry	S T	L	35	VL	8	VL	7	VL	50
Shepherdia canadensis	Buffaloberry, Russet	S	L	19	VL	5	L	6	L	30
Shepherdia rotundifolia	Buffaloberry, Roundleaf	S	VL	15	VL	5	VL	4	VL	24
Sibiraea laevigata	Sibiraea	S	L	11	L	3	L	3	L	17
Sidalcea malviflora	Mallow, Prairie	P	M	17			M	1	M	18
Silene acaulis	Moss Campion	P	M	8			M	1	M	9
Silene alpestris	Alpine Catchfly	P	M	10			M	1	M	11
Silphium perfoliatum	Cup Flower	P	M	5					M	5
Sisyrinchium angustifolium	Grass, Blue-Eyed	P	M	15			M	1	M	16
Sisyrinchium macrocephalum	Grass, Yellow-Eyed	P	M	9					M	9
Sisyrinchium montanum	Grass, Blue-Eyed	P	M	10			M	1	M	11
Solidago 'Golden Baby'	Goldenrod, Golden Baby	P	L	15			L	1	L	16
Solidago decumbens	Goldenrod, Dwarf	P	L	13			H	1	L	14
Solidago missouriensis	Goldenrod, Prairie	P	L	9			M	1	L	10
Sophora japonica	Japanese Pagoda Tree	T	M	26	L	6	M	3	M	35
Sorbaria sorbifolia	Spirea, Ural False	S	L	22	M	3	M	4	M	29
Sorbus alnifolia	Mountain Ash, Korean	T	M	15	L	2	L	2	M	19
Sorbus aucuparia	Mountain Ash, European	S T	M	35	M	6	L	5	M	46
Sorbus decora	Mountain Ash, Showy	T	M	12	L	2	L	2	M	16
Sorbus hybrida	Mountain Ash, Oak Leaf	S	M	9	L	2	L	2	M	13
Sorbus intermedia	Whitebeam, Swedish	T	M	8	M	1	M	1	M	10
Sorbus mougeotii	Whitebeam, Austrian	T	M	6	M	1	M	1	M	8
Sorbus scopulina	Mountain Ash, Native	S T	M	24	M	3	M	4	M	31
Sorghastrum nutans	Grass, Indian	P	L	19	L	2			L	21
Spartina pectinata	Grass, Prairie Cordgrass	P	M	12	L	1	H	1	M	14
Sphaeralcea coccinea	Prairie Mallow	P	VL	17	VL	2	VL	1	VL	20
Sphaeralcea munroana	Globe Mallow, Orange	P	VL	12			VL		VL	12
Spiraea albiflora	Spirea, Japanese White	S	M	15	M	3	M	2	M	20
Spiraea arguta 'Compacta'	Spirea, Compact Garland	S	L	9	M	2	M	2	M	13
Spiraea decumbens	Spirea, White Lace	S	L	6	M	2	M	2	L	10
Spiraea fritschiana	Spirea, Fritschiana	S	L	10	M	3	M	2	M	15
Spiraea japonica	Spirea, Japanese	S	M	21	L	4	M	3	M	28
Spiraea nipponica	Spirea, Snowmound	S	L	23	M	5	M	3	M	31
Spiraea prunifolia	Spirea, Bridalwreath	S	L	23	M	4	M	3	L	30
Spiraea thunbergii	Spirea, Thunberg	S	L	5	M	1	M	1	L	7
Spiraea trilobata	Spirea, Threelobe	S	L	9	M	3	M	3	M	15
Spiraea x 'Goldmound'	Spirea, Goldmound	S	M	22	M	4	M	3	M	29
Spiraea x billardii	Spirea, Billard	S	M	9	M	3	M	3	M	15
Spiraea x bumalda	Spirea, Bumald	S	M	17	M	3	M	2	M	22
Spiraea x cineria 'Grefsheim'	Spirea, Grefsheim	S	M	11	M	2	M	3	M	16
Spiraea x vanhouttei	Spirea, Vanhoutte	S	M	25	M	4	M	3	M	32
Sporobolus wrightii	Grass, Giant Sacaton	P	VL	5	L	1			L	6
Stachys byzantina	Lamb's Ears	GCP	L	25	VL	1	VL	2	L	28
Stachys coccinea	Nettle, Scarlet Hedge	P	L	10					L	10
Stanleya pinnata	Prince's Plume	P	VL	11	VL	1	L	2	VL	14
Stewartia koreana	Korean Stewartia	S	M	5	H	1	H	1	M	7
Stipa comata	Grass, Needle-and-Thread	P	L	10	L	2			L	12
Stipa gigantea	Needlegrass, Giant	P	L	4					L	4
Stipa lettermani	Grass, Needle	P	L	7					L	7
Stipa neomexicana	Needlegrass, New Mexico	P	L	8					L	8
Stipa tenuissima	Grass, Mexican Feather	P	L	16	L	2	L	2	L	20
Stokesia laevis	Aster, Stokes'	P	M	10			L	1	M	11
Styrax japonicus	Snowbell, Japanese	T	H	6	H	2	H	2	H	10
Sutera cordata	Bacopa	A	L	9			M	2	M	11
Symphoricarpos albus	Snowberry, White	S	L	24	L	4	L	3	L	31
Symphoricarpos occidentalis	Wolfberry	S	L	13	L	3	L	4	L	20
Symphoricarpos orbiculatus	Coralberry, Red	S	L	20	L	3	M	3	L	26

Appendix E
Plant Water Requirement Estimates (GreenCO-CSU Crop Coefficient Survey 2004)

Estimated Water Usage for Plant: VL=Very Low <25%; ET₀ L=Low 25%-50%; ET₀ M=Medium 50%-75%; ET₀ H=High >75% ET₀

Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Symphoricarpos oreophilus	Snowberry, Mountain	S	L	15	L	5	L	5	L	25
Symphoricarpos x chenaultii	Coralberry, Chenault	S	L	18	L	3	M	1	L	22
Symphoricarpos x doorenbosii	Snowberry	S	L	13	L	3	L	2	L	18
Symphytum grandiflorum	Comfrey	P	M	12			M	1	M	13
Syringa laciniata	Lilac, Cutleaf	S	L	14	L	3	L	3	L	20
Syringa meyeri 'Palibin'	Lilac, Dwarf Korean	S	L	27	L	5	L	4	L	36
Syringa microphylla	Lilac, Littleleaf	S	L	14	L	3	L	3	L	20
Syringa oblata 'Cheyenne'	Lilac, Cheyenne Early	S	L	15	L	4	L	4	L	23
Syringa patula 'Miss Kim'	Lilac, Miss Kim Dwarf	S	L	27	L	5	L	4	L	36
Syringa pekinensis	Lilac, Peking	S T	L	28	L	6	L	5	L	39
Syringa reflexa	Lilac, Nodding	S	L	8	L	3	L	2	L	13
Syringa reticulata	Lilac, Japanese Tree	S T	M	34	L	7	L	5	L	46
Syringa vulgaris	Lilac, Common Purple	S	L	35	L	6	L	6	L	47
Syringa x chinensis	Lilac, Chinese	S	L	21	L	4	L	4	L	29
Syringa x hyacinthiflora	Lilac, Hybrid	S	L	18	L	4	L	4	L	26
Syringa x josiflexa 'Royalty'	Lilac, Hybrid Purple Singl	S	L	13	M	3	M	3	L	19
Syringa x persica	Lilac, Persian	S	L	15	L	5	L	3	L	23
Syringa x prestoniae	Lilac, Canadian	S	L	22	M	5	L	4	L	31
Tagetes spp.	Marigold	A	L	23	L	1	L	3	L	27
Tanacetum densum amani	Partridge Feather	GCP	VL	19	VL	1	VL	1	VL	21
Tanacetum niveum	Tansy, Snow Daisy	P	L	15	L	1	VL	1	L	17
Tanacetum parthenium 'White Star'	Feverfew, White	P	L	16	M	1			L	17
Tanacetum x coccineum	Painted Daisy	P	L	17			M	1	L	18
Taxodium distichum	Bald Cypress	T	M	23	H	2	H	2	M	27
Taxus cuspidata	Yew, Spreading Japanese	S	M	21	H	4	H	2	M	27
Taxus x media	Yew, Anglojap	S	M	25	H	4	H	2	M	31
Teucrium canadensis	Germander, Creeping	P	L	10					L	10
Teucrium chamaedrys	Germander, Wall	GCP	L	14			L	1	L	15
Thalictrum aquilegifolium	Meadowrue, Columbine	P	M	17	M	1	M	1	M	19
Thalictrum delavayi 'Hewitt's Double'	Meadowrue, Hewitt's Double	P	M	9			M	1	M	10
Thalictrum dipterocarpum	Meadowrue, Yunnan	P	M	9			M	1	M	10
Thalictrum fendleri	Meadowrue, Fendler's	P	M	7	M	1	M	1	M	9
Thalictrum flavum glaucum	Meadowrue, Yellow	P	M	11					M	11
Thalictrum rochebrunianum	Meadowrue, Lavender Mist	P	M	10			M	1	M	11
Thelesperma ambiguum	Navajo Tea	P	L	6	VL	1			VL	7
Thelesperma filifolium	Threadleaf Thelesperma	P	L	10			VL	2	L	12
Thermopsis divaricarpa	Golden Banner	P	L	10	L	2	M	3	M	15
Thermopsis rhombifolia	Golden Banner, Arroyo	P	L	6	L	1	L	2	L	9
Thuja occidentalis	Arborvitae, American	T	M	32	M	4	M	3	M	39
Thuja orientalis	Arborvitae, Oriental	T	M	23	H	3	M	3	M	29
Thuja plicata	Arborvitae, Giant	T	M	15	H	1	H	1	M	17
Thymus 'Elfin'	Thyme, Elfin	GCP	L	15	L	1	VL	1	L	17
Thymus argentia	Thyme, Silver Posy	P	L	7			VL	1	L	8
Thymus praecox 'Pseudolanuginosus'	Thyme, Woolly	GC	L	6	L	1	VL	1	L	8
Thymus praecox arcticus	Thyme, Mother of	GCP	L	19	L	2	L	4	L	25
Thymus serpyllum	Thyme, Wild	GCP	L	16	L	2	L	2	L	20
Thymus vulgaris	Thyme, Garden	P	L	15			VL	1	L	16
Thymus x citriodorus	Thyme, Lemon	P	L	19	L	1	L	1	L	21
Tiarella cordifolia	Foamflower	P	M	11			M	1	M	12
Tiarella wherryi	Foamflower, Wherry's	P	M	11			M	1	M	12
Tilia 'Euchlora'	Linden, Crimean	T	M	17	M	3	M	3	M	23
Tilia americana	Linden, American	T	M	33	M	6	L	4	M	43
Tilia cordata	Linden, Littleleaf	T	M	36	M	5	M	3	M	44
Tilia mongolica	Linden, Mongolian	T	M	11	M	2	L	2	M	15
Tilia tomentosa	Linden, Silver	T	M	16	M	3	M	2	M	21
Tithonia rotundifolia	Sunflower, Mexican	A	L	15			L	1	L	16
Townsendia exscapa	Easter Daisy, White	P	L	10			L	2	L	12
Townsendia grandiflora	Easter Daisy, Large-flower	P	L	7			L	1	L	8
Townsendia parryi	Easter Daisy, Violet-Blue	P	L	4			L	1	L	5
Tradescantia andersoniana	Spiderwort	P	M	20	M	1	M	1	M	22
Tradescantia occidentalis	Spiderwort, Western Blue	P	L	16	VL	1	M	1	L	18
Tricyrtis hirta	Toad Lily	P	M	6					M	6
Trollius chinensis	Globeflower	P	M	16	M	1	M	1	M	18
Trollius pumilus	Globeflower, Dwarf	P	M	8					M	8
Tropaeolum majus	Nasturtium	A	L	21			L	2	L	23
Tsuga canadensis 'Cole's Prostrata'	Hemlock, Canadian Creeping	S	H	10	H	2	H	2	H	14
Tsuga canadensis 'Gracilis'	Hemlock, Dwarf Spreading Canad	S	H	10	H	2	H	2	H	14
Typha angustifolia	Cattail, Narrowleaf	P	H	10			H	1	H	11
Typha latifolia	Cattail, Common	P	H	10			H	1	H	11
Ulmus americana	Elm, American	T	M	30	M	4	M	3	M	37
Ulmus cultivars	Elm	T	M	23	L	2	L	2	M	27
Ulmus glabra	Elm, Scotch	T	L	12	L	3	L	2	L	17
Ulmus parvifolia	Elm, Lacebark	T	L	19	M	3	L	4	M	26
Ulmus wilsoniana	Elm, Wilson	T	M	8	M	3	M	3	M	14
Vaccinium	Blueberry	S	M	8	H	2	H	2	M	12
Valeriana officinalis	Garden Heliotrope	P	M	8					M	8
Verbascum 'Helen Johnson'	Mullein, Peach	P	L	4					L	4
Verbascum bombyciferum	Mullein, Woolly	P	L	16			VL	1	L	17
Verbascum undulatum	Mullein, Wavy-leafed	P	L	4					L	4
Verbena bipinnatifida	Verbena, Native	P	L	19					L	19
Verbena bonariensis	Verbena, Tall	A	L	16	VL	1			L	17
Verbena canadensis	Verbena, Rose	P	L	12	M	1			M	13
Verbena hastata	Vervain, Blue	P	M	5					M	5
Verbena x hybrida	Verbena, Garden	A	L	16	L	1	L	3	L	20
Veronica 'Royal Candles'	Speedwell, Royal Candles	P	L	4					L	4

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Plant Type: A=Annual; P=Perennial; T=Tree; V=Vine; GC=Ground Cover; S=Shrub; TU=Turf

Botanic Name	Common Name	Plant Type	East Slope	East Slope Votes	West Slope	West Slope Votes	Mountain	Mountain Votes	All Regions	Total Votes
Veronica 'Sunny Border Blue'	Speedwell, Sunny Border Blue	P	L	18	L	2	M	1	L	21
Veronica Crystal River	Speedwell, Crystal River	GCP	L	10	L	2	L	2	L	14
Veronica allionii	Speedwell, Allioni	GCP	L	15	L	2	L	2	L	19
Veronica austriaca	Speedwell, Hungarian	P	L	12	L	1	M	1	L	14
Veronica filiformis	Speedwell, Birdseye	GCP	L	11	VL	1	L	2	L	14
Veronica gentianoides	Speedwell, Gentian	P	L	8					L	8
Veronica liwanensis	Speedwell, Turkish	GCP	L	21	L	3	L	2	L	26
Veronica longifolia	Speedwell, Long Leaf	P	L	5					L	5
Veronica orientalis	Speedwell, Oriental	P	L	6					L	6
Veronica pectinata	Speedwell, Wooly Creeping	GCP	L	20	L	4	L	2	L	26
Veronica peduncularis 'Georgia Blue'	Speedwell, Georgia Blue	P	L	10	L	1			L	11
Veronica prostrata	Speedwell, Prostrate	GCP	L	12	L	2	L	2	L	16
Veronica repens	Speedwell, Creeping	GCP	L	17	L	3	L	2	L	22
Veronica spicata	Speedwell, Spike	P	M	18	L	1	L	1	M	20
Veronica spicata incana	Speedwell, Wooly	P	L	16			L	1	L	17
Veronicastrum virginicum	Bowman's Root	P	M	11					M	11
Viburnum carlesii	Viburnum, Koreanspice	S	M	30	M	3	L	2	M	35
Viburnum dentatum	Viburnum, Arrowwood	S	M	24	M	4	L	2	M	30
Viburnum dilatatum	Viburnum, Linden	S	L	6	M	1	M	1	M	8
Viburnum lantana	Wayfaringtree	S T	L	34	L	7	L	4	L	45
Viburnum lentago	Viburnum, Nannyberry	S	L	26	L	5	M	3	L	34
Viburnum opulus	Viburnum, European	S	M	26	M	5	L	2	M	33
Viburnum plicatum tomentosum	Viburnum, Doublefile	S	M	18	M	3	M	2	M	23
Viburnum prunifolium	Viburnum, Blackhaw	S	M	16	L	4	L	2	M	22
Viburnum rufidulum	Viburnum, Rusty Blackhaw	S	M	5	M	1	M	1	M	7
Viburnum sargentii	Viburnum Sargent	S	M	13	L	3	L	2	L	18
Viburnum trilobum	Viburnum, American Cranberrybush	S	M	24	L	5	L	2	M	31
Viburnum x bodnantense 'Pink Dawn'	Viburnum, Pink Dawn	S	M	15	M	2	M	2	M	19
Viburnum x burkwoodii	Viburnum, Burkwood	S	M	27	L	4	L	1	M	32
Viburnum x carlcephalum	Viburnum, Fragrant Snowball	S	M	16	L	3	L	2	M	21
Viburnum x juddii	Viburnum, Judd	S	M	18	M	3	L	2	M	23
Viburnum x rhytidophylloides 'Alleghany'	Viburnum, Alleghany	S	L	23	L	4	L	2	L	29
Viguiera multiflora	Showy Goldeneye	P	L	5					L	5
Vinca major	Periwinkle, Big-Leaf	GCP	M	16	M	2	M	2	M	20
Vinca minor	Periwinkle	GCP	L	24	L	3	M	2	L	29
Viola canadensis	Violet, Canadian	P	M	6			M	1	M	7
Viola cornuta	Pansy, Tufted	P	M	15	M	1	M	1	M	17
Viola corsica	Violet, Corsican	P	M	16	M	1	M	1	M	18
Viola odorata	Violet, English	P	M	13			M	1	M	14
Viola tricolor	Viola, Johnny-jump-up	A	M	22			M	2	M	24
Viola x wittrockiana	Pansy	A	M	21			M	3	M	24
Vitis cultivars	Grape cultivars	S V	M	22	M	4	M	1	M	27
Vitis riparia	Grape, Frost	S V	M	11	M	3	M	1	M	15
Waldsteinia ternata	Strawberry, Barren	GCP	L	20	L	3	L	2	L	25
Weigela florida	Weigela	S	M	22	M	4	M	2	M	28
Wisteria floribunda	Japanese Wisteria	V	L	2					L	2
Wisteria sinensis	Wisteria, Chinese	V	M	16					M	16
Xanthoceras sorbifolium	Yellowhorn	T	L	10	L	2	H	1	M	13
Yucca baccata	Yucca, Banana	S	VL	26	VL	6	VL	4	VL	36
Yucca elata	Soap Tree	S	VL	23	VL	5	VL	4	VL	32
Yucca filamentosa	Adam's Needle	S	L	27	VL	5	VL	3	L	35
Yucca glauca	Soapweed	S	VL	28	VL	6	VL	6	VL	40
Yucca recurvifolia	Yucca, Spineless	S	VL	15	VL	4	VL	3	VL	22
Zauschneria californica latifolia	Hummingbird Flower	P	L	19	VL	1			L	20
Zauschneria garrettii 'Orange Carpet'	California Fuchsia, Orange	P	L	23	VL	2			L	25
Zelkova serrata	Zelkova, Japanese	T	M	11	M	3	M	2	M	16
Zinnia elegans	Zinnia	A	L	23	L	1	L	2	L	26
Zinnia grandiflora	Paper Flower	P	VL	23	VL	3	VL	1	VL	27

ATTACHMENT F

WATER DEMAND CALCULATION DOCUMENTS
(FOR APPENDIX F)

CWCB Water Conservation Study Water Demands

Annual Water Demand (AWD)
$AWD = \left(\frac{ET \times LC - WM}{SP} \right) \times AREA$

Reference Evaporation Transpiration
ET 3.18 ft/yr/ac

Landscape Coefficient (LC)			
Turf Description	Turf Coef.	Planting Description	Land. Coef.
Bluegrass	90%	Traditional	70%
Fescue	70%	Moderate	50%
Buffalo Grass	50%	Native	30%

System Performance (SP)	
SP= Application Method x Installation Method	
Application Method	
Spray	75%
Rotor	80%
Subsurface Drip	95%
Installation Method	
Excellent	100%
Good	80%
Poor	60%

Irrigated Area		
Du/Acre	Turf (sf)	Planting (sf)
5	2,000	1,500
5	1,500	1,000
5	1,000	500

5 du/acre = 8712
 20% dedicated to roads = 1742
 Lot Size = 6970
 50% lot impervious = 3470
 Max Irrigated Area = 3500
 Lot Size = 6970

Water Management (WM)	
WM= Effective Precipitation x Technology	
Effective Precipitation	12.98 in
Technology	
Active	80%
Passive	40%
None	0%

Base Case for Annual Water Demand	
Planting Area	1,500 sqft
Turf Area	2,000 sqft
Planting coefficient	70% Traditional
Turf coefficient	90% Bluegrass
Evapo. Transpiration	2.59 ft/yr/ac
System Performance	60% (App: Spray) (Install: Good)
Water Management	0 (Tech: None)
AWD Planting	0.128 ac-ft/yr
AWD Turf	0.219 ac-ft/yr
AWD Total	0.347 ac-ft/yr

ATTACHMENT G

WATER DEMAND SENSITIVITY ANALYSIS DOCUMENTS
(FOR APPENDIX G)

CWCB Water Conservation Study Water Demands

Annual Water Demand (AWD)
$AWD = \left(\frac{ET \times LC - WM}{SP} \right) \times AREA$

Reference Evaporation Transpiration
ET 3.18 ft/yr/ac

Landscape Coefficient (LC)			
Turf Description	Turf Coef.	Landscaping Description	Land. Coef.
Bluegrass	90%	Traditional	70%
Fescue	70%	Moderate	50%
Buffalo Grass	50%	Native	30%

System Performance (SP)	
SP= Application Method x Installation Method	
Application Method	
Spray	75%
Rotor	80%
Subsurface Drip	95%
Installation Method	
Excellent	100%
Good	80%
Poor	60%

Irrigated Area		
Du/Acre	Turf (sf)	Landscape (sf)
5	2,000	1,500
5	1,500	1,000
5	1,000	500

5 du/acre = 8712
 20% dedicated to roads = 1742
 Lot Size = 6970
 50% lot impervious = 3470
 Max Irrigated Area = 3500
 Lot Size = 6970

Water Management (WM)	
WM= Effective Precipitation x Technology	
Effective Precipitation	12.98 in
Technology	
Active	80%
Passive	40%
None	0%

Base Case for Annual Water Demand	
Landscape	1,500 sqft
Turf	2,000 sqft
Landscape coefficient	70% Traditional
Turf coefficient	90% Bluegrass
Evapo. Transpiration	2.59 ft/yr/ac
System Performance	60% (App: Spray) (Install: Good)
Water Management	0 (Tech: None)
AWD Landscape	0.128 ac-ft/yr
AWD Turf	0.219 ac-ft/yr
AWD Total	0.347 ac-ft/yr

CWCB Water Conservation Study

Water Demands for Variable Irrigated Areas

Constant Variables from Base Case		
Landscape Area	Variable	sqft
Turf Area	Variable	sqft
Landscape Coefficient	70%	Traditional
Turf Coefficient	90%	Bluegrass
Evapo. Transpiration	3.18	ft/yr/ac
System Performance	60%	(App: Spray) (Install: Good)
Water Management	0	(Tech: None)

Landscape Area (sqft)	Landscape Demand (ac-ft/yr)	Turf Area (sqft)	Turf Demand (ac-ft/yr)	Total Area (sqft)	Total Water Demand (ac-ft/yr)
500	0.043	1,000	0.110	1,500	0.152
500	0.043	1,500	0.164	2,000	0.207
500	0.043	2,000	0.219	2,500	0.262
1,000	0.085	1,000	0.110	2,000	0.195
1,000	0.085	1,500	0.164	2,500	0.249
1,000	0.085	2,000	0.219	3,000	0.304
1,500	0.128	1,000	0.110	2,500	0.237
1,500	0.128	1,500	0.164	3,000	0.292
1,500	0.128	2,000	0.219	3,500	0.347

What is 0.45 acre feet demand area at a Landscape to Turf ratio of 1500 to 2000?

Adjust Landscape number only, turf will automatically be calculated

Landscape Area (sqft)	Landscape Demand (ac-ft/yr)	Turf Area (sqft)	Turf Demand (ac-ft/yr)	Total Area (sqft)	Total Water Demand (ac-ft/yr)
1,950	0.166	2,600	0.285	4,550	0.451

Total Irrigated Area =	4550 sf		
Total Impervious Area =	4550 sf	20% Every Acre for Roads =	8712 sf
Total Lot Area =	9100 sf	Total Lot Area per Acre =	34848 sf
Total Area for Lots per Acre =	34848 sf		
du/acre =	3.83 acre		

CWCB Water Conservation Study Water Demands for Variable Landscaping

Constant Variables from Base Case		
Landscape Area	1,500	sqft
Turf Area	2,000	sqft
Landscape Coefficient	Variable	
Turf Coefficient	Variable	
Evapo. Transpiration	3.18	ft/yr/ac
System Performance	60%	(App: Spray) (Install: Good)
Water Management	0	(Tech: None)

Turf Maintenance		Landscape Maintenance		Turf Demand (ac-ft/yr)	Land. Demand (ac-ft/yr)	Total Demand (ac-ft/yr)
Bluegrass	90%	Traditional	70%	0.219	0.128	0.347
Fescue	70%	Traditional	70%	0.170	0.128	0.298
Buffalo Grass	50%	Traditional	70%	0.122	0.128	0.249
Bluegrass	90%	Moderate	50%	0.219	0.091	0.310
Fescue	70%	Moderate	50%	0.170	0.091	0.262
Buffalo Grass	50%	Moderate	50%	0.122	0.091	0.213
Bluegrass	90%	Native	30%	0.219	0.055	0.274
Fescue	70%	Native	30%	0.170	0.055	0.225
Buffalo Grass	50%	Native	30%	0.122	0.055	0.176

CWCB Water Conservation Study

Water Demands for Variable System Performance

Constant Variables from Base Case		
Landscape Area	1,500	sqft
Turf Area	2,000	sqft
Landscape Coefficient	70%	Traditional
Turf Coefficient	90%	Bluegrass
Evapo. Transpiration	3.18	ft/yr/ac
System Performance	Variable	(App: Variable) (Install: Variable)
Water Management	0	(Tech: None)

Application Method		Efficiency		System Performance	Turf Demand (ac-ft/yr)	Land. Demand (ac-ft/yr)	Total Demand (ac-ft/yr)
Spray	75%	Excellent	100%	75%	0.175	0.102	0.277
Rotor	80%	Excellent	100%	80%	0.164	0.096	0.260
Subsurface Drip	95%	Excellent	100%	95%	0.138	0.081	0.219
Spray	75%	Good	80%	60%	0.219	0.128	0.347
Rotor	80%	Good	80%	64%	0.205	0.120	0.325
Subsurface Drip	95%	Good	80%	76%	0.173	0.101	0.274
Spray	75%	Poor	60%	45%	0.292	0.170	0.462
Rotor	80%	Poor	60%	48%	0.274	0.160	0.433
Subsurface Drip	95%	Poor	60%	57%	0.231	0.134	0.365

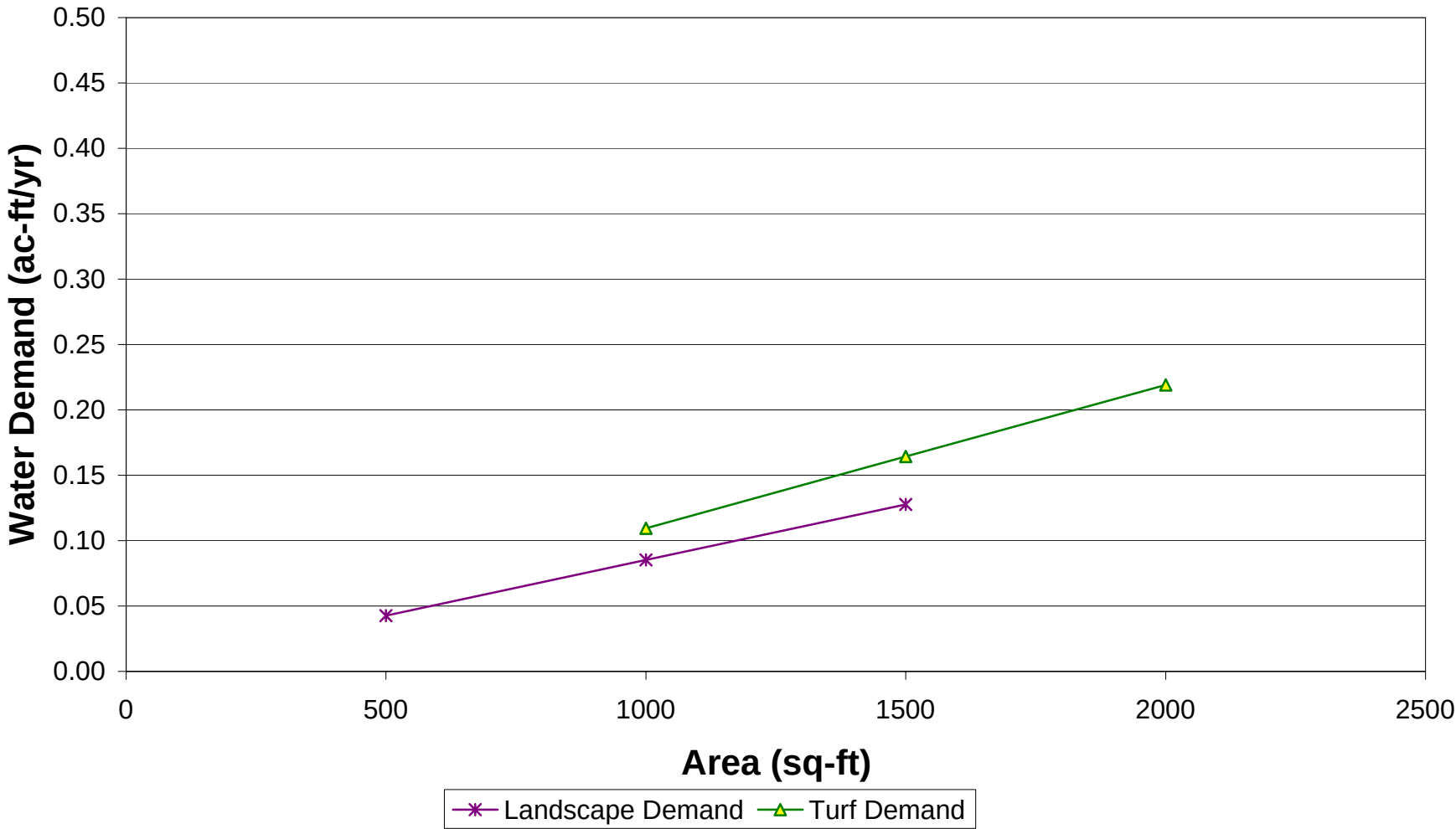
CWCB Water Conservation Study

Water Demands for Variable Water Management

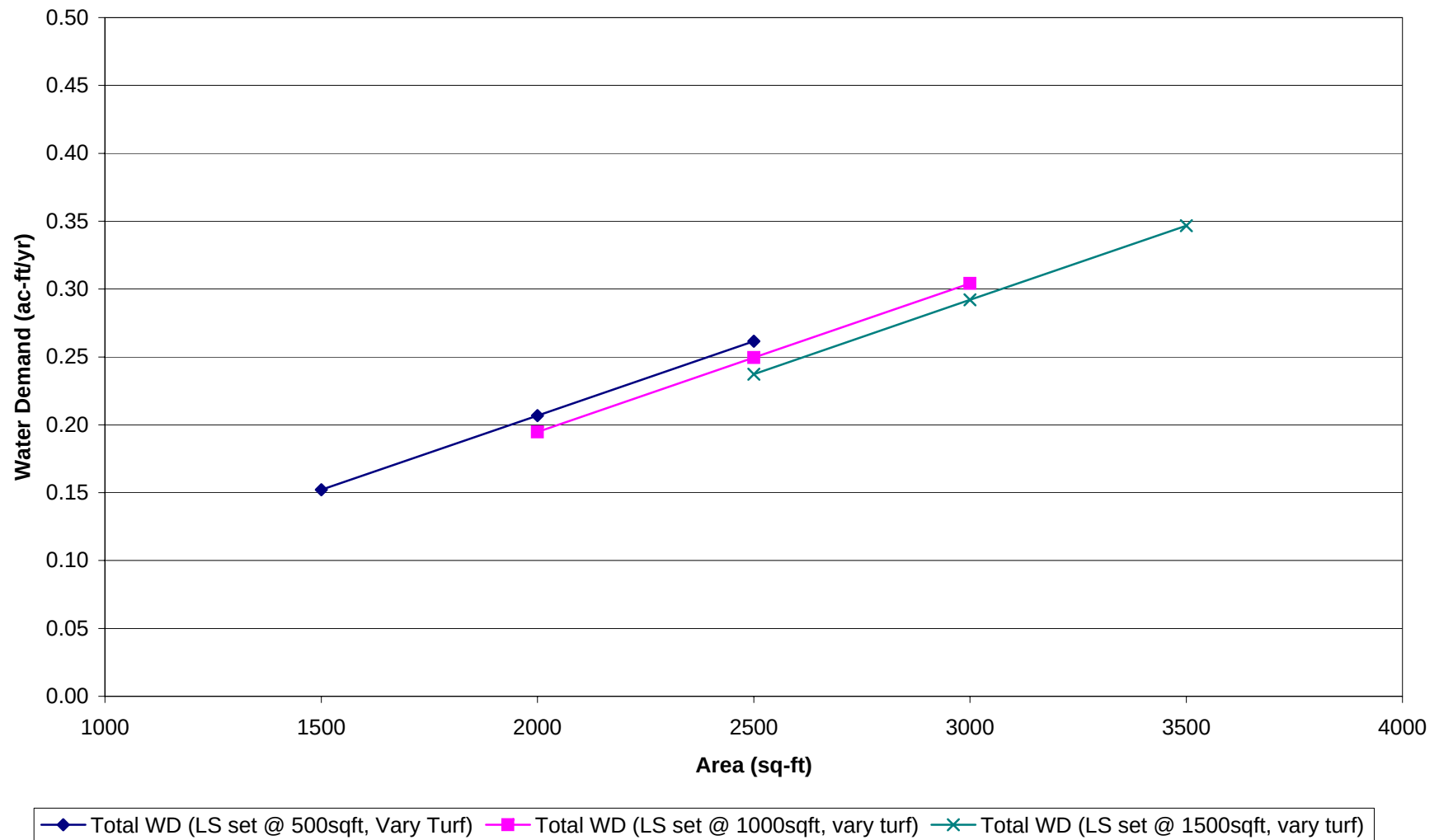
Constant Variables from Base Case		
Landscape Area	1,500	sqft
Turf Area	2,000	sqft
Landscape Coefficient	70%	Traditional
Turf Coefficient	90%	Bluegrass
Evapo. Transpiration	3.18	ft/yr/ac
System Performance	60%	(App: Spray) (Install: Good)
Water Management	Variable	

Technology		Effective Precipitation (in)		Water Management (ft)	Turf Demand (ac-ft/yr)	Land. Demand (ac-ft/yr)	Total Demand (ac-ft/yr)
Active	80%	Average	12.98	0.87	0.153	0.078	0.231
Passive	40%	Average	12.98	0.43	0.186	0.103	0.289
None	0%	Average	12.98	0.00	0.219	0.128	0.347

Water Demand Variable Irrigated Area

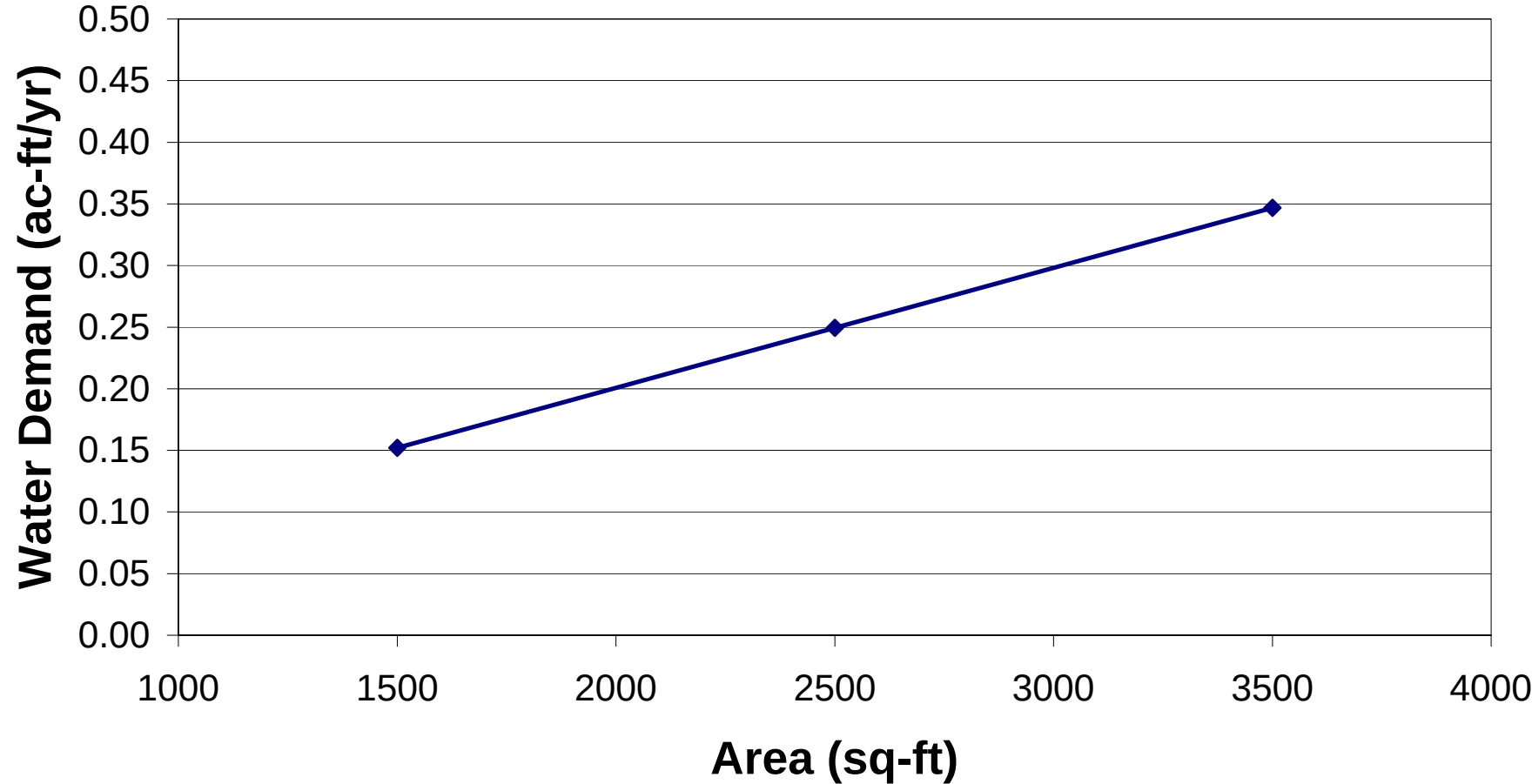


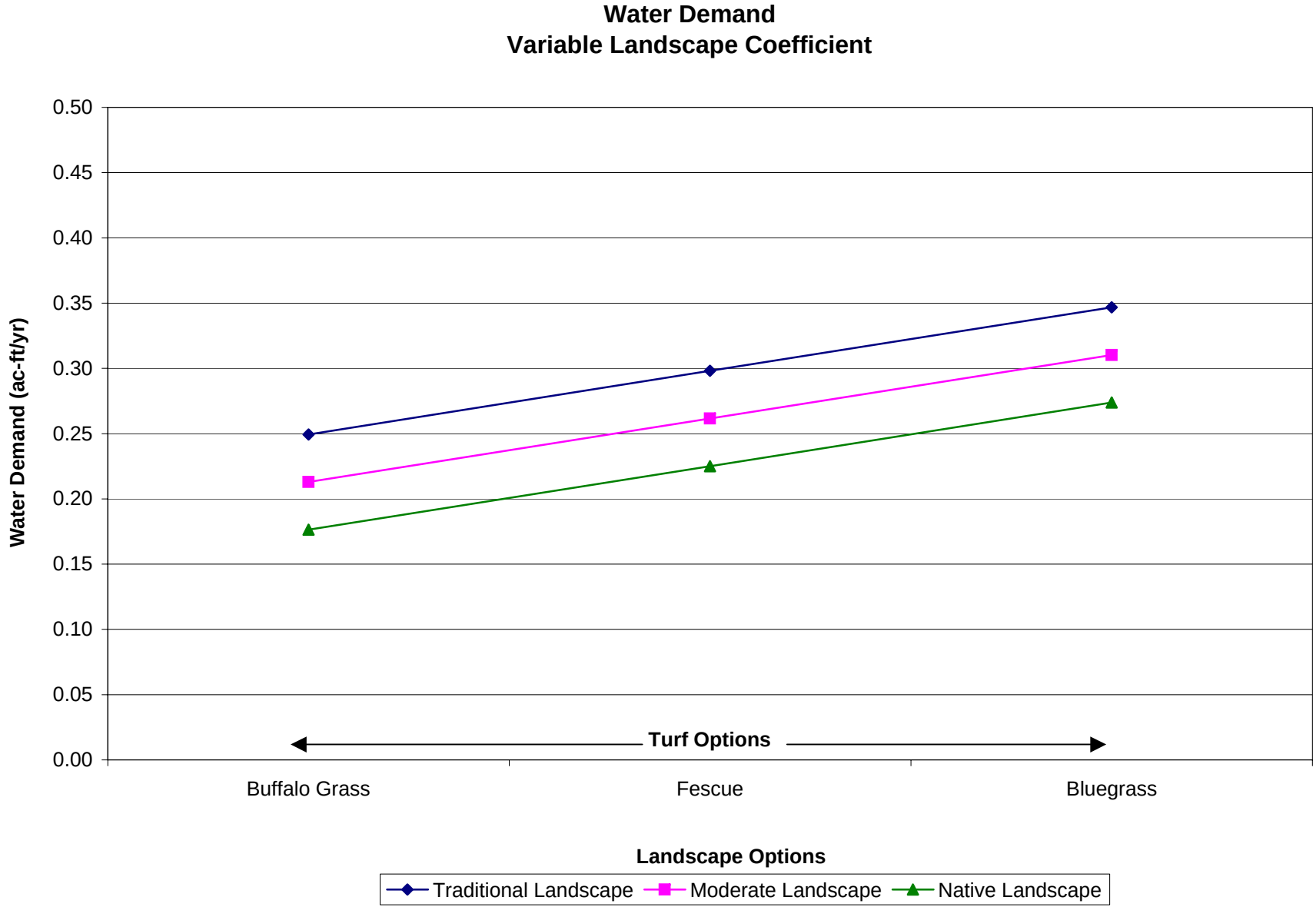
Water Demand Combined Turf and Landscape Irrigated Area



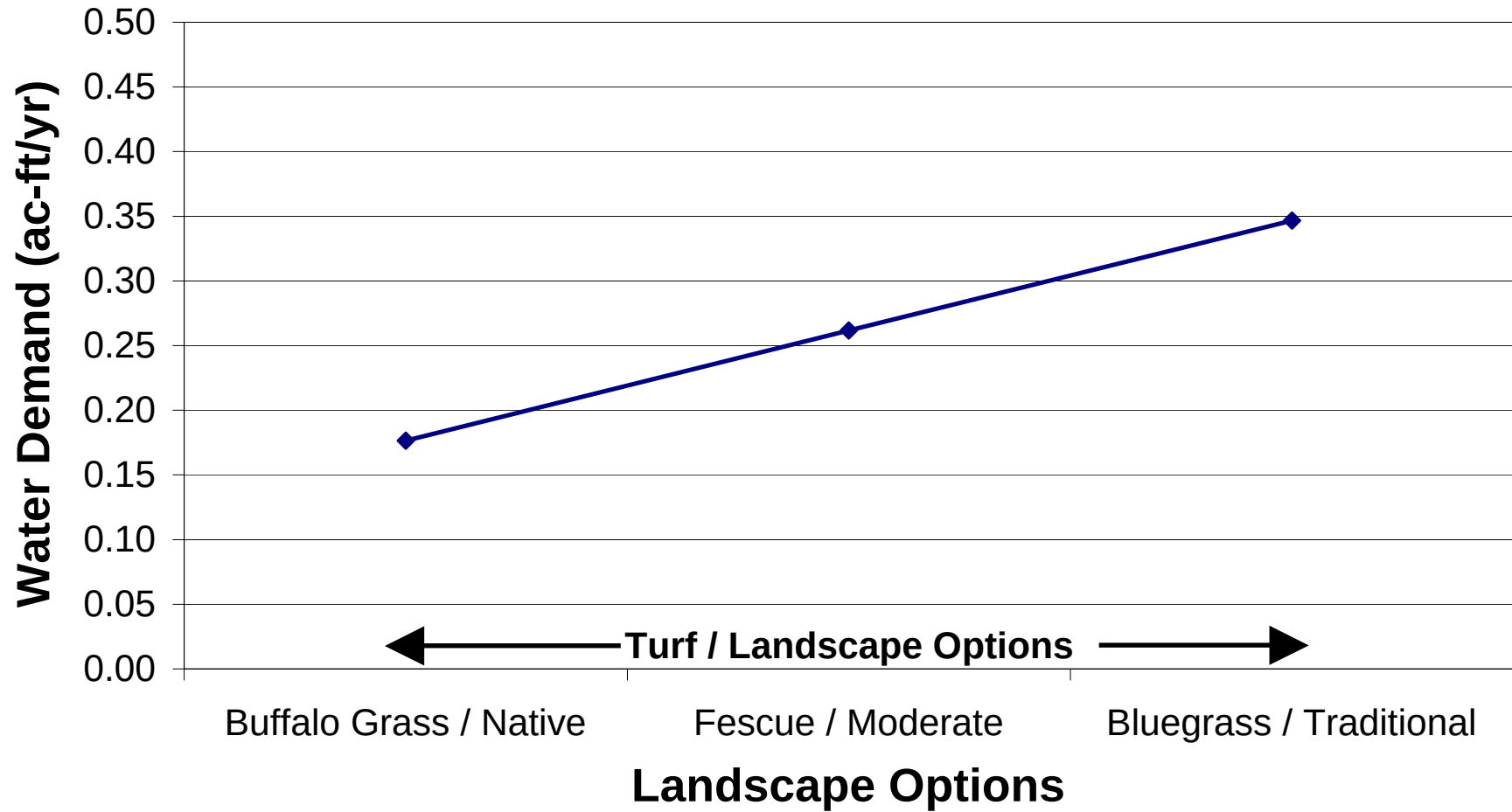
Water Demand

Bluegrass and Traditional Landscape Irrigated Area

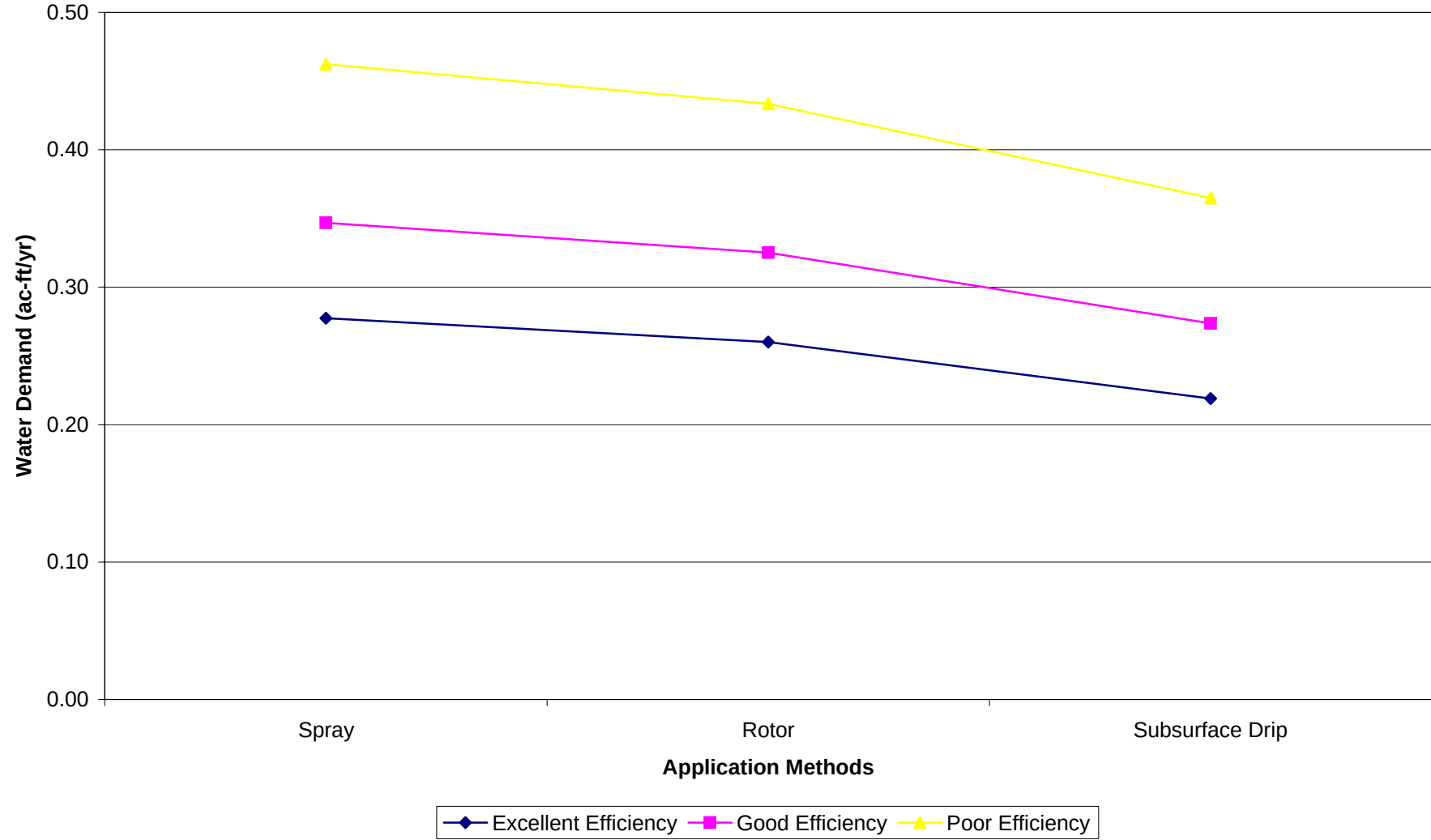




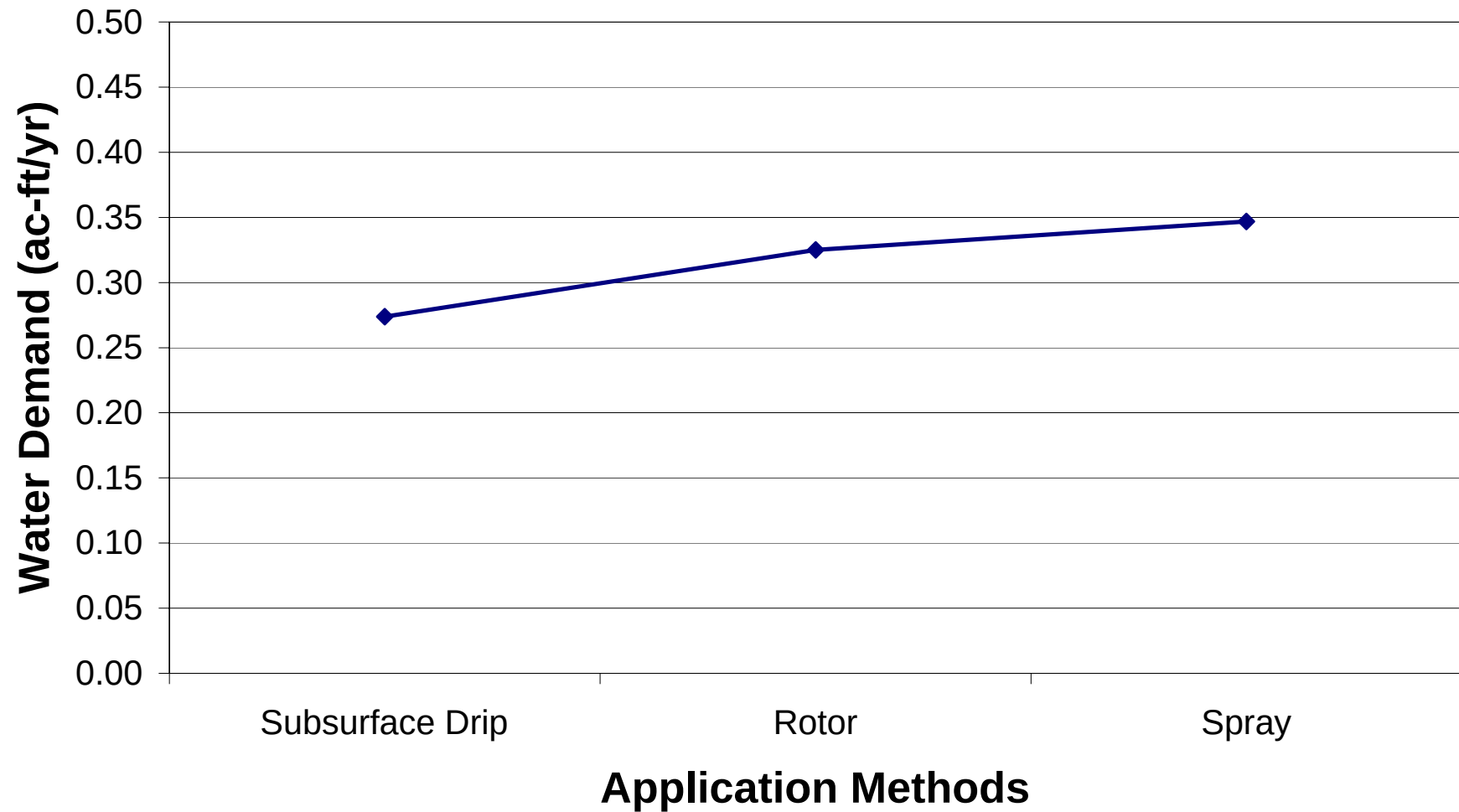
Water Demand Variable Landscape Coefficient



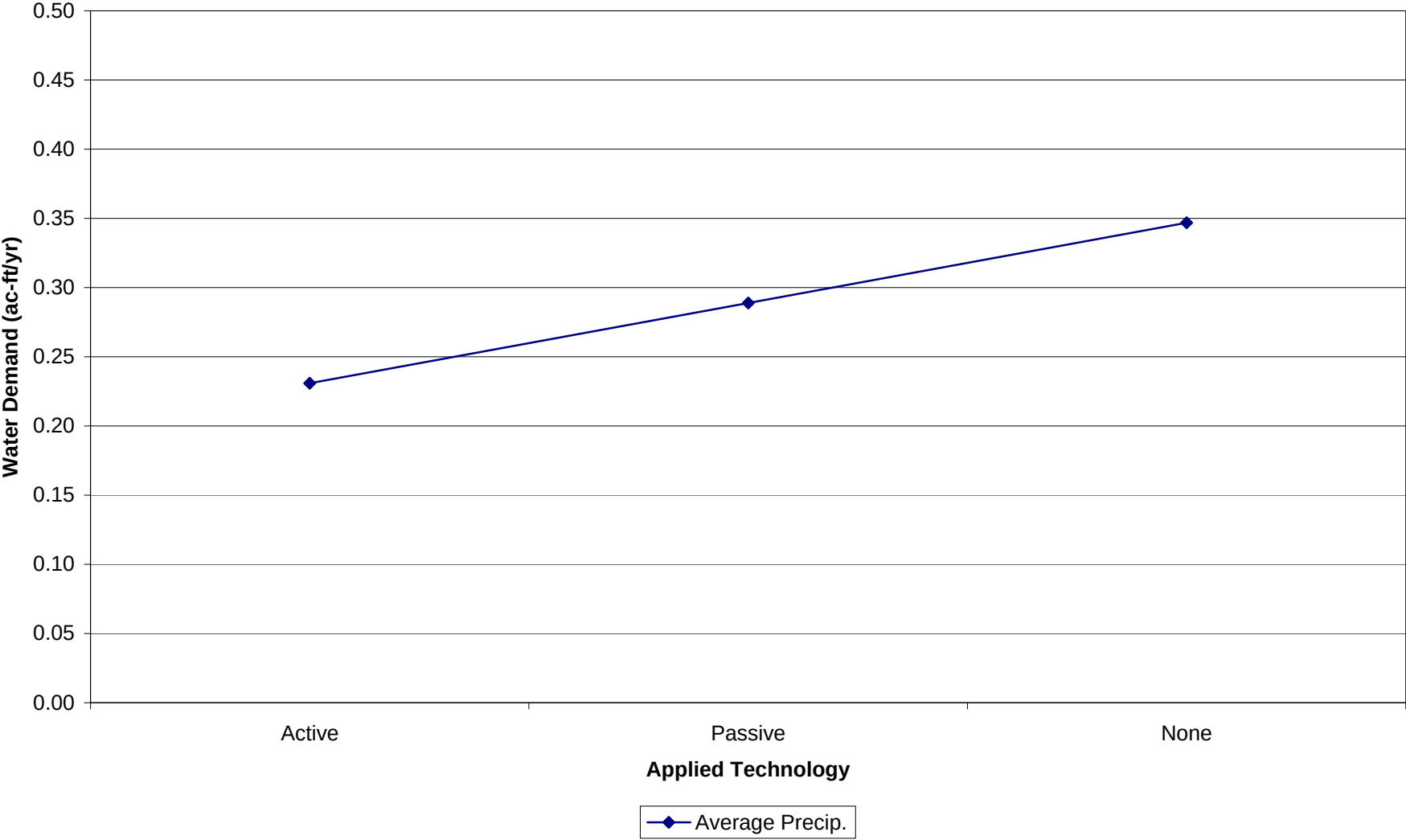
**Water Demand
Variable System Performance**



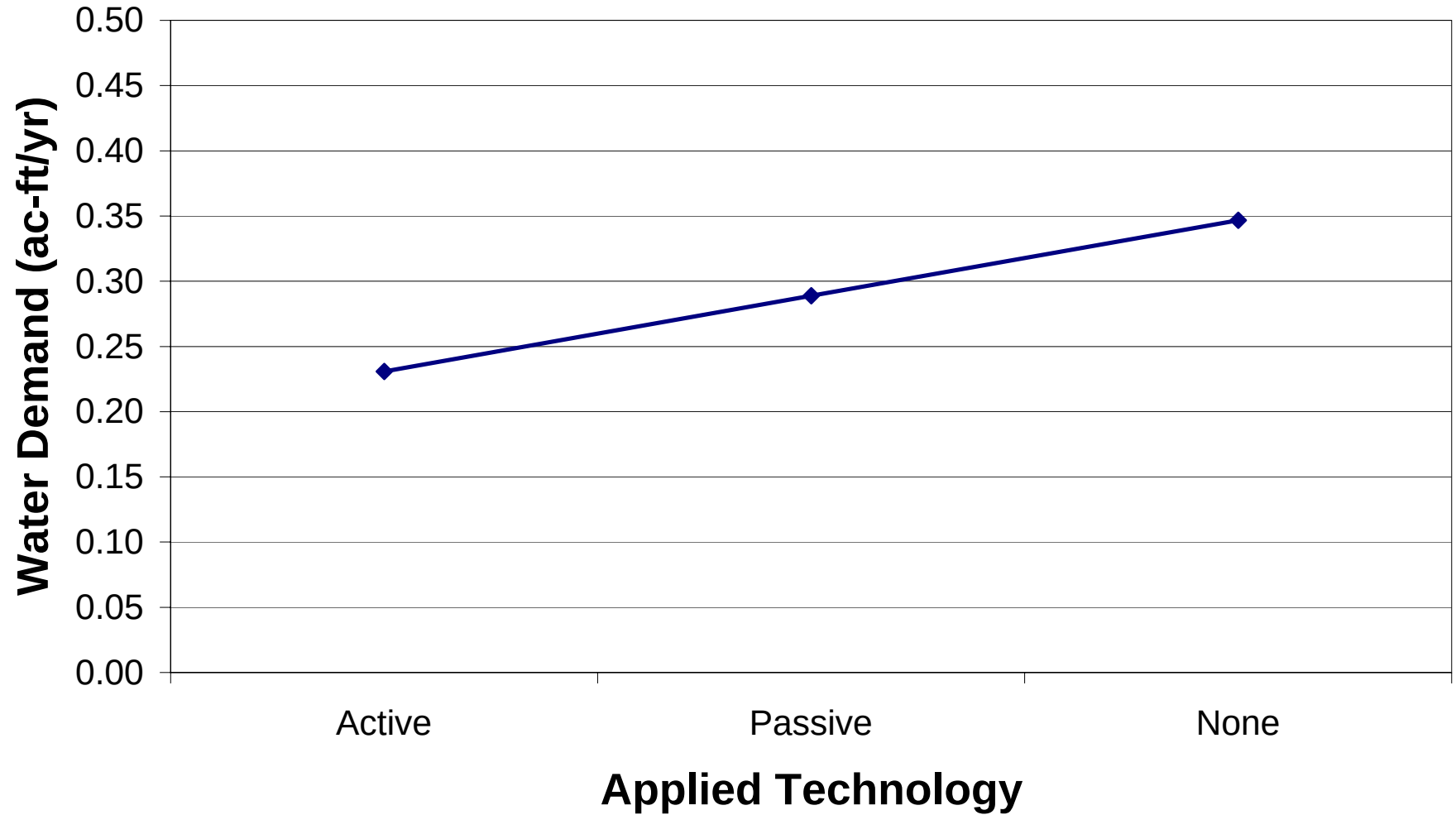
Water Demand
Bluegrass and Traditional Landscape Variable System Performance



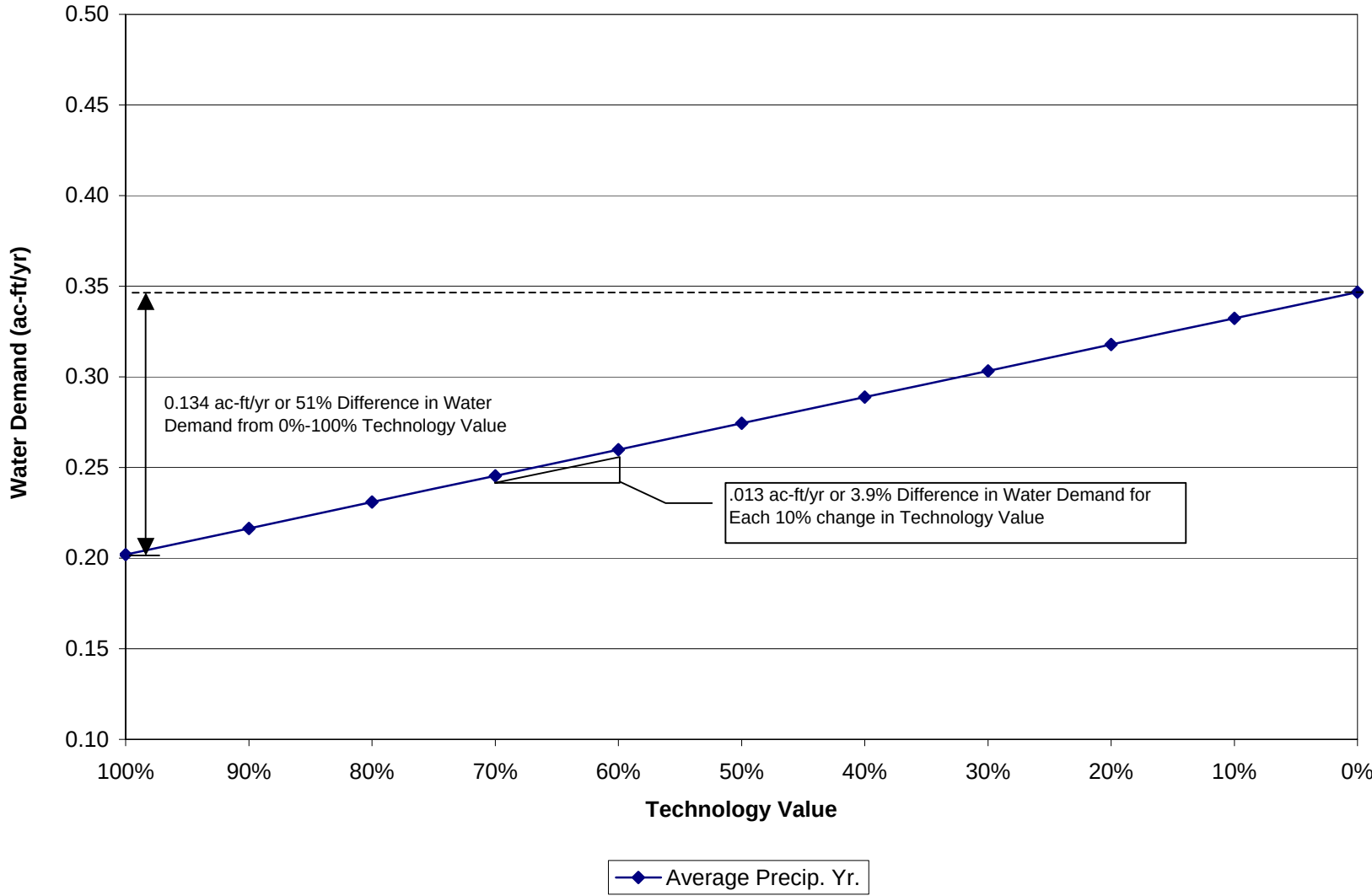
**Water Demand
Variable Water Management**



Water Demand Bluegrass and Traditional Landscape Variable Water Management



**Water Demand
Variable Technology Sensitivity**



ATTACHMENT H

DOUGLAS COUNTY
WATER DEMAND CALCULATION DOCUMENTS
(FOR APPENDIX H)

Appendix H.1

Water Demands for Variable Irrigated Areas

Douglas County Base Case

Constant Variables from Base Case		
Landscape Area	Variable	sqft
Turf Area	Variable	sqft
Landscape Coefficient	70%	Traditional
Turf Coefficient	90%	Bluegrass
Evapo. Transpiration	3.18	ft/yr/ac
System Performance	60%	(App: Spray) (Install: Good)
Water Management	0	(Tech: None)

Landscape Area (sqft)	Landscape Demand (ac-ft/yr)	Turf Area (sqft)	Turf Demand (ac-ft/yr)	Total Area (sqft)	Total Water Demand (ac-ft/yr)
500	0.043	1,000	0.110	1,500	0.152
500	0.043	1,500	0.164	2,000	0.207
500	0.043	2,000	0.219	2,500	0.262
1,000	0.085	1,000	0.110	2,000	0.195
1,000	0.085	1,500	0.164	2,500	0.249
1,000	0.085	2,000	0.219	3,000	0.304
1,500	0.128	1,000	0.110	2,500	0.237
1,500	0.128	1,500	0.164	3,000	0.292
1,500	0.128	2,000	0.219	3,500	0.347

What is 0.45 acre feet demand area at a Landscape to Turf ratio of 1500 to 2000?
Adjust Landscape number only, turf will automatically be calculated

Landscape Area (sqft)	Landscape Demand (ac-ft/yr)	Turf Area (sqft)	Turf Demand (ac-ft/yr)	Total Area (sqft)	Total Water Demand (ac-ft/yr)
1,950	0.166	2,600	0.285	4,550	0.451

Total Irrigated Area =	4550 sf		
Total Impervious Area =	4550 sf	20% Every Acre for Roads =	8712 sf
Total Lot Area =	9100 sf	Total Lot Area per Acre =	34848 sf
Total Area for Lots per Acre =	34848 sf		
du/acre =	3.83	acre	

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Irrigation Demand Alternatives

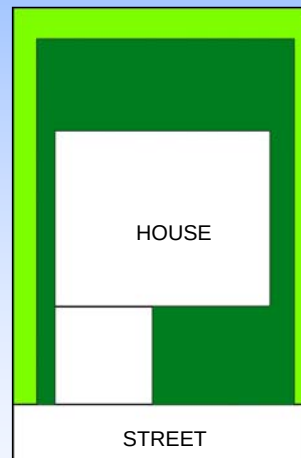
Estimated Lot Size Based on Douglas County Water Demand Criteria

- Douglas County Water Demand Criteria 0.75 acre-feet
- Inside Use (Assumed Based on 3 People Per Unit, 89 gpd per Person) 0.30 acre-feet
- Outside Water Use 0.45 acre-feet



What Size Lot Meets Irrigation Demand of 0.45 acre-feet?

20% of Every Acre is Dedicated for Roads
 50% of Every Lot is Impervious Area
 Turf = Bluegrass
 Landscape = Traditional
 Turf to Landscape Ratio = 1.0:0.75
 System Performance = Spray with Good Efficiency
 Water Management = None



	Area	System Supply
○	Impervious	4,550 sf
●	Turf	2,600 sf
●	Planting	1,950 sf
●	Non Irrigated	0 sf
	Total Lot	9,100 sf
	Annual Demand	0.45 ac-ft

Lot Size Relates to A Density of 3.8 Units Per Acre.

ATTACHMENT I

WATER USE SCENARIO DOCUMENTS
(FOR APPENDIX I)

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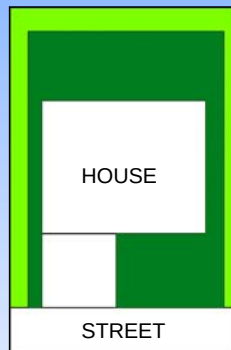
Irrigation Demand Alternatives

Example: Sterling Ranch – New Residential Development with Individual Cisterns (1,500 sf rooftops only)

- Sample Lot Layout: 5 units per acre
- 20% of Every Acre is Dedicated for Roads

Traditional

Total Irrigation Area = 50.2% of Lot



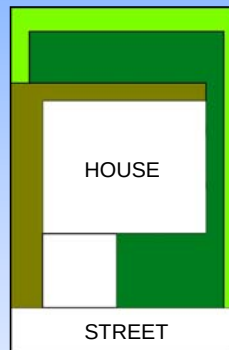
Turf = Bluegrass
Planting = Traditional
System Performance = Spray with Good Efficiency
Turf to Planting Ratio 1.0:0.75
Water Management = None



	Area	System Supply	Cistern Supply
○	Impervious	3,470 sf	3,470 sf
●	Turf	2,000 sf	165 sf
●	Planting	1,500 sf	125 sf
●	Non Irrigated	0 sf	3,210 sf
	Total Lot	6,970 sf	6,970 sf
	Annual Demand	0.35 ac-ft	0.04 ac-ft

Moderate

Total Irrigation Area = 35.8% of Lot



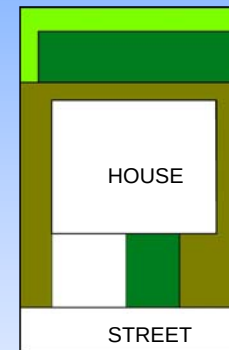
Turf = Fescue
Planting = Moderate
System Performance = Rotor with Good Efficiency
Turf to Planting Ratio 1.0:0.67
Water Management = None



	Area	System Supply	Cistern Supply
○	Impervious	3,470 sf	3,470 sf
●	Turf	1,500 sf	260 sf
●	Planting	1,000 sf	175 sf
●	Non Irrigated	1,000 sf	3,065 sf
	Total Lot	6,970 sf	6,970 sf
	Annual Demand	0.16 ac-ft	0.04 ac-ft

Water Wise

Total Irrigation Area = 21.5% of Lot



Turf = Fescue
Planting = Native
System Performance = Subsurface with Good Efficiency
Turf to Planting Ratio 1.0:0.50
Water Management = Passive



	Area	System Supply	Cistern Supply
○	Impervious	3,470 sf	3,470 sf
●	Turf	1,000 sf	365 sf
●	Planting	500 sf	185 sf
●	Non Irrigated	2,000 sf	2,950 sf
	Total Lot	6,970 sf	6,970 sf
	Annual Demand	0.08 ac-ft	0.04 ac-ft





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USE OF TECHNOLOGY, EFFECTIVE COMMUNICATION, AND TO CONTINUOUS
IMPROVEMENT OF OUR CONTRIBUTIONS TO OUR CLIENTS AND COMMUNITY.**

WE FOSTER A CHALLENGING, STIMULATING AND FULFILLING WORK EXPERIENCE.