

**Green Industry
Best Management Practices (BMPs)
for the Conservation and Protection
of Water Resources in Colorado:
Moving Toward Sustainability**

Prepared for

The Green Industries of Colorado (GreenCO)
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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)



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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 Extension *Planttalk* Colorado Website:
www.ext.colostate.edu/ptlk.

- Colorado State University Extension Gardening On-line Website: www.ext.colostate.edu/pubs/garden.
- Colorado State University Extension Tri-River Area, Western Slope Gardening Website: www.westernslopegardening.org/ (including various publications by Curtis Swift, Ph.D.)
- Denver Water Conservation and Xeriscape Website: http://www.denverwater.org/cons_xeriscape/cons_xeriscapeframe.html. (Particularly with regard to Xeriscape, a term copyrighted by Denver Water in 1981.)
- Irrigation Association Water Management Committee. 2005. *Turf and Landscape Irrigation Best Management Practices*. Falls Church, VA: Irrigation Association. Also see www.irrigation.org.
- Morton Arboretum (Chicago), American Nursery and Landscape Association (ANLA), the International Society of Arboriculture (ISA), the American Society of Landscape Architects (ASLA), the Associated Landscape Contractors of America (ALCA), Tree Care Industry Association (TCIA), and the American Society of Consulting Arborists (ASCA). 2005. Avoiding Excessive Soil Over the Root Systems of Trees: A Best Management Practice. Work Group Chairperson Gary Watson.
- Northern Colorado Water Conservancy District Website: www.ncwcd.org/
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- 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, with an emerging ethic of working toward sustainable landscaping practices. 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 judgment 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, as well as sustainable use of natural resources and enhancement of the environment. For the most recent version of this manual, please refer to the GreenCO Website (www.greenco.org).

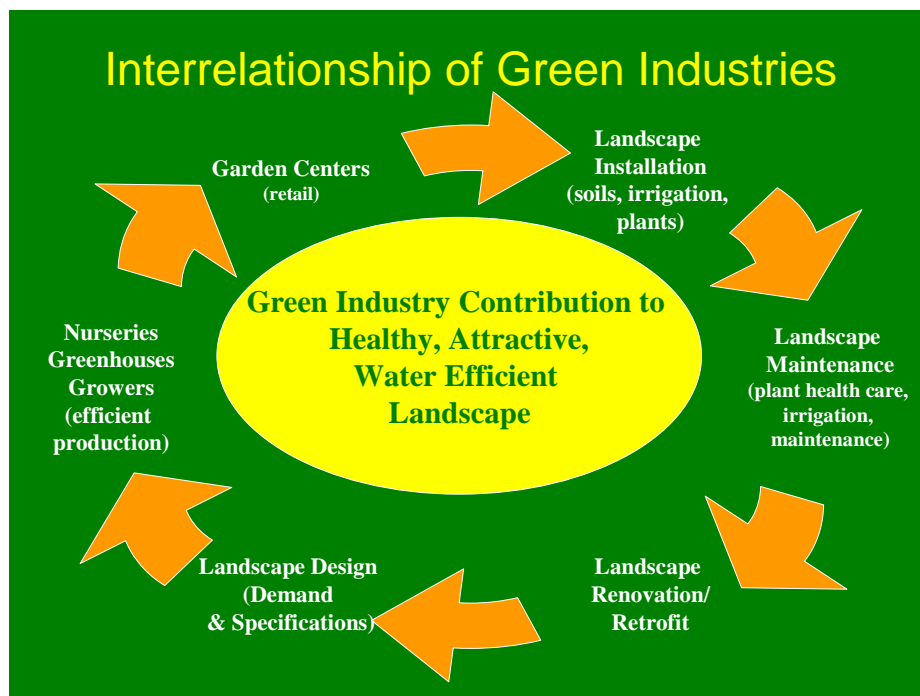
Background

The Green Industries of Colorado (GreenCO) is an umbrella trade organization representing the common interests of eight 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 Nursery and Greenhouse Association (CNGA)
- Garden Centers of Colorado (GCC)
- International Society of Arboriculture/Rocky Mountain Chapter (ISA)
- Rocky Mountain Chapter/Golf Course Superintendents Association of America (GCSAA)
- Rocky Mountain Sod Growers Association (RMSGGA)

GreenCO members represent diverse interests including sod growers, landscape architects, greenhouse growers, nurseries, retailers, contractors, lawn care professionals, golf course superintendents, and arborists. Each of GreenCO's members has in common an economic dependence on built landscapes. Each industry is part of the life cycle of landscaping (Figure 1).

Figure 1. Interrelated Nature of Green Industry Members: Life Cycle of Landscape



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. To begin addressing these issues, representatives from GreenCO's eight trade associations worked with diverse partners including Colorado State University 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 and other natural resources are inextricably linked. During the 2008 update of this Manual, the GreenCO Advisory Committee emphasized the desire to promote sustainable practices throughout the Green Industry, consistent with the "green movement" underway in the U.S. GreenCO's original water-related goals, as well as new goals related to sustainability include:

- 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.
- Promote sustainable landscape practices at all levels of the Green Industry from landscape design, to production and sale of landscaping materials, to maintenance of landscapes.
- Recognize the unique opportunities of the Green Industry to *improve* natural resources including water and air quality and wildlife habitat, as well as provide energy conservation benefits.

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. In 2004 and 2008, GreenCO has continued to revise and expand the BMPs to not only consider water resources, but also the natural environment.

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 resources and the natural environment. The GreenCO BMPs are intended to serve as the industry standard for water conservation and natural resources protection. 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 Program 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 conservation and natural resources protection and enhancement 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. Additionally, trees and vegetated areas can provide shade and cooling effects that reduce energy consumption in urban areas, as well as help to improve air quality.
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 trade marked 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. In many ways, Xeriscape can simply be considered to be "good horticultural practice."
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. Landscapes designed, installed and maintained in accordance with sustainable principles can *enhance* the environment, providing multiple benefits to water resources, wildlife, air quality, and reduced energy consumption.
6. Improved water quality and natural resources protection, water conservation, and movement toward more sustainable use of natural resources 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 are the industry standard and 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 natural resources protection and water conservation, and the consequences of failing to implement these BMPs, in order for behavioral change to occur.

Overview of BMPs

The BMPs in this manual are listed according to general practice category, beginning with general design concepts and principles, then moving into specific areas of practice. For example, the principles of sustainability, Xeriscape and water budgeting provide the foundation of the manual. Specific areas of practices follow such as landscape design, soil amendment, tree-related practices, irrigation and various landscape maintenance practices. BMPs related to growers and retailers are provided next, as well as water quality-related BMPs and educational practices. Many of the recommendations in this manual can be considered “good horticultural practice” that results not only in natural resources protection, but also attractive, healthy landscapes. For many Green Industry professionals, these practices will not be “new”, but will serve as a reminder of the many decisions and factors that must be considered to achieve the objectives of water conservation, natural resource protection and sustainability. Additionally, the BMPs provide an industry-wide perspective that may extend beyond an individual’s area of expertise. Table 1 provides an overview of the BMPs, along with applicability to various member industries.

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 or maintenance/ 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.
- Call-out boxes on special topics, for certain BMPs.

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 eight 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 bibliography of these references, along with website hyperlinks, is also provided at the end of this document.

As part of the 2008 update to this manual, additional supplemental resources and checklists were added to increase the usefulness of this manual, including:

- Historical Grass Reference ET Tables
- Irrigation Efficiency Audit: Pre-audit Checklist
- Salt Tolerant Plant List
- Continuing Education Opportunities
- Industry Checklists to Promote Water Conservation

**Table 1. Master List of GreenCO BMPs and Supporting Information
with Applicability to Member Industries**

General Category	Status	BMP Order	BMP	BMP Description	ASLA	ALCC	CALCP	CNGA	GCC	ISA	RMSG	GCSAA
Sustainability	New	1	Sustainable Landscaping	This BMP introduces basic sustainability and energy conservation concepts that Green Industry professionals can consider integrating into their professional practice.	X	X	X	X	X	X	X	X
Xeriscape	2004	2	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
Water Budgeting	2004	3	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
Design	Sig. Rev.	4	Landscape Design (including Plant Selection & Placement and Hardscapes)	Plan and design landscaping comprehensively to conserve water and protect water quality.	X	X	X	X	X	X	X	X
Landscape Installation: General	2004	5	Landscape Installation/Erosion and Sediment Control	Minimize erosion and control sediment leaving the construction site during landscape installation.	X	X	X			X	X	X
Soils	Sig. Rev.	6	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
Trees	New	7	Tree Protection	Identify trees suitable for preservation and implement measures to protect these trees during construction activities.	X	X	X			X		X
Trees	New	8	Tree Placement in Urban Landscapes	Trees must be placed in the urban landscape so that adequate soil and space for root growth are provided for the long-term growth and health of the tree.	X	X	X	X	X	X		
Trees	New	9	Tree Planting	Properly plant trees, shrubs and other woody plants to promote the long-term health of the tree.	X	X	X	X	X	X		X
Irrigation	Sig. Rev.	10	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	Sig. Rev.	11	Irrigation System Design	Design the irrigation system for the efficient and uniform distribution of water.	X	X	X	X	X	X	X	X
Irrigation	Sig. Rev.	12	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	X
Irrigation	Sig. Rev.	13	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
Irrigation	New	14	Irrigation Efficiency Audits	Auditing existing irrigation systems to identify needed improvements is a key tool in reducing landscape water waste and improving irrigation efficiency.		X	X					X
Irrigation	New	15	Irrigation Technology and Scheduling	Irrigation systems can be equipped with a variety of water conserving devices such as soil moisture sensors, rain sensors and shutoff devices, weather stations, high wind shutoff devices, freeze protection devices, and advanced, automated, "Smart" control systems that incorporate evapotranspiration (ET) conditions. Because one of the key benefits of advanced irrigation technology with regard to controllers (clocks) is increased ease of scheduling and more precise scheduling, irrigation scheduling is also discussed as part of this BMP.	X	X	X	X	X	X	X	X
Irrigation	New	16	Irrigation Using Nonpotable Sources	Nonpotable water may be used for irrigation purposes as a method to conserve potable or higher quality water sources for human consumption (drinking water).	X	X	X	X		X	X	X
Maintenance: General	2004	17	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		X
Maintenance: Trees	Sig. Rev.	18	Tree and Other 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
Maintenance: Herb. Plants	2004	19	Herbaceous Plant Care	Properly plant and maintain herbaceous plants to maximize plant health and conserve water.	X	X	X	X	X			X

**Table 1. Master List of GreenCO BMPs and Supporting Information
with Applicability to Member Industries**

General Category	Status	BMP Order	BMP	BMP Description	ASLA	ALCC	CALCP	CNGA	GCC	ISA	RMSG	GCSAA
Maintenance: Turf	2004	20	Turf Management	Plan, properly install and maintain practical turf areas.	X	X	X		X		X	X
Maintenance	2004	21	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
Maintenance	2004	22	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
Maintenance	2004	23	Pesticide, Fertilizer and Other Chemical Storage, Handling and Disposal	Properly apply, store, handle and dispose of pesticides, herbicides, fertilizers, fuel and other maintenance chemicals to prevent contamination of surface water and groundwater.		X	X	X	X	X	X	X
Maintenance	2004	24	Lawn Aeration	Aerate lawns to reduce thatch, thereby improving nutrient and water uptake, reducing runoff and reducing compaction.		X	X		X		X	X
Maintenance	2004	25	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
Maintenance	2004	26	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		X	X
Maintenance	2004	27	Mulching	Use organic mulches to reduce water loss through evaporation, to reduce soil loss due to exposure to wind and runoff, suppress weeds, and provide a more uniform soil temperature.		X	X	X	X	X		X
Maintenance	2004	28	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
Snow	New	29	Snow Removal	Conduct snow removal practices in a manner that minimizes adverse impacts to vegetation, soils and water quality.	X	X	X	X	X	X	X	X
Production	2004	30	Production Practices for Nurseries, Greenhouses, and Sod 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
Production	2004	31	Water Management Practices for Nurseries, Greenhouses, Sod Growers and Holding Yards	Manage production and holding areas to promote the efficient use of water.					X	X	X	X
Retail	2004	32	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			
Large Landscapes	2004	33	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
Drainage	New	34	Landscape Features in Low Impact Development	Properly design, install and maintain landscape features serving stormwater runoff water quality treatment and volume reduction functions. Low Impact Development (LID) designs seek to approximate pre-development runoff hydrology by allowing storm runoff to infiltrate into the landscape rather than routing urban runoff directly into the storm sewer.	X	X	X	X	X	X	X	X
Drainage	2004	35	Revegetation of Drainageways	Establish a robust cover of vegetation to promote proper functioning of engineered drainage structures such as grass-lined channels, detention basins, retention ponds, and wetlands.	X	X	X			X	X	X
Drainage	2004	36	Riparian Buffer Preservation	Preserve wide, undisturbed natural riparian areas along streams.	X	X	X			X	X	X
Education	2004	37	Employee Education	Educate industry employees on water quality and water conservation practices.	X	X	X	X	X	X	X	X
Education	2004	38	Public Education	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
Education	2004	39	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
Support	Sig. Rev.	40	References	References used in Manual with hyperlinks.	X	X	X	X	X	X	X	X

**Table 1. Master List of GreenCO BMPs and Supporting Information
with Applicability to Member Industries**

General Category	Status	BMP Order	BMP	BMP Description	ASLA	ALCC	CALCP	CNGA	GCC	ISA	RMSGA	GCSAA
Support	New	41	Glossary	Basic definitions of key terms.	X	X	X	X	X	X	X	X
Support	2004	42	Appendix A Basic Erosion Sediment Control	Basic erosion and sediment control guidance from Urban Drainage and Flood Control District, Denver.	X	X	X					X
Support	2004	43	Appendix B Basic Stormwater BMPs	Basic stormwater BMP guidance from Urban Drainage and Flood Control District, Denver.	X	X	X					X
Support	2004	44	Appendix C Potentially Applicable Regulations	Overview of representative regulations affecting the Green Industry.	X	X	X	X	X	X	X	X
Support	2004	45	Appendix D Water Budget Calculator	Overview of GreenCO's on-line water budget calculator from www.greenco.org .	X	X	X	X	X	X	X	X
Support	2004	46	Appendix E Plant Water Requirements (Kc/ET)	Plant lists rated according to water requirements; "Kc List".	X	X	X	X	X	X	X	X
Support	New	47	Appendix F Historical Grass Reference ET Tables	Historical grass reference ET for various Colorado communities.	X	X	X	X	X	X	X	X
Support	New	48	Appendix G Irrigation Efficiency Audit--Pre-audit Checklist	Pre-irrigation audit checklist developed by Colorado WaterWise Council.		X	X					X
Support	New	49	Appendix H Salt Tolerant Plants	Summary of relative salt tolerance of various plants, prepared by Curt Swift, CSU Extension, Tri-Rivers Area.	X	X	X	X	X	X	X	X
Support	New	50	Appendix I Continuing Education	Summary of continuing education and certification opportunities.	X	X	X	X	X	X	X	X
Support	New	51	Appendix J Industry Checklists	Checklists of key practices for various GreenCO member industries.		X	X	X	X	X	X	

ASLA = American Society of Landscape Architects (Colorado Chapter)
ALCC = Associated Landscape Contractors of Colorado, Inc.
CALCP = Colorado Association of Lawn Care Professionals
CNGA = Colorado Nursery and Greenhouse Association
GCC = Garden Centers of Colorado
ISA = International Society of Arboriculture (Rocky Mountain Chapter)
RMSGA = Rocky Mountain Sod Growers Association
GCSAA = Golf Course Superintendents Association of America (Rocky Mountain Chapter)

Literature Review

In 2002, a key component of the original project was to identify to the degree to which the Green Industry BMPs have been developed. As of 2008, over 350 references have been considered in development of the GreenCO BMPs. 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, combined with the GreenCO training program, will serve as a key step toward 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 Extension experts was included as reasonable guidance for the industry with an acknowledgement that best professional judgment 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 Extension resources and others. Links to member industry websites and several other key sources of information are provided below. Green Industry members should also check the websites for local governments where they work for special requirements related to all phases of landscaping. Appendix I provides a list of industry certification programs that can be pursued to go further in depth into specific areas of practice.

Industry Websites

American Nursery and Landscape Association (ANLA) Website: www.anla.org.

American Society of Landscape Architects (ASLA) Website: www.asla.org.

Associated Landscape Contractors of Colorado (ALCC) Website: www.alcc.com.

Colorado Association of Lawn Care Professionals (CALCP) Website:
www.lawncarescolorado.org/.

Colorado Nursery and Greenhouse Association (CNGA) Website: www.coloradonga.org.

Garden Centers of Colorado (GCC) Website: www.gardencentersofcolorado.org.

Golf Course Superintendents Association (GCSAA) Website: www.gcsaa.org/.

Golf Course Superintendents Association, Rocky Mountain Chapter (RMGCSAA) Website
www.rmgcsa.org/

GreenCO Website: www.greenco.org.

International Society of Arboriculture (ISA) Website: www.isa-arbor.com/.

International Society of Arboriculture, Rocky Mountain Chapter (ISA/RMC) Website:
www.isarmc.org.

Professional Landcare Network (PLANET) Website: <http://www.landcarenetwork.org>.

Rocky Mountain Sod Growers Association (RMSGGA) Website:
www.rockymountainsodgrowers.com.

Colorado State University Extension Resources

Colorado State University Extension Gardening On-line Website:
www.ext.colostate.edu/pubs/garden.

Colorado State University Extension Drought Task Force Website: www.drought.colostate.edu/.

Colorado State University Extension Planttalk Colorado Website: www.ext.colostate.edu/ptlk.

Colorado State University Extension Soils Program Website:
www.extsoilcrop.colostate.edu/Soils/pub.htm.

Colorado State University Extension Tri-River Area, Western Slope Gardening Website:
www.westernslopegardening.org/.

Colorado State University Turfgrass Program Website: csuturf.colostate.edu/.

Colorado Water Resources Research Institute Website: cwri.colostate.edu.

Other Resources

Colorado Department of Local Affairs. 2004. *Water Efficient Landscape Design Model Ordinance*. Website: www.dola.state.co.us/smartgrowth/. Denver, CO: Colorado Department of Local Affairs, Office of Smart Growth.

Colorado Springs Utilities Xeriscape Website: www.csu.org/xeri.

Colorado Water Conservation Board. Website: www.cwcb.state.co.us.

Colorado WaterWise Council Website: coloradowaterwise.org/

Denver Public Library Xeriscape Information Website:
www.denver.lib.co.us/dpl/news/xeriscape.html.

Denver Botanic Gardens and Colorado State University Extension Plant Select® Website:
www.plantselect.org.

Denver Water Conservation and Xeriscape Website:
www.denverwater.org/cons_xeriscape/cons_xeriscapeframe.html

Irrigation Association Website: www.irrigation.org.

Irrigation Training and Research Center, Cal-Poly State University, San Luis Obispo, California
Website: www.itrc.org.

Northern Colorado Water Conservancy District Website: www.ncwcd.org/.

Rocky Mountain Water Environment Association Website: www.rmwea.org/.

Save Our Shade Website: saver.denverwater.org/saveourshade.asp.

Trees Are Good Website: www.treesaregood.com/.

Turf Resource Center Website: www.turfgrassod.org.

U.S. Composting Council Website: www.compostingcouncil.org.

U.S. Environmental Protection Agency, Greenscapes Program Website
www.epa.gov/greenscapes/.

U.S. Environmental Protection Agency, WaterSense Program Website
www.epa.gov/WaterSense.

U.S. Green Building Council Websites: www.gbci.org/ or www.usgbc.org/.

Water Reuse Association Website: www.watereuse.org.

X-Rated® Gardening Website: www.xratedgardening.com/.

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GreenCO BMPs for the Protection and Conservation of Water Resources in Colorado: Moving Toward Sustainability

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**Sustainability:
General Principles, Relationship to GreenCO
BMPs and Energy Conservation**

Description

Both national and local efforts are underway to improve the sustainability of landscaping and development. Definitions of sustainable landscaping vary, with three representative definitions including:

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

1. “A sustainable Colorado landscape balances resource use with tangible benefits to the local, regional and global environment throughout its lifespan.” (Front Range Sustainable Landscaping Coalition 2008).
2. “Sustainable landscaping should include an attractive environment that is in balance with the local climate and requires minimal resource inputs, such as fertilizer, pesticides and water. Sustainable landscaping begins with an appropriate design that includes functional, cost efficient, visually pleasing, environmentally friendly and maintainable areas.” (Colorado State University Extension 2008).
3. “Design, construction, operations and maintenance practices that meet the needs of the present without compromising the ability of future generations to meet their own needs.” (Sustainable Sites Initiative™ 2007).

“Sustainable Landscaping” has different meanings, depending on the audience, and may best be described along a continuum that progresses from conventional practices, which are often dependent on significant natural resource and energy inputs, to sustainable practices, which require less natural resource and energy use. For some audiences, the endpoint is to become “neutral” in terms of natural resource consumption and environmental benefits; whereas for other audiences, the endpoint is to move beyond “neutral” into restorative and regenerative landscape designs (Reed 2006). Regardless of the endpoint, the Green Industry has many opportunities to work toward sustainable landscaping practices.

National and Local Sustainability Initiatives

In 2007, the national “Sustainable Sites Initiative” was launched as an interdisciplinary partnership between the American Society of Landscape Architects (ASLA), the Lady Bird Johnson Wildflower Center, the United States Botanic Garden and a diverse group of stakeholder organizations to develop guidelines and standards for landscape sustainability. The motivation behind this initiative stemmed from the desire to protect and enhance the ability of landscapes to provide services such as climate regulation, clean air and water, and improved quality of life. Sustainable Sites™ is a cooperative effort with the intention of supplementing existing green building and landscape guidelines, as well as becoming a stand-alone tool for site sustainability. This national effort spawned the local Front Range Sustainable Landscaping Coalition effort. For more information on these two efforts, see (www.sustainablesites.org) and (www.frslc.wetpaint.com).

As stated by the U.S. Environmental Protection Agency, “sustainable development marries two important themes: that environmental protection does not preclude economic development and that economic development must be ecologically viable now and in the long run.” The Green Industry has many opportunities to both thrive economically and protect and restore the environment.

During the 2008 revision of this manual, sustainability concepts moving beyond water issues were of substantial interest to the GreenCO advisory committee; however, at the time of this publication, many of these concepts were in the development phase under local and national sustainable sites initiatives and were not fully developed or adopted by GreenCO members. This BMP introduces basic sustainability and energy conservation concepts that Green Industry professionals can consider integrating into their professional practice. These concepts are likely to be further developed in future GreenCO efforts.

Basic Practice Guidelines

This BMP focuses primarily on 1) increasing familiarity of Green Industry members with general sustainability concepts advocated by local and national efforts, and 2) energy conservation opportunities for the Green Industry, which have not been addressed in previous releases of the GreenCO BMP Manual. Table 1 cross-references the GreenCO BMPs to key sustainability concepts envisioned at the local and national levels.

Guiding Principles for Sustainability Advocated by the Front Range Sustainable Landscaping Coalition

The Front Range Sustainable Landscaping Coalition is in the process of developing sustainable landscape practices that provide specific recommendations for site preparation, planting, water management, mulching, hardscapes, mobilization, maintenance and other practices. Underlying these forthcoming specific practices are the following principles:

- Minimize use of non-renewable resources
 - Energy
 - Use local materials
 - Reduce energy use in buildings
 - Use renewable energy
 - Water
 - Retain water on site
 - Use efficient irrigation
 - Compost use (instead of harvesting topsoil and peat)
- Restore “ecological functioning” (or ecosystem services)
 - Support healthy soil, which provides these benefits:
 - Absorbing and cleaning runoff and precipitation
 - Absorbing and neutralizing air pollution
 - Fixing/sequestering carbon
 - Provide habitat
- Minimize waste: reduce, reuse, recycle
- Protect and minimize disturbance to healthy ecosystems

Table 1. Relationship of GreenCO BMPs to Various Sustainability Principles

Soils	Energy Conservation
Soil Amendment/Ground Preparation	Sustainable Landscaping
Soils, Hydrology, Materials, Vegetation	Water Conservation Focused Practices <i>(note: all GreenCO practices interrelate to promote water conservation)</i>
Landscape Design (including Plant Selection & Placement and Hardscapes)	Water Budgeting
Xeriscape	Drought and General Water Conservation Practices for Landscapes
Park, Golf Course and Other Large Landscape Design and Management	Irrigation Efficiency
Vegetation-focused Practices (provide guidance promoting healthy vegetation, while minimizing chemical usage)	Irrigation Efficiency Audits
Fertilizer Application	Irrigation System Design
Herbaceous Plant Care	Irrigation System Installation
Landscape Maintenance	Irrigation System Maintenance
Lawn Aeration	Irrigation Technology and Scheduling
Mowing	Irrigation Using Nonpotable Sources
Mulching	Production Practices for Nurseries, Greenhouses, and Sod Growers
Pesticide and Herbicide Application	Retail Practices for Nurseries, Greenhouses and Garden Centers
Pesticide, Fertilizer and Other Chemical Storage, Handling and Disposal	Water Management Practices for Nurseries, Greenhouses, Sod Growers and Holding Yards
Tree Placement in the Urban Landscape	
	Hydrology/Drainage/ Water Quality Related Practices
Tree Planting	Landscape Installation/Erosion and Sediment Control
Tree Protection	Revegetation of Drainageways
Turf Management	Riparian Buffer Zone Preservation
Woody Plant Care	
Waste Reduction	Role of Landscaping in Low Impact Development
Lawn Waste Disposal/Composting	Snow Removal and Management

Guiding Principles for Sustainability under the Sustainable Sites Initiative™

Guiding principles of the Sustainable Sites Initiative™ follow, along with specific goals which may be directly related to the Green Industry, as summarized in Table 2. See the Sustainable Sites Initiative™ website for more detail and the most current versions of these concepts.

1. Do No Harm¹: Make no changes to the site that will degrade the surrounding environment. Promote projects that occur where there has been previous disturbance or development that presents an opportunity to regenerate ecosystem services through sustainable design.
2. Precautionary Principle: Be cautious in making decisions that could create risk to human and environmental health. Some actions can cause irreversible damage. Examine a full range of alternatives—including no action—and be open to input from all affected parties.
3. Design with Nature and Culture: Create and implement designs that are responsive to economic, environmental, and cultural conditions with respect to the local, regional, and global context.
4. Use a Decision-Making Hierarchy of Preservation, Conservation, and Regeneration: Maximize and mimic the benefits of ecosystem services by preserving existing environmental features, conserving resources in a sustainable manner, and regenerating lost or damaged ecosystem services.
5. Provide Regenerative Systems as Intergenerational Equity: Provide future generations with a sustainable environment supported by regenerative systems and endowed with regenerative resources.
6. Support a Living Process: Continuously re-evaluate assumptions and values and adapt to demographic and environmental change.
7. Use a Systems Thinking Approach: Understand and value the relationships in an ecosystem and use an approach that reflects and sustains ecosystem services; re-establish the integral and essential relationship between natural processes and human activity.
8. Use a Collaborative and Ethical Approach: Encourage direct and open communication among colleagues, clients, manufacturers, and users to link long-term sustainability with ethical responsibility.
9. Maintain Integrity in Leadership and Research: Implement transparent and participatory leadership, develop research with technical rigor, and communicate new findings in a clear, consistent, and timely manner.

¹ Although the term “do no harm” is adopted directly from the Sustainable Sites Initiative, it is important to recognize that there are inevitable effects from changing the natural environment. Green Industry members may choose to consider ways to “minimize” or “avoid” harm.

Table 2.
General Goals of the Sustainable Sites Initiative to Progress Toward Site Sustainability
(Source: Sustainable Sites Initiative 2007)

SOILS

1. Maintain and/or improve soil health so that on-site and surrounding ecosystem services are sustained or enhanced.
2. Avoid the use of pollutants, chemicals, or soil amendments that can harm human and ecological health.
3. Create a net zero waste site.
4. Reduce greenhouse gas emissions.

HYDROLOGY

1. Value all water on the site.
2. Maintain or regenerate healthy hydrologic processes.
3. Promote water quality and healthy aquatic habitats.

VEGETATION

1. Design and maintain vegetation so that on-site and surrounding ecosystem services are sustained or enhanced.
2. Reduce resource consumption and waste.

MATERIALS

1. Manage resources and materials efficiently.
2. Select and use sustainable landscape materials.
3. Reduce energy use, both embodied and operational.
4. During all phases, avoid materials, products and practices that are harmful to humans and the environment.

HUMAN WELL-BEING

1. Design and maintain conditions to promote health and physiological benefits.
2. Enhance human cognitive function.
3. Promote positive social dynamics.

Energy Conservation

1. In addition to sustainability practices related to water conservation and water quality protection, the Green Industry has many opportunities for energy conservation as it continues to encourage sustainability. In a general sense, the typical areas to seek energy conserving opportunities include: building envelopes, windows, lighting systems (including daylight), electrical systems, plug loads and HVAC systems. Although this BMP Manual does not go into detail on this topic, basic practices that can be implemented across the Green Industry include these first steps (NREL 2008):
 - Replace incandescent lights with electronically ballasted (T-8) compact fluorescent lights. These use about 70 percent less electricity than incandescents.
 - If motors are used in the greenhouse, switching to variable speed equipment and using the lowest speed appropriate can decrease energy use.
 - Maintain all heating, water pumping, mowing and irrigation equipment for optimum performance to reduce energy use.
 - Caulk and seal building shell leaks and penetrations in greenhouses.
 - Turn off equipment when not in use and reduce vehicle idling times during deliveries.
 - When replacing trucks and transportation fleets, consider gas mileage and alternative fuel sources.
2. Based on research completed by NREL, energy conservation in the greenhouse is an area of limited research and focus relative to some other industries. Alternative fuel sources for greenhouses include geothermal energy (particularly in the southwest corner of Colorado), solar energy and wind energy. One area that has been developed to some extent includes basic principles of solar greenhouse design, including the following very general principles:
 - Orient glazing to receive maximum solar heat during the winter.
 - Use heat storing materials to retain solar heat.
 - Have large amounts of insulation where there is little or no direct sunlight.
 - Use glazing material and installation methods that minimize heat loss.
 - Rely primarily on natural ventilation for summer cooling.
3. For large landscapes, the following energy-saving tips are recommended by the U.S. Environmental Protection Agency under its “Greenscape” program:
 - Strategically plant vegetation outside and around buildings to reduce indoor heating and cooling needs.

Drops to Watts: Have You Made the Water Use—Energy Connection? (Excerpted from USEPA 2008)

“Although most people understand that heating water requires energy, they don't always consider the energy it takes to treat and deliver the water they use. In 2005, the nation's municipal water infrastructure consumed about 56 billion kilowatt hours of electricity—that's enough energy to power more than 5 million homes for an entire year. Plus, as the demand for water grows, water utilities must pump water from more distant and deeper sources, which, in turn, requires even more energy...That's why simple [water efficient devices and practices] can really make a difference when it comes to addressing global warming—the less water we use, the fewer greenhouse gases will be produced to generate electricity.”

- Use hand or electric equipment where ever feasible to reduce emissions.
- Use biobased fuels and lubricants in place of petroleum.
- Implement a regularly scheduled equipment maintenance program for increased efficiency and reduced emissions
- Use compost to improve soils (it also makes an excellent air filter media for volatile organic compounds).
- Specify Green Building requirements for building structures.
- Plant trees to replace those removed or damaged during construction.
- Buy locally produced goods and services whenever possible to reduce transportation emissions and costs.
- Purchase or rent fuel efficient vehicles for your fleet.
- Use high efficiency lighting for roadways, parking lots, security, and landscaping.
- Use solar powered lighting and signage wherever possible.
- Utilize solar, wind, and other renewable energy sources. Purchase "green power" from renewable energy sources if available.

Greenscape Concepts: Reduce, Recycle, Reuse and Rebuy (“the 4 Rs”)

The U.S. Environmental Protection Agency is encouraging “Greenscape” concepts focused on environmentally beneficial landscaping, taking into consideration conservation opportunities associated with reducing waste, reusing materials, recycling materials and rebuying recycled materials. Many of the Greenscape concepts are consistent with the GreenCO BMPs, whereas a few of the recommended practices such as recycling gray water are not regionally permissible. To download the USEPA Greenscapes Tip Sheet, cost calculator and other brochures to see which practices could be incorporated into your business, go to www.epa.gov/greenskapes.

Regional or Industry Considerations/Adaptations

1. Many efforts to move toward more sustainable sites that relate to the Green Industry have been in existence for some time and others continue to evolve. Representative examples include:
 - U.S. Green Building Council’s (national) Leaders in Environmental Design (LEED) program (<http://www.gbci.org/> or <http://www.usgbc.org/>)
 - Built Green Colorado (statewide) (<http://www.builtgreen.org/>)
 - Partners for a Clean Environment (PACE) (local-Boulder) (<http://www.ci.boulder.co.us/www/pace/index.html>)
2. Related efforts include focus on specific components of sustainability such as:
 - Energy Star: A joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy designed to reduce energy use and protect the environment through energy efficient products and practices. (<http://www.energystar.gov/>).

- WaterSense: EPA's new program to provide certification of water products and training programs that promote water conservation and efficiency. (<http://www.epa.gov/watersense/>).
 - As of 2008, Xcel energy had a solar rewards program in place in support of its Renewable Energy Compliance Plan that may be a source of rebates related to renewable energy sources. The Solar*Rewards program allows residents or businesses to receive cash back for installing a photovoltaic (PV) system based on the size of the system installed. See www.xcelenergy.com for more information.
3. Some national sustainability and recognition programs may not fully account for regional constraints for some practices. For example, rainwater harvesting, greywater and blackwater recycling onsite are restricted under Colorado Water Law and/or the Colorado Department of Public Health and Environment.
 4. While the general concepts presented in the Sustainable Sites Initiative are consistent with GreenCO's BMPs, GreenCO and its member industries have not yet either endorsed or rejected the standards and practices proposed as part of the Sustainable Sites Initiative.

Key References

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Built Green Colorado (www.builtgreen.org/).

City of Boulder, Partners for a Clean Environment (PACE) (www.ci.boulder.co.us/www/pace/index.html).

Colorado Governor's Office of Energy (www.colorado.gov/energy/)

National Renewable Energy Laboratories, 2008. *Sustainable Energy for Nurseries and Greenhouses: Growing Profits with Energy Efficiency and Renewable Energy*, Presentation by Bob Noun, Executive Director of External Affairs, NREL. January 23, 2008 presentation at Pro-Green Expo, Denver, CO. (www.nrel.gov).

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U.S. Environmental Protection Agency, WaterSense Program (www.epa.gov/WaterSense).

U.S. Environmental Protection Agency, Greenscapes Program (www.epa.gov/greenscapes/).

U.S. Green Building Council (www.gbci.org/ or www.usgbc.org/).

Xcel Energy, 2008. Solar*Rewards Program (www.xcelenergy.com).

Xeriscape

Description

Implement the seven basic landscape principles of xeriscape: planning and design, soil improvement, hydrozoning of plants, creating practical turf areas, efficient irrigation, mulching and appropriate maintenance.

General Note: The term “Xeriscape” was coined by Denver Water in 1981. The seven Xeriscape principles are included as individual GreenCO BMPs. Integration of these seven BMPs provides a comprehensive approach that can be very effective for conserving water. A common misconception of Xeriscape is that it is a plant type—this is not the case; instead, Xeriscape is a combination of multiple practices that, when properly implemented, results in landscape water conservation.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

Basic Practice Guidelines

1. Plan and design landscaping comprehensively. Start with a site inventory and analysis, where existing conditions such as drainage, exposures, soil types, views, existing plants, etc., are noted. Next, develop a list of activities (“a program”) and their support facilities that need to be included in the design. Continue by diagramming possible locations for the activities from the program, while also allowing for planned traffic patterns and access or screening. Finally, use this information to develop a plan that integrates plants into the overall scheme. *(See the Landscape Design BMP for more information.)*
2. Evaluate soil and improve, if necessary. Improve soil before planting and installing the irrigation system. Soil improvement promotes better absorption of water, improved water-holding capacity and drainage of the soils. It also allows for better oxygen transfer within the root zone. *(See the Soil Amendment/Ground Preparation BMP for more information.)*



3. Create practical turf areas. Include turf areas where they provide defined functions (i.e., recreation, traffic areas, etc.). Grass is best separated from plantings of trees, shrubs, ground covers and flowers so it can be watered separately. Often, portions of turf areas can be replaced with more water-efficient ground covers and mulches. Choose the appropriate grass for the desired use. No one grass is ideal for all locations. Alternative grasses for some areas, depending on the area's purpose, may include tall fescue, buffalograss, blue grama and wheat grass. *(See the Turf BMP for more information.)*
4. Use appropriate plants and group according to their water needs (i.e., "hydrozoning"). Plants with lower water requirements such as native species adapted to Colorado's climate should be considered. However, other plants can have a place in xeriscape designs, even if they require larger amounts of water. The key is to use those plants in appropriate locations and not to interplant them with others that have very different, lower water requirements. In effect, the groupings of plants are separated into "zones" based on their water requirements, which allows them to be irrigated efficiently. *(See the Plant Selection and Placement BMP for more information.)*
5. Water efficiently with a properly designed irrigation system. Irrigate according to the condition of the plants, not on a fixed schedule. Well-planned sprinkler systems can save water when properly installed and operated. Turf areas should be watered separately from beds, shrubs and trees. Apply only as much water as the soil can absorb to avoid runoff. Trees, shrubs, flowers and ground covers can be watered more efficiently with low volume drip emitters. To promote deep rooting, water infrequently, but deeply. *(See the Irrigation Efficiency BMP for more information.)*
6. Use organic mulches to reduce surface evaporation of water and weeds. Mulched planting beds are an ideal replacement for expansive turf areas. Mulches cover and reduce temperature extremes in the soil, minimize evaporation, reduce weed growth and slow erosion. Mulches also provide landscape interest. Organic mulches are typically bark chips, wood grindings or pole peelings. Inorganic mulches include rock and various gravel products. Place mulch directly on the soil or on breathable fabric. Do not use impermeable sheet plastic beneath mulched areas. *(See the Mulching BMP for more information.)*
7. Practice appropriate landscape maintenance. Proper pruning, weeding, mowing and fertilization, plus attention to the irrigation system, are needed to maximize water savings. Regular maintenance preserves the intended beauty of the landscape and saves water and maintenance costs. Always water according to plant needs and current soil moisture conditions and not on a rigid schedule. Remember that frequent, shallow watering promotes shallow roots, which defeats the purpose of xeriscaping. *(See the Landscape Maintenance BMP for more information.)*



A well-designed and maintained Xeriscape not only conserves water, but is also aesthetically pleasing, incorporating a variety of landscaping.

Source: Denver Water.

Special Regional or Industry Considerations/Adaptations

1. Xeriscape principles are applicable industry-wide and in all locations in Colorado.

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Water Budgeting

Description

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. Overall property water budgets can be developed to include both indoor and outdoor water requirements.

Basic Practice Guidelines

1. A “water budget” is a general term that can have varied meanings, depending on the context in which the term is used. Two of the more common definitions that Green Industry professionals may encounter include: 1) a “water allotment” by a water utility or 2) a landscape water budget based on the plant water requirements, as described below.
2. A water budget in the context of a “water allotment” or “water allocation,” is typically assigned by a local government in the context of water rate structures designed to encourage water conservation and help the utility stretch existing water supplies. For example, a city may develop a monthly water budget for each water utility customer that includes the sum of the indoor and/or outdoor allocation. The allocation is typically calculated based on reasonable and necessary indoor and/or outdoor use, water conservation, and other relevant factors associated with water use in the city. For outdoor water use, a common outdoor water allocation target is a maximum of 15 gallons per square foot of landscaped area per customer. (See Example 1.) Customers that use more than this allotment are charged higher rates for water use than those who remain within their water budget. The typical approach to water budgeting in the context of a water allocation is as follows:

$$\begin{aligned} \text{Total Irrigation Water Allotment (gal/yr)} = \\ \text{Landscaped Area (sq. ft.)} \times \text{Allotment (gal/sq. ft./yr)} \end{aligned}$$

Example 1. Designing a landscape to meet a water allocation.

A local water provider’s rate structure is based on a water budgeting approach. The landscape water allotment is 15 gallons/sq. ft./year. Design a 5,000 sq. ft. landscape to meet this allotment of (15 gal/sq. ft./ yr x 5,000 sq. ft. = 75,000 gal/yr). The designer can experiment with various plant types grouped in hydrozones with comparable water needs until the target water allocation is met. One possible design could include 3,500 sq. ft. of bluegrass, which would use about 18-20 gal/sq. ft./yr, and 1,500 sq. ft. of very low water plants, which would require about 0-5 gal/sq. ft./yr based on data from Appendix D. Simplified calculations would be:

$$\begin{aligned} & 19 \text{ gal/sq. ft.} \times 3,500 \text{ sq. ft.} = 66,500 \text{ gal/yr} \\ & + 2.5 \text{ gal/sq. ft.} \times 1,500 \text{ sq. ft.} = 3,750 \text{ gal/yr} \\ \text{Total Landscape Water Requirement} & = 70,250 \text{ gal/yr (about 14.1 gallons/sq. ft.)} \end{aligned}$$

BMP Type			
Design			X
Installation			
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

3. A water budget can also mean: 1) the total amount of water that a landscape needs to remain healthy (regardless of the source or availability of water) or 2) the amount of irrigation that a landscape needs in order to remain healthy after accounting for effective precipitation. A property manager can use this type of water budget to determine how much water a landscape needs and compare it to how much irrigation is being applied in order to better manage irrigation practices and control costs. This type of water budgeting can be conducted much like balancing a checkbook. To calculate the site landscape water budget (gallons of water required for the landscape for either the year or month) and the irrigation water requirement, the following approach can be used:

Step 1. Determine Plant Water Requirement for a Landscape

$$\text{Plant Water Requirement} = \frac{(ET_o)(K_c)(LA)(0.623)}{IE} = \text{gallons of water}$$

Where:

Plant Water Requirement = Water Needed for Plants (gallons per year)

ET_o = Reference evapotranspiration (inches per year during the growing season or month or billing cycle) (See Appendix F for more information.)

K_c = Crop coefficient for plant type (See Appendix E for more information.)

LA = Landscaped Area (square feet)

0.623 = Conversion Factor (to gallons per square foot)

Step 2. Determine Landscape Water Requirement, incorporating the irrigation system and assuming all water is supplied by irrigation. In this step, the plant water requirement is adjusted by the efficiency of the irrigation system (IE). Irrigation efficiency varies for each site. For calculation purposes, a properly designed irrigation system can be assigned an irrigation efficiency of 0.75 to 0.80. Where drip irrigation is used, a factor of 0.9 may be used. (The irrigation contractor can provide site-specific estimates of efficiency to replace these rules of thumb.) This term recognizes that inefficient irrigation systems require additional irrigation application in order to meet plant water requirements.

$$\text{Landscape Water Budget} = \frac{(ET_o)(K_c)(LA)(0.623)}{IE} = \text{gallons of water}$$

Step 3. Determine irrigation water requirements for a closely managed irrigation system, incorporating effective rainfall. This step in the water budget can be used by landscape or irrigation managers who are adjusting irrigation based on rainfall at their particular site. At the planning level, this step is often **not** included in water budgets because of uncertainty regarding when rainfall will occur and how much rainfall will occur at a given site during a given growing season. However, for those using rain sensors or other smart controllers, irrigation application can be reduced by effective precipitation. As a general rule of thumb, effective rainfall (Re) can be estimated as approximately 70 percent of measured rainfall.

$$\text{Irrigation Water Budget} = \frac{[(ET_o * K_c) - Re](LA)(0.623)}{IE} = \text{gallons of water}$$

Example 2. Developing a water budget based on plant water requirements.

For purposes of a simple example, assume that 70% of a 5,000 sq. ft. northern Front Range landscape is Kentucky bluegrass, irrigated with a properly designed automatic irrigation system using an 80% irrigation efficiency rule of thumb. The remaining 30% of the landscape is "low to very low" water use plants, irrigated with a drip irrigation system with a 90% irrigation efficiency. The seasonal grass reference ETo value for this northern Front Range location is 34.53 inches for cool season grass mowed at 5 inches. *Effective* precipitation is estimated at 5.94 inches for the growing season. For the turf area, a crop coefficient (Kc) of 0.9 is applied to represent a nice quality Kentucky bluegrass lawn mowed at a 3-inch height. The "low to very low" water use plants require about 25% of grass reference ETo. Water budget and irrigation management calculations are as follows:

Step 1. Calculate total plant water requirement.

$$\begin{aligned} \text{Water for Turf Area} &= (34.53'' * 0.9) * 3500 \text{ sq. ft.} * 0.623 = 67,763 \text{ gal/yr} \\ + \text{Water for Other Area} &= (34.53'' * 0.25) * 1500 \text{ sq. ft.} * 0.623 = 8,067 \text{ gal/yr} \\ \text{Total Plant Water Requirement} &= 75,830 \text{ gal/yr (15.2 gal/sq. ft.)} \end{aligned}$$

Step 2. Determine the landscape water requirement incorporating irrigation system efficiency, without precipitation.

$$\begin{aligned} \text{Water for Turf Area} &= [(34.53'' * 0.9) * 3500 \text{ sq. ft.} * 0.623] / 0.8 = 84,705 \text{ gal/yr} \\ + \text{Water for Other Area} &= [(34.53'' * 0.25) * 1500 \text{ sq. ft.} * 0.623] / 0.9 = 8,963 \text{ gal/yr} \\ \text{Total Landscape Water Requirement} &= 93,668 \text{ gal/yr (18.7 gal/sq. ft.)} \end{aligned}$$

Step 3. Determine estimated irrigation water requirement for a closely managed system, adjusting irrigation based on effective precipitation.

$$\begin{aligned} \text{Water for Turf Area} &= [((34.53'' * 0.9) - 5.94'') * 3500 \text{ sq.ft.} * 0.623] / 0.8 = 68,514 \text{ gal/yr} \\ + \text{Water for Other Area} &= [((34.53'' * 0.25) - 5.94'') * 1500 \text{ sq.ft.} * 0.623] / 0.9 = 2,796 \text{ gal/yr} \\ \text{Total Irrigation Water Requirement} &= 71,310 \text{ gal/yr (14.3 gal/sq. ft.)} \end{aligned}$$

The irrigation water needed for this landscape would likely range between 14.3 and 18.7 gal/sq. ft. depending on how the irrigation requirement is managed. If a water allocation of 15 gal/sq. ft. were assigned by a water provider, a reasonably healthy landscape should be able to be maintained, when properly managed.

4. Regardless of the water budgeting approach used, the landscape design process should incorporate a general outdoor annual water budget to be used as a guideline for irrigation design and long-term landscape management. The water budget should be developed by the landscape architect or designer as part of the plant selection and grouping process (turf, trees, shrubs, ground covers, etc.).
5. Irrigation scheduling should be based on calculation of a monthly and annual water budget for existing sites.
6. The water budget (landscape water requirement) provides the total gallons per year that the site needs to thrive under average conditions. In either wetter or drier years, the water

budget will need to be adjusted. The irrigation water requirement can be calculated after reducing the landscape water requirement by effective precipitation.

7. Evapotranspiration (ET) is the rate at which water is transpired from vegetation and evaporated from soil and plant surfaces. Temperature, humidity, wind and light all influence the ET rate.
8. In order for water budgets to be reasonably accurate, it is necessary to provide accurate information on factors such as crop coefficients. See the GreenCO web site (www.greenco.org) and Appendix E for recommended crop coefficients to be used in calculating water budgets.
9. It should be noted that the grass reference ET (ET_o) in the water budget equation is for a theoretical cool season grass that is well-maintained and never lacking for water or nutrients. Turf grasses used in the landscape such as Kentucky bluegrass can be attractive and viable at much lower ET rates and can be very drought tolerant. For properly established turf, the actual irrigation water needs of turf can vary, depending on desired appearance and horticultural practices.
10. The water budget does not apply to the initial establishment period of plantings, which can vary from a 2-4 weeks for annuals to several growing seasons, depending on plant type and the timing of planting. One year is typical for many perennials and shrubs to become established.
11. Water features, outdoor pool(s), and/or any other outdoor water uses should be included in the water budget.
12. If a property manager/landscaper knows the water budget for each month, he/she can compare actual use to the site water budget and adjust irrigation practices accordingly. Excessive water use may also be attributed to irrigation system deficiencies, which should be corrected.
13. Weather-based or soil moisture based controllers (also called "smart" controllers) are one tool that can facilitate landscape irrigation according to the needs of the plants (and therefore the water budget). It is important to remember that:
 - a. Low water use plants don't automatically save water (they are easily and often over-watered). Using a "smart" controller can ensure that the proper irrigation is applied to low water use plants.
 - b. High water use plants (such as turf) don't automatically waste water. They are often over-watered. Using a "smart" controller can ensure that the proper irrigation is applied to higher water use plants.
14. Often the retrofitting of poor performing irrigation systems and the use of "smart" controllers will provide a payback in saved water. In order to calculate the payback time, use the water

budget to measure how much water is actually needed, versus how much has historically been used.

15. GreenCO provides a simple water budget calculator on its website at www.greenco.org and as shown in Appendix D. Green Industry professionals can use this calculator with customers to demonstrate that water budgeting is a manageable approach to understanding water needs for a given property and adjusting watering practices accordingly.

Regional or Industry Considerations/Adaptations

1. Water budgets can be incorporated into development project financial models and incorporated into projected budget and fees for Homeowners Associations, office parks, etc.
2. Water budgets can be used by water utilities to determine how much water they need versus how much they sell or have. The difference is how much water could be saved, or how much more water needs to be purchased.
3. Water budgeting approaches adopted by utilities typically include ET-based irrigation scheduling combined with tiered pricing for increasing water usage. Tiered pricing provides incentive to conserve because it gradually increases the price of larger quantities of water. At the time of this manual's publication, this approach had been adopted in other water-limited states such as California and Arizona, as well as in several Colorado communities such as City of Boulder (<http://www.ci.boulder.co.us/>) and the Centennial Water and Sanitation District in Highlands Ranch (http://www.highlandsranch.org/06_wsan/06_wsan_home.html).
4. Colorado's *Water Efficient Landscape Design Model Ordinance* (see www.dola.state.co.us/smartgrowth/) is based on water budgeting with a goal of 15 gallons/square foot/year of water required for the landscaped area.
5. Check the GreenCO website (www.greenco.org) for more information on water budgeting techniques.

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Landscape Design

Description

Plan and design landscapes comprehensively to conserve water and protect water quality. This BMP includes plant selection and placement guidance, as well as other design features.

Basic Practice Guidelines

Design Principles

1. Consider existing grade (slope), existing plants to preserve/protect, exposure to natural (e.g., wind, sun) and human elements (e.g., pedestrian traffic), soils, availability of natural precipitation and supplemental irrigation, and drainage when designing the overall landscape.
2. Base designs on sound landscaping practices. Consider and implement the seven basic principles of Xeriscape: planning and design, soil improvement, zoning of plants, practical turf areas, efficient irrigation, mulching and appropriate maintenance. (*See the Xeriscape BMP for more information.*)

Irrigation and Drainage

3. Design the site for efficient irrigation, including both state-of-the-practice irrigation technologies and management practices. Landscape plans should also include specific irrigation plans. (*See the Irrigation BMPs for more information.*)
4. Develop plant lists for landscape components based on hydrozones. For example, identify zones of high, moderate and low water usage and then identify water requirements and appropriate plants for each zone.
5. Design landscapes to take advantage of site runoff, enabling plants to benefit from natural precipitation, while minimizing runoff into stormwater drainage systems. Such site designs disconnect impervious areas with landscape areas that enable infiltration of runoff into the soil. (*This practice should be implemented in a manner that does not compromise the necessity of protecting building foundations from water damage.*) Vegetated swales and buffers can be used to direct water flow to cultivated areas. Also see the Landscape Features in Low Impact Development BMP for more information on practices such as porous landscape detention, which can be implemented in parking medians, residential lots and other locations.
6. To the extent possible, design the site to blend with existing topography, following existing contours to preserve the overall natural major drainage patterns. (This should not be confused with localized site grading at the micro-drainage level that can provide water quality and water conservation benefits.)

BMP Type			
Design			X
Installation			
Maintenance/Operations			
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

7. Consider installing terraced gardens on slopes to allow heavy rains to soak in rather than to runoff and cause erosion.
8. Use porous paving materials (e.g., brick, gravel, flagstone) for patios and walkways to keep water in the garden rather than in the gutter. A variety of porous paving materials are also available for roads, driveways and overflow parking areas. See the Urban Drainage and Flood Control District (www.udfcd.org) and/or Ferguson (2005) for design criteria for porous paving materials.

Soils

9. Collect representative soil samples for analysis early in the project design to determine what types of soil amendments may be needed and to identify problem soil conditions. (High salt levels in soils can be a real problem on the Western Slope). For example, native soils may be adequate in areas where native plants will be used, but soil amendment to improve soil texture and nutrient content may be needed in areas planned for turf. For already developed sites with existing landscaping, this process is relatively straightforward; however, for larger scale site development where extensive clearing and grading is planned, several soil samples will likely be needed. For example, soil samples can be collected prior to clearing and grading, or stockpiled topsoil can be sampled to determine what types of soil amendments will be needed prior to redistribution of the topsoil on the site. In cases where topsoil is being imported to the site, the imported soil should also be tested to determine what type of soil amendment is needed. *See the Soil Amendment BMP for more detail, including recommended tests for soils and soil amendment classifications.*
10. Provide appropriate specifications to ensure soils are properly prepared and amended during landscape installation. (*See the Soil Amendment/Ground Preparation BMP for more information.*)
11. Low Impact Development design approaches also encourage early review of Natural Resources Conservation Service (NRCS) soil mapping for the site to identify areas with soils with higher infiltration capacities (e.g., NRCS Type A or B soils) that may be suitable to be left undisturbed as part of a natural area in a development.
12. For trees growing in urban areas, such as within cutouts in paving or sidewalks, provide a minimum of 60 cubic feet of soil for every anticipated inch of diameter at breast height (DBH). Strategies to provide the proper amount of soil include root paths, structural soils, and Silva Cells. These strategies will help ensure optimum growth and tree survival while minimizing root/hardscape conflicts. Also see the *Tree Placement in Urban Landscapes* BMP.

Plant Selection and Placement

13. Select plants that are well adapted to the climate, topographic and soil conditions at the site, considering microclimates that may be present within a site. Native plants and plants with documented lower water requirements should be given priority in landscape design. (*Keep in*

mind that some native plants may have relatively high water requirements, such as those associated with riparian or wetland areas.) Avoid plants with high susceptibility to pests and disease.

14. Consider using plants with low water requirements. Information on water requirements for various plants can be obtained from many sources, including Appendix E of this Manual. Several key resources to assist in plant selection include the *Annual and Perennial Plant Guide* and *Rocky Mountain Plant Guide* published by the Colorado Nursery and Greenhouse Association (www.coloradonga.org) and the X-rated gardening website maintained by the Garden Centers of Colorado (www.gardencentersofcolorado.org/xratedgardening2/).
15. When selecting plants, consider factors such as the size of the area to be covered, soil type, exposure conditions, steepness of slope, pedestrian traffic, area usage, drainage conditions and maintenance requirements along with the aesthetic desires. Also consider the potential habitat-related benefits (e.g., attract butterflies, birds, etc.) when selecting and placing plants.
16. Group plants together that have the same water requirements. Plants located within the drip line for large trees and shrubs should have water requirements similar to the trees and shrubs.
17. Choose plants with lower water requirements for areas with southern and western exposures.
18. Where possible, retain significant native vegetation that is already adapted to the site. Preserve existing healthy trees—established plants have often developed a root system that is adapted to lower water conditions. Preserving healthy trees means following industry standards to protect canopies, trunk and critical root zones during construction and when modifying the landscape. (*See the Tree Preservation BMP for more information.*)
19. Remove species that are designated state noxious weeds, especially ornamental species such as purple loosestrife, oxeye daisy, tamarisk, myrtle spurge and yellow toadflax. (See www.ag.state.co.us/DPI/weeds/weed.html for a complete listing of such weeds.)
20. Consider using groundcovers with lower water requirements for slopes and hard-to-mow locations.
21. When designing plant placement on slopes, place lower-water demand plants at the tops of slopes and higher-demand plants at the bottom.
22. A good rule of thumb is to place plants with higher water use in lower-lying drainage areas, near downspouts or in the shade of other plants.
23. On steep slopes, select plant species that produce dense, fibrous roots to help prevent soil erosion. Maintenance safety issues should also be considered in selecting plants for these



areas. For example, mowing may not be safe on steep slopes; therefore, alternatives to manicured turf should be explored.

24. A temporary “nurse crop” of grasses and legumes may be required to provide immediate soil stabilization on steep slopes. Consult with the Natural Resources Conservation Service, CSU Extension or the Colorado State Forest Service for information to avoid planting overly aggressive species that may compete with permanent ground cover.
25. Incorporate trees into the landscape to provide shade, reduce stormwater runoff, stabilize soil and protect against wind. A goal of at least 20 percent canopy coverage for Front Range communities is ideal.
26. Many turfgrass species are commercially available, so it is also important to select the appropriate grass for the intended use, expected maintenance effort and site conditions. Consider using improved blends and mixes with lower water requirements. See the CSU Turfgrass Program website (<http://csuturf.colostate.edu/>) for the latest studies for advantages and disadvantages of various grass species. See the *Turf Management BMP* for a summary of the advantages and disadvantage of three grass species (Koski 2008).



Thoughtful plant selection, placement and maintenance contribute to a water efficient, aesthetically pleasing landscape. (Source: Denver Water.)

27. In areas where irrigation is not planned, a mix of mainly native bunch and sod-forming grasses can be used.
28. Avoid using turf in areas less than 10 feet wide and on slopes steeper than 4:1. (Although turf provides effective erosion-control, maintaining regularly mowed turf on a steep slope can be difficult and/or dangerous.)
29. Use weed barrier fabrics and organic or inorganic (e.g., gravel, rock) materials to reduce weeds while still allowing water and air to penetrate the soil. Do not use black plastic because it prohibits water and air penetration into the soil.

30. Landscape bare areas to reduce soil erosion. Good landscaping practices can reduce stormwater runoff rates and volumes, sediment loads and pollutants. Turfgrass can be particularly effective in erosion-prone areas and can be used in buffer strips and grassy swales to filter out sediment. Consider installing grassy buffers in areas adjacent or contiguous to open waterways or known recharge areas to provide extra filtering of runoff.

Buffers and Wetlands

31. Maintain wide, undisturbed riparian (stream) corridors or consider installing wetland "edge" treatments. Check with local regulations for specific setbacks for streams—these may vary from 25 to 200 feet, depending on site conditions and local standards.
32. Protect existing wetlands and consult with the U.S. Army Corps of Engineers prior to dredging, filling or enhancing a wetland. It is illegal to dredge or fill a jurisdictional wetland under the federal Clean Water Act without obtaining a 404 permit.

Water Features

33. When water features are part of designed landscapes, recirculating systems should be used to prevent stagnant water and algae build-up. Other factors that should be carefully considered include: lining the pond or water feature with impermeable materials, evaporation and addition of make-up water, management of water quality (e.g., nutrients) in the pond, algae control, aeration, periodic flushing and draining of water.

Wildfire

34. Particularly in mountain areas prone to wildfire, plants should be selected and placed at locations that take wildfire hazard and “defensible space” into consideration. Native species are generally the best plant materials for landscaping in defensible space. However, all vegetation, naturally occurring and otherwise, is potential fuel for fire. Its type, amount and arrangement has a dramatic effect on fire behavior. There are no truly "fireproof" plant species, so plant choice, spacing and maintenance are critical to defensible space landscaping. Where and how you plant may be more important than what you plant. This is increasingly critical in areas experiencing beetle kill. See CSU Extension Fact Sheet No. 6.302 Creating Wildfire Defensible Zones (Dennis 2006), Fact Sheet No. 6.303 Fire-Resistant Landscaping (Dennis 2007) and Fact Sheet No. 6.305 FireWise Plant Material (Dennis 2008) for more information, including recommended plant lists.

Hardscapes

35. Hardscapes are an important aspect of landscape design that should be thoughtfully integrated to maximize benefits to the environment. See adjacent text box for guidelines.

Front Range Sustainable Landscape Coalition (2008)

Sustainable Landscaping Practices for Hardscape and Rock Work

The Front Range Sustainable Landscape Coalition (FRSLC) has developed a checklist for landscape professionals with the objective of promoting sustainable landscapes that balance resource use with tangible benefits to the local, regional and global environment throughout its lifespan. The checklist covers multiple topics, many of which are consistent with the GreenCO BMPs. During the 2008 update to the GreenCO Manual, the GreenCO Advisory Committee recognized that the topic of hardscapes warranted more attention in the GreenCO Manual and has incorporated the FRSLC hardscapes checklist, as summarized below. As a general design philosophy, FRSLC recognizes that hardscapes are the most permanent and most energy-, labor- and resource-intensive elements of the landscape and recommends that they be used wisely; specific practices recommended by FRSLC include:

1. Minimize disturbance to site while moving and stockpiling materials.
2. Design practical hardscape areas, considering the potential negative impacts of increased runoff associated with impermeable surfaces.
3. Consider and use on site resources (e.g., existing boulders) when designing the site.
4. Properly install hardscapes: "Build it well, so it's not redone next year."
5. Use local sources for the majority of heavy and bulky materials (e.g., within 100 miles).
6. Consider using non-motorized options for moving and setting materials, where feasible.
7. Save use of large boulders for maximum impact, consider alternate focal objects.
8. Recognize effects of hardscape on landscape, such as:
 - Creating microclimates for plants.
 - Redirecting runoff to plantings.
 - Using permeable materials in appropriate areas.
 - Locating hardscape and selecting colors with consideration for reflective and heat absorbing qualities.
 - Balancing benefits of raised beds with increased drainage and water use.
 - Considering channel drains in driveways.
9. Use "green" materials, where feasible. Examples include using recycled materials, buying new materials with recycled content, avoiding toxic materials, and others.
10. Allow for the evolution of hardscape by implementing these practices:
 - Use weed barrier/geotextile to separate soil from gravel road base paving.
 - Match materials and methods to anticipated longevity of landscape.
 - Consider using materials and construction methods that allow for future re-use of materials (e.g., drystack methods, where appropriate).
11. Outdoor Lighting Practices: When designing lighting, minimize energy use of outdoor lighting (e.g., solar, LED) and avoid light pollution (follow Dark Sky guidelines).

See the FRSLC website (<http://frslc.wetpaint.com/?t=anon>) for more information on these and other practices.

Regional or Industry Considerations/Adaptations

1. Nurseries and garden centers can help promote use of lower-water-requiring plants by providing a good selection of plants that are drought-tolerant or require less water and by educating customers on the value of selecting these plants.
2. In mountain areas, consider length of growing season, soil and exposure before selecting plants. Select shrubs from northern sources, when possible, and plant these shrubs in the spring. Ground covers in mountain areas may take two to three years to become established. See the Colorado State University Extension (1998) Yard Gardening Series publications “Ground Covers for Mountain Communities (no. 7.413)” and “Shrubs for Mountain Communities (no. 7.407)” by J.R. Feucht for lists of species appropriate to mountain areas.
3. The Colorado Native Plant Society maintains a list of suggested native plants for horticultural use on the Front Range of Colorado, which can be accessed at www.conps.org.
4. Be aware that federal, regional, state and local water quality regulations may require integration of stormwater management facilities (e.g., detention ponds, constructed wetlands) into landscape design. Work closely with the general contractor, civil engineer, and relevant regulatory agencies or local government staff when these facilities are necessary.
5. Large landscaped areas such as parks and golf courses have special design considerations. On large sites, written landscape plans that include specifications for soil preparation, plant materials, irrigation design, mulch, and maintenance instructions are particularly important. (*See the Parks, Golf Courses and Other Large Landscapes BMP for more information.*)
6. In some parts of Colorado (e.g., Western Slope, parts of the Arkansas River basin), landscaped areas may overlay soil and geologic formations high in salts and selenium where leaching of these constituents into groundwater is a concern. In these areas, practices such as unlined ponds and over-watering that may result in water infiltration into soil below the root zone should be avoided. See *Water Wise: Residential Landscape and Irrigation Guides for Western Colorado* (Swift 2007) and *Water Wise Pond Construction for Residential and Commercial Properties* (Swift 2007) for more information.
7. Ultra-urban landscapes also have special design considerations, particularly with regard to soil space allocated to trees. See the *Tree Placement in Urban Landscapes BMP* for more information.

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Landscape Installation and Erosion and Sediment Control

Description

Minimize erosion and control sediment leaving the construction site during landscape installation and provide proper care of the landscape during installation.

Basic Practice Guidelines

Erosion and Sediment Control/Site Protection

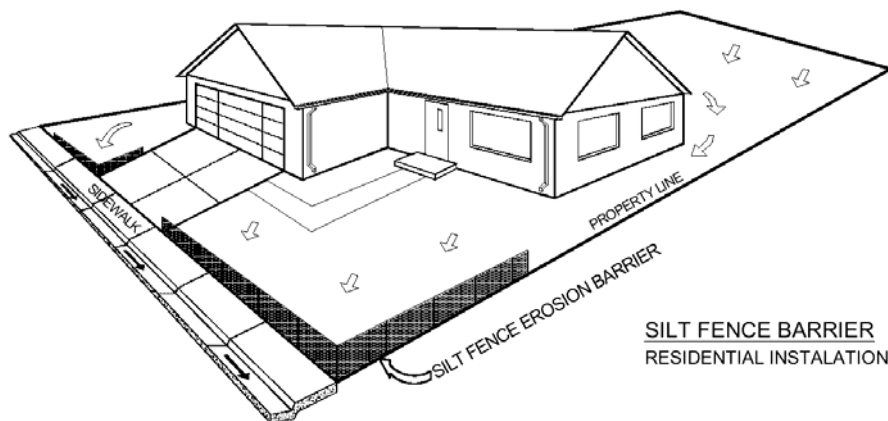
1. During construction, protect drainageways from runoff from exposed areas. Applicable practices may include straw bales, silt fences, berms, check dams, sediment basins, etc. See Appendix A for more detail on these measures.
2. Be aware of, and comply with, all stormwater construction permit requirements. As of July 1, 2002, most construction sites disturbing 1 acre or more will require such a permit and corresponding stormwater and erosion and sediment control plans. Coordinate with the General Contractor to ensure that applicable provisions of the permit are followed.
3. Minimize the amount of exposed land area and duration of exposure by phasing construction and landscape installation.
4. Avoid storing topsoil or soil amendments delivered to the site on the street or in the gutter. Dry-sweep residual soil into a wheelbarrow and dispose of it appropriately rather than using a hose to wash residual material into the storm sewer system.
5. During construction, store and protect topsoil for later use. This may require covering the stockpiled soil, and typically requires berms around the stockpile to prevent the soil from washing away during storm events.
6. Roughen slopes to be planted and provide a convex shape to slow water runoff. Apply mulches or netting over seeded slopes in exposed conditions or with a slope of 3:1 or greater to prevent erosion. Slope stabilization should be completed at the earliest practical time and in accordance with the timeframes specified by local regulations (e.g., 14 to 30 days).
7. Protect the root zone of existing trees to be retained on the site. Clearly delineate root zones with protective fencing and by posting “keep out” signs. Maintain positive drainage to these areas and adequate irrigation during and following construction. Grading and trenching in the critical root zone should be avoided. (See the Tree Protection BMP for more information.)
8. Turfgrass sod provides excellent erosion and sediment control benefits and should be installed as soon as possible in areas where sediment runoff is likely. Temporary cover crops and other groundcovers may also be installed to protect these areas.

BMP Type			
Design			
Installation		X	
Maintenance/Operations			
Green Industry Relevance			
ASLA	X	GCC	
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA		GCSAA	X

9. Repair and stabilize areas of excessive erosion.
10. Properly handle, store and dispose of pesticides, fertilizers, equipment maintenance products (e.g., oil, fuel) and other waste used during landscape installation. (*See the Chemical and Equipment Handling BMP for more detail.*)

Planting and Landscape Installation

11. Perform a comprehensive soil analysis and apply fertilizer and other amendments if specified. Slow-release type fertilizers should be used to reduce weed growth and protect water quality.
12. Properly amend soil prior to planting or laying sod. This typically requires 3 to 5 cubic yards (1 to 2 inches) of organic material per 1,000 square feet of the site. If the site has been compacted, tilling to a depth of approximately 4 to 6 inches or more is also recommended. Proper soil preparation can substantially reduce irrigation requirements.
13. For landscape areas being started from seed, sow seed mixtures at the proper time of year specified for the mixture.
14. Mulch all seeded areas and adequately secure the mulch. Maintain mulch by adding and redistributing, as necessary.
15. Keep all containerized nursery stock in a live and healthy condition prior to installation.
16. Provide adequate irrigation during the vegetation establishment period.
17. Routinely inspect landscapes following planting to implement follow-up measures to increase success. Immediate attention to a problem (e.g., weed infestation, failure of seed to germinate) can prevent total failure later.



Proper placement of residential erosion control barriers.

Source: Urban Drainage and Flood Control District (1999) and City of Broomfield.

Regional Considerations or Industry Adaptations

1. As a rule of thumb along the Front Range and in the mountains, the latter part of May and first part of June typically experience frequent storm events. During this time, landscapers should be particularly aware of the impact of the weather and phase construction/installation accordingly.

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Soil Amendment/Ground Preparation

Description

Evaluate soil and improve it, if necessary, to promote efficient water usage and healthy plants. A soil amendment is any material added to the soil to improve its physical properties (tilth), such as water retention, permeability, water infiltration, aeration and structure. The goal is to provide a better environment for plant roots (Davis and Wilson 2005). Soil amendments can also improve the nutrient content of soil.

BMP Type			
Design			
Installation		X	
Maintenance/Operations		X	
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

Basic Practice Guidelines

1. The best soils for growing plants are uniform in texture throughout the root zone and have a good balance of minerals, air and organic matter. Soil improvement is a continual process.
2. Test soils prior to planting and irrigation system installation to identify appropriate amendments to improve the physical and nutrient characteristics of the soil. Soil tests are relatively inexpensive and can help to minimize costs associated with soil amendment. In areas where low quality well water or reclaimed water are used for irrigation, or where salt-affected, corrosive, or high pH soils are known to exist, periodic soil testing should be conducted so that irrigation and fertilization practices can be adjusted appropriately. (See reference list for CSU Soil Testing Lab contact information.)
3. Before adding nutrients to the soil, it is good practice to determine first whether a problem is due to inadequate nutrition, cultural issues such as overwatering, or a physical soil property such as poor texture. Use soil test results to determine the correct amount and type of nutrients needed—only apply nutrients the plants can use.
4. Add proper organic matter to the soil, as indicated by soil test results, to increase the water-holding capacity and improve drainage. If a soil is too sandy or too high in clay, the solution to both extremes is often adding organic matter. Although organic matter is typically a key component of soil improvement in Colorado, proper addition of organic matter also means not applying too much, which can lead to salt accumulation or conversely leaching of salts and nutrients into groundwater.

**Quick Facts from CSU Extension
(Fact Sheet No. 7.235, prepared by Davis and Wilson 2005)**

- Soil amendments improve the physical properties of soils.
- Amendments are mixed **into** the soils. Mulches are placed **on** the soil surface.
- The best soil amendments increase water- and nutrient-holding capacity and improve aeration and water infiltration.
- Wood products can tie up nitrogen in the soil.
- Sphagnum peat is superior to Colorado mountain peat.
- When using biosolids, choose “Grade 1” biosolids.

5. Proper soil and ground preparation is critical to the success of a lawn or garden. If the soil has less than 3 percent organic matter, a rule of thumb is to work 3 to 5 cubic yards of organic matter into the soil to a depth of 4 to 6 inches for every 1,000 square feet of area to be seeded, planted or sodded. If native plants are being used, then soil amendment may not be necessary, provided that native topsoil has been retained at the site. Soil test results in combination with the needs of the proposed plant types determine the appropriate type and amount of amendment.

6. When selecting soil amendments, give attention to amendment characteristics such as salt content and pH, weed seed content, degree of decomposition, potential for nutrient leaching (particularly nitrogen and phosphorus), decomposition rate, and other factors. Also consider site or soil characteristics such as the soil texture, soil salinity and salt sensitivity of plants. Many soil amendments exist with widely varying properties that help to improve various components of the soil such as texture, nutrients, drainage, etc. For example, soil amendments could include fertilizer, organic amendments (peat, plant compost, animal waste compost, municipal sludge, etc.), inorganic amendments (zeolites, shales, pea gravel), topsoil, etc. Organic soil amendments often improve both the nutrient content and physical properties of soils. Some potential soil amendments should be avoided in Colorado. For example, sawdust can worsen common Colorado soil problems, sand can cause clay soils to develop a concrete-like consistency, cattle manure or compost made from cattle manure can increase salt content, and Colorado mountain peat harvesting has negative environmental impacts.

7. Several key characteristics of various soils and several common soil amendments are summarized in Tables 1 and 2, respectively. Soils with high or low permeability or water retention can be balanced by addition of proper amounts of soil amendments with counterbalancing characteristics, as shown in Table 2. Inattention to either the soil or the amendment characteristics can worsen soil conditions by selection of the wrong soil amendment. Table 3 (at the end of this BMP) provides quality classifications for compost.

**Thoughts on Soil Properties
in Colorado**

(Klett and Feucht 2007)

Many of our population centers are on heavy, clay soil. These soils have poor aeration that limits root growth. Thus the ability of plants to replenish water loss brought about by low humidity and prevailing winds is limited. Adding more water to such soils further complicates the problem because the water that is added reduces the amount of air in the soil and causes oxygen starvation to the roots. Little can be done to modify humidity and wind, so the obvious solution is to improve the soil.

**Table 1. Selected Characteristics of Various Soil Types
(Source: Davis and Wilson 2005)**

Soil Texture	Permeability	Water Retention
Sand	High	Low
Loam	Medium	Medium
Silt	Low	High
Clay	Low	High

**Table 2. Selected Characteristics of Several Common Soil Amendments
(Adapted from Davis and Wilson 2005)**

Amendment	Decomposition Rate	Permeability	Water Retention
<u>Fibrous</u> Peat Wood chips Hardwood bark	Slow (possibly years) <i>(all amendment subcategories)</i>	Low-medium High High	Very high Low-medium Low-medium
<u>Humus</u> Compost Aged Manure	Moderate (about 6 months) <i>(grass clippings and un-aged manures decompose more rapidly)</i>	Low-medium Low-medium	Medium-high Medium
<u>Inorganic</u> Vermiculite Perlite	Negligible <i>(all amendment subcategories)</i>	High High	High Low

8. Biosolids, a byproduct from municipal sewage treatment, are increasingly available as compost, either alone or combined with another product. From a sustainability perspective, biosolids provide opportunities to “reuse” and “recycle.” The primary concerns with biosolids are heavy metal content, pathogen levels and salts. To alleviate these concerns, select “Grade 1” biosolids. (Biosolids should not be used for “root crops” where the edible portion of the plant comes in contact with the soil.)
9. Fresh manure can harm plants due to elevated ammonia levels; therefore, only aged manure (at least six months old) should be used. Composted manure should reach temperatures of 160 to 170 degrees Fahrenheit to kill pathogens prior to use in vegetable gardens.
10. Some composts and manures are high in salts and have a high pH. Addition of soil amendments high in salts can make salt-affected soil problems worse. As a general rule, an amendment with up to 10 mmhos/cm of total salts is acceptable if it is well mixed into low-salt soils (< 1 mmho/cm). Avoid horse manure, which contains seeds for weeds and undesirable grasses unless it is well composted. Also avoid cattle manure because it is high in salt and fine textured. These precautions are particularly important for soils already high in salts (> 3mmhos/cm), or when growing salt-sensitive species. Sphagnum peat and compost from purely plant sources are low in salts and good choices for such locations.
11. When soil tests indicate that salts are a problem, this should be corrected (if possible) prior to planting. In situations where this problem cannot be corrected, selecting plants tolerant of the salt conditions is one possible approach to consider when designing the landscape. See Appendix G for a list of salt tolerances of various plants.
12. Soil pH is important in determining which plants are appropriate and may also affect the plants’ fertility and responses to fertilization. Soil testing should be performed to obtain an initial pH, phosphorus and nitrogen level, organic matter content and soluble salt level.

13. Information on soil permeability, water holding capacity and maximum allowable depletion are needed to establish appropriate irrigation rates and schedules. See the Irrigation Technology and Scheduling BMP for more information.
14. Once the soil has been prepared for planting, keep construction equipment off of the prepared surface.
15. When planting balled-and-burlapped or container stock, avoid soil interface problems by amending the backfill slightly (up to one-third) to provide a transition between the soil in the root ball and the surrounding soil. Scarify or break up the soil on the sides of the hole to help in this transition.
16. Liquid soil treatment products are not a substitute for soil amendments.
17. Wood products (e.g., sawdust, bark) used as soil amendments can result in nitrogen deficiency in plants.
18. Aerate the lawn and cultivate planting beds periodically, to decrease compaction and improve penetration of water, air and nutrients into root zones.

Regional or Industry Considerations/Adaptations

1. Some communities in Colorado have begun to adopt soil amendment ordinances (e.g., Aurora, Denver, Westminster) for new developments. Be sure to obtain and follow requirements in local ordinances.
2. Consider regional soil conditions when determining watering requirements. See Swift (2001) "Watering Established Lawns in Western Colorado, Colorado State University Extension Tri-River Area" for recommendations for water requirements for soils in western Colorado.
2. See the Turf Management BMP for information on working with alkaline and high salt soils.
3. The only soils that can benefit from adding gypsum are sodic (sodium absorption ratio [SAR] greater than 15) or black alkali soils, which are typically found where there is a high water table and poor drainage.
4. Some areas of Colorado, especially some mountain areas, contain corrosive soils with very high pH (pH of 9 and higher). In these areas, no amount of amending will allow ornamental plants to survive; the soil may need to be replaced to a depth of 2 feet or more with good topsoil in such extreme cases.

Table 3. Rocky Mountain Region Compost Classifications and Standards
(Source: <http://www.extsoilcrop.colostate.edu/Soils/projectscompost.htm>)

<i>Note: There is no implied warranty or product performance guarantee associated with this Classification System</i>	CLASS I Fully composted, stable, mature product	CLASS II Fully composted, stable mature product	CLASS III Semi-composted dehydrated product	CLASS IV Non-composted feedstock product
Minimum Stability Indicator (Respirometry)	Stable to Very Stable	Stable	Unstable to Moderately Unstable	Unstable
Maturity Indicator Expressed as Ammonia N / Nitrate N Ratio	< 4	< 6	N/A	N/A
Maturity Indicator Expressed as Carbon to Nitrogen Ratio	< 12	< 18	< 25	N/A
Maturity Indicator Expressed as Percentage of Germination / Vigor	80+ / 80+	N/A	N/A	N/A
pH – Acceptable Range (1:5 by weight)	6.0 - 8.4	6.0 - 8.4	6.0 – 9.0	N/A
Soluble Salts – Acceptable Range (1:5 by weight)	0 - 5 mmhos/cm	5 - 10 mmhos/cm	< 30 mmhos/cm	N/A
Testing and Test Report Submittal Requirement	STA / TMECC	STA / TMECC	STA / TMECC	Primary & Secondary Nutrient Testing
Chemical Contaminants	Meet or exceed US EPA Class A standard, 40 CFR 503.13, Tables 1& 3 levels	Meet or exceed US EPA Class A standard, 40 CFR 503.13, Tables 1& 3 levels	Meet or exceed US EPA Class A standard, 40 CFR 503.13, Tables 1& 3 levels	N/A
Bulk Density; % Inorganics; % Moisture; Particle Size Distribution, Primary, Secondary Nutrients; Trace Elements; Organic Matter Expressed in Percentage and Pounds Per CY	Must Report	Must Report	Must Report	Must Report
Pathogens	Meet or exceed US EPA Class A standard, 40 CFR 503.32(a) levels	Meet or exceed US EPA Class A standard, 40 CFR 503.32(a) levels	Meet or exceed US EPA Class A standard, 40 CFR 503.32(a) levels	N/A
Minimum Manufacturing Production Requirement	Each composting facility must be fully permitted by the Colorado Department of Public Health and Environment or their appropriate state agency. If it is exempt from state permitting requirements, it will certify that it follows all guidelines and procedures for production of compost meeting EPA 40 CFR 503.13 requirements for production and marketing of Class A material for unrestricted use and distribution. Written certification from manufacturer is required.			
Applications <i>Note: The listed applications for the various compost class designations are intended for general consideration purposes. The actual use or application of any class of material can be subjective depending on the soil characteristics, quantity used, the method of incorporation, and other factors utilized by the buyer or user.</i>	Horticultural, Nursery, Container Mixes, Turf, Sod, Seed Bed Preparation, Raised Garden, Vegetable Gardens, Top Soil Blends, Backfill, Erosion Control. Watering to leach excess salts not required. Can be applied at high volume. Incorporation can be at shallower depths.	Turf, Sod, Seed Bed Preparation, Raised Garden, Vegetable Gardens, Top Soil Blends, Backfill, Erosion Control. If possible, incorporate at least 60 days prior to planting and water thoroughly before and after planting. Incorporation is important.	Crop production, Turf and Top Soil blends with limitations. Backfill, Erosion Control, Mulch. If possible, incorporate at least 90 days prior to planting. Deep incorporation and thorough mixing very important.	Agriculture
Best Management Practices (BMP) (How the compost is applied/incorporated; effect on product performance.)	The BMP used by the buyer, user, or applicator will effect the performance of products and also the applications for any product. BMP's will also affect the risks regarding plant germination and vigor associated with the use of soil amendments and compost			
Incorporation Notes	Can be used as a high percentage of the soil profile. Incorporation not critical (top 4" recommended).	Should not be used as a high percentage of the soil profile (30% max). Incorporation in top 6" recommended.	Cannot be used as a high percentage of the soil profile (15% max). Incorporation in top 8" or more recommended.	Cannot be used as a high percentage of the soil profile. Incorporation in top 10" or more recommended.

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Tree Protection

Description

Identify trees suitable for preservation and implement measures to protect these trees during construction activities.

Basic Practice Guidelines

1. During site development, trees can be injured in several ways, some of which may not be apparent at the time of injury. Potential sources of injury include: soil compaction during grading or due to construction traffic, direct equipment-related injury such as bark removal, branch breakage, surface grading and trenching, and soil cut and fill. In order to minimize these injuries that may lead to immediate or later death of the tree, tree preservation plans must be developed during site design, implemented at the beginning of a construction project, as well as continued during active construction. Preserved mature tree maintenance must continue in the post-construction period, as well.
2. The tree protection process at development sites includes these basic steps:
 - a. Inventory trees at a development site and determine suitability for preservation. A qualified city forester, certified arborist, or registered consulting arborist should consider factors such as species (desirable or weed), size, vigor, defects, insects and disease, special historic status, cost of preservation and removal cost.
 - b. Assess potential impacts to trees due to site development. Can the tree tolerate the impacts of development? Can the roots, trunk and branches be adequately protected? Can the tree be moved and replanted?
 - c. Prepare list of trees to be protected. It is cheaper to preserve mature trees than to replace them.
 - d. Prepare a written tree protection plan that is referenced in construction, grading, landscaping, and planting plans. Information on tree protection requirements should be provided as part of pre-construction conferences with contractors.
 - e. Monitor tree health during and after construction for signs of stress.
 - f. Prepare post-construction maintenance plan for preserved trees.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	
ALCC	X	ISA	X
CALCP	X	RMSGGA	
CNGA		GCSAA	X

Quick Facts from CSU Cooperative Extension
(Fact Sheet No. 7.420, prepared by Bernard, Dennis and Jacobi 2003)

- Evaluate established, healthy trees to see if tree protection is worthwhile and feasible.
- Involve all parties in planning for tree preservation.
- Establish specific guidelines to prevent tree injury.
- Properly size barricades to prevent tree injury.
- Mechanized equipment can damage tree trunks, root systems and soil structure.
- Soil compaction and grade changes limit root growth, cause dieback and death.

3. In some cases, smaller trees that are expected to be impacted by development activities can be removed and maintained off-site or in another portion of the site until time to replant. If size permits, trees should be spade- or hand-dug then irrigated and protected by a designated contractor until replanting can occur.
4. Be aware that some large, mature trees are not structurally sound or in adequate health to warrant preservation. Older trees do not adapt to environmental changes as well as younger trees. Some species adapt to change more easily than others, as summarized in Table 1 (Bernard, Dennis and Jacobi 2003).

Table 1. Tree Adaptability to Root Disturbance

(Source: Bernard, Dennis and Jacobi 2003; as modified by GreenCO 2008)

Most Adaptable	Moderately Adaptable	Least Adaptable
Ash, green and white	Aspen	Bolleana white poplar
Common hackberry	Black locust	Black walnut
Cottonwood	Boxelder	Colorado blue spruce
Crabapple	Bur oak	English oak
Ginkgo	Eastern redbud	Lombardy poplar
Honey locust	Linden	Northern red oak
London plane tree	Norway maple	White spruce
Serviceberry	Pine (most species)	
White ash	White oak	
Willow	Silver maple	

5. Before beginning construction operations, establish a Tree Protection Zone (TPZ) around trees to be preserved by installing barriers and construction fences. Allow enough space from the trunk to protect the root zone from soil compaction and mechanical damage, and the branches from mechanical damage (see Table 2). If low branches will be kept, place the fence outside of the drip line. Where this not possible, place barriers and fencing as far away from the trunk as possible. In order to maintain a healthy tree, be aware that about 60 percent of the tree's root zone extends horizontally from the tree beyond the dripline.

Table 2

Determining the Tree Protection Zone

(Source: Matheny and Clark, 1998)

Species Tolerance to Damage	Distance from Trunk (ft) per inch of DBH		
	<i>Young</i>	<i>Mature</i>	<i>Over mature</i>
<i>Good</i>	0.5'	0.75'	1.0'
<i>Moderate</i>	0.75'	1.0'	1.25'
<i>Poor</i>	1.0'	1.25'	1.5'

Notes: DBH = diameter at breast height (4.5' above grade); Young = <20% of life expectancy; Mature = 20%-80% of life expectancy; Over mature =>80% of life expectancy

6. Most tree roots grow within the top 12"-18" of soil. Grade changes within the TPZ should be avoided to the maximum extent practicable because seemingly minor grade changes can either smother roots (in fill situations) or damage roots (in cut situations).
7. Place and maintain a layer of mulch 4-6" thick from the tree trunk to the fencing, keeping a 6" space between the mulch and the trunk. Mulch helps to preserve moisture and decrease soil compaction if construction traffic is unavoidable. When planting operations are completed, the mulch may be reused throughout planting areas.
8. Limit access and appoint one route as the main entrance and exit to the TPZ. Within the TPZ, do not allow any equipment to be stored, chemicals to be dumped, or construction activities to take place (except as noted below). Be aware that soil compaction can cause extreme damage to tree health that may appear gradually over a period of years. Soil compaction is easier to prevent than repair.
9. When it becomes necessary to enter the TPZ, such as for fine grading, irrigation system installation, and planting operations, follow these guidelines:
 - a. Preserve the existing grade around protected trees in as wide an area as practicable.
 - b. Where possible, locate utilities outside of the TPZ; where utilities must be located within the TPZ, either bore underneath the roots or use hand tools, taking extreme care not to sever critical roots. (Critical roots are those which are essential to the physical support and health of the tree; their size varies depending on the size and maturity of the tree, and some species are more sensitive to root disturbance than others.) Where critical roots are encountered, tunnel under the roots and wrap exposed critical roots in wet burlap and keep moist while the trench is open.
 - c. Where critical roots must be cut due to extensive grade changes, expose them by hand digging and cut cleanly. Ragged cuts generally do not callus (heal) properly, and may leave the tree open to pests and pathogens. Refill the trenches as soon as possible to avoid moisture loss.
 - d. Where trenching near trees has already occurred from previous construction operations, make every effort to confine trenching operations to the previously-created trenches, while adhering to the conditions set forth in 9b.
 - e. When fill is added around a tree base, it acts as a blanket that prevents normal air and moisture circulation to the roots. Fill around trees should be avoided to the maximum extent practicable. Minor fills with organic matter (less than 3 inches) will not harm most trees. If major grade changes are required, then a drywell may be needed.
 - f. When soil cuts are unavoidable around trees as part of site grading, terrace the grade to maintain the tree's root system, where practicable.
 - g. For mature, drought tolerant species grown in dry conditions, no irrigation or planting should occur closer than 8'-10' from the trunk, as watering in this situation can lead to root disease and rot. Where irrigation must occur within the TPZ, drip irrigation should be used wherever possible. Additionally, only plants with low water needs should be planted within the TPZ of drought tolerant tree species, spaced far apart

where close to the tree. Plants may be spaced closer together near the outer edge of the TPZ.

10. As part of routine construction inspections, ensure that tree protection remains in good repair and report potential tree health problems to the owner and appropriate contractor or arborist.
11. Post-construction maintenance should begin with evaluation of the condition of preserved trees. Consult with a qualified arborist about necessary maintenance and monitoring needs. Provide clear maintenance guidelines to the site contractor to ensure that proper maintenance (e.g., irrigation, pruning of damaged branches, etc.).
12. Some trees harmed by construction can be treated, but action must be taken immediately. Trees may need watering, mulching, bracing, pruning, or even removal. Each tree should be evaluated individually to ensure that it receives the appropriate treatment, repair, and follow up care.
13. Optimum soil pore space for good root growth and water/air penetration is between 25% and 50%. Especially in clay soils, soil compaction significantly decreases soil oxygen and water holding capacity, inhibiting water and root penetration, thus resulting in tree health decline. Although some remediation methods are more effective than others, compacted soil cannot easily be corrected. The best solution is to prevent excessive compaction wherever possible.

Regional or Industry Considerations/Adaptations

1. Preservation of existing trees impacts energy use in buildings and can substantially reduce the need for air conditioning in the summer and subsequently decrease the amount of carbon dioxide production associated with development (IES 2007). See the *Sustainability BMP* for more information.
2. Many planners, landscape architects and designers, and contractors are unaware of the requirements for protecting trees during construction. Consult an ISA Certified Arborist or ASCA Registered Consulting Arborist during the planning, design and construction stages to assess potential impacts to trees to be preserved.
3. To provide incentive for tree protection during construction, the owner may include tree damage fees in the construction contract. Tree preservation bonds may be necessary to ensure noncompliance fines, which should be based on tree value and the amount and type of damage.

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Tree Placement in Urban Landscapes

Description

Trees must be placed in the urban landscape so that adequate soil and space for root growth are provided for the long-term growth and health of the tree. Tree placement in urban landscapes is provided as a unique BMP because trees need more space than is provided in many contemporary urban designs.

This BMP is adopted directly from the work of James Urban, FASLA, as contained in “Up By Roots,” Lecture Notes as presented at Pro Green Expo 2008. Citation of this BMP should include reference to Urban (2008).

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSG	
CNGA	X	GCSAA	

Basic Practice Guidelines

The following ten principles are intended to guide integration of trees into landscapes from the initial concept sketches through construction and the beginning of the maintenance cycle. The principles evolve around three strategies: Soil, Trees and Management, and cover all aspects of designing a tree into an urban space. ***To be successful, the principles must become an integral part of the project’s design goals, being considered prior to the construction document phase. These principles cannot be easily applied once the design direction is set. Space allocated to tree requirements must be vigorously protected through the entire development process.***

Soil Based Strategies

These strategies identify, protect and improve soil resources for trees.

1. **Plant The Easy Places First.** Develop design options that plant large trees in large soil resources. In the urban environment there are always easier places to grow trees. Differences in growth possibilities may be only a few yards apart, reflecting a change in soil or drainage patterns or suggesting a slight variation in design. These subtle differences may be identified in the site assessment or noticed by the designer with experience working with tree and soil principles. By starting the design with the easier locations, success will be more certain and cheaper to attain. Working with existing soil resources is fundamental to the principles of sustainable design.
2. **Make Bigger Planting Spaces.** Balance the size of paving and open soil areas. Another simple way to improve the health of trees in urban areas is to reduce the area of paving and increase areas of open soil. Of all the principles, this may be the easiest to undertake. Competition for space in the city is severe, but rarely is the question asked, "Could the paving be reduced, even slightly, to improve tree growth?" Architects, civil engineers, and landscape architects see paving as a primary element in the design. They may not know how their decisions affect tree health or may believe that the tree can be replaced if it dies. Dimensions of paved areas may be set by larger aesthetic considerations or existing standards. But, studies indicate that roads can be narrower, sidewalks can modulate in width,

and plaza paving can be reduced. Fewer, larger spaces for clustered trees are better than many smaller isolated tree planting spaces. Small change in the widths of drives and walks can result in large increases in the amount of available soil. Formulas for determining the amount of soil needed to support a large tree are available. Use them to gain support for larger soil areas.

3. **Preserve And Reuse Existing Soil.** Sustainability starts with preservation of resources. There are often usable soils to be found at urban sites. If these soils can be identified, incorporated into the design and protected during the construction, a small piece of the environment has been preserved. It is hard to make good soil. When it exists, its reuse should be an option. If a project has sustainability goals, preserving, protecting and reusing existing soil must be a priority. Soil reuse, protection and preservation are not an easy task in a complex construction process. It demands nearly the same level of effort required to build around existing trees.
4. **Improve Soil And Drainage.** Break compaction, amend or replace soil, maintain or create drainage. Make the soil "right for the tree". Sometimes simply tilling a compacted soil is a sufficient improvement. Other times, complete soil replacement may be required. Knowledge of soils, drainage, and the cultural requirements of the trees to be planted are necessary to make the right decisions. Improper soil amendments may be worse than no amendments. Too much water creates more problems in the urban landscape than too little. Plants can adapt to dry conditions, but if there are drainage problems, they can be difficult to fix, especially if they are not discovered until after the rest of the project is constructed. Poor drainage will undo all the other principles.

Tree Based Strategies

These strategies respond to the needs of the tree.

5. **Respect The Base Of The Tree.** Do not pave within the area of the tree's future trunk flare. Trees have a pronounced swelling at the base of the tree just before the trunk disappears underground and this flare must be treated with respect. The trunk flare will expand to dimensions dictated by the tree, not the designer. Just beyond the trunk flare, the first set of large roots extends out underground and rapidly tapers over the next 6 to 8 feet away from the trunk. These are the roots that cause the most conflict with paving and curbs and must be acknowledged in the design.
6. **Make Space For Roots.** Design spaces for roots under the pavement and utilize different approaches to root space design as conditions change. It may be impossible to provide sufficient soil for the tree in an area separate from paved areas, and designers must then provide space for roots growing under the pavement. How this is accomplished may limit the type of paving that can be used and will increase the cost of the project. It is possible to encourage root growth under pavement in ways that do not impact the stability of the pavement. There are many approaches available to improve rooting space under sidewalks. Use as many of them as are appropriate to optimize the budget to grow large, healthy trees.

- 7. Select The Right Tree.** Put the right tree in the right place and make the place right for the tree. After the previous six principles have been followed, the designer can make tree selections. By adopting this order of priority, a much wider range of trees will be available. Trees can be selected primarily for their ability to perform desired functions and or aesthetic contributions. Selecting the right tree also assumes a high level of professional competence about these requirements. Designers must learn the nuances of arboriculture. This is more than a quick look at a text book or a digital plant selection program. They are a good beginning but are no substitute for personal experience with the plants being considered. Local climate, maintenance, nursery availability, regional soil differences and other variables must be considered. Once the tree has been selected, make sure that the site has been made right for that particular tree.

Management Based Strategies

These strategies implement the soil and tree based strategies.

- 8. Establish Reasonable Tree And Soil Budgets.** Balance the design quality of all elements in the landscape. Planting and maintaining a large, healthy urban tree requires about the same budget resources as is required to install and maintain a good quality street light. As budgets become limiting, adjust the quality or quantity of everything a little bit. For example, it may be necessary to plant fewer trees and use less expensive paving material in order to save money for better soil and drainage.
- 9. Create Detailed Tree And Soil Construction Documents.** Make construction decisions that are project specific and respect the science of trees and soils. Once the concept design has been developed that supports trees, the construction document process must continue with the same commitment to the principles of soil science and tree biology. There is a big leap from the soil and planting concept plan to construction. Prepare a separate soil and drainage installation plan and make detailed sections of each condition. Draw the trees in sections to scale, accurately depicting the root ball size. Make sure that it fits in the space at the time of construction and that the mature root system will fit in the space in 30 or 40 years. Draw the predicted mature root system, at least during the detail development period, to test the suitability of details. Create buildable plans and specifications. Can the contractor actually place the soil in the locations and in the sequences of other construction? Avoid typical details. Concepts will invariably fail when the conditions are not "typical". Make frequent inspections of materials at their source and during the construction process to ensure quality. The problem of root balls with overly deep roots or circling roots must be corrected in the nursery, not at the job site. Soil must be tested and reviewed to assure that it supports the plants selected and is compatible with the drainage assumptions. Many contractor mistakes are quickly covered with soil and mulch: drainage systems, subgrade conditions, soil installation, soil compaction, and root balls must be reviewed while they are exposed.
- 10. Design for Maintenance.** Create designs that are maintainable. Urban environments are dependant on maintenance. In intensely used urban settings the concept of low maintenance is not a practical reality. The source and capability of that maintenance must be identified during the design process. Understanding the maintenance capabilities of the client should be a fundamental design criterion. Many projects that receive wide acclaim for design success

have small armies of maintenance staff who can overcome soil design flaws. When another designer tries to emulate these award-winning projects without the same level of maintenance, plant failure is almost assured. Design choices do impact the ability to maintain the design. Maintenance providers must be equally knowledgeable as the designers in soil and tree biology when making maintenance decisions. How soil and trees are treated during the maintenance periods is as crucial as it was during construction.

Regional or Industry Considerations/Adaptations

1. A related topic in urban landscapes involves the use of “structural soils” in ultra-urban settings to provide space for tree roots, while still allowing paved surfaces. Structural soil is a mixture of stone aggregate and soil, with a small amount of polymer gel to hold the mix together. This soil mix can be compacted to 95% of dry density to support paving and still allow for tree root growth. The mix takes advantage of the fact that there are about 20% to 25% void spaces between pieces of compacted gravel, in which roots will grow. Structural soils can play a key role in landscape-based stormwater management practices in urban settings, when cautiously designed and adequate soil space is provided. Be sure to obtain detailed design guidance and specifications accepted by local governments before implementing structural soils.

Key References

Urban, J. 2008. Up By Roots. Lecture Notes from the Pro Green Expo, Denver Colorado.

Urban, J. 2008. Absorbent Soil Volumes Under Pavement for Rainwater Management and Healthy Tree Growth, Lecture Notes from the Pro Green Expo, Denver Colorado.

Other References:

See the reference lists for the following GreenCO BMPs:

- Tree and Woody Plant Care
- Tree Planting
- Landscape Design

Tree Planting

Description

Properly plant trees, shrubs and other woody plants to promote the long-term health of the tree.

This BMP is adopted directly from *Avoiding Excessive Soil Over the Root Systems of Trees: A Best Management Practice (Morton Arboretum et al. 2005)*. These best management practice guidelines are intended to assist growers, landscape professionals, and arborists in learning to recognize, prevent, and take action to correct root systems that are too deep. This BMP focuses on trees being planted and managed in urban and suburban landscapes, generally 2-inch caliper and larger. This BMP is not intended to apply directly to lining-out stock sold in nurseries that will be grown in the field or in containers, though practices used during such production can ultimately affect trees in the landscape. Trees with root balls can be produced by several methods, and these guidelines apply to all of them.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	
CNGA	X	GCSAA	X

Basic Practice Guidelines

How Deep Should Structural Roots Be?

1. Generally, on a young tree, the uppermost structural roots (two or more) should be within the top 1 to 3 inches of the soil surface, measured 3 to 4 inches from the trunk. As a tree matures, roots thicken faster on the top side, effectively reducing the amount of soil above the structural roots and forming the root flare. Special situations requiring exceptions to this general guideline include the following:
 - Some species may develop more strongly descending root systems; therefore, the structural roots may have to be located nearer the trunk.

Background on Development of this BMP

An industry-wide working group was formed in 2003 to develop consensus on a complex national issue: tree decline and death in the landscape resulting from excessive amounts of soil over the root system. When structural roots are too deep below the soil surface, lack of oxygen can kill roots and lead to decline and death of the tree, especially in urban soils. In some species, prolonged moisture at the base of the trunk may increase root and collar rot diseases. This effort was coordinated by The Morton Arboretum in Chicago, with Gary Watson as chair of the group. The working group currently includes representatives of the American Nursery and Landscape Association (ANLA), the International Society of Arboriculture (ISA), the American Society of Landscape Architects (ASLA), the Associated Landscape Contractors of America (formerly ALCA, now PLANET), Tree Care Industry Association (TCIA), and the American Society of Consulting Arborists (ASCA). The working group completed these BMP guidelines based on the practical experience of many professionals and the relevant scientific research available at this time.

- On landscape sites with poorly drained soil, the roots may need to be even shallower for adequate survival. Structural roots may need to be at, or slightly above, the surrounding grade under extreme conditions.
- In some species, the roots regenerated after transplanting can grow back toward the trunk and become girdling roots. Initial research shows that very little soil over the structural roots could be problematic. *Celtis occidentalis* (hackberry), *Fraxinus pennsylvanica* (green ash), *Acer rubrum* (red maple), *Tilia cordata* (littleleaf linden), *Populus* spp. (poplars), and *Malus* spp. (crabapples) are species for which this is known to be a problem. Other species with aggressive root systems may also exhibit this tendency.

How to Locate Structural Roots

2. Checking root depth can be done in the nursery before digging (preferred), or in the B&B or container root ball just prior to planting.

Presence of a visible root flare is a good indicator that the structural roots are just below the soil surface. However, on grafted trees, be careful not to confuse the swelling of the trunk below the graft union with the actual root flare. A gap around the trunk at the soil line is a sure sign that the first roots are at least several inches below the soil surface.

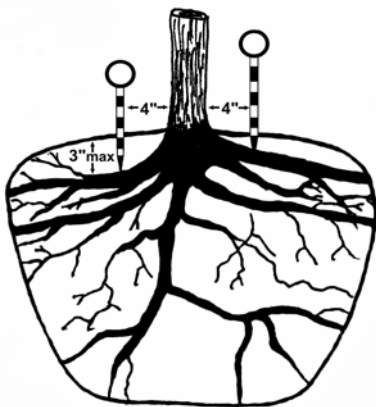


Figure: A root ball can be probed nondestructively to locate at least two roots within 1 to 3 inches of the soil surface. A surveyor's chaining pin is a convenient tool to use.

Terms and Definitions

Balled and burlapped (B&B): Established in the ground and dug with a portion of the root system and undisturbed soil immediately around the roots.

Container grown: Grown and marketed in a container.

Containerized: Grown in the ground and subsequently dug with a soil ball (described as "balled and processed" by ANSI Z60.1) or bare root (described as "process balled" by ANSI Z60.1) and placed in a container until sold.

In-ground fabric bag: A method used to grow trees in the ground using a specially designed fabric bag to restrict root spread.

Root flare, trunk flare: Interchangeable terms for the area of transition between the vertical stem and structural roots at the base of the tree's stem or trunk. The "flare" develops over time as the tree grows and may not be evident on young trees.

Structural roots: Woody roots relatively large in diameter, giving characteristic form and shape to a root system.

3. If none of these easily recognized signs are present in the field, or if the root ball burlap and twine cover the base of the tree, a surveyor's chaining pin or similar tool can be used to quickly and nondestructively probe for the roots. Probing approximately 3 to 4 inches away from the trunk will determine the true depth of the roots, rather than the depth of the enlarged root flare, if present. At least two roots (preferably more) should be located within 1 to 3 inches of the soil surface.

Nursery Stock Selection and Handling

4. It is possible for trees to leave the nursery with structural roots too far below the surface of the root ball. Depth of structural roots can increase at several stages of nursery production, including planting, cultivating, transplanting, and harvesting, and possible changes in root architecture can occur during the production process. It is always preferable to avoid trees with roots too deep below the soil surface rather than trying to make corrections later.
5. The American Standard for Nursery Stock (ANSI Z60.1, 2004) states that, for B&B trees, “soil above the root flare ... shall not be included in the ball depth measurement and should be removed.” If the resulting depth measurement of the root ball does not meet the minimum provided in the standard, the ball is not deep enough to encompass a sufficient mass of roots for the vigor of the tree in the landscape, and the tree can be rejected. Be sure growers and suppliers understand what is expected. It can be difficult and time consuming to evaluate and adjust root balls on site or to reject nursery stock with root balls of insufficient depth.

Planting Process

6. When root balls arrive on site, the depth of the structural roots should be checked before placing the tree in the planting hole.
7. Bud-grafted cultivars, and some seedling trees, are cut back during production. Evidence of the “dog leg” in the stem and of a change in bark texture should be approximately 1 to 2 inches above the soil surface for a young tree, with a maximum of 4 to 5 inches between the pruning wound and the uppermost structural roots.
8. If the structural roots have been located within 3 inches of the surface, the root ball should be planted with the surface no lower than the same level as existing grade. One to two inches higher usually is preferable to allow for settling and “pancaking” of the root ball. Unless conditions are extreme, do not plant so high that the cut ends of the structural roots at the edge of the root ball are above the surrounding grade. Planting the tree any higher may expose roots after minor erosion or contribute to surface root formation in the long run.
9. If the structural roots are found to be deeper than 3 inches below the root ball surface, the root ball and the planting depth will have to be adjusted. Elevate the root ball so that the structural roots are at the correct depth relative to surrounding grade. It is best to leave B&B root balls intact until placed in the planting hole, rather than to unwrap them and strip the soil off the top before moving the root ball into the planting hole. Moving an unwrapped root ball may cause unnecessary damage.
10. If there is extra soil over the structural roots, it may be acceptable in some situations to leave the root ball intact, with the extra soil remaining above grade through the guarantee period. Some contractors prefer to leave the burlap, rope, and wire basket in place for a time to keep the root ball more stable and make it easier to straighten later, if needed. If the wrappings are not removed at planting time, the tree should be checked at the end of the guarantee period, and any remnants of the wrappings or excess soil remaining above grade should be removed.

11. Suddenly removing excess soil could be problematic for other reasons. The extra soil over the structural roots could be filled with fibrous roots which, if removed suddenly, could cause extra stress. There have been reports of cold or sunscald damage of the newly exposed tissue on trees when the extra soil was suddenly removed from the base of the trunk (this could actually be a portion of the original primary root [tap root], in some cases). Late-fall plantings may be the most susceptible to cold damage. Earlier plantings may have time to harden off normally. Thin-barked trees may be most susceptible to sun injury.
12. Until this situation is more fully understood, exercise caution when removing soil and exposing tissue that has been below grade. Leaving the extra soil in place above grade to be removed slowly or erode away may help to protect sensitive trunk tissues. Mulch can be used to hide the protruding root ball. If the soil is removed, covering newly exposed tissue with organic mulch may help to protect it from sun and cold damage. A trunk wrap may provide some protection from the sun. This material should degrade within one year or must otherwise be removed from the tree in that time period.

Mulching

13. Mulching is an excellent way to conserve soil moisture, reduce competition from other plants, and prevent lawn mower injury. Two inches of mulch is the appropriate depth for 2- to 3-inch-caliper trees. Later applications to “refresh” the mulch should not increase the depth. Keep the mulch away from the trunk. Avoid thick layers of mulch around the base of the tree (often called “volcano mulching”), as is far too often seen in landscapes. Do not pile the extra soil around the base of tree and use mulch to hide it—excess soil should be removed from the planting site. Avoid organic material that can mat down and create a hydrophobic layer.

Remediation

14. There are many trees already planted in the landscape with the structural roots too deep. These trees are likely to have reduced vigor and shorter life spans if no remedial action is taken. For recently planted trees (less than two to three months of warm soil for root growth), the greatest long-term benefit will be achieved by replanting the tree at the proper depth. For partially established trees, the best remedial treatment may depend on several factors. Replanting a partially established tree will cause additional stress; therefore, the benefits of replanting such a tree must outweigh the risks. If the tree is in good health and growing vigorously, it may be best to do nothing. A tree that appears to be struggling may need to be replanted at the proper depth, as long as the tree is in good enough health to survive the additional stress of replanting. Do not waste money replanting trees that already show signs of serious decline. Trees on low-quality, poorly drained soils are more likely to need to be replanted than those on high-quality sites.
15. For larger, fully established trees, a practice being used regularly by arborists is a root collar excavation to remove the excess soil in contact with the trunk. Removal of this soil reduces the possibility of basal and collar rot diseases, and it improves aeration to the structural roots at lower depths.

16. Roots regenerated after planting originate mostly at the perimeter of the root ball and usually grow up to their natural depth closer to the surface. Do not expose these roots. When the structural roots moved with the tree are too deep, the newly generated roots sometimes have been observed to grow toward the trunk rather than away from the trunk, as is normal. Removing the soil near the trunk can expose these “misdirected” roots and allow their removal so that they do not become girding roots. The excavated soil is sometimes replaced with well-aerated mulch or gravel.

Regional or Industry Considerations/Adaptations

1. At the time that this manual was released, Green Industry opinion on wire baskets was undecided.

Primary Reference

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See the Reference List of the *Tree and Woody Plant Care BMP* for additional information.

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Irrigation Efficiency (General Principles)

Description

Properly design, install and maintain irrigation systems to ensure uniform distribution and efficient delivery of water, thereby conserving water and protecting water resources.

Basic Practice Guidelines

The five established overall BMPs for irrigation systems are:

1. Assure the overall quality of the irrigation system.
2. Design the irrigation system for uniform distribution and efficient management of water.
3. Install the irrigation system according to the design criteria.
4. Maintain the irrigation system to adhere to the design criteria, for optimum performance.
5. Manage the irrigation system according to changing plant water requirements.

See the Irrigation Association’s (2005) publication titled “Turf and Landscape Irrigation Best Management Practices” (downloadable from www.irrigation.org) for detailed information on these guidelines. These principles are applicable to Green Industry professionals in established landscapes, as well as in the nursery/greenhouse. This BMP is divided into two sections corresponding to these industry sectors.

Landscape Irrigation

1. Do not over water—most established vegetation does not require more than 1 to 1½ inches of supplemental water per week on the Front Range depending on the season and rainfall. Plants will develop deeper roots and ultimately require less frequent watering, when not over-watered.
2. Never water if the soil is visibly wet. When determining the watering needs of planted areas, probe the soil 4 to 6 inches to determine the moisture content. Do not worry about the dryness of the top inch of soil. If the soil is too dry to form a ball when squeezed in the hand, it needs water.
3. Irrigate according to the requirements of the plants, not on an irrigation schedule that is based

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

Basic Concepts

Irrigation can be defined in terms of:

- **Rate:** the irrigation precipitation rate, typically in inches/hour.
- **Duration:** the length of time of an irrigation event, in minutes or hours.
- **Frequency:** the number of days between irrigation events.

Efficient Irrigation is applying the right amount of water at the right time.

Distribution Uniformity is how evenly water is applied.

on fixed (unchanged) *duration* and *frequency*.

4. Irrigation strategies may be constrained by local regulations or other factors. For this reason, two basic approaches to adjusting the irrigation schedule are recommended:
 - Preferred irrigation strategy: water all plants deeply but infrequently to encourage deeper, healthier rooting. Provide prolonged intervals between watering (*frequency*) to encourage plant root zone development. The *duration* of irrigation should be based on replacing the managed soil moisture depletion in the root zone (i.e., managed allowable depletion [MAD]).
 - Alternative irrigation strategy: if the *frequency* of irrigation is fixed by an administrative authority (e.g., odd/even addresses, every third day or designated days), then the *duration* of irrigation should be modified based on plant water use (e.g., evapotranspiration [ET]).
5. Apply only enough irrigation water to replace the soil moisture depletion and the leaching fraction. Match irrigation application to soil type and root depth. Avoid applying more water than can be contained in the root zone. Daily plant stress observation is optimal to determine the appropriate changes in the irrigation schedule. If impractical, weekly plant stress observation should be conducted, at a minimum.
6. Until plants have developed deep roots, they may need more frequent watering than established plants. Because the root zone is not fully developed, irrigation should also be shorter in *duration*.
7. Water early in the morning or between the hours of 12 midnight and 6 A.M. when temperatures and winds are at their lowest levels to reduce evaporative water loss. Sprinklers also typically have better performance during these times due to higher water pressure.
8. Excessive irrigation after fertilization may cause leaching and surface runoff that pollutes waterbodies, while lack of irrigation may result in inefficient utilization of the fertilizer.
9. Water lawns and shrubs/perennial beds separately. (These should be on different irrigation zones, with different irrigation schedules.)
10. Water trees and shrubs, which have deeper root systems, longer and less frequently than shallow-rooted turf and plants.
11. When watering plants on slopes and/or in areas with compacted or clay soils, a series of several light applications (cycle and soak), instead of one continuous application, is typically appropriate to account for the lower infiltration rates of these soils. Irrigation schedules should also apply more water at the top of the slope and less at the base to prevent runoff.
12. Watering too frequently prevents oxygen from getting to the roots and may promote some diseases in the landscape.

13. Irrigation efficiency is equally dependent upon a good design, correct installation, good water management and proper maintenance. Use only qualified (e.g., licensed, certified as needed) irrigation professionals for all phases of irrigation projects.

Nursery, Greenhouse and Garden Center Irrigation Practices

In greenhouses and retail garden centers, consider the following practices to improve irrigation efficiency:

1. Group plants together that have the same water requirements (i.e., use hydrozoning).
2. Space containers under fixed overhead irrigation systems to maximize plant irrigation and reduce waste between containers.
3. Use drip tubes or spray sticks for each individual container, when practical.
4. When using programmable irrigation booms, adjust travel rate and flow rates (change in nozzle size) to crop needs.
5. Choose sub-irrigation systems where appropriate using ebb and flood or capillary mat irrigation technologies with a water-capture and reuse system. Fertilizer application rates for most sub-irrigation systems can be reduced by 50 percent.
6. Minimize leaching from containers by pulse-irrigating containers. Many textbooks recommend leaching greenhouse and nursery crops to 10 percent excess. This rate can be reduced to close to zero by reducing fertilizer rates and closely monitoring the electrical conductivity of the soil leachate or the root substrate.
7. Consider capturing leachate and pot-overspray water for recirculation. Fertility and pathogen levels in the collected water must be monitored. Water pasteurization systems including UV, ozone, chlorine and heat are all acceptable solutions. Storage of recycled water with fertilizers may be an issue.
8. Plug sprinklers that are not watering plants, keep sprinklers as low as possible to the plants and use larger water droplet size to reduce irrigation time.

Regional or Industry Considerations/Adaptations

1. Irrigation systems should be designed to account for local climate variation. Smart controllers are one tool that can be used to adjust watering to changing local conditions throughout the irrigation season. Also see the Irrigation Technology and Scheduling BMP.
2. Winter watering can be critical to minimize stress to trees, shrubs, plants and turf in areas receiving low winter precipitation. This is especially likely to be the case with newly planted evergreens. Use a hose connected to a frost-free hydrant for winter watering, instead of reactivating the irrigation system.

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Irrigation System Design

Description

Design the irrigation system for the uniform distribution of water. As part of the design process, develop a base irrigation schedule to promote the efficient use of water.

This BMP is based largely on practice guideline 2 from “Turf and Landscape Irrigation Best Management Practices” (The Irrigation Association 2005).

Basic Practice Guidelines

Design Principles

1. Design irrigation systems based on a direct knowledge and comprehensive understanding of site conditions including: soil type and infiltration rate; plant type, treatment and placement; site microclimates; site grading, slopes, exposure to wind and sun; water availability and source; size of irrigated area; available flow and pressure; water quality; water cost; historical reference evapotranspiration and annual rainfall; and the construction budget.
2. Consider site and irrigation system hydraulic factors, such as pressure, flow, friction losses, elevation changes, gravity drainage, pressure circumstances that require control devices and other factors associated with the water supply, when designing irrigation systems.
3. Irrigation systems should be designed to avoid runoff, low-head drainage, overspray or other conditions where water flows onto adjacent property, non-irrigated areas or hard surfaces such as sidewalks and roads.
4. Meet all applicable plumbing and electrical codes and specify proper protection of the water source (e.g., backflow prevention devices).
5. Follow these maximum safe flow practices with the lowest safe flow prevailing as the design guideline:
 - The maximum allowable pressure loss through the meter should be less than 10 percent of the inlet pressure at the meter.
 - The maximum flow rate through the meter should be 75 percent of the manufacturer’s specified maximum flow rate for the meter.
 - The velocity of water flow through the service line or pipe supplying the meter should not exceed 7.5 feet per second (fps).
 - Select main and lateral pipe sizes so that the velocity of water moving through the irrigation pipe does not exceed state and local requirements, or the industry standard of 5 fps.

BMP Type			
Design			X
Installation			
Maintenance/Operations			
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

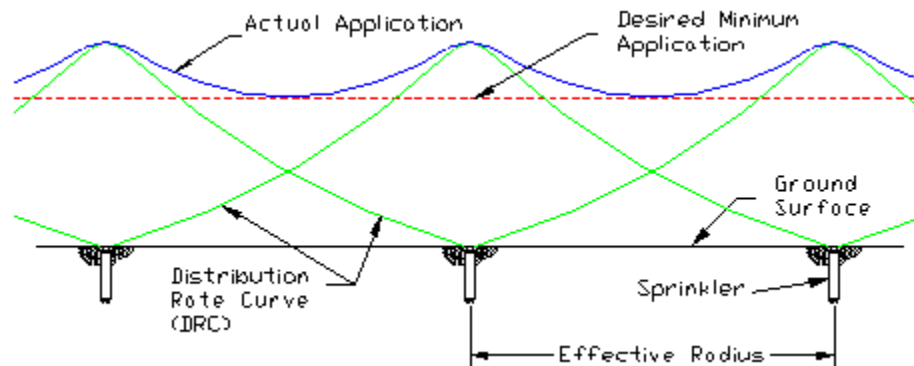
6. Design for an overall *operational* site lower-quarter distribution uniformity (DU_{LQ}) as shown in Table 1. These values recognize that some small or odd shaped areas are difficult to irrigate efficiently, while large open areas will likely be irrigated more efficiently.

Table 1
Minimum Operational Uniformity

Type of Zone	Type of Uniformity	Minimum Uniformity
Spray	Lower Quarter DU	55%
Rotor	Lower Quarter DU	70%
Drip/micro-irrigation	Emission Uniformity	80%

7. Design the layout of heads and other emission devices for zero overspray across or onto a street, public driveway or sidewalk, parking area, building, fence, or adjoining property. Overspray may occur during operation of the irrigation system due to actual wind conditions that differ from the design criteria.
8. When selecting system components, place a high priority on avoiding surface runoff. Select components to keep the sprinkler precipitation rate below the infiltration rate of the soil and/or use repeat cycles to allow the water to soak into the root zone. Separate stations/zones for sprinklers at the top and toe of sloped areas.
9. Properly size pipes for less than 10 percent variation in pressure within a zone, between the most distant sprinklers.
10. Base zone layout on soil properties, slope, plant water requirements, root zone depth, weather conditions, site conditions, supply pressure, and minimum/maximum acceptable application rates. Irrigation system design goes hand-in-hand with the landscape design—irrigation zones should correspond to hydrozones and microclimates on landscape plans. Always zone turf separately from plants and shrubs.
11. Specify manufacturer, model, type, and size of all components to eliminate ambiguity at construction and to facilitate management of the system. The selection of pipe, electrical wire and other materials shall be based on design parameters, environmental conditions and code requirements. Properly size valves and pipelines to maintain proper pressure and coverage (distribution uniformity) in irrigation system. The selected equipment should be appropriate for the size and use of the landscape to minimize water waste.
12. Design the system in accordance with the manufacturer’s recommendations for the selected system components.
13. For systems on a municipal supply, allow for a reduction in static pressure of up to 10 psi to accommodate possible expansion in the supply network.
14. Specify pressure regulation where variable or excessive static pressure exists.

15. Specify the recommended operating (working) pressure at the maximum design flow rate of the system.
16. Where applicable, specify a water source that meets peak demands for landscape water with an irrigation duration of no more than 10 hours per day. This guideline helps determine the correct size of the supply meter. Also consider local statutes, anticipated irrigation intervals, or site uses that may dictate different irrigation durations (for example, golf courses). This guideline is intended to match the system requirements to the particular site, not dictate the actual hours of operation on any given day.
17. Sprinklers and emitters should be selected for proper area coverage, consistent application rates, operating pressure, adjustment capability and ease of maintenance. Never mix different types of sprinklers within the same zone, or mix sprinklers from different manufacturers.
18. Properly space sprinklers based on nozzle performance and pressure requirements to provide uniform coverage, making sure to account for influences such as slopes and wind. The recommended maximum sprinkler spacing to obtain reasonable uniform coverage is “head-to-head.” Ensure that irrigation laterals have matched precipitation rates for the sprinkler arcs.



Head-to-head sprinkler spacing for uniform water distribution.
(Source: Stephen Smith, Aqua Engineering; as modified by Ram Dhan Khalsa).

19. For drip irrigation systems, properly select drip emitters to meet the different water needs of plants. On slopes, drip emitters should be placed uphill of the plants. Properly designed drip systems have a “potential” DU_{LQ} of 0.90 or higher. Specific design guidelines include:
 - a. Specify filtration at the control valve to remove particulate matter.
 - b. Separate drip/micro-irrigation zones from overhead irrigated zones since drip/micro-irrigation systems are not as susceptible to water losses due to evaporation, wind, or surface runoff. Separate zoning allows the irrigator to adjust water requirements given these differing conditions.
 - c. Consider differing plant water requirements and root zone depths and use separate

drip/micro-irrigation zones where practical.

- d. Specify pressure-compensated devices to improve overall uniformity.
 - e. Specify pressure regulation upstream from the drip/micro-irrigation components. Typically, the pressure of city water sources may be increased periodically by the city for flushing or other purposes, and can potentially damage a drip/microirrigation system that has no pressure regulator on the zone controls. Pressure compensated emitters do not serve this function. Pressure regulating devices can be omitted only when the absolute maximum possible pressure is known to be lower than the maximum allowable pressure for all drip/micro-irrigation components.
 - f. Connect (loop) the ends of individual laterals to improve system uniformity and limit possible contamination if drip tubing is damaged. This helps to equalize system pressure and can increase uniformity, and also allows water to flow from both sides of damaged drip tubing, thus flushing out any debris.
 - g. Use air release valves to minimize ingestion of dirt or other contaminants into the emitters.
 - h. Use flush valves to flush the laterals after completion of the irrigation cycle.
20. For commercial installations, specify a metering device that measures the total landscape water use separate from other use. For residential installations, a separate metering device is recommended.
21. Ease of installation, operation, and maintenance repair should be considered in the design. The selection and placement of sprinkler and drip/micro-irrigation components should be guided by the expected size of larger specimen plants through a minimum three-year establishment period for shrubs and ten years for trees.
22. Include provisions for future expansion, as needed, such as installation of spare control valve wires or larger components such as mainline pipe, etc.
23. Use drip/micro-irrigation where appropriate to reduce evaporation losses and surface runoff, and to avoid applying water on hardscapes.
24. Provide a monthly irrigation water budget.
25. In communities where a landscape water allowance applies, include an estimate of the future monthly landscape water allowance, based on historical reference ET, landscape area, and the landscape water adjustment factor provided by the purveyor or water provider.
26. Provide monthly base irrigation schedules where the frequency of irrigation (when to irrigate) depends on replenishing allowable depletion (how much to irrigate) of the soil moisture between irrigations based on monthly reference historical evapotranspiration data. For each station/zone (or hydrozone as applicable), the designer shall specify the plant type, soil type, average root zone depth, precipitation rate, lower quarter distribution uniformity,

area square footage, target gallons per minute flow rate, recommended operating pressure range, and maximum recommended cycle run time without runoff. The designer shall recommend a site specific rainfall factor to convert historical rainfall to effective rainfall. This is useful for budgeting purposes and for schedule compensation when a rain shutoff device is not installed.

Alternative Water Sources (*Also see the Nonpotable Water BMP.*)

27. Use recycled or non-potable water to the greatest extent possible, based on local availability and compliance with applicable regulations. Non-potable water supplies should be explored for large landscaped areas such as parks and golf courses. Design hardware should be compatible for use with non-potable sources, should they become available.
28. When designing systems using reclaimed water, ensure that applicable regulations are followed. For example, provide for required signage and cross-connection inspection in accordance with Colorado Department of Public Health and Environment Water Quality Control Commission *Regulation No. 84: Reclaimed Domestic Wastewater Control Regulation*.

Water Conserving Equipment and Methods (*Also see the Irrigation Technology and Scheduling BMP.*)

29. For long, narrow or small irregularly-shaped landscape areas, use drip irrigation designs to reduce evaporation losses and to avoid applying water on hardscapes such as roadways, parking areas, driveways, sidewalks, patios and decks. Planting beds and narrow turf strips can be particularly well suited to subsurface drip irrigation (SDI) systems. Do not install spray type sprinkler systems for median strips less than 8 to 10 feet wide.
30. Install a master valve to minimize leakage from a damaged irrigation system.
31. Consider soil infiltration rate, slope, and sprinkler precipitation rate when selecting sprinklers to reduce potential for runoff.
32. Specify low-angle sprinklers in windy areas to mitigate wind drift effect.
33. Specify water-conserving devices such as check valves, flow regulators and pressure regulators. Also, use climate sensors such as rain, freeze and wind sensors, etc., to suspend irrigation when unfavorable weather conditions exist. Proper location and installation are necessary in order for these technologies to be effective.
34. Install anti-drain (check) valves to minimize or prevent low-head drainage, or use sprinklers with a built-in anti-drain feature.
35. Pressure regulating valves should be used where pipeline pressure is greater than 10 psi or 20 percent different from design operating pressure. Flow regulators can be used in individual sprinklers to correct for differences in lateral pressure.

36. Specify water-conserving irrigation management methods such as smart controller technology that uses ET data or soil moisture sensors to automatically schedule irrigation.
37. Specify an irrigation controller that allows for flexible irrigation scheduling and water management, including features such as the use of repeat cycles to minimize runoff, water budgeting, and interfaces with various climate or environmental sensors to manage programmed irrigation schedules. (*Also see the Irrigation Technology and Scheduling BMP.*)
38. Avoid oscillating sprinklers and sprinklers that produce mists or fine sprays.
39. Consider pump intake filters to prevent plugging the pump impeller, and finer mesh filters on the discharge side of the pump where source water quality is an issue and to decrease plugging of irrigation equipment.

Documentation and Follow-up

40. Provide temporary irrigation schedules to establish new vegetation.
41. Provide a complete irrigation design package to the owner. Written irrigation plans should include: the precipitation rate for each zone; the calculated flow rate for each emitter or low-volume zone; an irrigation schedule for both the establishment and post-establishment plant life cycle periods; and a general operating schedule of run-times based on projected plant ET for each zone, during each month of the irrigation season. The manufacturer and part numbers for specified system components should also be provided. See the Irrigation Association for more detailed recommendations.
42. Assure overall quality of the irrigation system by ensuring that the properly-designed irrigation system is properly installed, managed, and maintained.

Regional or Industry Considerations/Adaptations

1. For landscape managers or growers who obtain water from irrigation companies, it is particularly important to identify and understand the method used to measure the amount of water provided, the delivery schedules, and water rights issues when designing an irrigation system.
2. In areas where drain ditch water is used, water may not be of sufficient quality for irrigation. A salt test (e.g., electrical conductivity [EC]) should be conducted on such water prior to selecting plant materials. *See the Nonpotable Irrigation BMP for more information.*

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Irrigation System Installation

Description

Install the irrigation system according to the design specifications, which should be in accordance with manufacturer’s specifications, local code requirements and sound principles of efficient and uniform water distribution.

This BMP is based directly on practice guideline 3 from “Turf and Landscape Irrigation Best Management Practices” (The Irrigation Association 2005).

BMP Type			
Design			
Installation		X	
Maintenance/Operations			
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

Basic Practice Guidelines

1. Install the irrigation system to meet the design criteria.
2. Contract with a licensed, insured, experienced and reputable irrigation professional to complete the installation.
3. Before commencing installation, verify that the point of connection, water supply, flow rate and static and dynamic pressures meet design criteria.
4. Contact all appropriate utility companies prior to beginning installation, to locate underground utilities including gas lines, electrical, telephone, cable, and so forth. State laws (and some Federal laws) require anyone who digs to notify utility companies before starting. Installation shall not be started until all underground utilities are located and marked.
5. Review planting plans prior to installation to minimize conflicts between larger plants and irrigation heads. Also review construction plans for conflicts between hardscape and sprinkler head placement.
6. Inform the property owner and irrigation designer of unusual or abnormal soil conditions which may impact the design and management of the irrigation system.
7. Ensure that the site drainage has not been altered for existing plant communities that are not planned to receive supplemental irrigation.
8. Install the irrigation system’s components according to the design specifications and manufacturer’s published performance standards.
9. Where deviations from the design are required (e.g., running pipe around a tree or other structure or adding sprinklers to an area larger than the plan shows), consult with the designer prior to making the change to ensure that the change is within design performance specifications. Redline the plan drawing to note any deviations.
10. Require that the architect, irrigation designer or local water district representative perform one or more field observations during system installation to check for adherence to the

design. The purpose of the observation is to check for proper installation and function of the backflow prevention assembly, main line, pipes, valves, sprinklers, control wire, irrigation controller and water conserving devices.

11. Furnish “as-built” record drawings to the owner of the system. The record drawings should describe the system layout and components including all changes from the original design.
12. Test the irrigation system to verify that the system meets the design criteria.
13. Create an irrigation schedule to meet the water requirements of the plants. Review the irrigation schedule, specifically its rationale and how to set irrigation days, station (zone) run times and start times. Review advanced programming features such as multi-cycle irrigation to prevent run-off and the use of the percentage water increase/decrease function.
14. Explain to the end user (or owner) the location and operation of the irrigation controller, valves, sensors, pressure regulators, backflow prevention device and sprinklers. Review advanced programming features such as multi-cycle irrigation to prevent run-off and the use of the percentage water increase/decrease function. Educate the owner on features and capabilities of the system including the maintenance requirements.
15. Provide the end user (or owner) with recommendations for landscape water conservation. Emphasize the following topics:
 - a. Maintaining proper operation of system components.
 - b. Landscape irrigation is meant to supply water to supplement rainfall.
 - c. Plant water requirements may change from day-to-day.
 - d. Importance of hydrozoning according to plant water requirements.
 - e. Benefits of using drip/micro-irrigation components.
 - f. Benefits of applying water-conserving landscaping practices such as the use of mulch and soil amendments.
 - g. Benefit of assigning someone to be held accountable for water use in the landscape.
16. Provide the end user (or owner) with product warranties and operating instructions for all equipment.
17. Perform an irrigation audit using an accepted procedure. Provide the end user (or owner) with system specifications and a performance summary report by station/zone that includes the plant type, soil type, average root zone depth, precipitation rate, lower quarter distribution uniformity (DU_{LQ}), area square footage, target gallons per minute flow rate, recommend operating pressure range, and maximum recommended cycle run time without runoff. Retain a reference of each station/zone’s DU_{LQ} , precipitation rate, operating pressure, and flow rate at the controller. A reference of each zone’s precipitation rate should be

retained at the irrigation controller.

Regional or Industry Considerations/Adaptations

1. Additional equipment protection may be necessary depending on site conditions. Extreme UV exposure, heat, wind or sub-zero temperatures may affect the equipment's service life.
2. Seal pipe threads, but do not over-tighten a plastic-cased sprinkler onto the riser: it can crack the sprinkler body, causing leaks.
3. Be sure to "flush-out" the irrigation system after installation to ensure that rocks, debris and soil are removed before the sprinklers are installed, so that the system functions properly.
4. When installing reclaimed water irrigation systems, be sure to provide appropriate cross-connection prevention devices and obtain appropriate inspections in accordance with the Colorado Department of Public Health and Environment Water Quality Control Commission *Regulation No. 84: Reclaimed Domestic Wastewater Control Regulation*.

Key References

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Irrigation System Maintenance

Description

Maintain the irrigation system for optimum performance, ensuring efficient and uniform distribution of water. Modify the irrigation system operation as needed to accommodate the changing plant water needs.

This BMP is based primarily on practice guidelines 4 and 5 from "Turf and Landscape Irrigation Best Management Practices" (The Irrigation Association 2005).

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

Basic Practice Guidelines

Basic System Maintenance Practices

1. Establish a systematic maintenance schedule for inspecting, testing and reporting on performance conditions of the irrigation system. Report any deviations from the original design. As part of a systematic maintenance program, it is important to:
 - Check, adjust and repair irrigation equipment on a regular basis, ideally on a weekly schedule and within 24 hours of mowing, whenever possible. Identify irrigation system leaks and repair them promptly. As part of day-to-day maintenance, staff should understand the irrigation system basics and be able to recognize system problems.
 - Post irrigation schedules, zone location map and other relevant programming information in each controller (or clearly identify where information is kept).
 - Inspect the irrigation system after annual activation in the spring and bring the system up to specified operating conditions. Particularly for large systems, make written notes of repairs so that a history profile can be developed to prioritize future improvements to the system.
 - For properties of one acre or more, employ a certified landscape-irrigation auditor at least once every five years to conduct a thorough and comprehensive check for efficiency of water application.
2. Immediately shut off irrigation systems and adjust whenever irrigation water falls or runs onto hard surfaces such as sidewalks, streets or driveways. Signs of leakage include overgrown or particularly green turf areas, soggy areas around spray heads and aboveground hoses, jammed spray heads and torn hoses. In drip systems, leakage problems may be due to damaged tubing from foot traffic or gnawing by animals.
3. Periodically perform a thorough inspection of the system components to verify that the components meet the original design criteria for efficient operation and uniform distribution of water, including:

- Verify that the water supply and pressure are as stated in the design. Differences in the sprinkler system's required design operating pressure and actual water pressure can affect distribution uniformities and operation efficiency. Install pressure reducing valves (PRVs) on laterals where needed, and flow control devices on individual sprinklers to stop misting due to excessive pressure. Verify that pressure regulators are adjusted for desired operating pressure.
 - Verify that the backflow prevention device is working correctly; annual testing is ideal, but not required in all areas.
 - Adjust valves and flow regulators for proper pressure and flow operation. Valves must shut off tightly to prevent leakage and soggy spots, and operate without slamming open or closed to prevent pipeline and sprinkler damage from water surges.
 - Verify that sprinklers are properly adjusted—check the nozzle, arc, radius, level and attitude with respect to slope.
 - Verify that sensors are working properly and are within their calibration specifications.
 - Look for debris (e.g., rocks, sand, and dirt) lodged in sprinklers and drip emitters and watch for salt build-up around drip emitters.
 - Examine filters and clean filtration elements as required.
 - Verify proper operation of the controller. Confirm correct date/time input and functional back-up battery.
 - Repair or replace broken hardware and pipelines with originally specified materials, thereby restoring the system to the original design specifications.
 - Complete repairs in a timely manner to support the integrity of the irrigation design and to minimize the waste of water.
 - Notify the end-user (or owner) of any deviations from the original design.
 - Test all repairs.
4. Ensure that the replacement hardware used for system repairs matches the existing hardware, and is in accordance with the design. Aftermarket replacement nozzles may not match original parts well enough to preserve distribution uniformity and the precipitation rate. Conduct a performance audit every three to five years to assure that the system is working efficiently and with the desired DU_{LQ} and precipitation rate specifications.
5. As plants mature, trim or remove vegetation as required to preserve system performance. Add additional sprinklers or other hardware as required to compensate for blocked spray patterns or changes in the irrigation needs of the landscape. Ensure that system modifications are in keeping with design specifications and do not cause landscape water demand to exceed the hydraulic capacity of the system.

6. Establish a “winterization” protocol (if required) and a corresponding process for system activation in the spring. Winterization primarily consists of removing all the water from the irrigation system and equipment to prevent cracked pipes, broken sprinklers and other problems. This is typically accomplished by turning off the main water supply, opening all drains and blowing the water out of all pipelines, valves and sprinklers with compressed air.
7. Whenever possible, update and retrofit existing irrigation systems to take advantage of new water-saving technology (e.g., rain shut-off devices, “Smart” controllers, soil moisture sensors, rotator nozzles and drip irrigation).
8. Ensure that the maintenance contractor is licensed, insured, experienced and reputable. The maintenance contractor should be legally authorized to maintain irrigation systems in the local jurisdiction.

Maintenance Practices for Managing Changing Water Needs of Plants

9. Manage the irrigation schedules to respond to the changing/seasonal requirements for plant water needs in the landscape. The most efficient systems match irrigation application amounts to landscape water requirements through effective irrigation scheduling. Whenever possible, irrigation scheduling should incorporate the use of evapotranspiration data, soil moisture measurements and precipitation data.
10. Reset automatic controllers according to the seasonal plant needs. Irrigation controllers should be inspected at least bi-monthly to change irrigation frequencies or run times.
11. Understand the capabilities of the irrigation controller and use these features to efficiently irrigate (*See the Irrigation Technology and Scheduling BMP.*)
12. Establish a water budget based upon system performance and plant water requirements. Use the water budget to compare actual water usage to the amount of water budgeted.
13. Perform irrigation audits (if current data don’t exist) to obtain precipitation rates and distribution uniformity data needed to create irrigation schedules.
14. Understand and use a reliable source for grass reference ET (ET_o) rates (See Appendix F). Appropriately modify reference ET to calculate local water needs (plant ET) for the various plants and turfgrass in the landscape. Identify soil types and root depths of each zone and determine soil water-holding capacities. Calculate the run-time of each zone to supply the needed water based upon the “actual” distribution uniformity and precipitation rate of the sprinkler zones, the water-holding capacity of the soil, the changing weather conditions (ET) and the plant’s water requirements. Set the schedule cycles to minimize runoff.
15. Periodically verify that the plant material is healthy and that soil moisture is adequate. Use a soil probe to visually inspect root depth, soil structure and moisture.

16. The irrigation system is a management tool and cannot replace the sound judgement of trained professionals. The best-designed irrigation system will fail without regular maintenance.

Regional or Industry Considerations/Adaptations

1. In cases where maintenance BMPs cannot be met due to existing problems with the irrigation system, it may be necessary to recommend system renovation or replacement. Also see the Irrigation Audit BMP.
2. Large, managed landscapes, such as golf courses and parks, require trained managers for operating irrigation systems. This requires understanding of the irrigation equipment as well as parameters such as plant ET and soil infiltration rates. Water audits of these large systems are important to ensure that the system is performing properly.
3. Large, managed landscapes and commercial operations should prepare a written irrigation management site plan that clearly identifies responses and priorities during water-limited situations such as various stages of drought. The plan should be part of a comprehensive landscape management plan that addresses other management practices such as mowing, fertilizing, etc.
4. Cross-connection and backflow prevention devices must be inspected on an annual basis by a certified cross-connection control technician if recycled (reclaimed) domestic water is used.

Key References

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Irrigation Efficiency Audits

Description

Auditing existing irrigation systems to identify needed improvements is a key tool in reducing landscape water waste and improving irrigation efficiency. This process is sometimes called a “catch can test.” This BMP is divided into two important components: the pre-audit to correct existing malfunctions in the irrigation system and the irrigation audit itself, which is used to assess distribution uniformity and precipitation rates for the irrigation system.

BMP Type			
Design			
Installation			
Maintenance/Operations			X
Green Industry Relevance			
ASLA		GCC	
ALCC	X	ISA	
CALCP	X	RMSGGA	
CNGA		GCSAA	X

Basic Practice Guidelines

The majority of the guidelines presented in this BMP were developed by the Irrigation Association (IA 2007) and are intended to function as recommendations in the evaluation and performance of landscape irrigation systems. The IA recommends conducting irrigation audits approximately once every five years. These guidelines have been designed to aid landscape professionals in fieldwork procedures and in irrigation performance calculations and techniques. Recommendations and projections from the guidelines and their accuracy depend upon the quality of measurements and data provided by the individual user. The Irrigation Association makes no warranty, implied or expressed, as to the results obtained from these procedures. The Irrigation Association intends that these procedures be used as guidelines, not a set of regulations or standards.

STEP #1: PRE-AUDIT ASSESSMENT AND SYSTEM CORRECTION

1. Complete a pre-site inspection to document system components and conditions. As part of this step, obtain as-built drawings and water use history for the past three years, where available.
2. Determine whether irrigation system meets all local codes.
3. Repair operational defects so that the system is in working condition. Make sure all heads are in proper position.
4. Schedule the inspection after a mowing day to reduce interference from tall grass.

The Colorado WaterWise Council has developed a “pre-audit” form, which can be used as a checklist to document the landscape and irrigation system conditions. This form is provided in Appendix G and can be easily understood by a homeowner. In many cases, correction of the items identified in the pre-audit significantly improves irrigation system performance.

Representative items covered in the pre-audit checklist include:

- Documentation of existing irrigation schedule and methods of adjustment over the irrigation season.

- Description of irrigation system zone (station) equipment.
- Description of water saving devices (e.g., rain shutoff, soil moisture sensor, weather-based controllers).
- Description of landscape features (e.g., slope, exposure, soil conditions, plant types and conditions in each zone).
- Condition of sprinkler nozzles (e.g., broken, tilted, spray direction) and drip systems (e.g., plugged, missing pressure regulator).

STEP #2: IRRIGATION EFFICIENCY AUDIT

The irrigation efficiency audit, which assesses distribution uniformity and precipitation rates, is completed by conducting a catch-can test and comparing the average distribution uniformity of the lower quarter of the catchment samples (DU_{LQ}) with the overall average of catchment samples (DU_{AVG}). A good distribution uniformity is indicated by the average values of the lower quarter being similar to the overall average.

Test Conditions (as specified by the Irrigation Association)

1. Maximum wind allowable during audit = 5 mph or less (ASAE S398.1). Wind speed must be monitored and recorded every 5 minutes during audit.
2. Audit must be conducted under normal operating conditions.
3. Pressure tests must be conducted at normal operating conditions at the sprinkler using the appropriate pressure testing device at the beginning, middle and end of operation of each audited zone.

Placement of Catchments

4. Catchments (“catch cans”) for a test area should be aligned on a grid layout. All catchments must be uniform in size and type. See photo.
5. The catchments along the edge of the zones should be placed 12 to 24 inches in from the edge.
6. Catchment spacing
 - a. For fixed spray sprinklers – near a head and half-way between the heads.



Placement of catch cans for irrigation efficiency audit.
Photo Source: Kenneth Solomon

- b. For rotor heads, less than 40 ft radius – near a head and every 1/3 of the distance between the heads.
 - c. Rotor heads, greater than 40 ft radius – near a head and every 1/4 of the distance between the heads.
7. Unusual areas
- a. Large areas, rotor sprinklers – uniform grid, 10 to 15 ft spacing (i.e., infield for baseball field).
 - b. Small areas, spray sprinklers – uniform grid, 5 to 8 ft spacing (i.e., narrow turf area less than 6 ft wide).

Test Run Times

- 8. Test run times must be consistent among zones.
- 9. When the test area contains multiple zones, the zone run times must be adjusted to achieve a matched precipitation across the test area.
- 10. Rotor sprinklers must run for a minimum of five rotations during the test.
- 11. All catchment volumes must be read in milliliters (mL), and it is recommended that a minimum of 25 mL of water be collected.

Data Collection and Recording

12. The following data must be documented:
- a. Catchment locations
 - b. Catchment volumes
 - c. Testing run times
 - d. Sprinkler locations
 - e. Sprinkler spacing
 - f. Pressure readings with locations
 - g. Make, model, nozzle of sprinklers
 - h. Soil types and root zone depths
 - i. Wind speed readings
 - j. Date and time of testing

STEP #3. CALCULATE DISTRIBUTION UNIFORMITY

13. The lower quarter distribution uniformity (DULQ) is calculated with the following method:

Step 1: Order the individual catch-can volumes in a list from smallest to largest. (Spreadsheets help to significantly reduce calculation time. Download the Turf Irrigation Management Program [TIM] from Northern Colorado Water Conservancy District [www.ncwcd.org] for an Excel spreadsheet that automates this process.)

Step 2: Separate out the catchment values for the quarter of the cans containing the least amount of water. Calculate the average catchment volume of these cans (V_{LQ}).

Step 3: Calculate the average catchment volume for all the cans (including the low quarter) (V_{avg}).

Step 4: Calculate the lower quarter distribution uniformity (DU_{LQ}) as a percentage using the following formula:

$$DU_{LQ} = (V_{LQ} / V_{avg}) \times 100$$

Where:

V_{LQ} = Average Catch Volume in Lower Quarter (mL)

V_{avg} = Average Catch Volume in Zone (mL)

DU_{LQ} = Distribution Uniformity (in %)

Figure 1. Turf Irrigation Management Audit Spreadsheet
(download from www.ncwcd.org)

Northern Colorado Water Conservancy District							
<i>Irrigation Auditing Calculation Sheet</i>							
Date:	<input style="width:100%;" type="text"/>			Auditor:	<input style="width:100%;" type="text"/>		
Site:	<input style="width:100%;" type="text"/>			Controller:	<input style="width:100%;" type="text"/>		
Audit Column	A	B	C	D	E	F	G
Audit Area	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
Precip. Rate:							
Total Volume:							
# of Catch Cans:							
Average Volume:							
LQ Ave Volume:							
DU_{LQ}:							
Sprinkler Area Data							
Run Time:	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
Catch Can Area:	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
Catch Can Readings							
1	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
2	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
3	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
4	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
5	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
6	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
7	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
8	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
9	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
10	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
11	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
12	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
13	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
14	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
15	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
16	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>
17	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>	<input style="width:100%;" type="text"/>

14. Table 1 can be used to assign a qualitative rating to the lower quarter uniformity (DU_{LQ}) for overhead irrigation systems, rated as “excellent, very good, good, fair, or poor” based on the type of sprinkler head used in the zone. If the overall DU_{LQ} has a rating of “fair” or “poor,” consider redesigning the system, replacing sprinkler heads that are not performing well, adjusting sprinkler head spacing, adjusting alignment and radius of throw, adjusting relative timing of overlapping zones, and correcting operating pressure problems.

Table 1. Irrigation Association Ratings of Lower Quarter Distribution Uniformity for Sprinkler Zones (Source: Irrigation Association 2001)

Type of Zone	Excellent (%)	Very Good (%)	Good (%)	Fair (%)	Poor (%)
Fixed Spray	75	65	55	50	40
Gear Driven Rotor	80	70	65	60	50
Impact Rotor	80	70	65	60	50

15. Table 1 can be used as a guideline for initial planning and design purposes in addition to use in system performance evaluation. While DU_{LQ} as measured with catch-cans is a good indication of sprinkler hardware performance, it does not always accurately reflect soil moisture uniformity within the root zone. This is because of the tendency of soil moisture to migrate horizontally, which is not reflected in catch-can measurements. Based on a study in turfgrass irrigation using test plots with different soil textures, an improved representation of soil moisture uniformity *for scheduling purposes* is the *lower-half* of the distribution uniformity (Irrigation Association 2005).
16. The catch can results can also be used to calculate the net precipitation rate for irrigation scheduling purposes. The net precipitation rate (PR_{net}) is based on the amount of water that actually reaches the landscape using the following formula:

$$PR_{net} = (3.66 \times V_{avg}) / (t_R \times A_{CD})$$

Where:

- PR_{net} = zone precipitation rate (inches/hr)
- V_{avg} = average catch volume for zone (mL)
- t_R = test run time (min)
- A_{CD} = catch device throat area (in^2)
- 3.66 = constant for unit conversion

Regional or Industry Considerations/Adaptations

1. Some local governments may offer rebates for irrigation audits, particularly for large commercial properties or other high volume irrigation customers. Check with your water utility to see what programs or incentives are currently offered for large irrigators.

2. The Irrigation Association offers a software program to calculate the DU_{LQ} and precipitation rate, along with generic audit forms, downloadable from www.irrigation.org.
3. The Irrigation Association offers guidance on scheduling methodology and procedures are provided in the Golf Irrigation Auditor and Landscape Irrigation Auditor Manuals.

Key References

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Irrigation Technology and Scheduling

Description

Irrigation systems can be equipped with a variety of water conserving devices such as soil moisture sensors, rain sensors and shutoff devices, weather stations, high wind shutoff devices, freeze protection devices, and advanced, automated, “Smart” control systems that incorporate evapotranspiration (ET) conditions. Over the past decade, such devices, which were once used predominantly for large landscapes, are now affordable for many homeowners and smaller commercial properties. Green Industry professionals should be aware of the benefits of water conserving technology and encourage its use.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGAA	X
CNGA	X	GCSAA	X

Irrigation scheduling addresses the frequency (how often) and duration (how long) of water application. Because one of the key benefits of advanced irrigation technology with regard to controllers (clocks) is increased ease of scheduling and more precise scheduling, irrigation scheduling is also discussed as part of this BMP.

Basic Practice Guidelines

1. Be aware of the various categories of irrigation technology that can increase water efficiency and know the strengths and weaknesses of each. Table 1 summarizes some common water waste problems and identifies some technology-based solutions to the problems.

Representative categories of water saving devices include:

- | | |
|---|--|
| <ol style="list-style-type: none"> a. Rain sensors or shutoff devices b. Soil moisture sensors c. Wind shutoff devices d. Smart controllers (ET or soil moisture controllers) e. ET add-ins to conventional controllers (e.g., add an ET component without replacing the whole controller) f. Drip irrigation for non-turf areas g. Sub-surface drip for turf areas h. Rotary nozzles for spray heads | <ol style="list-style-type: none"> i. Real-time flow sensing (this feature identifies abnormally high water use and shuts down the system) j. Mini-weather stations that incorporate rain, wind and freeze devices k. Central control systems for large common areas, playing fields, golf courses, etc. l. Pressure regulating devices (e.g., flow compensating nozzles at individual sprinklers or pressure regulators on irrigation valves) |
|---|--|

2. In addition to these specific devices, many contemporary basic irrigation controllers incorporate a “percent key” or “global adjust key” that enables adjustment of the irrigation system based on a water budget. For example, in May, a user could easily schedule the controller to apply only 25% of the peak water budget for July.

Table 1. Common Sources of Water Waste in Irrigation Systems and Possible Technology Based Solutions (Source: Adapted from Rain Bird 2008)

Runoff Problem	Irrigation System Related Solution
Misting and fogging due to high pressure	<ul style="list-style-type: none"> • Install pressure regulating devices, which can have an added benefit of reducing water waste when the nozzle is missing or damaged. In addition to reducing misting and fogging, distribution uniformity can be improved because the nozzle will be operating at optimum pressure.
System leakage at low point	<ul style="list-style-type: none"> • Install in-stem check valves to prevent water from draining out of the system at the lowest head.
Overwatering due to nozzle issues	<ul style="list-style-type: none"> • Replace mismatched nozzles to ensure matched precipitation rates. • Separately zone spray heads and nozzles. • Consider replacing old nozzles with high efficiency nozzles being sure to match precipitation rates and adjust irrigation scheduling accordingly.
Runoff due to compacted soils or slopes	<ul style="list-style-type: none"> • Install controllers with multiple start times (“cycle and soak”) features to enable irrigation precipitation rates to be less than the soil infiltration rate.
Overwatering of shrubs and beds	<ul style="list-style-type: none"> • Install drip irrigation systems to deliver water directly to the plants roots.
Overwatering due to Weather or Seasonal Changes	<ul style="list-style-type: none"> • Automatic shutoff devices when raining or windy. • Controllers with rain delay features (postpones irrigation following rain). • Controllers with water budget features and weather based (e.g., ET) programming. • Controllers based on soil moisture sensors (e.g., based on “managed allowable depletion” [MAD]).
Overwatering due to varying plant types and environmental conditions	<ul style="list-style-type: none"> • Controllers with multiple independent programs that accommodate watering based on “hydrozones” requiring differing frequencies and durations of irrigation.

3. Minimum features that should be included on irrigation controllers include:
 - a. Select watering days
 - b. Multiple start times (cycle and soak feature)
 - c. Multiple run times for different zones
 - d. Programmable rain delay
 - e. “Percent key,” “global adjust key” or basic water budgeting features
 - f. Master valve option
 - g. For more complex controllers, a diagnostic feature to help identify problems and battery backup
4. Technology has also evolved for sprinklers; a few examples to consider include:
 - a. Rotary nozzles for spray heads which allow lower precipitation rates (e.g., 60-75% less than conventional spray nozzles) and more heads per zone, reducing overall system complexity and cost. These nozzles have multiple rotating streams that uniformly distribute water, typically in the 10 to 30 foot range.
 - b. Check valves that eliminate water draining out of the lowest head.
 - c. Pressure regulating sprinkler heads for improved uniformity.
5. Drip irrigation systems should include operating specifications that include pressure compensating and non-draining emitter features.
6. Central control systems are not discussed in detail in this Manual due to their nuances and site-specific complexity. Briefly, these are computer-based systems that allow programming, monitoring and operation from a central location. Example applications include a single large site such as an office park or multiple sites owned by a single entity such as a school district or parks department. Central controls can monitor and automatically adapt system operation and irrigation run times in response to conditions in the system (e.g., pipe break) and surrounding weather. Green Industry professionals operating such systems should be well-trained to ensure proper operation of the system. Often, the product vendor offers training on this type of product.
7. Irrigation equipment manufacturer’s catalogues are good sources of information. Typically, a good catalogue will identify which types of sprinklers are designed for different areas (e.g., turfgrass at high or low mowing heights, high traffic areas, high winds, high vandalism areas, reclaimed water, etc.). Keeping these catalogues handy in maintenance vehicles can also help to ensure that nozzle replacements are based on matched precipitation rates when sprinklers are repaired. Similarly, catalogues will also identify which types of valves are most appropriate for lower quality water, high pressure systems or reclaimed water.
8. Educate employees and clients on the proper functioning of water conserving technology. An improperly programmed advanced irrigation controller can result in as much or more water waste than conventional technology. Also, advanced controllers do not correct existing problems in distribution uniformity or other irrigation system damage—these controllers are

just one tool to promote water efficiency.

9. Consider these issues when using advanced irrigation technology:
 - a. The best irrigation technology is only as good as the operator who uses it.
 - b. Do not disconnect or override technology without good reason.
 - c. Be sure to reset controllers to the active technology mode after manual operation.
 - d. New technology must be learned. Do not hesitate to contact the manufacturer for information on operation and maintenance.
 - e. Keep operation manuals, zone descriptions (e.g., locations, precipitation rates, landscape types, irrigation types) and irrigation schedules with the controller for future reference.
 - f. Train customers on the operation of all new irrigation equipment and educate the customer regarding irrigation schedules.
 - g. For new landscape installations, the landscape installation is not complete until the initial landscape establishment irrigation schedule is replaced with the normal irrigation schedule.
10. Be aware that advanced irrigation technologies have in many cases decreased significantly in cost, enabling cost recovery over a shorter time period of time, which may be particularly relevant in locations where tiered rate structures are in place. Some water providers also offer rebates for certain water saving devices.
11. Several resources are easily downloadable for use in evaluating the benefits and drawbacks of various control technologies, including:
 - Irrigation Association Smart Water Advanced Technology (SWAT™) performance reports for various technologies (www.irrigation.org).
 - U.S. Environmental Protection Agency's new WaterSense labeling program (U.S. Environmental Protection Agency (www.epa.gov/WaterSense)).
 - U.S. Bureau of Reclamation's (2007) report: *Weather and Soil Moisture Based Landscape Irrigation Scheduling Devices*, which evaluated the performance of weather based controllers from 20 different manufacturers and soil moisture based products for eight manufacturers. See (www.usbr.gov/waterconservation/docs/Controller2006.pdf) for the evaluation results.
 - Northern Colorado Water Conservancy District has demonstration projects utilizing various technologies (http://www.ncwcd.org/ims/ims_turfandurban_demos.asp) and hosts an annual Field Day in the fall.



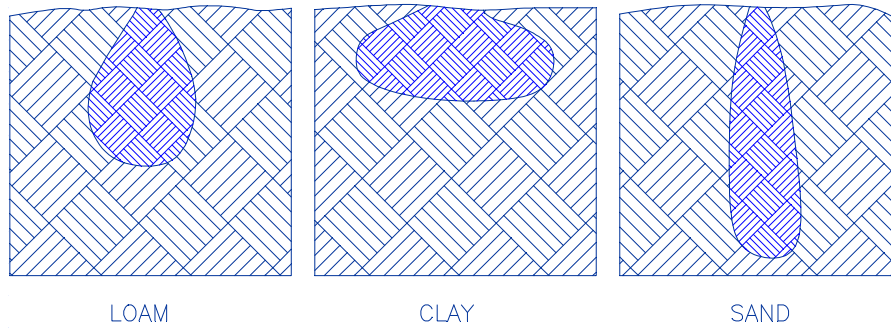
WaterSense is a partnership program sponsored by the U.S. Environmental Protection Agency. Its mission is to protect the future of our nation's water supply by promoting and enhancing the market for water-efficient products and services. The WaterSense program will intersect the Green Industry in two areas: 1) certification of irrigation professionals and 2) labeling of products. For more information on products with the EPA WaterSense label, go to <http://www.epa.gov/watersense/>.

EPA established specifications on October 27, 2006, to recognize certification programs for irrigation professionals in three areas: system design, installation and maintenance, and system auditing. Any certification program that meets the criteria outlined in the specification for one of these areas will be eligible for the WaterSense label.

With regard to products, the program focuses on labeling of weather- or sensor-based irrigation control technology that uses local weather and landscape conditions to tailor irrigation schedules to actual conditions on the site or historical weather data. Instead of irrigating according to a preset schedule, advanced irrigation controllers allow irrigation to more closely match the water requirements of plants. These new control technologies offer significant potential to improve irrigation practices in homes, businesses, parks, and schools across the United States. WaterSense plans to label landscape irrigation systems and controls.

Irrigation Scheduling

1. Irrigation scheduling is where all aspects of the green industry come together: soils, slopes, plant types and health, aspect/exposure, irrigation technology, etc. To properly schedule irrigation, it is necessary to consider all of these factors in order to determine the appropriate application rates and frequencies. Schedules should be based on a water budget that considers:
 - Sprinkler precipitation rates (know how much water is being applied). Be sure to recognize differences for drip irrigation systems such as the size and number of emitters, as well as scheduling run times in terms of hours rather than minutes.
 - Soil characteristics such as infiltration rates, water holding capacity and maximum allowable depletion (precipitation rates should not exceed infiltration rates; this can be controlled by multiple cycles instead of one continuous cycle).
 - Plant water requirements (based on ET, adjusted seasonally).
 - Weather monitoring/rain shut-off features.
 - Local government regulations governing water times and frequencies (in some cases).



When establishing irrigation durations and frequencies, take into consideration the water holding capacity of soil.

Diagram Source: Stephen Smith, Aqua Engineering.

2. When selecting a controller, it is important to match the customer and expected maintenance staff to the complexity of the device so that irrigation scheduling is completed correctly and adjusted regularly. The controller selected should be reliable, flexible and relatively easy to use based on the experience of the operator.
3. Irrigation application rates should not exceed the infiltration rate of the soil. This is particularly relevant on clay soils and slopes. See Table 2 for maximum precipitation rates recommended by the U.S. Department of Agriculture, based on slope, soil texture and vegetative cover.

Table 2. Maximum Precipitation Rates for Slopes

Maximum Precipitation Rates for Slopes (inches/hour) (Source: U.S. Department of Agriculture)								
Soil Type	0% to 5% slope		5% to 8% slope		8% to 12% slope		12%+ slope	
	Cover	Bare	Cover	Bare	Cover	Bare	Cover	Bare
Coarse sandy soils	2.00	2.00	2.00	1.50	1.50	1.00	1.00	0.50
Coarse sandy soils over compact subsoils	1.75	1.50	1.25	1.00	1.00	0.75	0.75	0.40
Light sandy/loam soils	1.75	1.00	1.25	0.80	1.00	0.60	0.75	0.40
Light sandy/loam soils over compacted subsoils	1.25	0.75	1.00	0.50	0.75	0.40	0.50	0.30
Silt/loam soils	1.00	0.50	0.80	0.40	0.60	0.30	0.40	0.20
Silt/loam soils over compacted subsoils	0.60	0.30	0.50	0.25	0.40	0.15	0.30	0.10
Heavy clay or clay/loam soil	0.20	0.15	0.15	0.10	0.12	0.08	0.10	0.06

4. Be aware that scheduling for drip emitters requires longer run times than conventional pop-ups and rotors. Adjust irrigation run-times according to the desired application volume.

Table 3. Guidance for Drip Emitters (adapted from Hunter 2008)

Emitter Discharge Selection (gallons per hour [gph])									
Soil Type	Heavy Clay			Loam			Sandy		
Discharge	0.5 gph			1 gph			2 gph		
Number of Emitters/Plant									
Canopy (ft)	1'-2'	3'-4'	4'-5'	6'-7'	8'-9'	10'	11'-12'	13'-14'	15'
# of Emitters	1	2	3	4	5	6	7	8	9

- Spreadsheet-based scheduling tools can aid in combining the various factors (e.g., soils, plant types, sprinkler precipitation rates, ET data) needed to develop a sound irrigation schedule. Northern Colorado Water Conservancy District offers two free downloadable programs: the Turf Irrigation Management Program (TIM) and the Checkbook Irrigation Scheduling (CIS) Program (www.ncwcd.org). (Tip: To enable macros to run properly, set Microsoft Excel security to “medium.”)

Figure 1. Example Irrigation Scheduling Spreadsheet (www.ncwcd.org)

Northern Colorado Water Conservancy District
Irrigation Scheduling Worksheet

Date: Site Description:

Reference ET:

Ret. Period (Days): Irrigation Frequency:

Soil Type: Root Depth (in): Avail. Water:

Audit Column (A, B, C, etc.)	PR	DU	K _c	Average Daily Plant Water Rqmt	Run Time Mult.	Zone
1						1
2						2
3						3
4						4
5						5
6						6
7						7
8						8
9						9
10						10
11						11
12						12

Schedule

Cycles

Run Time Range	Max Cycle Length	Total Run Time	Run Time Per Cycle	Zone
				1
				2
				3
				4
				5
				6
				7
				8
				9
				10
				11
				12
Total Minutes				

Enter Cycle Start Times:

Program	1	2	3	4
A				
B				
C				
D				

Regional or Industry Considerations/Adaptations

1. Be aware that many local communities designate certain watering days, regardless of whether advanced technology is being used. In many cases, the watering days are implemented to manage water pressure and peak demand capacity for the water supplier, regardless of whether drought restrictions are in place.
2. Many irrigation supply companies provide purple covers for spray heads (as well as other system components) to identify non-potable or reclaimed water as a source. Additionally, reclaimed water users should select valves that are resistant to chemicals and conditions present in reclaimed water.
3. When using reclaimed water, be aware that some soil moisture sensor based systems provide an added benefit of identifying when salt concentrations have reached levels requiring leaching, based on electrical conductivity (EC) measurements.

Key References

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U.S. Environmental Protection Agency (www.epa.gov/WaterSense)

Irrigation Using Nonpotable Water

Description

Nonpotable water may be used for irrigation purposes as a method to conserve potable or higher quality water sources for human consumption (drinking water). Nonpotable water sources are not treated to potable (drinkable) water standards and may include water from ditches, lakes, ponds, or a reclaimed (wastewater) treatment system. Use of reclaimed (treated sanitary wastewater) water, is a viable nonpotable water source in some of Colorado. Where available, usage of reclaimed water (treated wastewater) for irrigation can help to preserve potable water resources. In Colorado, use of reclaimed water for irrigation is most common on large landscapes used for recreation or commercial properties.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

This BMP is divided into general non-potable water practices, followed by reclaimed water practices. Although rainwater harvesting and greywater reuse are advocated as conservation measures for landscape irrigation in some parts of the country, these practices are not legally permitted under most circumstances in Colorado (see sidebar at the end of this BMP).

Many of the practice guidelines related to reclaimed water use in this BMP have been developed based directly on work completed for Denver Water by Aqua Engineering (2004) and Yaling Qian, Colorado State University (2005). These papers were provided courtesy of Donna Pacetti, Denver Water. These sources should be credited as sources of much of the technical information contained in the reclaimed water portion of the BMP.

Basic Practice Guidelines

General Nonpotable Water Guidelines

1. Where untreated water is available for irrigation and is of reasonable water quality to support vegetation, such sources should be considered to conserve potable water sources. Prior to relying on such sources, water quality should be tested to determine its suitability and/or potential mitigation strategies needed for the water source. In situations where problematic water quality and/or soil quality conditions are identified, the landscape professional should consult a qualified expert for guidance.
2. Salt problems may be introduced to a landscape through a combination of irrigation water management strategies, salt in the water, fertilizer, pre-existing high salt content in the soils, a high water table, or previous irrigation practices. Soils should be tested a minimum of once per irrigation season at sites using nonpotable water for irrigation without a history of soil problems, and more frequently at sites with poor vegetation conditions or that have a history of soil problems.
3. In addition to water chemistry considerations, the physical characteristics of the water must be taken into consideration, for example, water transferred in ditches or pumped directly

from streams or ponds may contain sediment that can clog or damage irrigation equipment. Filters or screens should be considered when designing such irrigation systems.

4. All new underground raw irrigation water conveyance systems should comply with the existing standards of the responsible irrigation or drainage company, district, association, or other entity. In designing such systems, factors such as water rights, pipe materials specifications, pressure and flow velocities, backfill materials and other typical design criteria must be considered. A special consideration for raw water includes inlet design features that minimize the intake of trash and sediment. Standard drawings are available from the Natural Resources Conservation Service, county governments and others regarding design of such features. Additionally, the pipes should be designed to enable flushing sediment from the pipe.

Reclaimed Water for Irrigation

Reclaimed (treated) wastewater for landscape irrigation is an approach to maximize existing water resources and help to stretch existing urban water supplies. For this reason, it is encouraged as a BMP by GreenCO. However, when reclaimed water is used, it is critical that those involved in planning, design, installation and maintenance be well informed of special measures needed to protect human health, the irrigated landscape, and surface and groundwater quality. These BMP guidelines provide a brief overview of some of the water quality/human health considerations for reclaimed water, followed by landscape-related guidelines.

Factors to Consider Before Planning a Reclaimed Water Irrigation System

5. Green Industry professionals must comply with Colorado Department of Public Health and Environment (CDPHE) regulations when designing, installing, maintaining and operating reclaimed water systems.
6. Prior to implementing a reclaimed water irrigation system, documentation of reclaimed water quality characteristics is required, particularly with regard to sodium, salinity and nutrient content (Qian 2005).
7. In addition to the reclaimed water quality, existing site conditions must also be clearly understood. Soil type, turf type, shrub and tree species, and irrigation efficiency should also be considered. For example, clay soils are more prone to salt accumulation and sodium deterioration. Additionally, shallow groundwater can introduce salts to the root zone (reduce leaching). A thorough understanding of these types of existing conditions is important when evaluating the initial feasibility of reclaimed water use at a site, as well as in developing long term irrigation and landscape management strategies.
8. For new landscape installations that will be irrigated with reclaimed water, proper soil amendment and preparation, typically including rototilling high quality, low-salt soil amendment, is important, based on results of soil tests. Additionally, soil compaction from construction equipment should be avoided after the soil is amended. (See the Soil Amendment BMP for more information.)

9. Plan for a separate water source for blending or leaching, adhering to applicable regulations (e.g., cross-connection controls). This source can be a raw surface water supply, potable water supply, or other source.
10. Assess the requirements (or economic advantages) of providing seasonal or daily operational volume of onsite reclaimed water storage (e.g., a golf course pond).
11. Remember to specify purple piping and appurtenances, including heads and valve covers.

Water Quality Regulations

12. Use of reclaimed water in Colorado is regulated by the CDPHE Water Quality Control Division under Regulation No. 84, Reclaimed Water Control Regulation. (Additionally, the supplier of the reclaimed water must possess water rights allowing the use of the reclaimed water for irrigation. Water rights in Colorado are administered by the State Engineer’s Office.) This regulation identifies how reclaimed water may be used for irrigation, identifies minimum treatment requirements and water quality standards, identifies conditions of use, public education/signage, and monitoring, record keeping and reporting requirements. Representative standards are summarized in Tables 1 and 2. In order to legally use reclaimed water for irrigation, both the entity treating the wastewater and the end user must receive a Notice of Authorization from the Water Quality Control Division prior to any use of reclaimed water. Civil and criminal penalties may apply to improper use of reclaimed water for landscape irrigation. For this reason, Green Industry professionals must familiarize themselves with the terms of use of reclaimed water on properties that they maintain or manage. Obtaining information about the source of water, water quality and seasonal water quality fluctuations is important for Green Industry professionals.

Table 1. Water Quality Standards for Categories of Reclaimed Water

(Source: CDPHE 2007)

Water Quality Category	E. coli (#/100 mL)	Total Suspended Solids (mg/L)	Turbidity (NTU)
1 (Secondary Treatment +Disinfection)	126/100 ml monthly geometric mean and 235/100 ml single sample maximum.	30 mg/L as a daily maximum.	NA
2 (Secondary Treatment +Filtration + Disinfection)	126/100 ml monthly geometric mean and 235/100 ml single sample maximum.	NA	Not to exceed 3 NTU as a monthly average and not to exceed 5 NTU in more than 5 percent of the individual analytical results during any calendar month.
3 (Secondary Treatment +Filtration + Disinfection)	None detected in at least 75% of samples in a calendar month and 126/100 ml single sample maximum.	NA	Not to exceed 3 NTU as a monthly average and not to exceed 5 NTU in more than 5 percent of the individual analytical results during any calendar month.

Table 2. Approved Uses of Reclaimed Water for Landscape Irrigation
(Source: CDPHE 2007)

Approved Landscape Irrigation Uses	Category 1	Category 2	Category 3	Additional Conditions (See Notes)
Restricted Access	Allowed	Allowed	Allowed	
Unrestricted Access	Not Allowed	Allowed	Allowed	1
Resident-Controlled	Not Allowed	Not Allowed	Allowed	1,2
Applicable Table Notes from CDPHE (2007):				
<p>¹No reclaimed water piping shall be extended to or supported from any residential structure and there shall be no accessible above grade outlets from the reclaimed water system at any residential structure. At least one exterior hose bib, supplied with potable water, shall be provided at each residential structure.</p> <p>²The treater shall develop and implement a public education program to inform residents and plumbing contractors and inspectors who deal with the Resident-Controlled Landscape Irrigation systems about the need to: a) strictly prohibit cross-connections between the reclaimed water and potable water systems; b) clearly and distinctively identify the potable service lines and plumbing from the reclaimed water service lines and plumbing; and c) avoid contact with and strictly minimize ponding or runoff of the reclaimed water. The treater shall implement a cross-connection inspection program and shall have the authority to discontinue reclaimed water service to any resident who flagrantly or repeatedly misuses reclaimed water in a manner inconsistent with this regulation. The treater shall maintain a map indicating all areas where reclaimed water is provided for Resident-Controlled Landscape Irrigation.</p>				

13. Operation of the reclaimed water irrigation system, including valves, outlets, couplers, and sprinkler heads may be performed only by personnel authorized by the user and trained regarding health hazards. Workers must be informed of the potential health hazards involved with contact or potential ingestion of reclaimed water and must be educated regarding proper hygienic procedures to protect themselves (CDPHE 2007).
14. Regulation 84 states that irrigation application rates must be controlled to strictly minimize ponding and runoff and to minimize the amount of applied water and associated pollutants that pass through the root zone of the plants to be irrigated (e.g., rain shutoff devices, application at evapotranspiration rates adjusted for irrigation efficiency, daily inspections, or other means). The regulation defines agronomic application rates as the rate of application that is necessary to satisfy the plants' nutritional and watering requirements, while strictly minimizing the amount of nutrients that run off to surface waters or which pass below the root zone of the plants (CDPHE 2007).
15. Irrigation may only be conducted at times and conditions (e.g., access may be restricted) specified in the CDPHE Notice of Authorization (CDPHE 2007).

Practices to Promote Healthy Landscapes Irrigated with Reclaimed Water

16. Prior to choosing reclaimed water as the irrigation water source, it is critical to consider the existing and expected long-term conditions present in the landscape. For example, in a landscape with poorly drained soils, poor water quality will have a more detrimental impact on the landscape than a landscape that has ideal drainage conditions. In well drained soils,

constituents are less likely to accumulate and be taken up by plants because they are easily leached (Aqua Engineering 2004).

17. In addition to water quality monitoring required under Regulation No. 84, it is also important to monitor water quality and soil conditions both prior to implementing a reclaimed water use program, as well as over the long-term as irrigation continues. Collect and test soil samples from a wide variety of test locations in the landscape, and at an adequate frequency, so subsequent test results can be monitored and actual trends measured. Prior to beginning irrigation, it is important to establish soil quality and water quality baselines (Aqua Engineering 2004). Representative recommended constituents for analysis are described in Table 3, and Table 4 identifies salt contents that will require special management measures. For context, Aqua Engineering (2004) provides this brief overview regarding the landscape implications for several key water quality parameters:

- Salinity – The total soluble salt content in water, measured as electrical conductivity (EC_w) or total dissolved solids (TDS). When salt content in irrigation water is too high, the ability of plants to use water is impacted. Salts tend to accumulate in the soil profile because plants use the irrigation water and leave the salts behind. Over time, salts will build up in the soil profile to concentrations that are higher than that of the irrigation water applied. If salts are not removed from the root zone, soil salt concentrations will become detrimental to landscapes.
- Sodium Adsorption Ratio (SAR) – A measure of the proportion of sodium ions to calcium and magnesium ions in a water solution. A high SAR value indicates that sodium ions are high relative to calcium and magnesium ions. High SAR water applied to soils tends to disperse soil, which can create water infiltration problems. The adjusted SAR (SAR_{adj}) is also used to measure the additional influence that bicarbonates in irrigation water have on infiltration. The salinity and SAR should be considered together when evaluating sodium impacts on infiltration.
- Sodium – Excess sodium ions in irrigation water may also be toxic to plants when taken up through the roots or when absorbed through the leaves from sprinkler irrigation. Sodium toxicity can physically damage the appearance of plants.
- Boron – Excess boron ions in irrigation water can accumulate in the soil to levels that are toxic to plants. Although boron is needed to some degree to maintain plant health, high levels can physically damage plants.
- Chloride – Excess chloride ions in irrigation water are toxic to plants. Chloride ions can be taken up through the soil or be absorbed through the leaves of the plant.
- Nitrogen – Excess nitrogen in irrigation water can over-stimulate growth, delay plant maturity, and contribute to poor plant quality. (Typically, references to nitrogen are in the form of nitrate (NO₃-N), because nitrate-nitrogen (NO₃-N) is the form of nitrogen that occurs most frequently in irrigation water).

Table 3. Guidelines for Interpretation of Water Quality for Irrigation
(Source: Ayers and Wescot [1985], as summarized by Aqua Engineering [2004])

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity				
EC _w	dS/m	< 0.7	0.7 - 3.0	> 3.0
TDS	mg/L	< 450	450 - 2000	> 2000
Infiltration				
SAR =	EC _w =			
0 - 3		> 0.7	0.2 - 0.7	< 0.2
3 - 6		> 1.2	0.3 - 1.2	< 0.3
6 - 12		> 1.9	0.5 - 1.9	< 0.5
12 - 20		> 2.9	1.3 - 2.9	< 1.3
20 - 40		> 5.0	2.9 - 5.0	< 2.9
Specific Ion Toxicity				
Sodium (Na)				
<i>Surface Irrigation</i>	SAR	< 3	3 - 9	> 9
<i>Sprinkler Irrigation</i>	mg/L	< 70	> 70	
Chloride (Cl)				
<i>Surface Irrigation</i>	mg/L	< 140	140 - 350	> 350
<i>Sprinkler Irrigation</i>	mg/L	< 100	> 100	-
Boron (B)	mg/L	< 0.7	0.7 - 3.0	> 3.0
Bicarbonate (HCO ₃)				
<i>Sprinkler Irrigation</i>	mg/L	< 90	90 - 500	> 500
Miscellaneous Effects				
Nitrogen (NO ₃ - N)	mg/L	< 5	5 - 30	> 30
pH			Normal range 6.5 - 8.4	

Summary of assumptions used to develop guidelines (see Ayers and Wescott (1985) for more detail on applying these guidelines):

- 1 mg/L = 1 ppm
- EC_w = electrical conductivity of water; SAR = sodium adsorption ratio. SAR can be compared directly with adjusted SAR (SAR_{adj}).
- TDS = Total Dissolved Solids = EC_w x 640, expressed in mg/L (approximate).
- Soil textures range from sandy-loam to clay, with good internal drainage. Rainfall is low and does not play a significant role in meeting crop water demand or leaching requirements. Drainage is assumed to be good, with no uncontrolled shallow water table present.
- Normal sprinkler irrigation methods are used. Water is applied infrequently as needed, and the crop utilizes a considerable portion of the available stored soil water (50% or more) before the next irrigation. At least 15% of the applied water percolates below the root zone.
- Salinity increases with depth and is greatest in the lower part of the root zone. The average salinity of the soil solution is about three times that of the applied water.
- These guidelines are intended to apply to traditional agricultural crops but also apply to turf grass and landscape ornamentals.

Table 4. Classification of Salinity Limits for Irrigation Water
(Source: Bauder, Waskom and Davis, 2007, CSU Fact Sheet No. 0.506)

Classes of Water	Electrical Conductivity (EC _w) in dS/m
Class 1, Excellent	<0.25
Class 2, Good	0.25-0.75
Class 3, Permissible ¹	0.76-2.00
Class 4, Doubtful ²	2.01-3.00
Class 5, Unsuitable ²	>3.00
¹ Leaching or special management needed.	
² Good drainage need. Sensitive species may be impacted	

18. Soil conditions should also be monitored for the constituents listed in Table 3, along with phosphorus, calcium, magnesium and exchangeable sodium percentage (ESP). Qian (2004) summarizes a few representative guidelines for soils including:

- An EC higher than 4.0 mmhos/cm is considered saline, and ESP or SAR values greater than 15 indicate sodic soils with excessive sodium in soil particles. Excess sodium can cause soil to be hard and cloddy when dry, to crust badly, and to absorb water very slowly. High ESP or SAR can reduce soil permeability and water percolation rate. Salt leaching would become less effective when soil percolation and infiltration rates are reduced. Sometimes, sodium can initiate deterioration of soil structure at ESP well below 15. ESP that is greater than 9 can cause problems on fine-textured (clay) soils over time, on highly trafficked sites, or when irrigation water is too pure. (When water is too pure, there are few cations to counteract with sodium).
- Mass (1978) provides guidelines for boron content in soils. Sensitive plants (such as some fruit trees) will show growth decline as soil boron exceeds 0.5-1.0 mg/kg. Moderately sensitive plants will start to decline when soil boron exceeds 1.0-2.0 mg/kg. Kentucky bluegrass can tolerate soil boron content at 2.0-4.0 mg/kg.

19. When using reclaimed water, the following irrigation practices are important (Qian 2005):

- Provide adequate leaching and sufficient drainage to remove excess sodium and salts from the root zone. (*Note: This must also be conducted in a manner that fulfills the CDPHE requirement to “strictly minimize leaching.”*) The leaching requirements can be estimated using the technique presented in Doorenbos and Pruitt (1975) based on the electrical conductivity of the reclaimed water or other local guidance.
- Carefully irrigate based on evapotranspiration and leaching requirements. Use drip irrigation for shrubs or trees when possible.
- Select appropriate irrigation frequency to avoid frequent wetting and drying cycles on the tree leaves.

- Depending on the water quality, it may be necessary to either blend conventional water with reclaimed wastewater or use the two sources in rotation. As a last resort, it may be necessary to provide dual plumbing to irrigate greens with conventional water in cases of excessively high sodium absorption ratio (SAR) or high salinity. See Regulation No. 84 for strict requirements regarding reduced pressure principle backflow prevention devices or air gaps when supplemental water sources will be used.
20. Implement soil compaction controls such as deep aeration and/or water injection to maintain oxygen diffusion and water movement. Additionally, traffic control programs may need to be implemented to control compaction (Qian 2005).
 21. When determining fertilization requirements, be sure to account for nutrients already present in the reclaimed water, which will likely reduce the amount of supplemental nitrogen and phosphorous needed. Conversely, proper fertilization may be needed to alleviate nutrient imbalances in the reclaimed water (Qian 2005).
 22. Based on soil monitoring over time, additional chemical amendments may be periodically required to displace sodium and reduce ESP. Gypsum may be added to irrigation water to adjust the SAR of the water (Qian 2005).
 23. When selecting plants for landscapes using reclaimed water, select varieties that are climate and soil adapted and that include salt tolerant species and cultivars (Qian 2005). See Appendix G for the salt tolerances of various plants. Annual and Kentucky bluegrass are more sensitive to high soil salt levels than perennial rye grass and fescue (Swift and Koski 2003). Trees, shrubs, and ornamental plantings are typically more sensitive than turf grass (Ayers and Westcot 1985). Investigations into the use of recycled water at golf courses in Colorado have shown that pine trees are particularly sensitive to long-term salt accumulation. Denver Water (2003) has published a guide to using recycled water on trees and shrubs called “Recycled Water for Trees & Shrubs” (Aqua Engineering 2004).
 24. Closely observe plant health and adjust maintenance practices as needed because healthy plants are better able to withstand higher salinity (Qian 2005).
 25. Document and measure all management changes implemented to address water quality induced problems (Aqua Engineering 2004).
 26. Improve and increase drainage capabilities in selected areas that exhibit drainage concerns (Aqua Engineering 2004).
 27. Continually improve irrigation management and irrigation scheduling (Aqua Engineering 2004).
 28. Table 5 provides a summary of practices that may be used to address water quality concerns. These recommendations were developed by Aqua Engineering (2004) for Denver Water’s use in their reclaimed water irrigation program.

Table 5. Recommended Management Practices for Mitigating Potential Negative Impacts of Reclaimed Water Quality Limitations (Source: Aqua Engineering 2004)

Water Quality Concern	Management Practices for Mitigating Negative Impacts
Salinity	Leaching Improve drainage (artificial & soil aeration) Select less sensitive plants
Ion Toxicity	Blend with higher quality water
Sodium	Alter watering schedule: less frequent, low temperature (night), low wind, high humidity Irrigate sensitive plants with methods that minimize overhead spraying
Sodium - Infiltration	Improve aeration physically through cultivation (increase soil aggregation) Leaching Apply calcium based amendments (e.g. gypsum) Acid-injection or sulfur burner if accompanied by high bicarbonates and pH levels
Nitrogen	Monitor levels and adjust fertilizer program Apply growth regulators in problematic areas Remove grass clippings Mixing and selective irrigation with higher quality water Irrigation water aeration

Regional or Industry Considerations/Adaptations

1. Many streams in Colorado are identified as impaired due to elevated selenium concentrations. In such locations, care should be taken with irrigation practices so that these problems are not exacerbated by excessive leaching. See the Gunnison Basin and Grand Valley Selenium Task Force for specific guidance on the Western Slope. (<http://www.seleniumtaskforce.org/>).
2. Local governments may have design and installation standards for irrigation water conveyance for development. For example, the Grand Valley Wise Water Use Council has developed such standards.
3. Contact information for the CSU soil testing laboratory is: Soil - Water - Plant Testing Lab; Soil and Crop Sciences Department & Coordinating with CSU Extension; Colorado State University; Fort Collins, Colorado; (970) 491-5061(office); (970) 491-2930(fax); <http://www.extsoilcrop.colostate.edu/SoilLab/soillab.html>
4. Reclaimed water is available in many locations along the Front Range, but is not available in all areas.
5. Long-term effects of reclaimed water irrigation are complex and further research is needed to provide more detailed guidelines to maintain healthy landscapes. This BMP will be updated periodically as additional guidelines become available in Colorado.
6. For irrigation sites using reclaimed water near parking lots and other structures, overspray onto these surfaces should be avoided due to spotting that results from higher levels of dissolved solids.

Rainwater Harvesting

Rainwater harvesting is the process of intercepting storm-water runoff and putting it to beneficial use. Rainwater harvesting typically involves collecting rainwater from rooftops, concrete patios, driveways and other impervious surfaces.

The diversion and use of rainwater is subject to the Constitution of the State of Colorado, state statutes and case law. The use of water in Colorado is governed by the “prior appropriation doctrine,” which significantly differs from the “riparian” water rights in the eastern United States. The prior appropriation system controls who uses how much water, the types of uses allowed, and when those waters can be used. While this issue is very complex, the bottom line is that rainwater harvesting is illegal under Colorado water rights, unless a water right is in place specifically allowing this use. Although no specific statute has yet been written specifically directed at harvesting rainwater, the act of intercepting and diverting the water could be in violation Colorado water rights. Practically speaking, in most river drainages in Colorado, a person cannot divert rainwater and put it to a beneficial use without a plan for augmentation that replaces the depletions associated with that diversion.

Greywater Systems

Greywater refers to the reuse of water from baths, showers, washing machines, and bathroom sinks (household wastewater excluding toilet wastes) for irrigation and other water conservation applications.

Practically speaking, the use of greywater systems is not viable for most homeowners in Colorado. Currently, the treatment, disposal, and potential use of greywater is regulated by the State of Colorado Guidelines on Individual Sewage Disposal Systems and applicable county Individual Sewage Disposal System (ISDS) regulations. The Colorado Department of Public Health and Environment (CDPHE) does not currently separate greywater from blackwater in its regulations. Consequently, surface applications require permitting and are thus impractical for most residential users. Surface application of greywater requires a permit from the CDPHE that triggers a weekly monitoring requirement.

If greywater is discharged below the soil surface and below the root zone in the manner of a leach field, a permit from the local Health Department is all that is required. If greywater is used to irrigate below the soil surface, but within the root zone (above frost line), a local permit plus monitoring is required. Many county ISDS regulations prohibit the issuance of any type of individual sewage disposal system permit for a lot within 400 feet of service by a municipal or community sewage treatment facility. Many municipalities have similar connection and usage requirements that technically prohibit the use of greywater in urban areas. In addition to public health considerations, water rights considerations may be involved with the use of greywater for irrigation purposes.

For More Detailed Information

For more information on these topics and exceptions to these general rules, contact the Division of Water Resources (with regard to water rights constraints) and the Colorado Department of Public Health and Environment (for human health and water quality regulations).

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Landscape Maintenance

Description

Practice landscape maintenance appropriate for the site including practices such as pruning, weeding, mulching, fertilization and attention to the irrigation system.

Basic Practice Guidelines

1. Implement regular maintenance schedules that include checking, adjusting and repairing irrigation equipment; resetting the automatic irrigation controller; aerating turf; replenishing mulch; applying fertilizer; pruning and weeding. *See the related GreenCO BMP fact sheets on these specific topics for more detailed information.*
2. Keep leaves, grass clippings and other turf wastes cleared off sidewalks and streets so they don't wash into storm drains and ultimately into streams and ponds. Power blowers should be used to blow clippings onto grass for fertilizer, not blow them into the gutter.
3. Frequently remove dead or dying plants and all weeds that compete with healthy plants for available water. Clean up plant litter and remove weeds before they go to seed.
4. Maintain a buffer zone along waterways where chemicals are not applied in accordance with product labels, local ordinances and state and federal regulations. The purpose of this practice is to keep pesticides, herbicides and fertilizers out of surface waterbodies. Recommended buffer widths may vary based on the sensitivity of the waterbody, slope, soils, vegetation, type of chemicals used, etc.
5. Before moving directly to chemical methods to control weeds, consider the following practices:
 - Mechanical: physically remove weeds by hand pulling, digging or cultivation.
 - Exclusion/Cultural: maintain dense stands of desirable plants that will successfully out-compete weeds, or consider using mulches to exclude weeds.
 - Biological: using specific insects and plant pathogens to control weeds is an area of growing research. When such methods are demonstrated to be appropriate and effective, consider their use.
6. Aerate turf in the spring and in the fall, if needed, to eliminate compaction and improve the turf's ability to take up moisture, nutrients and air.
7. Monitor landscape quality to identify strengths and weaknesses of existing landscape management. Results should be used to revise management and maintenance strategies.

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	
CNGA		GCSAA	X

8. Frequently and routinely inspect equipment (e.g., mowers, irrigation system) to determine when maintenance and repair are needed. Maintain equipment for optimum performance. This is particularly critical for irrigation systems. (*See the Mowing and Irrigation System Maintenance BMPs for more information.*)
9. When maintaining equipment such as lawn mowers, tractors, etc., properly capture and dispose of oil, grease, fuel, etc., so that it does not damage turf areas and enter storm drains and waterbodies.
10. When sediment is found on impervious surfaces, such as streets, gutters, sidewalks, and driveways, these materials should be shoveled and disposed so they do not end up in runoff and streams.



Well-designed and maintained landscapes provide multiple values such as stormwater management, recreation and aesthetic benefits.

Source: Wright Water Engineers, Inc.

Regional or Industry Considerations/Adaptations

1. Regional variations in soil moisture, air temperature, water quality and soil chemistry will all affect maintenance schedules.
2. Check local utility department websites for watering restrictions and practice recommendations during drought conditions. Also see CSU Extension websites for specific recommendations during drought.

3. Be aware of state and county-specific noxious weeds that must be controlled.
4. Limited fall and winter watering may be required in some cases (e.g., newly planted trees, golf courses) to prevent root damage and winter desiccation. If required, only water when air and soil temperatures are above freezing.
5. Particularly for large sites, keep records to document changes on the site including turf quality, irrigation system efficiency, water quality, pest levels, etc. A computerized database or spreadsheet is recommended for large landscapes.

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Tree and Other Woody Plant Care

Description

Properly plant and maintain trees, shrubs and other woody plants to maximize the plants' health.

Basic Practice Guidelines

1. Plant and prune trees in accordance with the International Society for Arboriculture (ISA) and ANSI A-300 standards.
2. When selecting and planting trees and shrubs, be sure to consider:
 - Soil types.
 - Susceptibility to insects and disease (also consider species diversity for protection against tree loss during insect or disease outbreaks).
 - Appropriateness for climate (hardiness) and water requirements. See Appendix E for relative water requirements of various species.
 - Mature size and location relative to underground utilities and power lines.
3. Consider selecting native trees and shrubs for use in landscape design. For specific plant lists by elevation, exposure, moisture requirements, mature size and other information, see these CSU Fact Sheets: Native Trees for Colorado Landscapes (No. 7.421) and Native Shrubs for Colorado Landscapes (No.7.422). (www.ext.colostate.edu/pubs/garden/pubgard.html#tree). Also see Appendix H for a list of the relative salt tolerances of various shrubs and trees.
4. Proper tree planting with the root collar (root crown) at grade or 1 to 2 inches above grade helps in better establishment and long-term health of a tree. Planting holes should be

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSG	
CNGA	X	GCSAA	X

Environmental Benefits of Trees (Xcel Energy 2005; IES 2007)

- Decreased energy use in homes and buildings due to shade and wind reduction.
- Improved air quality by trapping particulates, absorbing carbon dioxide and producing oxygen.
- Carbon sequestration (may help to slow climate change).
- Interception of precipitation, thereby reducing runoff associated with urbanization.
- Improved wildlife habitat.
- Increased property values.
- Enhanced social interaction in communities and decreased noise.

shallower than the root ball for this to occur. See the *Tree Planting BMP* for more detail.

5. When planting balled-and-burlapped or container stock, avoid soil interface problems by amending the backfill to provide a transition between the soil in the root ball and the surrounding soil. Do not amend soil beneath the root ball. Place root balls on firm, undisturbed or compacted soil. Also score root balls and the sides of the hole to aid in transition. Do not fertilize during planting or during the first year.
6. When planning irrigation for trees, consider zoning them separately from turf where possible because trees adapt better to the site with deep, less frequent waterings.
7. Regular, appropriate watering of trees is important because moisture stress is a precursor to many diseases and insect problems. Trees may be deceiving in that they may not show stress for several years after drought damage. It is also important to keep in mind that too much water can also cause problems by causing roots to rot and decreasing the availability of oxygen in the soil.
8. Trees and other woody plants typically require additional watering for one to two growing seasons to become established (As a rule of thumb, trees require one year per inch of caliper to become established). This includes winter watering for newly planted trees, particularly evergreens when snow is absent.
9. Tree root systems can spread two to four times wider than the height of the tree. Most of the tree's absorbing roots are in the top 12 to 18 inches of the soil, depending on soil type. Water should be applied within the dripline, deeply and slowly. Apply water so it moistens the critical root zone to a depth of at least 12 inches. For evergreens, water should also be applied 3 to 5 feet beyond the dripline. Methods for watering individual trees include a deep root fork or needle, soaker hose or soft spray wand. Apply water to many locations under dripline. If a deep root fork or needle is used, insert the device no deeper than 8 inches into the soil.
10. Trees in heavily urbanized areas, such as in streetscapes, still require the proper amount of soil to support growth and long-term health. See the *Tree Placement BMP* for more information.



Large roots and small feeder roots occupy a large area under ground. Typically, the root system of a tree extends outward well past the dripline, up to two to four times the height of the tree.

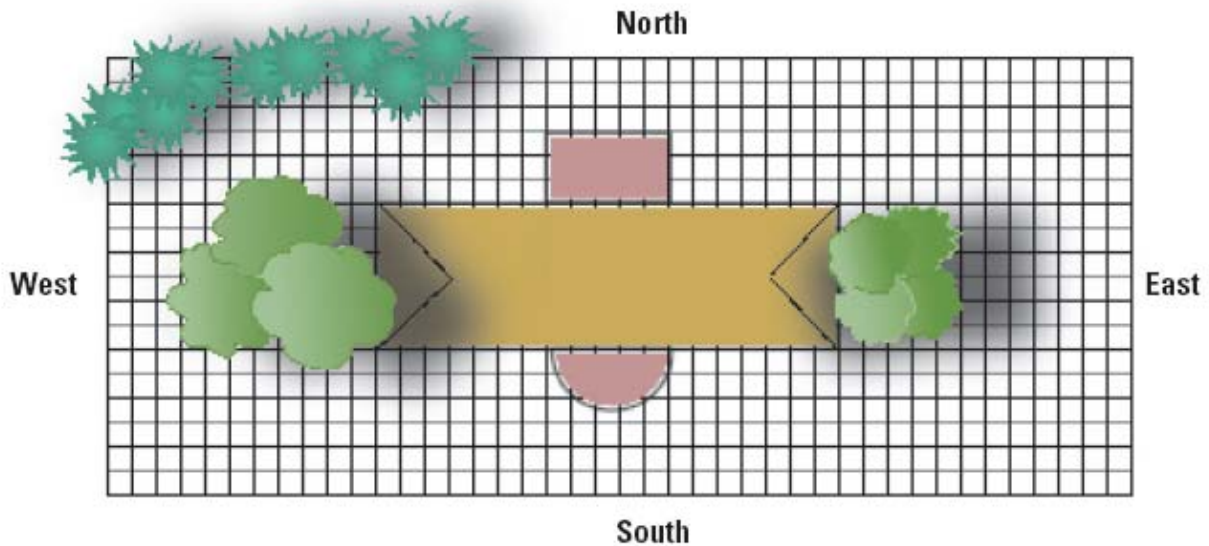
(Source: <http://saver.denverwater.org/saveourshade.asp>)

11. During prolonged dry periods in the fall and winter (October –March), some species may need watering one to two times per month. Water only when temperatures are above 40 degrees and no snow cover exists.
12. The desired water application rate for trees varies by trunk diameter and irrigation device, see <http://saver.denverwater.org/saveourshade.asp> for recommended application rates by tree size, watering device and season. Watering frequency should be determined based on the moisture content of the soil and root ball, which can be assessed through a “soil ball” test (see www.mt.nrcs.usda.gov/technical/ecs/agronomy/soilmoisture/index.html for guidance). For a general “rule of thumb” for small and medium size trees with moderate water needs, use approximately 10 gallons of water per inch of trunk diameter (measured 4-6 inches above grade) for each watering. The frequency of watering for small trees (1-3”) is once per week throughout the season. Medium size trees (4”-8”) may require watering three times per month throughout the season. Water large trees (10”+) twice per month at a rate of 15 gallons of water per inch of trunk diameter. See Appendix E for relative water requirements of various trees. The CSU Extension tree fact sheet series also identifies the relative water needs of various trees and shrubs (www.ext.colostate.edu/pubs/garden/pubgard.html#tree).
13. Apply organic mulch within the dripline at a depth of 4 inches to conserve moisture. Leave a 6-inch space between the mulch and trunk of trees to discourage pest damage to the root collar. Mulch materials may include wood chips, bark, leaves and evergreen needles.
14. Practice plant health care (PHC) programs and proper tree maintenance to create healthy trees and landscapes.
15. Properly prune young trees to establish good structure and minimize the potential for damage from snow and wind.
16. Prune trees to remove dead, broken, insect-ridden and diseased branches to maximize plant health and to minimize pest invasion. For branches that are heavily infested with scale insects, pruning can be an effective management strategy. Do not “top” or “lion tail” trees. By careful placement of trees relative to power lines, topping or severe pruning of trees can be avoided.
17. Protect young trees from winter sun damage by wrapping the trunk with tree wrap. A general rule is to wrap on November 1 and unwrap on April 1. It is important to remove the wrap in the spring to prevent insects and diseases from harboring beneath it.
18. Many tree species are harmed by herbicides used in the lawn. Trees already stressed by drought can be harmed by a heavy application of herbicide in the root zone.

Regional or Industry Considerations/Adaptations

1. When purchasing trees from a nursery, try to find out where the stock was grown. Stock originating from the South and West Coast may be less hardy than stock grown in northern nurseries.

2. For trees planted near streams and drainages, it may be necessary to install wire cages around trunks to prevent beaver damage.
3. Trees that have recently received root injury due to construction work need supplemental care if the root system has been compromised. See the Tree Protection BMP for more information.
4. In Front Range communities, a goal of 20 percent canopy coverage is recommended. The “urban forest” provides multiple benefits such as reducing stormwater runoff, providing shade and protecting against wind. Consider the energy-reducing benefits of trees when choosing planting locations.



Tree Placement for Energy Conservation

To save energy, Xcel Energy recommends planting trees that shade your house on the east and west sides in summer. The trees will then shed their leaves in the fall to allow heat gain from the winter sun. Evergreens planted on the north or northwest side can provide a winter windbreak. (Diagram Source: Xcel Energy 2005). Additionally, “solar shade trees” that shed their leaves in winter can also be beneficial when planted on the south side of a building.

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Herbaceous Plant Care

Description

Properly plant and maintain herbaceous plants to maximize plant health and conserve water.

This BMP is directly adapted from *Flower Management Before, During and Following Drought* by J.E. Klett, J L.Vickerman, and C. Wilson, as posted on the GreenCO website

(<http://www.greenco.org/downloadables/Drought%20Flower%20Management.pdf>).

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	
CALCP	X	RMSGGA	
CNGA	X	GCSAA	X

Basic Practice Guidelines

1. Prepare soil before planting by loosening it to 12 inches. If a heavy clay or sandy soil is present, add 2 to 3 inches of compost on the soil surface and then till in to a 12-inch depth.
2. Apply 1 to 2 inches of organic mulch between flowers to reduce evaporation and control water-using weeds. This practice is particularly critical during drought conditions, but helps to conserve water under all conditions.
3. Fertilizing perennials is generally not needed if proper soil preparation is done prior to planting. Fertilizer causes lush growth that requires more water. If fertilization is needed, a slow release fertilizer can be applied in the spring.
4. Moderate fertilization for bedding plants (annuals) is recommended either in liquid or granular form or a combination of both.
5. Annual and perennial flowers under water stress will have drooping leaves and a lack of blooms. Foliage often appears gray-green in color. Water when signs of stress become obvious. Apply irrigation in the evening or early morning to minimize evaporation. Avoid watering between the hours of 10 A.M. and 6 P.M.
6. Overhead spray irrigation is the least water-wise method because much water is lost to evaporation and wind drift. Soaker hoses or drip irrigation are more efficient because they deliver water to the ground level near roots. Hand watering is another alternative that maximizes delivery of water to the soil and roots.
7. When selecting plants, be aware that some perennials are more efficient at utilizing water than others. Choose plants to match the site conditions and consider plants with lower water needs.
8. Irrigation practices affect plant rooting depth. By watering less frequently and more deeply, some native and low water use plants will develop deeper roots, decreasing supplemental irrigation requirements. Irrigation practices should be changed gradually for best results.

9. Group plants with similar water needs together and water accordingly. See Appendix E for water requirements of various plants in different portions of Colorado.
10. Gray-leaved annuals and perennials are often more drought tolerant. Spring bulbs are drought avoiders, as they complete their life cycle prior to the onset of hot weather.

Regional or Industry Considerations/Adaptations

1. When water restrictions are expected or mild restrictions are in place, annuals can be watered two to three times per week if approximately 1 inch of water is applied during each irrigation cycle. Water perennials deeply (1 inch of water or more) two times per week during hot, dry periods.
2. During drought restrictions when no watering is allowed, annuals and perennials should not be planted.
3. Following removal of drought restrictions, it is important to resume watering. Water perennials well in the fall and monthly during dry winters with no snow cover to ensure survival during the dormant season. Mulching the crowns of dormant perennials will prevent frost heaving and conserve moisture in the plant through the winter.
4. Some drought-tolerant annuals include:

Annual Fountain Grass – (*Pennisetum setaceum*)
Bachelor Button – (*Centaurea cyanus*)
Cockscomb – (*Celosia plumosa*)
Coreopsis – (*Coreopsis tinctoria*)
Cosmos – (*Cosmos sulphureus*)
Creeping Zinnia – (*Sanvitalia procumbens*)
Cup Flower – (*Nierembergia hippomanica* var. *violacea*)
Dusty Miller – (*Senecio cineraria*)
Gazania – (*Gazania rigens*)
Globe Amaranth – (*Gomphrena globosa*)
Johnny-Jump-Up – (*Viola tricolor*)
Mealy Cup Sage – (*Salvia farinacea*)
Mexican Sunflower – (*Tithonia rotundifolia*)
Moss Rose – (*Portulaca grandiflora*)
Periwinkle – (*Catharanthus roseus*)
Rocket Larkspur – (*Conslida ambigua*)
Rudbeckia – (*Rudbeckia hirta* var. *pulcherrima*)
Spider Flower – (*Cleome hassleriana*)
Sweet Alyssum – (*Lobularia maritima*)

5. Some drought tolerant perennials include:

Artemisia – (*Artemisia* species)
Blanket Flower – (*Gaillardia x grandiflora*)

Blue Fescue – (*Festuca cinerea*)
Creeping Phlox – (*Phlox subulata*)
Creeping Potentilla – (*Potentilla neumanniana*)
German Statice – (*Goniolimon tataricum*)
Globe Thistle – (*Echinops ritro*)
Hens and Chicks – (*Sempervivum tectorum*)
Ice Plant – (*Delosperma* species)
Lambs Ear – (*Stachys bysantina*)
Lavender Cotton – (*Santolina chamaecyparissus*)
Little Bluestem – (*Schizachyrium scoparium*)
Oriental Poppy – (*Papaver orientale*)
Ozark Primrose – (*Oenothera missouriensis*)
Penstemon – (*Penstemon* species)
Plumbago – (*Ceratostigma plumbaginoides*)
Poppy Mallow – (*Callirhoe involucrata*)
Prairie Coneflower – (*Ratibida columnifera*)
Prairie Dropseed – (*Sporobolus heterolepis*)
Purple Coneflower – (*Echinacea purpurea*)
Russian Sage – (*Perovskia atriplicifolia*)
Snow-in-Summer – (*Cerastium tomentosum*)
Stonecrop – (*Sedum* species)
Yarrow – (*Achillea* species)

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Turf Management

Description

Plan, properly install and maintain practical turf areas. Healthy, properly maintained turf can reduce stormwater runoff rates and volumes, sediment and pollutant loads, reduce heat island effects and provide other environmental benefits.

Basic Practice Guidelines

Design

1. Design and allocate appropriate space for turf areas based on desired functional, recreational and/or aesthetic benefits.
2. Select turfgrass species that will best meet the requirements and purposes of the lawn area. Areas that receive wear and tear will require sod-forming species such as Kentucky bluegrass. Table 1 provides a summary of the advantages and disadvantages of several turfgrasses. Areas that are difficult to mow, or are only for visual appeal, may be appropriate for slower-growing, lower maintenance, lower-water-requiring species such as buffalograss or blue grama. Soil conditions, such as soluble salt level, should also be taken into consideration when selecting turfgrass species.
3. Consider turf alternatives such as native or low-water-use plantings, patios, decks or mulches or low-water turfgrasses for some areas (e.g., narrow strips, hard-to-water areas, steep slopes, low-usage areas), when these alternatives meet the needs of the area.
4. When considering lower-water-requiring alternatives to Kentucky bluegrass, base turf selection on the results of a soil analysis. In sandy soils in particular, some alternative species do not perform as well.
5. When possible, avoid placing turf in long narrow areas, on steep slopes, hard-to-maintain corners and isolated islands due to difficult mowing and irrigation challenges. Turf is better suited to larger, relatively flat areas.
6. Good surface drainage can be achieved by sloping the lawn away from buildings and properly grading low areas and steep slopes to prevent future trouble spots. Where appropriate, grade to allow turf to take advantage of runoff from impervious surfaces such as driveways and roofs.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	
CALCP	X	RMSGGA	X
CNGA		GCSAA	X

Table 1. Comparison of Tall Fescue, Buffalograss, and Kentucky Bluegrass for Lawn Use
 (Source: Turfgrass Species/Variety Selection Guidelines, Tony Koski, CSU Extension,
 Colorado State University, Department of Horticulture & Landscape Architecture)

Characteristic	Tall Fescue	Buffalograss	Kentucky Bluegrass
NATIVE TO COLORADO?	No	Yes	No
LEAF TEXTURE	Somewhat coarser, soft	Very fine, soft	Fine, soft
COLOR	Light to dark green	Light green to blue green	Light to dark green
LENGTH OF GREEN SEASON	Long; March-December	Short; May-September	Long; March-December
MOWING REQUIREMENT	More frequent	Infrequent/none	Less often
MOWING QUALITY*	Can be poor	Good	Generally good
FERTILIZER REQUIREMENT	Lower	Very low	Higher
IRON CHLOROSIS	Infrequent	Infrequent	More frequent
DISEASE PROBLEMS	Infrequent	Almost none	More frequent
INSECT PROBLEMS	Almost none	Almost none	More frequent
TRAFFIC TOLERANCE	Excellent	Fair	Good
RECUPERATIVE POTENTIAL**	Poor to fair	Good to excellent	Good to excellent
THATCH FORMATION	Little (slow to form)/none	Generally not a problem	Can be excessive
COMPACTION TOLERANCE	Fair	Very good	Good
HEAT/COLD TOLERANCE	Excellent	Excellent	Excellent
SHADE TOLERANCE	Good/Excellent	Poor to fair	Poor to fair
SALT TOLERANCE	Very good	Fair	Poor to fair
SOD AVAILABILITY/COST	Less available/higher cost	Uncommon/highest cost	Very common/low cost
IRRIGATION REQUIREMENT	Often lower than bluegrass, but can be the same - or higher	Very low to none required	Low to high, depending on soil

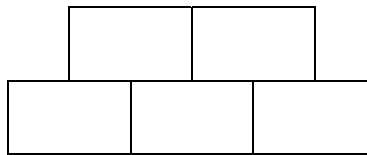
*A dull mower blade can shred the tips of grass leaves (most common with tall fescue), which then turn brown.

**The ability of a grass to recover from traffic injury, spreading to fill-in worn, bare areas in the lawn.

Installation

7. Although turf can be established from seed or sod, sod provides the additional benefits of lower initial water use, quick establishment and the ability to handle heavy rains with less susceptibility to erosion. (See <http://www.rockymountainsodgrowers.com/install.html> for more detailed sod installation guidance.)
8. Prepare the site prior to the arrival of the sod.

- Remove weeds and debris.
 - Establish a rough grade and eliminate low spots.
 - Spread and rototill a minimum of 3 cubic yards of organics per 1,000 square feet at least 4 inches deep.
 - Level and rake the installation site until it is smooth.
 - Grade areas along sidewalks and driveways approximately 1½ inches below top of concrete.
9. Have all hoses and sprinklers on-site for the initial watering.
- Make sure sprinkler system is performing properly.
 - Understand the operation of the sprinkler clock for proper watering of the new and established lawn.
10. Order sod to be delivered once site is prepared and the sprinkler system is understood and operating properly.
11. Install the sod immediately after delivery.
- Arrange the rolls so there is a minimum amount of traffic on the prepared soil and the newly installed grass.
 - Lay sod in a horizontal brick pattern.



- Once an area of approximately 15 feet by 15 feet has been laid, rolled and fertilized, water immediately. The objective is not to let the sod dehydrate.
 - Butt ends and sides of the sod strips making sure there is no overlapping.
 - Fit the sod around obstacles or in smaller places by merely cutting the dirt side with a sod knife.
12. Water properly, as follows:
- Once all the sod is laid, begin watering to build up the sub-soil moisture. This is the most critical time to apply water. Up to one-half inch of water per day for the first two to three days may be required. Probe the soil to determine if the moisture has penetrated at least 4 inches.

- During the following two weeks, the amount of water needed will be similar to that provided in Table 2. Each day may require more than one application depending upon wind and temperature. The reason for several light applications is to keep the root zone and blades moist.
- Week three is used as a transition period from daily watering with frequent applications per day to an increased number of days between watering. During this time the grass should be ready for routine maintenance. By the end of the establishment period, the grass should be able to go several days between waterings depending on the season and weather.

13. After the initial three weeks, adjust watering times and sprinkler clocks to conform to any water restriction program in your area.
14. When starting a lawn from seed, amend the lawn in a manner similar to sod and work in a starter fertilizer at the rate recommended on the label. Frequent, light waterings are needed until the seed has germinated and should then be reduced.

Maintenance

15. The approximate amount of water that needs to be applied each week for an average, traditional lawn to supplement normal rainfall is listed in Table 2.

**Table 2. Approximate Supplemental Water for an Average Traditional Lawn
(inches per week)**

Condition	April*	May	June	July	Aug	Sept	Oct**
Non-Drought Conditions	1/4"	1"	1 1/2"	1 1/2"	1 1/4"	1"	1/2"
During Drought Restrictions (approx. 20% reduction)	1/4"	3/4"	1 1/4"	1 1/4"	1"	3/4"	1/2"

*For established lawns, water may not be required during April. Base decision on weather conditions.

**For established lawns, water is typically not required after Oct 15.

The data in Table 2 are based on historical averages and should be used as a guideline and not as a substitute for good judgment, reason and common sense. Under less-than-average rainfall conditions, the amounts shown in the chart should be increased. If there is greater-than-normal rainfall, then the amount of supplemental water should be reduced.

16. Measure the water applied by using rain gauges or cans placed on the lawn in areas covered by sprinklers.
17. Become aware of dehydration signs: 1) Stage 1: grass has a purplish tint; 2) Stage 2: blades turn steel gray and foot prints are left when walked upon; and 3) Stage 3: grass blades turn straw color.

18. Mulch-mowing turfgrass at a height of 2.5 to 3.0 inches helps turfgrass develop deeper root systems. Mulched grass clippings can return roughly 25 to 30 percent of the needed nitrogen that grass requires to be healthy, thereby reducing fertilizer requirements. Avoid throwing grass clippings onto streets and sidewalks to reduce nutrient pollution to surface waterbodies.
19. If thatch deeper than ½ inch is present, aerate the lawn with a core-aerator to allow grass penetration into the root zone and water infiltration. Minimize thatch development by mowing frequently, avoiding overwatering, preventing overfertilization and aerating the lawn.
20. Fertilize the turfgrass at a rate appropriate to the turfgrass species, season and soil conditions. Over-application of fertilizer can result in runoff and leaching. Slow-release fertilizers may reduce the chances of nutrients leaching into groundwater or running off-site. *See the Fertilizer Application BMP for fertilizer application guidelines.*
21. Apply fertilizer timed to the needs of the plants. Cool season grasses such as Kentucky bluegrass need to be fertilized when the growing season is cool. Apply no more than one pound of nitrogen per thousand square feet at each application. Warm season grasses such as buffalograss need less fertilizer and are best fertilized when the temperature is warm. One application about mid-June and another at the beginning of August is usually sufficient.
22. Water the lawn uniformly until the soil is moist to a depth of 4 to 6 inches to encourage deep roots. Frequent, light sprinklings moisten only the surface and may cause shallow-rooted turf and increase weed seed germination.
23. Proper irrigation can minimize the amount of fertilizer and other chemicals that are leached below the root zone of the grass or washed away by runoff. Properly maintain the irrigation system to ensure that the irrigation is being applied at appropriate rates and to the turfgrass, not the sidewalk. (*See the Irrigation BMPs for more information and <http://www.rockymountainsodgrowers.com/irrigation.html>.)*
24. Follow a proper maintenance schedule to prevent stress, disease and turf injury. (See <http://www.rockymountainsodgrowers.com> for guidance.)

Regional or Industry Considerations/Adaptations

1. Particularly during recent drought conditions, Kentucky bluegrass has received significant attention as a high-water use plant. However, field studies have shown that bluegrass, with a base of properly prepared soil and proper irrigation, performs well at half of the recommended rate (evapotranspiration or ET) for supplemental irrigation. Therefore, the water use for bluegrass is not so much the grass itself, but how it is cultivated. For more information, see http://www.ncwcd.org/ims/ims_turfandurban_demos.asp.
2. Some areas of Colorado, particularly the western slope, have serious problems with high salt levels in soils. A soil test should be conducted to determine the salt level. Salt in soils can be reduced by improving internal drainage through addition of good-quality organic matter mixed to a depth of at least 6 inches then watering heavily to help flush salts below the root

zone. In cases where the irrigation water has high salts, alternative grass species may be required. Kentucky bluegrass does poorly where salt levels are greater than 6 mmhos/cm. Use perennial ryegrass, fine fescue, tall fescue, wheatgrass or alkaligrass for lawns where salt levels are high. Nurseries and garden centers serving areas with salt problems should carry these more salt-tolerant grass species. More information on salt-tolerant grasses can be obtained from www.ext.colostate.edu/pubs/garden/07227.html.

3. In areas with salt problems, a high water table may aggravate the salt problem. In these cases, a tile drain or gravel-filled trench system may be required to move salt-laden water away. Prior to installing such a system, consult with relevant local, state and/or federal officials to determine any regulatory constraints or permit requirements.
4. Sodic soils (“black alkali”) contain an excess of sodium and often need to be amended prior to planting turfgrass. Before leaching sodic soils, test the soil through a reputable lab to determine if amendments such as gypsum are required. Leach the soil only after addition of any required amendment.
5. Turf water requirements for the western slope can be obtained from Swift (2001) “Watering Established Lawns in Western Colorado,” Colorado State University Extension Tri-River Area, www.coopext.colostate.edu/TRA/PLANTS/lawnwat.html.

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Fertilizer Application

Description

Properly apply fertilizers based on the specific needs of plants, particularly as identified by appropriate soil or plant tissue tests.

Basic Practice Guidelines

1. Apply fertilizer when needed to achieve a clearly defined objective such as increasing shoot growth, root growth, flowering or fruiting; enhancing foliage color and plant appearance; or correcting or preventing nutrient deficiencies.
2. Because manufactured fertilizers can be relatively high in nutrient content, it is critical to follow the manufacturer’s directions, using the minimum amount recommended. Over-application “burns” leaves and may lead to water pollution, thatch buildup and excessive mowing.
3. Only apply nutrients the plants can use. Fertilizer labels identify product contents in terms of ratios that indicate percentage of ingredients by product weight.
4. When practical and appropriate, base fertilizer application on soil analysis. Be aware that at many new home sites, “basement” topsoil may make obtaining representative soil samples challenging.
5. Prior to fertilizing, amend soil as needed to improve nutrient uptake. (*See the Soil Amendment BMP for more detailed guidance.*)
6. Utilize split applications of slow-release (controlled-release) fertilizer forms such as IBDU, sulfur-coated urea and natural organic-based fertilizers (not to be confused with raw manure) to minimize the risk of nutrients leaching into groundwater or running off in surface water. When properly applied, other forms of fertilizer can also be safely used, provided that over-watering and over-fertilization do not occur.
7. When applying fertilizer, broadcast it uniformly over the targeted area of the landscape.
8. If possible, properly irrigate turf following fertilization to help grass utilize applied nutrients and to minimize the potential for fertilizer burn. Care should be taken to avoid excessive irrigation that would result in fertilizer being washed away. Similarly, avoid application of fertilizer immediately prior to heavy rainfall.
9. Fall is the best time of year to fertilize bluegrass lawns to promote a healthier turf before winter, a healthier root system, and turf that greens up earlier in the spring without excessive top growth. Fertilize with nitrogen sometime during late September to early November

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

along the Front Range, and earlier in the mountains to ensure nitrogen is applied two to three weeks before the ground freezes.

10. Over-application of nitrogen fertilizer in April may cause grass to grow too fast before roots can support the growth, resulting in less heat tolerance.

11. Recommendations for fertilizer application vary among industry professionals. CSU Extension’s fertilizer recommendations for established Colorado lawns are provided in the table below. Site-specific conditions should also be considered when determining the need for fertilizer.

Turfgrass Species	CSU Extension Recommendations for Nitrogen Application Rate in Pounds/1,000 sq. ft.				
	Mid-March to April ^{A,B}	May to Mid-June ^B	July to Early August ^B	Mid-August to Mid-September ^{B,C}	Early October to Early November ^{B,D}
High Maintenance Bluegrass Ryegrass	0.5-1	1	Not Required	1	1-2 (optional)
Low Maintenance Bluegrass	0.5	0.5-1	Not Required	1	1 (optional)
Tall Fescue	0.5	0.5-1	Not Required	1	1 (optional)
Fine Fescue	0.5	0.5-1	Not Required	0.5-1	None
Buffalograss, Blue Grama, Bermudagrass	None	0.5-1	0.5-1	None	None

Notes:

^AThe March-April nitrogen application may not be needed if prior fall fertilization was completed. If spring green-up and growth is satisfactory, delay fertilizing to May or June.

^BApplication rates may be reduced by 1/4 to 1/3 when grass clippings are left on the lawn.

^COn very sandy soils, do not fertilize turf after late September to prevent nitrogen from leaching into groundwater during the winter months.

^DApply when the grass is still green and at least 2-3 weeks prior to the ground freezing. Optional nitrogen applications are indicated for use where higher quality or heavily-used turf is present.

Source: T. Koski and V. Skinner, CSU Extension, 2003.

12. As a general rule, the Colorado Nursery and Greenhouse Association recommends waiting until the second growing season to fertilize ornamental (woody) plants. Commercial fertilizer should not be used in the backfill where it comes in direct contact with the roots. After the plant becomes established, the proper use of fertilizer is beneficial to the health, vigor, and vitality of the plant.
13. Correcting iron deficiencies in soils is difficult. For best results, choose plants adapted to alkaline soils.
14. Keep fertilizer off of streets, sidewalks and driveways to prevent water pollution. Fertilizer that inadvertently falls on impervious surfaces should be swept back onto the lawn.
15. Maintain a buffer zone around wells or surface waterbodies where fertilizers are not applied to minimize pollution. Consult the fertilizer product label and local regulations and landscape ordinances for appropriate distances. Research in this area is limited; however, CSU Extension recommends a buffer of 6 to 10 feet for mowed turf areas.

Special Regional or Industry Considerations/Adaptations

1. Phosphorus is commonly overused and application should always be based on soil tests. Phosphorus washing into surface waterbodies leads to excessive algae growth in state waterbodies. Phosphorous does not move out of the soil like nitrogen, so constant additions are unnecessary.
2. Soils along the Front Range and in many mountainous areas contain abundant potash, so it's unnecessary to add more.
3. In areas with sandy soils, it is particularly important to avoid over-application of fertilizer that could leach into groundwater. These areas may be particularly well suited to slow-release fertilizer forms and conservative application rates.

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Pesticide and Herbicide Application

Description

Apply pesticides and herbicides at minimal levels in accordance with the label and targeted to specific pest problems.

Basic Practice Guidelines

General Guidelines

1. Accurately diagnose the pest. Disease and insect symptoms can mimic each other in many plants. A fungicide will not control an insect, and an insecticide will not control a disease.
2. Apply pesticides and herbicides according to the label—it's the law!
3. Apply pesticides and herbicides only when needed and use in a manner to minimize off-target effects.
4. Ensure chemical applicators receive thorough training and proper certification prior to chemical use. Individuals and companies hired to apply pesticides must be licensed in the appropriate categories by the Colorado Department of Agriculture (CDA). Limited commercial applicators and public applicators applying restricted pesticides must register with the CDA. Limited commercial applicators and public applicators not applying restricted pesticides who have submitted to the jurisdiction of the CDA, must follow all record-keeping and other procedures as established by the CDA.
5. Know characteristics of the application site, including soil type and depth to groundwater. Be aware of any drinking water wells downgradient of the operation.
6. Select pesticides and herbicides best suited to the characteristics of the target site and the particular pest or weed. Half-life, solubility and adsorption should be compared to site characteristics to determine the safest chemical. Choose least toxic and less persistent sprays whenever possible based on comparison of labels and associated material safety data sheets (MSDSs).
7. Employ application techniques that increase efficiency and allow the lowest effective application rate. Carefully calibrate application equipment and follow all label instructions.
8. Recognize that no landscape should be completely pest-free or weed-free.

Integrated Pest Management (IPM)/Plant Health Care (PHC)

9. Use an Integrated Pest Management (IPM)/Plant Health Care (PHC) approach, integrating a variety of management tools (e.g., scouting, monitoring, cultural practices, targeted pesticide application). The pros and cons of various tools should be weighed and used in an integrated manner to achieve pest control objectives in a safe, effective and cost-effective manner.

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

10. Consider spot treatments of pests rather than treating the entire area.
11. Consider pest occurrence and history when developing pest management strategies.
12. Time pesticide application to minimize host plant damage and maximize pest control.
13. Rotate annual garden plants to reduce the buildup of soil-borne pests.
14. Clean up plant litter and remove weeds before they go to seed.
15. Remove infested plant residue from the garden in the fall so that pests do not over-winter there.
16. Implement cultural controls such as proper plant selection, planting time and planting method to reduce susceptibility to insects, pests and diseases, thereby reducing pesticide usage.
17. Implement mechanical and physical controls where practical as an alternative to chemical application. Examples include a wide variety of practices such as "collars" around seedlings, mulching, solar heating, syringing, handpicking, mowing, hoeing and traps.
18. Use biological controls where appropriate to reduce pesticide usage. For example, introduce natural enemies of pests such as lady beetles and green lacewings. (Note: pesticides may kill these natural enemies.)
19. Consider applying environmentally friendly chemical alternatives such as insecticidal soaps, horticultural oils and other such measures when practical and effective.



Careful scouting for pests is a key component of integrated pest management/plant health care.

Source: Denver Water.

Application Practices

20. Do not apply pesticides or herbicides during high temperatures or windy conditions or immediately prior to heavy rainfall or irrigation.
21. Treat for and control noxious weeds prior to installing the landscape using an herbicide targeted to the weeds that are present and applied in accordance with the product label.
22. Be aware that some pesticide formulations are not compatible with other pesticides and combining them may result in increased potency and phytotoxicity.
23. Maintain a buffer zone around wells or surface water where pesticides are not applied. Consult local regulations and landscape ordinances, as well as the product label, for distances, which may vary depending on the type of chemical and the sensitivity of the waterbody. The purpose of this practice is to keep pesticides and herbicides out of surface waterbodies.

Disposal and Record-Keeping

24. Maintain records of all pesticides applied (both restricted and non-restricted use), including name and address for whom application was made, target pest, brand name, formulation, EPA registration number, amount, date and time applied, site, crop, commodity or structure treated, exact location of application, and name of applicator. Combine and file this information with irrigation water data, crop growth records and notes on effectiveness of alternative pest control measures to help identify and track measures to both save money and reduce pesticide usage.
25. Properly handle and dispose of containers, rinse water and waste. Store pesticides in secure and covered areas. Never pour lawn and garden chemicals down storm drains or sanitary drains and keep off impervious surfaces during application. Use local recycling centers to dispose of chemicals. (*See the Pesticide, Fertilizer and Other Chemical Storage, Handling, and Disposal BMP for more information.*)

Regional or Industry Considerations/Adaptations

1. See the Production Practices for Nurseries, Greenhouses and Growers BMP for more detailed guidance for these industries.
2. Be familiar with existing state and federal regulations on pesticide application, certification and weed control, as well as CSU Extension horticultural guides. Several federal and state laws control the handling, storage, application, disposal and reporting of chemical spills. Examples include the Colorado Pesticide Applicator's Act, the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the Superfund Amendments and Reauthorization Act (SARA), the Emergency Planning and Community-Right-to-Know Act (EPCRA) and Occupational Safety and Health Administration (OSHA) requirements, particularly the Hazard Communication Standard. The Colorado Water Quality Control Act (25-8-601 and 25-8-606) also contains requirements for notification of the Colorado Water Quality Control

Division of spills and accidental discharges and provides the Division with the authority to order cleanups. It may also be necessary to file information with the local fire department based on these and other laws.

3. Senate Bill 90-126, The Agricultural Chemicals and Groundwater Protection Act, identifies special requirements for facilities handling more than 3,000 pounds (or 500 gallons) of bulk-formulated pesticides. Even if this threshold is not reached, the general principles of this act provide good guidance for pesticide users.

Key References

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Pesticide, Fertilizer and Other Chemical Storage, Handling and Disposal

Description

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. Misuse of pesticides and herbicides can result in adverse impacts to aquatic life, even at low concentrations. Misuse of fertilizer can result in increased algae growth in waterbodies due to excessive phosphorus and nitrogen loading.

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

Basic Practice Guidelines

Application and Handling

1. Apply fertilizers, pesticides and other chemicals according to manufacturer's directions. The label is the law for pesticide usage. (*See the Pesticide Application and Fertilizer Application BMPs for more discussion on proper application.*)
2. Keep pesticide and fertilizer equipment properly calibrated according to the manufacturer's instructions and in good repair. Recalibrate equipment periodically to compensate for wear in pumps, nozzles and metering systems. Calibrate sprayers when new nozzles are installed.
3. All mixing and loading operations must occur on an impervious surface.
4. To prevent possible backflow and contamination of a water supply, never submerge a water supply hose in a chemical tank or container. Provide proper backflow prevention devices where required by the Colorado Plumbing Code.
5. Do not apply pesticides during extremely high temperatures or windy conditions.
6. Avoid application of any pesticide, herbicide or fertilizer immediately prior to forecasted or inclement heavy rainfall or irrigation that would result in runoff of the chemicals.
7. Keep records of pesticide application and provide signage as required by law.

Storage

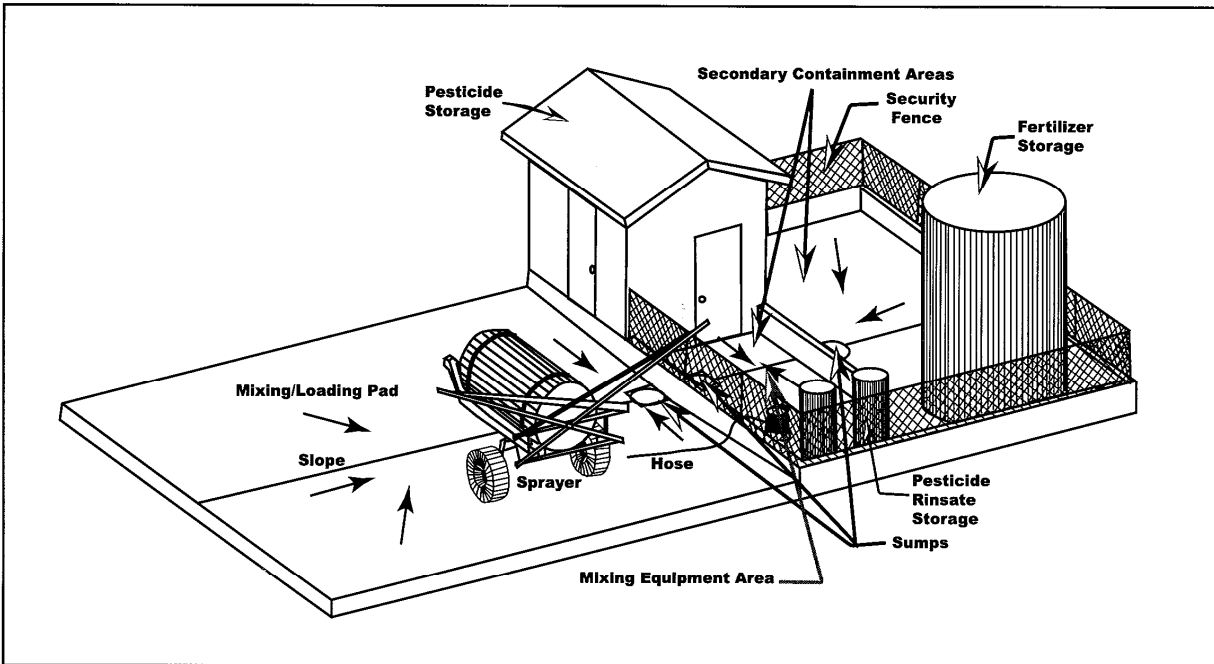
8. Storage areas should be secure and covered, preventing exposure to rain and unauthorized access. Basic safety equipment such as fire extinguishers, warning signs (e.g., "no smoking"), adequate light and ventilation and spill clean-up materials should be present. Floors and shelves should be non-porous (e.g., metal, concrete) to prevent sorption of chemicals. If possible, temperature control should be provided to avoid excessive heat or cold. Storage areas should be kept clear of combustible material and debris.

9. Many above-ground fuel storage tanks require a concrete enclosure (secondary containment) in the event of a tank rupture. Also, greenhouses and nurseries that are storing recycled water laden with fertilizer often are required to do the same.
10. Store nitrate-based and other oxidizing fertilizers separately from solvents, fuels and pesticides to reduce fire risk. Follow the general principle of storing like chemicals together.
11. Store chemicals in their original containers, tightly closed, with labels intact. Also inspect them regularly for leaks.
12. Dry chemicals should be stored above liquids and on pallets to ensure that they do not get wet.
13. Locate chemical storage and maintenance areas, as well as vehicle refueling and maintenance areas, away from wells and surface waterbodies in accordance with local regulations, typically at least 50 to 100 feet away.
14. Make available all Material Safety Data Sheets (MSDSs) in a readily accessible area. A list of all hazardous chemicals in the work place must be completed to ensure that all MSDSs are readily available.
15. Do not store large quantities of pesticides for long periods of time. Adopt the "first in, first out" principle, using the oldest products first to ensure that the shelf life does not expire. Buy smaller quantities of pesticides and fertilizers, thereby reducing storage issues.

Spills and Disposal

16. Keep chemical spill cleanup equipment, personal protective equipment and emergency phone numbers available when handling chemicals and their containers.
17. Properly manage chemical spills by cleaning them up as soon as possible, controlling actively spilling or leaking materials, containing the spilled material (e.g., with absorbents, sand), collecting the spilled material, storing or disposing of the spilled material, and following relevant spill reporting requirements. "Washing down" a spill with water is not an appropriate cleanup approach.
18. Basic spill reporting requirements include: name, address and phone number of person reporting and of person responsible for release; date and time; type, name and estimated amount of substance released, along with the reportable quantity of each substance; location/address of released substance; size/description of affected area; containment/cleanup actions taken; and other agencies/persons contacted.
19. Never pour lawn and garden chemicals or rinse water down storm drains (or sanitary drains) and keep chemicals off of impervious surfaces (e.g., streets, gutters) during application. Use local recycling centers to dispose of chemicals.

20. Follow label directions for disposal. This typically involves triple-rinsing empty containers, puncturing and crushing. All visible chemicals should be cleaned from the container prior to disposal.



Example: Suggested design for a combination mixing and storage area for pesticide and fertilizer handling which would meet Colorado regulations.

Source: *Designing Facilities for Pesticide and Fertilizer Containment* (MWPS-37)
MidWest Plan Service, Agricultural Engineering, Iowa State University, Ames, IA, 1991

Regional or Industry Considerations/Adaptations

1. Be familiar with existing state and federal regulations on pesticide application, certification and weed control, as well as CSU Extension horticultural guides. Several federal and state laws control the handling, storage, application, disposal and reporting of chemical spills. Examples include the Colorado Pesticide Applicator's Act, the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the Superfund Amendments and Reauthorization Act (SARA), the Emergency Planning and Community-Right-to-Know Act (EPCRA) and Occupational Safety and Health Administration (OSHA) requirements, particularly the Hazard Communication Standard. The Colorado Water Quality Control Act (25-8-601 and 25-8-606) also contains requirements for notification of the Colorado Water Quality Control Division of spills and accidental discharges and provides the Division with the authority to order cleanups. It may be necessary to file information with the local fire department based on these and other laws.
2. Colorado Senate Bill 90-126, The Agricultural Chemicals and Groundwater Protection Act, identifies special requirements for facilities handling more than 3,000 pounds (or 500 gallons) of bulk-formulated pesticides. Even if this threshold is not reached, the general principles of this act provide good guidance for pesticide users.

Key References

- Center for Resource Management. 1996. *Golf and the Environment: Environmental Principles for Golf Courses in the United States*. Salt Lake City, UT: The Center for Resource Management.
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Lawn Aeration

Description

Aerate lawns to improve nutrient and water uptake, reduce runoff, reduce compaction and help to control thatch.

Basic Practice Guidelines

1. Aeration, or core cultivation, reduces soil compaction and helps control thatch in lawns while helping water and fertilizer move into the root zone.
2. A lawn can be aerated at any time the ground is not frozen, but should not be done when it is extremely hot and dry. Heavy traffic areas will require aeration more frequently.
3. Aeration is most effective when actual cores or plugs of soil are pulled from the lawn. Do not use spike-type aerators, which compact the soil. Holes should be two to three inches deep and no more than two to four inches apart. Lawns should be thoroughly watered the day before aerating so plugs can be pulled more deeply and easily. Mark all sprinkler heads, shallow irrigation lines and cable TV lines before aerating so those lines will not be damaged.
4. On thatchy lawns, it is important to leave the cores on the lawn, allowing them to work back into the grass. Otherwise, core removal is optional. Lawns may be fertilized and seeded immediately after aeration. There is no need to top dress lawns following aeration.
5. Aerate turf once or twice per year, as needed, in the early spring and/or late fall to aid in capturing the natural precipitation during non-weed germination periods and prior to adding organic materials and fertilizers.

BMP Type			
Design			
Installation			
Maintenance/Operations			X
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	
CALCP	X	RMSGGA	X
CNGA		GCSAA	X

Regional or Industry Considerations/Adaptations

None identified.

Key References

Associated Landscape Contractors of America. 2003. *Landscape Maintenance Training*. Herndon, VA: ALCA. (As of 2008, offered by Professional Land Care Network [PLANET].)

City and County of Denver. 2000. *Denver Landscape Design and Maintenance Guidelines for Water Conservation on City Owned and Operated Properties*. Denver, CO: City.

Colorado State University Extension. 2003. *Lawn Aeration*. Planttalk Colorado 1505 (www.ext.colostate.edu/ptlk/1505). Ft. Collins, CO: CSU.

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Lawn Waste Disposal/Composting

Description

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.

Basic Practice Guidelines

Disposal

1. Keep lawn clippings and debris out of gutters.
2. Leave grass clippings on the lawn to provide supplemental nitrogen. Residential 5- to 7-horsepower recycling mowers are effective for this purpose.
3. When blowing walkways or mowing lawns, direct equipment so that the clippings blow back onto the lawn rather than into the street.
4. Chip and use trimmings of woody plant material from shrubs and trees as mulch for water conservation.
5. Leave spruce and pine needles under evergreen trees.
6. When site constraints require off-site disposal of lawn waste, use landfills and recycling/composting facilities designed for yard waste, whenever practical.

Composting

7. Compost organic plant material for later use as a soil amendment.
8. Select the compost location in an area with partial shade and protected from the wind.
9. Ensure that the plant material is not diseased or weed containing. Also, generally avoid plants treated with weed killers. Exceptions include soil-inactive glyphosphate products such as Roundup or Kleenup, when used in small quantities.
10. Alternate different types of plant material in 6 to 8 inch layers. Composting is effective on most yard wastes such as leaves, vegetable and flower plant parts, straw and a limited amount of woody prunings and grass clippings. Moderate sized plant materials of ½ to 1½ inches are most effective—avoid materials that are too large or too fine.
11. Avoid highly resinous wood and leaf prunings from plants such as junipers, pine, spruce and arborvitae. Although some grass clippings can be incorporated, they are best left on the lawn to recycle nutrients to the soil.
12. Compost should be kept moist, but not soggy.

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

13. Mix equal parts of green and dry material to maintain the best nitrogen balance.
14. Routinely mix and turn the compost to provide uniform aeration.
15. Rather than constantly adding new material to almost-finished compost, start a new compost pile.

Regional or Industry Considerations/Adaptations

1. Colorado winter temperatures may extend the time necessary to produce “finished” compost. Additionally, Colorado’s dry climate may require addition of supplemental moisture to compost to maintain microbial activity.

Key References

- City and County of Denver. 2000. Denver Landscape Design and Maintenance Guidelines for Water Conservation on City Owned and Operated Properties. Denver, CO: City.
- Colorado State University Extension. 2001. Soils, Amendments and Composting. *Planttalk* Colorado 1600 Series (www.ext.colostate.edu/ptlk/ptlk1600.html). Ft. Collins, CO: CSU.
- Wilson, C.R. and J.R. Feucht. 2001. Gardening—Composting Yard Waste Fact Sheet No. 7.212 (www.ext.colostate.edu/pubs/garden/07212). Ft. Collins, CO: Colorado State University Extension.
- Urban Drainage and Flood Control District. 2007. *Urban Storm Drainage Criteria Manual, Volume 3, Stormwater Best Management Practices*. Denver, CO: UDFCD.
- U.S. Composting Council Website: www.compostingcouncil.org.

Mowing

Description

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.

Basic Practice Guidelines

1. Mow the lawn frequently enough so that no more than one-third of the grass blade is removed during a single mowing. For example, if maintaining the grass at a height of 2½ inches, cut the grass by the time it reaches 3¾ inches tall. This requires changing the mowing schedule to reflect how quickly the grass grows. This can range from four to ten days between mowing.

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	
CALCP	X	RMSGGA	X
CNGA		GCSAA	X



Proper mowing, irrigation and maintenance of turfgrass results in deeper, more drought resistant root systems.

Source: International Turf Producers Foundation.

2. Grass undergoes less stress when the amount of blade left on the plant can still function efficiently. The preferred height of Colorado turfgrass species such as Kentucky bluegrass and long fescue is 2½ to 3 inches. The minimum height is 2 inches. Mowing grass to a height of less than 2 inches can reduce drought and heat tolerance, and cause a higher incidence of insect, disease and weed pest problems. “Scalping” is never recommended. Lawns with little foot traffic can be mowed as high as 4 inches during the hottest months.
3. Leaving clippings on the lawn can be beneficial to the plants and save mowing time. Clippings break down quickly, which allows nitrogen and other nutrients to be recycled. Clippings can also encourage the growth of beneficial soil microorganisms. Studies show

that it takes less time to mow more often and leave clippings on the lawn than to mow less often and catch and bag clippings for disposal.

4. Keep grass clippings and leaves off of streets and out of gutters. Using a mulching lawn mower to keep lawn clippings on the lawn is especially useful. Do not use a power blower to blow clippings into the gutter.
5. Keep grass extra-long during the hot summer months to reduce water needs. Remember to decrease irrigation when implementing this practice.
6. Mowing equipment should be well maintained. Sharpen blades several times per season. Shredded or white tips of grass blades are an indication of a dull or damaged mower blade that needs sharpening. Use the operating and service instruction manual provided with the mower, and consistently perform the suggested maintenance. A competent service person should thoroughly inspect the mower on a regular basis in accordance with manufacturer specifications.
7. Mowing after (but not during) the hottest period of the day, watering the lawn following mowing, and allowing the lawn to be dry for a day or two prior to mowing are all actions that help to reduce lawn stress. Mowing results are best when the lawn is dry, but not stressed.

Regional or Industry Considerations/Adaptations

1. Mowing can be an effective practice for weed control in unmanicured areas.
2. For commercial lawn care maintenance companies, proper mowing can usually be accommodated on the typical 7-10 day schedule, provided that the site is not over-fertilized or over-irrigated.

Key References

- Associated Landscape Contractors of America. 2003. *Landscape Maintenance Training*. Herndon, VA: ALCA. (As of 2008, offered by Professional Land Care Network [PLANET].)
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Mulching

Description

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.

Basic Practice Guidelines

1. Mulch planting beds with partially composted organic material in a layer 3 to 4 inches deep to reduce weeds, keep roots cool, keep soil moist and reduce the frequency of required watering. Also mulch tree and shrub bases as appropriate for each species.
2. Apply mulch to the soil surface, not against the plant stem or high against the base of tree trunks to minimize disease.
3. Organic mulch material includes bark, wood chips, chopped leaves and pine needles. For best results, avoid mulch made from construction debris (e.g., 2 x 4's, pallets). Better results are achieved when the materials have not been dried industrially and some moisture remains in the materials. Potentially appropriate inorganic mulch material includes gravel, pebbles and woven ground cloth; however, temperature effects of inorganic materials should be taken into account. Fabric material can be placed underneath the mulch to reduce weeds. Some plants are better suited to inorganic mulches due to propensity to root rot, so check with nursery professionals regarding suitable mulches for specific plants.
4. Apply mulch to areas of disturbed soil to prevent erosion and sediment transport to drainageways. In areas prone to significant runoff, inorganic mulches that are less easily washed away than bark should be used.
5. Check mulched areas on a routine basis, at least monthly, and replace mulch as needed.

Regional or Industry Considerations/Adaptations

None identified.

BMP Type			
Design			
Installation		X	
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	
CNGA	X	GCSAA	X



Mulch planted areas to help conserve water.

(Source: Denver Water.)

Key References

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Drought and General Water Conservation Practices for Landscape Management

Description

Manage landscapes using the most water-efficient techniques during drought conditions.

This BMP has been adapted with only minor modifications from “Coping with Drought: Water Restrictions and the Landscape” by Patrick McCarty, Colorado State University Extension Agent, Garfield County, and Dr. Curtis E. Swift, Area Extension Horticulture Agent, Grand Junction, as posted on www.colostate.edu/Depts/CoopExt/TRA/PLANTS/drought.html. This guidance will continue to be updated as conditions change.

Note: At the time of original publication of this BMP Manual, Colorado was experiencing a drought. Many websites and publications are available with specific guidance for drought. The information selected from McCarty and Swift (2002) has been reproduced in this manual because it provides a good overview of practices appropriate for drought consistent with the BMPs included in this manual.

Basic Practice Guidelines

Turfgrass Irrigation Practices

1. Base the first watering on soil moisture content. Spring is the time of maximum nutrient uptake. Watering too early in the spring cools the soil and reduces nutrient uptake. This stresses the grass and makes it more susceptible to insect and disease problems. Early spring watering can also saturate the soil, reducing the oxygen available to deeper roots, which results in the death of these deep roots. The loss of deep roots increases susceptibility to drought stress and increases the need for more frequent waterings.
2. Check the moisture content of the soil with a trowel, shovel or soil probe to a depth of 4 to 6 inches for turf areas and 6 to 8 inches for trees and shrubs. If the soil is dry, water. If the soil is moist, delay watering.
3. Irrigate according to the requirements of the plants, not on a fixed schedule. Apply only enough irrigation to replace water loss by evapotranspiration (ET). Match irrigation application rate to the soil type and root depth. Avoid applying more water than can be contained in the root zone. Daily observation is necessary to determine the appropriate changes to make to the irrigation system. ET controller technology is also available that can be added to irrigation controllers to more easily water according to ET requirements.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

4. When turfgrass requires water, it will:
 - Turn darker than normal (it appears as if a shadow is cast on the lawn).
 - Turn blue-gray.
 - Not spring back when walked on (depressions left by footprints do not bounce back).
 - Prevent the blade of a screwdriver or other such implement from easily penetrating into the soil any deeper than 2 inches.
5. Drought symptoms can appear in patches or over the complete turf area. When only small areas exhibit drought stress, water only those areas that need to be irrigated. Watering the complete lawn when only a small area requires water, or watering too frequently, results in shallow roots, increased susceptibility to drought (especially during the hot and dry days of July and August), and increased susceptibility to Melting-out Disease (Leaf-spot Disease).
6. Water deeply but only as needed; avoid shallow frequent waterings. Watering a lawn on a frequent, shallow basis results in death of deep roots, increasing the need to water.
7. In some instances, it may be necessary to water daily or every other day. This is especially true if the soil is very sandy as this soil texture dries out quickly. Turf on a shallow soil will likewise require more frequent irrigation. Soils should be amended with a good quality organic matter such as compost. This will help hold the soil moisture and reduce the need for frequent irrigation.
8. Water at night to reduce water loss from evaporation. Watering during the heat of the day can result in excessive levels of evaporation. Watering during the night (particularly after midnight) reduces problems with turf diseases and reduces the amount of water lost from evaporation, making the irrigation more efficient.
9. The most efficient and ideal time to irrigate turfgrass is between midnight and 6 A.M. Such timing, however, is difficult for all but those gardeners with an automatic sprinkler system. Gardeners not wishing to spend their night hours watering should consider watering during the day after the night moisture has been burned off by the morning sun, but prior to 10:00 A.M. Lawns should not be watered between the hours of 10:00 A.M. and 6:00 P.M. For further information on watering lawns, go to:
www.coopext.colostate.edu/TRA/PLANTS/lawnwat.html.
10. To reduce water loss from evaporation, do not water during windy times. Wind will also divert the water, resulting in some areas getting much more water than others, and leaving dry spots. Areas of the turf that do not receive adequate moisture will require more water to stay alive.

Irrigation System Maintenance

11. Check, adjust and repair irrigation equipment on a regular basis, weekly and within 24 hours

of mowing, whenever possible. Identify irrigation system leaks and repair them promptly.

12. Spring is a great time to check the irrigation system for consistency, uneven water coverage, and leaks. Place straight-sided cans or glasses in the area to be irrigated. Turn the sprinkler system on for a set length of time and measure the amount of water collected in the containers during that time. Using containers to measure the amount of water applied will pinpoint any variation in water distribution in the irrigated area. Plugged heads, improper spacing of sprinkler heads, etc., can be identified and subsequently corrected using this method. For information on self-auditing irrigation systems, see the Irrigation Audit BMP in this Manual or <http://www.ext.colostate.edu/pubs/garden/07239.html>.
13. The amount of water applied and the depth of water penetration should be rechecked occasionally during the summer months to avoid problems that develop from clogged or twisted heads. Reset or clean heads as necessary.
14. Immediately shut off irrigation systems and adjust whenever irrigation water falls or runs onto hard surfaces such as sidewalks, streets or driveways. Signs of leakage include overgrown or particularly green turf areas, soggy areas around spray heads and above-ground hoses, jammed spray heads and torn hoses. In drip systems, leakage problems may be due to damaged tubing from foot traffic or gnawing by animals.
15. Whenever possible, update and retrofit existing irrigation systems to take advantage of new water-saving technology (e.g., rain shut-off devices, ET controllers, soil moisture sensors, drip irrigation).
16. Manage the irrigation system to respond to the changing/seasonal requirements for water in the landscape. The most efficient systems match irrigation application to landscape water requirements through effective irrigation scheduling. Whenever possible, irrigation scheduling should incorporate the use of evapotranspiration (ET) and precipitation data.
17. Reset automatic controllers according to the seasonal needs of plants. Controllers should be inspected at least bi-monthly to correct run times.
18. *See the Irrigation BMPs of this Manual for more detailed guidance.*

Lawn Aeration

19. Aerate the lawn in the spring and again in the fall to obtain these benefits:
 - Improving water penetration into compacted soils and through thatch and mat layers.
 - Improving fertilizer movement to the turf roots.
 - Allowing greater levels of oxygen to reach the soil in exchange for carbon dioxide and other gases.
 - Enhancing turfgrass shoot and root development.

- Reducing water runoff (runoff from turf areas may carry pesticide residues and fertilizers into neighboring storm drains and streams causing pollution problems).

20. Use core-type aerators to loosen the soil, rather than spike-type aerators, which compact it.

Turfgrass Maintenance

21. Kentucky bluegrass can be allowed to go dormant without permanent and excessive injury if healthy. This is a worst-case scenario option if drought conditions persist. Watering properly when restrictions are lifted will allow Kentucky bluegrass to recover. Kentucky bluegrass can recover even after nine months without water.

22. If unsure what grass is in the lawn, take a sample to the local Colorado State University Extension office or local garden center for identification.

23. Weeds always seem to thrive regardless of the conditions and use water intended for other plants. Do not allow uncontrolled weeds to overtake the lawn or garden. Apply the proper methods necessary to prevent weed growth such as hand-pulling or careful herbicide application.

24. Carefully inspect the lawn at least weekly for disease and pests, correcting problems as they occur. During a year of potential high stress from drought, this becomes even more important. Early detection and control of problems is essential.

Fertilizer Application

25. Conduct a soil test to determine the nutrient needs by sending a soil sample to a reputable soil-testing laboratory. (For more information on soil testing go to: www.coopext.colostate.edu/TRA/PLANTS/soiltest.html.)

26. A properly fertilized lawn requires less water. Applying more fertilizer than is needed can deplete other nutrients and cause deficiencies. Excessive quantities of nutrients are often as detrimental as deficiencies. Adding excess may adversely affect the availability of other nutrients that were previously in sufficient supply. For example, adding too much phosphorus may result in a deficiency of available iron both within the soil and within plants grown in the soil. Nutrient-stressed plants with deficiencies are more susceptible to insect and disease problems, as well as drought stress.

27. Generally, for low-maintenance bluegrass lawns (common throughout Colorado), apply one pound of nitrogen fertilizer per 1,000 sq. ft. in the fall and fertilize lightly (one-half pound/1,000 sq. ft.) in the spring and again in early summer. (*See the Fertilizer Application BMP of this Manual for more detailed guidance.*)

28. Avoid the use of manure as top-dressing on lawns; applying manure can increase the need to water. Gardeners applying manure as a top dressing assume (incorrectly) that this meets the nutrient needs of the turf. Manures are very low in nitrogen with several inches of manure being necessary for each pound of nitrogen needed by the turf. Manures are typically high in

salt. Adding salt to a lawn increases the need to apply more water.

Mowing

29. Mow the lawn at a height of 2 ½ to 3 inches, removing no more than one-third of the grass blade at each mowing. The higher the lawn is mown, the deeper the roots (as long as the soil was prepared deeply).

Landscape Installation

30. If establishing a new lawn, prepare the soil properly; this will increase rooting depth and spread and increase drought tolerance of the grass. Proper soil preparation means the addition of organic matter and tilling the soil as deep as possible. Add 3 to 5 cubic yards of a decomposed organic matter per 1,000 square feet of lawn. Use a coarse, not a fine material. Cultivate the soil to a depth of 4 to 6 inches or more. While root depth is controlled in part by genetics, the depth of soil preparation determines the ultimate rooting depth. Shallow soil preparation causes shallow roots.
31. Because of limited water supplies, delay expanding the lawn or garden space. Small grass areas (turf islands) that are difficult to water, and the parts of the lawn that are not doing well may be candidates for change. Consider transforming these areas into drought-tolerant gardens. Always consider the use of xeric trees and shrubs (plants that are drought resistant or require less water) when planning new garden areas. Make sure to change the irrigation system accordingly.
32. For a great selection of xeric plants compiled by the Colorado State University/Denver Botanic Gardens Plant Select® program, go to: www.plantselect.org.

Key Drought-Related Websites and Other References for Up-to-Date Information

Colorado Springs Utilities Xeriscape Website: www.csu.org/xeri.

Colorado Climate Center Website: ccc.atmos.colostate.edu.

Colorado Division of Water Resources Flow Data Website:
<http://www.dnr.state.co.us/water/indexWater.asp>.

Colorado Office of Emergency Management: Drought Monitoring Website:
PublicInformation/Drought.

Colorado State University Extension Drought Task Force Website: www.drought.colostate.edu/

Colorado State University Turfgrass Website:
csuturf.colostate.edu/Pages/extensionfactsheets.htm.

Colorado Water Conservation Board Website: cwcb.state.co.us.

Colorado Water Resources Research Institute Website: cwri.colostate.edu.

Colorado WaterWise Council Website: coloradoet.org.

Denver Botanic Gardens and Colorado State University Extension Plant Select® Website: www.plantselect.org.

Denver Water Conservation and Xeriscape Websites: http://www.denverwater.org/cons_xeriscape/cons_xeriscapeframe.html.

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Mecham, B.Q. 2003. *Conservation Strategies for Lawn Watering During Drought or Water Shortages* (http://www.newcd.org/ims/ims_info/Irrigation_Strategies.pdf).

National Drought Mitigation Center, University of Nebraska—Lincoln, The National Drought Mitigation Center Website: www.drought.unl.edu.

Northern Colorado Water Conservancy District Website: www.newcd.org/.

U.S. Bureau of Reclamation Water Supply Information Website: www.usbr.gov/main/watersupply.

U.S. Department of Agriculture, Colorado Snow Survey Website: www.co.nrcs.usda.gov/snow/.

U.S. Department of Agriculture, SNOTEL (Snowpack Information) Website: www.co.nrcs.usda.gov/snow/snow/index.html.

U.S. Geological Survey National Water Conditions Website: water.usgs.gov/nwc.

U.S. Geological Survey Real Time Stream Flow Conditions for Colorado Website: waterdata.usgs.gov/co/nwis/rt.

Water Information Program Website: www.waterinfo.org.

Wilson, C.R. and D. Whiting. 2003. *Operating and Maintaining a Home Irrigation System*. Fact Sheet 7.239. (<http://www.ext.colostate.edu/pubs/garden/07239.html>). Ft. Collins, CO: Colorado State University Extension.

Snow Removal

Description

During the winter, many Green Industry professionals are involved with snow removal for the properties that they manage. Snow removal practices should be conducted in a manner that minimizes adverse impacts to vegetation, soils and water quality.

Basic Practice Guidelines

1. For obvious safety reasons, snow removal in Colorado is important; however, snow removal and management practices can adversely impact vegetation, soils, water quality and air quality. Green Industry professionals should be knowledgeable of these potential impacts and choose management measures with the fewest adverse impacts, while still protecting the public safety, health and welfare.
2. Physical removal of snow and ice by shovels, snowplows, or snow blowers usually does little damage to the landscape as long as snow and ice are not piled directly on landscape plants. The time to plan for snow storage locations that minimize landscape impacts is prior to winter.
3. The use of deicing chemicals can have a severe impact on plants growing near roads and sidewalks. Many deicing chemicals are salts and can adversely affect plants through either direct contact with foliage or through buildup in the soil over time. Representative impacts include:
 - Direct contact often occurs when the deicing chemicals accumulate on the plants due to drift during application, or when snow or ice containing the chemical is shoveled or blown onto nearby plants. Because these chemicals are salts, direct contact with the foliage may result in burning due to a rapid dehydration effect. This is most noticeable on evergreens since they will have foliage when deicing chemicals are normally applied. However, buds and twigs of both evergreen and deciduous plants may also be affected.
 - Buildup of de-icing chemicals in the soil may have even more detrimental effects. Repeated application over time (either during a particular winter season or over many seasons) may damage plants by making their roots unable to take up water. Symptoms will include wilting even when the soil is moist, leaf burn or needle tip burn, stunting or lack of vigor, and/or deficiency symptoms for one or more plant nutrients. The structure of clay soils can be changed to the point that they are unable to support plant life.
4. Deicing chemicals that are considered safer to use around plants include calcium magnesium acetate (CMA) or calcium chloride. As with all chemicals used in the landscape, be sure to read and follow label instructions and do not overapply.
5. The Colorado Department of Transportation (CDOT) has conducted multiple studies on

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA	X	GCSAA	X

deicing chemicals. The SeaCrest Group (2001) studied three groups of deicers for CDOT that were chloride-based, acetate-based, and sanding materials. The chloride-based deicers included magnesium chloride (FreezGard Zero® with Shield LS®, Ice-Stop™ CI, Caliber™ M1000, Ice Ban™ M50), calcium chloride (Liquidow®, Armor®), and sodium chloride (road salt and Ice Slicer®). The acetate-based deicers include Calcium Magnesium Acetate (CMA®), Potassium Acetate (CF7®), Sodium Acetate (NAAC®), and CMAK™ (a mixture of CMA and Potassium Acetate). Table 1 contains a partial summary of the study findings.

**Table 1. Potential Environmental Impacts of Various Deicers
(Source: The SeaCrest Group 2001)**

Deicer/ Parameter	Inhibited Magnesium Chloride (Liquid)	Caliber + Magnesium Chloride (Liquid)	Ice Ban + Magnesium Chloride (Liquid)	Sodium Chloride/ Ice Slicer (Solid)	Inhibited Calcium Chloride (Liquid)	CMA (Solid/ Liquid)	CMAK (Liquid)	Potassium Acetate (Liquid)	NAAC (Solid)	Sand
Chemicals	Trace metals	Trace metals, phosphorus, ammonia	Trace metals, phosphorus, ammonia, nitrates	Trace metals	Trace metals, ammonia, nitrates.	Trace metals	Trace metals, ammonia, nitrates.	Trace metals	Trace metals, phosphorus	Trace metals
Soil	Improves structure, increases salinity	Improves structure, increases salinity, oxygen depletion	Improves structure, increases salinity, oxygen depletion	Increases salinity; decreases stability	Improves structure, increases salinity	Improves structure; oxygen depletion	Improves structure; oxygen depletion	Improves structure; oxygen depletion	Decreases stability; oxygen depletion	Minimal effects
Water Quality	Increases salinity	Increases salinity; oxygen depletion	Increases salinity; oxygen depletion	Increases salinity	Increases salinity		Oxygen depletion	Oxygen depletion	Oxygen depletion	Increases turbidity
Air Quality	Minimal air pollution	Minimal air pollution	Minimal air pollution	Some air pollution	Minimal air pollution	Minimal air pollution	Minimal air pollution	Minimal air pollution	Some air pollution	High air pollution potential
Aquatic Organisms	Relatively low toxicity	Relatively low toxicity	Moderate toxicity	Relatively low toxicity	Relatively low toxicity	Relatively low toxicity	Moderate toxicity	Moderate toxicity	Relatively low toxicity	Can cover benthic organisms and cause mortality
Terrestrial Vegetation	Chlorides damage vegetation	Chlorides damage vegetation	Chlorides damage vegetation	Chlorides damage vegetation	Chlorides damage vegetation	Minimal damage to vegetation	Minimal damage to vegetation	Minimal damage to vegetation	Effects to vegetation not determined	Can cover vegetation and cause mortality
Terrestrial Animals	Does not attract wildlife	Does not attract wildlife	Does not attract wildlife	Attracts wildlife contributing to road kills	Does not attract wildlife	Not expected to attract wildlife	Not expected to attract wildlife	Not expected to attract wildlife	May attract wildlife contributing to roadkills	May cover burrows of small animals and cause mortality

Note: Trace metals that may be present include arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, and zinc. See <http://tmap.colostate.edu/Library/CDOT/CDOT-DTD-R-2001-15.pdf> for more information.

6. Highlights of the SeaCrest (2001) study regarding impacts associated with the three categories include:
 - a. The chloride-based deicers have been shown to have adverse effects on terrestrial vegetation. Damage to vegetation from deicing salts has been reported to a distance of 100-650 feet. However, there is a wide range of tolerance of different species of plants to the effects of chlorides. The chloride ions in deicers increase the salinity of the soil near the roadways where they are applied. The magnesium and calcium ions increase the stability and permeability of the soil, whereas sodium ions decrease soil stability and permeability.
 - b. The acetate-based deicers are organic and have different kinds of effects on the environment than the chloride-based deicers. The acetate ions are broken down by

soil microorganisms and may result in oxygen depletion of the soil, which can impact vegetation; however, the acetate deicers CMA and Potassium Acetate (CMAK) are not harmful to terrestrial vegetation at the concentrations typically used on roadways. However, NAAC may potentially have an adverse effect on vegetation because of the presence of the sodium ion, which decreases the stability and permeability of the soil. The depletion of oxygen in the soil from the breakdown of the acetate ion can have a negative effect on plant growth. However, field evidence of this effect is limited.

- c. Sand is not a deicer, but has been used for snow and ice control since the early 20th Century because it improves traction. Sand has a negative effect on water quality as a result of the increased turbidity caused by the presence of sand particles in water. Excessive quantities of sand can smother vegetation.
7. Where practicable, do not use deicers to completely melt snow or ice, but to make their removal easier. Deicers melt down through the ice or snow to the hard surface, then spread out underneath. This undercuts and loosens the snow so shoveling and plowing can be done. For this reason, it is helpful to apply deicers prior to snow events in some cases.
8. Research has shown that the shape of deicing particles affects the speed of their penetration through ice. Uniformly shaped spherical pellets of about 1/16" to 3/16" penetrate ice faster and more efficiently than other shapes. Irregularly shaped particles tend to melt randomly in all directions. Flakes melt as much horizontally as they do vertically.
9. Try to avoid the use of rock salt since this compound is generally most damaging to plants and soils as well as concrete and metal surfaces.
10. Landscape exposure to deicing salts may be unavoidable if the property is adjacent to a street or road subject to frequent salting and plowing. In these cases, it may be possible to select specific plant material that is more resistant to salt accumulation in the soil and salt exposure to the foliage. See Appendix H for salt tolerances of various plants.
11. Do not plow snow directly into streams or wetlands. Snow storage and disposal areas should be located in an area where snowmelt can infiltrate into the ground, filter through a vegetated buffer or be otherwise treated prior to reaching streams and wetlands. Provide adequate storage volume to trap sediment left behind by melting snow and plan regular maintenance to remove accumulated sediment.
12. In areas subject to heavy chemical deicing use, flushing the soil with water after the last freeze may alleviate burn potential.
13. Year-round practices of proper pruning, watering, and fertilization that promote plant health, will also make plants more tolerant to salt exposure. However, for the overall health of the landscape, the goal should be to reduce or minimize the use of deicing chemicals.

Regional, Industry or Sustainability Considerations/Adaptations

1. Particularly in mountain resort areas, Snow Management Plans may be required by local

regulations. Development plan submittals may require that snow storage locations be specified.

2. Municipalities covered under state stormwater discharge permits may have requirements for snow management and disposal.
3. For obvious safety reasons, snow should be cleared away from fire hydrants so that they remain readily accessible.
4. If an electric/mechanical snowmelting device is used to dispose of removed snow (e.g., The Can snowmelter, Snow Dragon, etc.), the owner or operator must obtain a Minimum Industrial Discharge (MINDI) permit from the Colorado Department of Public Health and Environment. Treatment of the discharge will be required and numeric limits on total suspended solids (TSS) will likely apply. If the discharge is to a storm sewer, the discharger must obtain permission of the owner of the storm sewer to discharge. (For additional detail, see www.cdphe.state.co.us/wq/PermitsUnit/Industrial/MINDI_overview.pdf).

Key References

- American Association of State Highway and Transportation Officials (AASHTO), 2007. Chapter 8, Winter Operations and Salt, Sand and Chemical Management. Website: http://environment.transportation.org/environmental_issues/construct_maint_prac/compendium/manual/8_1.aspx.
- Colorado Department of Public Health and Environment website: www.cdphe.state.co.us/.
- Kentucky Cooperative Extension-Franklin County Horticulture, 2007. Use of deicing chemicals can have impact on plants (<http://ces.ca.uky.edu/franklin/horticulture/2001/011401.htm>).
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Production Practices for Nurseries, Greenhouses and Sod Growers

Description

Nurseries, greenhouses and other growers should implement a variety of source, structural, cultural and managerial controls to use water efficiently and minimize pollution of water resources. Irrigation practices that minimize off-site transport of pollutants also typically conserve water.

The Greenhouse portions of this BMP are based primarily on "Pollution Prevention in Colorado Greenhouses, XCM-206" (Colorado State University Extension, 1998).

BMP Type			
Design			
Installation			
Maintenance/Operations			X
Green Industry Relevance			
ASLA		GCC	
ALCC		ISA	
CALCP		RMSG	X
CNGA	X	GCSAA	

Basic Practice Guidelines

1. Manage irrigation to use water efficiently and to minimize transport of chemicals from the soil surface or immediate crop root zone and to conserve water.¹ Follow these key practices:
 - Schedule irrigation according to crop needs and growing-medium water depletion. Watering requirements will vary and should be adjusted based on time of year, weather, methods of storage and type and stage of the plant (e.g., dormancy). Remember to adjust irrigation system timers for the appropriate season. Plants need less water during cool, rainy weather than during hot, dry, windy weather.
 - Group plants together that have the same water requirements (i.e., use hydrozoning).
 - Plug sprinkler heads that are not watering plants, keep sprinkler heads as low as possible to the plants and use larger water droplet size to reduce irrigation time.
 - Keep plant material free of weeds to decrease competition for water.
 - Schedule an annual irrigation audit to identify current and potential problems.
 - Repair or replace broken or leaking hoses, pipes, sprinkler heads and valves.
 - Reduce water application rates to ensure no runoff or percolation occurs during chemigation.

¹ See the Water Management Practices for Nurseries, Greenhouses, Sod Growers and Holding Yards for additional practices to consider. The irrigation practices below are the basics that should be achievable under most circumstances; several of these practices are also included in the Water Management BMP.

- Consider upgrading irrigation equipment to improve application efficiency, when financially feasible. For example, a computerized irrigation scheduler using a drip system can reduce overwatering and excessive leaching compared to an overhead system.
 - Consider implementing closed irrigation techniques (water recycling system) whenever water rights and site and financial constraints allow. (Note: recycled water should be ozonated or otherwise treated to remove pathogens from the water to prevent spread of disease.)
 - Proper backflow prevention devices are necessary to prevent cross-contamination of public water supplies. This is particularly critical if chemigation is used.
 - When designing ball and burlapped (B&B) storage areas, place more drought tolerant species on southern and western sides and the less tolerant species on the northern and eastern sides of the storage areas.
 - Use appropriate plant material to create a natural wind break for growing areas.
 - When B&B stock and containerized stock is received, it should be kept out of the wind and sun. Ideally, balls should be covered with moisture-retaining materials such as sawdust or wood chips if stock will be stored for a long time. Use shrink wrap to eliminate shock to the plant and therefore reduce water needs when transporting or holding for an extended period of time.
 - Heal-in mix for B&B plants should either be fully composted or inert material such as sand or its equivalent. This is necessary to prevent competition for water and nutrients and to maintain a lower soil temperature for the roots.
2. Use integrated pest management (IPM)/plant health care (PHC) in pest control decisions. This integrated approach keeps pests and their damage at acceptable levels. Follow these key practices:
- **Host Resistance:** When selecting crops and plant varieties, whenever possible, select varieties that have few or reduced problems with insects and diseases.
 - **Eradication/Sanitation:** Remove and dispose of diseased plants or plant parts. Also, properly disinfect tools and other equipment.
 - **Avoidance:** Avoid introduction of plant diseases by procuring disease-free plant material and isolating, inspecting and treating newly arrived plants.
 - **Cultural Practices:** Implement practices that create an unfavorable environment for disease development. Some key practices include:
 - Avoid overhead irrigation and frequent, light watering to reduce leaf spot diseases caused by many fungal and bacterial pathogens.

- Do not extend the period of leaf wetness beyond 12 hours to reduce disease problems.
 - Time pesticide application to minimize host plant damage and maximize pest control.
 - Continually monitor all stock for signs of insect or disease problems.
 - Spot-treat problem areas, rather than the entire greenhouse or nursery.
 - Improve plant vigor and pest tolerance by supplying adequate light, nutrients and water and by adjusting the greenhouse environment for optimum growth. It is important to monitor the nutrient needs of plants in nurseries. A newly containerized plant may need to have nutrients added. A container shipped from a grower and held in the nursery for more than one season may need additional nutrients.
- Crop Rotation: Rotate crops in greenhouses and nurseries to prevent the spread of disease.
 - Implement Chemical Alternatives: Only about 10 percent of plant diseases in Colorado require chemical controls. Use the controls described above plus beneficial insects and other biological controls whenever possible.
3. Apply pesticides only when needed and use in a manner to minimize off-target effects. Follow these key practices:
- Always follow the label—it's the law!
 - Ensure chemical applicators receive thorough training and proper certification prior to chemical use.
 - Know characteristics of the application site, including soil type and depth to groundwater under the greenhouse or nursery. Be aware of any drinking water wells downgradient of the operation.
 - Compare chemical leaching hazard, persistence and toxicity to site-specific conditions to determine suitability of the pesticide at each location.
 - Be aware that some pesticide formulations are not compatible and may result in increased potency and phytotoxicity.
4. Maintain records of all pesticides applied (both restricted and non-restricted use), including brand name, formulation, EPA registration number, amount and date applied, exact location of application, and name, address and certification number of applicator. Combine this information with irrigation water data, crop growth records and notes on effectiveness of alternative pest control measures to help identify and track measures to both save money and reduce pesticide usage.

5. Protect groundwater and surface water from spills and leaks of pesticides by properly designing pesticide storage, mixing and loading facilities. Follow these key practices:
 - Store all pesticides in a locked building with cement floors, located at least 100 feet away from any water supply.
 - Equip storage facilities with secondary containment dikes designed to contain liquid spills or leaks.
 - Use impermeable mixing/loading pads at pesticide loading sites.
 - Make material safety data sheets (MSDSs) available at the mixing station.
 - Provide worker safety features such as showers, protective clothing and spill cleanup kits in accordance with MSDS requirements.
6. Protect wellheads from potential sources of contamination. Follow these key practices:
 - Regularly inspect and maintain wells.
 - Install backflow prevention devices.
 - Stay at least 100 feet away from the well when mixing, loading and storing agricultural chemicals.
 - Monitor well water quality periodically and know site-specific variables affecting aquifer vulnerability.
7. Protect surface water from contaminated runoff. Follow these key practices:
 - Recover irrigation water and store it in impermeable tanks or reservoirs (if water rights obligations allow).
 - Keep greenhouse open runoff channels, condensate gutters and reservoirs separate from rainwater flows and catchment basins to prevent contamination of surface runoff.
 - Keep roof and site drainage directed away from greenhouse structures and separated from spill containment structures for petroleum, fertilizers and pesticides.
 - Monitor surface water periodically to determine whether pollution is occurring.

Regional or Industry Considerations/Adaptations

1. Also see the Sustainability BMP for energy-related considerations for nurseries and growers.

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Water Management Practices for Nurseries, Greenhouses, Sod Growers and Holding Yards

Description

Manage production and holding areas to promote the efficient use of water.

This BMP has been adapted in part from “Coping with Drought: Water Conservation Methods for the Greenhouse by Laura Pottorff, Regional Commercial Greenhouse Specialist, Colorado State University Extension, Adams County, May 2002.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA		GCC	X
ALCC		ISA	X
CALCP		RMSGGA	X
CNGA	X	GCSAA	X

Basic Practice Guidelines

The guidelines below are divided into three steps for ease of implementation. Step 1 should be implemented whenever feasible by all growers and in holding yards. Step 2 is strongly recommended for implementation whenever physically and financially possible. Step 3 illustrates the ideal.

Step 1: Reduce Wasted Water/Runoff

1. Group plants with similar water needs together (i.e., hydrozones) to improve irrigation efficiency. Adjust individual sections of the irrigation system to avoid excessive watering.
2. Space containers under fixed overhead irrigation to maximize plant irrigation and reduce waste between containers.
3. As inventory is sold, consolidate plant material to maximize benefit of water used.
4. Use drip tubes for each individual container, when reasonably practical. This ensures that the water is available for the plant’s use, not wasted on the ground.
5. When using programmable irrigation booms, adjust travel rate and flow rates to crop needs.
6. Choose sub-irrigation systems where appropriate using ebb and flood or capillary mat irrigation technologies with a water capture and reuse system. Fertility rates for most sub-irrigation systems can be reduced 50 percent.
7. Manage leaching from containers or pulse-irrigated containers. If fertilizer levels are reduced and the electrical conductivity monitored, the necessity for leaching may be reduced. If pulse-irrigation is used with less fertilizer and the monitoring of the electrical conductivity, leaching may potentially be obtained on occasion with far less wasted water than the 10 percent recommended by many textbooks.

8. Check growing media. The condition of the growing media is very important in determining irrigation efficiency. Many of the organic constituents used in growing media, such as peat moss, have hydrophobic or water repelling characteristics. These media may become difficult to “wet” after becoming excessively dry and therefore may require excess water. Wetting agents may be added to avoid these problems and repeated pulse-irrigation may reduce the amount of water needed to “wet” the soil.

Step 2: Examine and Improve Efficiency of Irrigation System

9. Work towards adapting new irrigation technologies to production systems to help lower costs and reduce water waste or runoff. A well-designed, efficient irrigation system is a large part of the water use reduction equation.
10. There are several means by which to supply a crop with irrigation water: overhead sprinkler, hand-watering, drip or trickle irrigation systems, and sub-irrigation. Overhead irrigation and hand watering are typically more wasteful delivery systems. These systems also wet the foliage, increasing the potential for disease. Drip or trickle systems are more efficient and provide the greatest control over the amount of water applied.
11. Sub-irrigation (ebb and flow, flood floors, troughs or capillary mats) systems are extremely effective at reducing water waste. These systems also require half the fertilizer of overhead irrigation and lead to less disease because the foliage remains dry. However, they can be expensive to install and water may need to be treated before reuse can occur.
12. Plug sprinkler heads that are not watering plants, keep sprinkler heads as low as possible to the plants and use larger water droplet size to reduce irrigation time.
13. Install rain sensors for outdoor nursery crops to ensure irrigation does not occur during rain. Also consider other water conserving devices such as check valves, pressure regulators, soil moisture sensors, ET controllers, wind sensors and other such devices.
14. Irrigate plants when needed based on media moisture levels, which can be assessed by these methods:
 - Appearance or Feel—water when the media will crumble easily when compressed in the hand. Examine the media at several depths.
 - Tensiometers—these devices are made of a porous ceramic tip attached to a vacuum gauge filled with water. The tip is inserted in the soil and the reservoir is filled with water. As the rooting media dries, water moves through the tip and the resulting tension is recorded.
 - Weight of Media Moisture—one potted plant on a bench is used as a control. It rests on a scale that is adjusted to trip a switch when the moisture level drops below a certain level. As the plant grows, the setting must be adjusted to account for added plant weight.

- Light Accumulators—based on the idea that increased light causes increased evaporation. A photoelectric cell and counter activate a solenoid valve when a predetermined level of light is received.
 - Soil Moisture Conductivity—several devices relate soil moisture to electrical conductivity. When the soil dries to a pre-set level, the electronic circuit activates the solenoid valve.
15. Properly maintain existing irrigation systems to maximize efficiency. This includes both manual inspection of equipment and attention to irrigation controllers. Some representative practices include:
- Replace washers to reduce leaks.
 - Replace leaking hoses, pipes and sprinklers.
 - Regularly monitor and adjust irrigation controllers to meet the seasonal needs of the plants. (Know how to use existing technology, including water budgeting features.)
 - Clean spray heads to ensure uniform distribution and proper application of water.

Step 3: Collect and Reuse/Recycle Irrigation Water

16. Many greenhouse operations across the country have already adopted capture and recycling systems. Whether voluntary or mandated, these capture systems have environmental *and* monetary benefits. While some greenhouses have made the switch due to irrigation cost savings, others have adopted these systems to ensure adequate supply of sufficiently high quality water during production. In Colorado, it is important to consider water rights constraints when adopting these systems.
17. Implementation of a new system means there will be an inevitable learning curve. Potential problems that may occur with recycled water systems can be easily avoided with careful planning and some monetary investment.
18. A common method of collection and reuse of water is the installation of retention basins, storage ponds, storage tanks and additional pumping capacity. Concerns related to these systems include build-up of salts, chemicals and nutrients, and changes in pH that can adversely impact crop quality. To mitigate these concerns, it is important to monitor and test irrigation water at least three times per year for salts, chemicals, nutrients and pH. Fertilizer application should be based on the results of these tests. If buildup of salts in recycled water becomes a problem, the water should be diluted with fresh water. Many growers use water treated through a process known as reverse osmosis (RO) to remove potentially harmful salts. The systems are relatively expensive but work well as a source of water for back blending.
19. Other concerns with recycled water systems include waterborne pathogens such as *Pythium sp.* that may be present in recycled water at relatively high concentrations and

that ultimately cause root rot. Unfortunately, there are no scientifically derived thresholds for levels of pathogens in irrigation water. Growers can proactively address waterborne pathogens such as *Pythium* by implementing these practices:

- Increase the frequency of scouting for signs of disease.
- Remove diseased plants from the system quickly.
- Monitor pathogen levels in irrigation water. Water can be sampled at different points to determine pathogen presence and levels.
- Treat water for disease organisms by retention and dilution, filtration, chlorination, ozonation, and/or UV light.

20. Costs associated with installation of holding ponds, tanks, pumps, and possible treatment systems eventually pay for themselves. Phasing installation of these capture systems helps spread capital outlay over a number of years.

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Key Drought-Related Web Sites for Up-to-Date Information

Colorado Climate Center Website: ccc.atmos.colostate.edu.

Colorado Division of Water Resources Website:

<http://www.dnr.state.co.us/water/indexWater.asp>.

Colorado Office of Emergency Management Drought Monitoring Website:

<PublicInformation/Drought>.

Colorado State University Website: www.drought.colostate.edu/.

Colorado Water Conservation Board Website: cwc.state.co.us.

Colorado Water Resources Research Institute Website: cwrri.colostate.edu.

Colorado WaterWise Council Website: coloradowaterwise.org/.

National Drought Mitigation Center, University of Nebraska—Lincoln, The National Drought Mitigation Center Website: www.drought.unl.edu.

Northern Colorado Water Conservancy District Website: www.ncwcd.org/.

U.S. Bureau of Reclamation Water Supply Information Website:

www.usbr.gov/main/watersupply.

U.S. Department of Agriculture, Colorado Snow Survey Website: www.co.nrcs.usda.gov/snow/.

U.S. Department of Agriculture, SNOTEL (Snowpack Information) Website:

www.co.nrcs.usda.gov/snow/snow/index.html.

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Retail Practices for Nurseries, Greenhouses and Garden Centers

Description

Retail businesses should operate in a manner to maintain the health of plants, conserve water and promote water conservation and water resource protection to the general public.

Basic Practice Guidelines

1. Group plants together that have the same water requirements (i.e., use hydrozoning) and water accordingly.
2. Schedule irrigation according to plant needs and growing-media water depletion. Watering requirements will vary and should be adjusted based on time of year, weather, methods of storage, and type and stage of the plant (e.g., dormancy). Plants need less water during cool, rainy weather than during hot, dry, windy weather.
3. Properly educate retail employees on the water needs of various plants so that both over-watering and under-watering are minimized.
4. Upgrade irrigation equipment to improve application efficiency.
5. Promptly repair leaking irrigation equipment—including hoses, bibs and couplings. Don't leave hoses running on the ground.
6. Implement closed irrigation techniques (water recycling system) whenever water rights and site constraints allow. Treat for water-transmitted root disease organisms before using recycled water for irrigation.
7. Plug sprinkler heads that are not watering plants, keep sprinkler heads as low as possible to the plants and use larger water droplet size to reduce irrigation time. Preventing water from being wasted on pathways not only saves money, but also reinforces water-wise practices to the visiting public.
8. Avoid introduction of plant diseases by procuring disease-free plant material and isolating, inspecting and treating newly arrived plants.
9. Implement cultural practices that create an unfavorable environment for disease development. For example, avoiding overhead irrigation and frequent, light watering can reduce spot diseases.
10. Protect plant vigor and pest tolerance by supplying adequate light, nutrients and water.

BMP Type			
Design			
Installation			
Maintenance/Operations		X	
Green Industry Relevance			
ASLA		GCC	X
ALCC		ISA	
CALCP		RMSGA	
CNGA	X	GCSAA	

11. Offer plants with lower water requirements or those adapted to local conditions and appropriately identify them in displays.
12. Be properly educated about the water requirements of plants when communicating with the public and recommend plants with lower water requirements or those native to local climate conditions. Don't be fooled by marketing campaigns touting low-water usage or native plants without the data to back up their claims.
13. Follow proper storage and handling requirements for pesticides and fertilizers. In cases of containers breaking or leaking, follow manufacturer's directions for cleanup and disposal. See the *Pesticide, Fertilizer and Other Chemical Storage, Handling and Disposal BMP* for additional guidelines.
14. In the event of broken bags of compost and soil, sweep up spilled materials and dispose of them rather than washing them into the gutter.
15. Consider establishing displays, signage, information brochure distribution shelves, or pilot-demonstration test sites for the purposes of effectively educating the public on water conservation and water quality protection practices.

Regional or Industry Considerations/Adaptations

None identified.

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Park, Golf Course and Other Large Landscape Design and Management

Description

Large landscaped areas such as parks and golf courses should be well designed and properly managed to be an aesthetically-pleasing environmental amenity and to minimize runoff to waterbodies.

This BMP is based primarily on “Guidelines for Water Quality Enhancement at Golf Courses Through the Use of Best Management Practices” (Wright Water Engineers and Denver Regional Council of Governments 1996).

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	
ALCC	X	ISA	X
CALCP	X	RMSGGA	
CNGA		GCSAA	X

Basic Practice Guidelines

Large landscaped areas such as parks and golf courses present significant opportunities to implement the various GreenCO BMPs at a larger scale, with potential for significant water conservation and water quality benefits. The basic practice guidelines for large landscapes are categorized into the design, construction and maintenance phases.

Design

1. A pre-design natural resources inventory and evaluation should provide the basis for subsequent planning and design, to avoid impacts to natural resources. It is essential to include appropriate parties such as the engineer, the landscape contractor and the golf course superintendent or park manager. A full range of issues should be considered such as aquatic life, terrestrial life, riparian corridors, wetlands, open space, native and endangered species, hydrology and drainage, soils, stream standards, irrigation, stormwater, groundwater, water rights, water sources, geology, geomorphology, topography, etc.
2. Identify applicable pollutant source controls early in the design stage by taking a “management unit” approach consistent with the principles of Integrated Pest Management (IPM). Think about maintenance issues up-front as part of the design process.
3. When designing overall site drainage, use “natural” drainage practices when possible such as:
 - Preserving or enhancing natural drainages, wetlands and ponds, etc.
 - Maintaining wide, undisturbed riparian (stream) corridors.
 - Avoiding flow concentration on site and to adjacent hydrologically connected areas.
 - Site-grading to maximize infiltration in the large available pervious areas.

- Reverse-grading in localized areas to limit direct discharges into wetlands and streams where necessary.
4. Large landscaped areas may require implementation of engineered stormwater detention facilities such as retention ponds (wet ponds) and detention basins (dry ponds). Such features should be designed in accordance with local drainage criteria regulations.
 5. Utilize “edge treatments” or buffer zones of natural vegetation along ponds, waterways and riparian corridors to provide water quality protection and stormwater management benefits.
 6. Uniform, dense grass buffer strips and grass-lined swales can be designed for sheet-flow conditions to treat return flows or natural runoff, improve water quality and limit the quantity of runoff, and to help protect wetland and sensitive areas from fertilizer and pesticide contamination. These features should be designed so that water does not “pond” for more than two days.
 7. Structural BMPs that control runoff velocities may be required in drainages at the boundaries of golf courses or within drainages on the course. Examples include drop structures and other energy dissipaters. These BMPs help to control erosion and water quality problems associated with sediment loading.
 8. Stream crossings should be minimized and, where necessary, should be designed with minimal impact. Always consult with the U.S. Army Corps of Engineers and obtain required permits when altering streams and wetlands.
 9. Man-made wetlands can be incorporated into site designs to enhance water quality where soil and hydrologic conditions are appropriate.
 10. Large landscape design should be based on advanced irrigation design principles. Water application rates should correspond to consumptive use requirements. Water budgets should be developed during the design phase and tracked as part of routine maintenance. Advanced irrigation technology using weather stations and centralized control systems should be used.
 11. Return flow reuse, stormwater reuse and use of treated wastewater effluent for irrigation should be used when environmentally, legally (e.g., water rights) and agronomically feasible. Recycled water must meet all applicable standards and not pose a health risk in accordance with Colorado Department of Public Health and Environment Water Quality Control Commission Regulation No. 84: Reclaimed Domestic Wastewater Control Regulation. See the *Irrigation Using Nonpotable Sources* BMP for special irrigation management considerations when nonpotable or reclaimed water sources are used.

Construction

12. Minimize exposure of large areas to wind and water erosion by developing a grading plan that minimizes the total acres graded and left exposed without a surface protection strategy. Proper scheduling and timing are essential.

13. Minimize disturbance of areas designated for native species. Replacement of native species is more difficult and costly than species protection. Protected habitats should be isolated during construction by a barrier system (e.g., fence).
14. Seed mixes used during erosion control and stabilization during construction should be compatible with the final seeding selection for the landscape.
15. Topsoil removed during construction should be carefully stored and treated as an important resource. Berms should be placed around topsoil stockpiles to prevent runoff during storm events.
16. Appropriate sediment control measures should be implemented to minimize off-site transport of pollutants in accordance with Colorado Discharge Permits System (CDPS) Stormwater Construction permits. (See Appendix A for more information.)

Maintenance

17. IPM should be implemented. This includes measures such as “prescriptive” pest control on a “management unit” basis; use of pest-resistant turfgrass and other plant cultivars; establishing populations of natural pest enemies; maintaining balanced turfgrass ecosystems; use of competitive species that put weeds and pests at a disadvantage; use of traps and attractants; and careful irrigation and fertilization.
18. Proper irrigation is a key component of an IPM system. Irrigation system design should consider the water resource, need for reuse, drainage requirements and water quality issues.
19. Proper fertilization is a key component of IPM. Fertilizer for each management unit should be based on soil or vegetation tests. Over-application of fertilizers can contaminate surface runoff and groundwater.
20. Landscaping and vegetative practices can reduce stormwater runoff rates and volumes, sediment loads and pollutants. A landscape and vegetation management plan should be established as part of the IPM plan.
21. A turf management plan that considers irrigation, fertilization, IPM and environmental constraints is vital to evaluate ongoing maintenance and operation.
22. Ponds and lakes require special attention to limit eutrophication. For example, runoff from fertilized areas should be controlled and in-lake management techniques such as aeration or maintaining flow-through conditions may also be required.
23. Proper storage and handling of pesticides, fertilizers, fuel and other maintenance chemicals is necessary to minimize pollutant loading. Be aware of regulatory requirements such as Community-Right-to-Know requirements, Material Safety Data Sheets (MSDS) and Spill Prevention Control and Countermeasures (SPCC) Plans for maintenance facilities.
24. Monitoring is useful to identify strengths and weaknesses of existing golf course management. Results should be used to revise management strategies.

25. Record keeping is important to document changes in turf quality, pest levels and water quality. A computerized database or spreadsheet is recommended.
26. Consult with state and local wildlife and water quality authorities on strategies for controlling water-quality impacts (e.g., fecal coliform) of high-density geese populations and burrowing animals that can damage drainage structures.
27. The best-designed BMPs will fail without regular maintenance including regular monitoring, repairs and other adjustments.

Drought Management Strategies

28. During drought, golf courses and other large landscapes must be prepared to implement management strategies that reduce water use, while protecting investment in their landscapes. Watson et al. (2003) reported the following representative drought management strategies used by Colorado golf courses during 2002 including:

- Use of wetting agents.
- Elimination of irrigation in selected areas.
- Reducing irrigation of rough areas.
- Hand-watering tees and portions of fairways.
- Adjusting fertilization practices.
- Reducing fairway irrigation.
- Raising mowing heights.
- Modifying the existing irrigation system.
- Shifts to nonpotable or reclaimed water.

Regional or Industry Considerations/Adaptations

1. The Irrigation Association offers a certification program for Golf Irrigation Auditors http://www.irrigation.org/certification/default.aspx?pg=cgia_program.htm#guidance.
2. Audubon International offers the Audubon Cooperative Sanctuary Program (ACSP), which is a certification program that helps golf courses protect the environment and preserve the natural heritage of the game of golf. The program promotes enhancement of valuable natural areas and wildlife habitats that golf courses provide, encourages improved efficiency, and minimizes potentially harmful impacts of golf operations. Also offered is the Audubon Signature Program, which provides comprehensive environmental planning assistance to new developments. The programs help landowners and developers design for the environment so that both economic and environmental objectives are achieved. Once construction is

complete, involvement in an Audubon Signature Program ensures that managers apply sustainable resource management practices in the long-term stewardship of the property. For more information, see <http://www.auduboninternational.org/programs/acss/golf.htm>.

3. Some local governments may have landscape and stormwater control ordinances in place with specific requirements that must be followed.

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Landscape Features in Low Impact Development

Description

Properly design, install and maintain landscape features serving stormwater runoff water quality treatment and volume reduction functions. Low Impact Development (LID) designs seek to approximate pre-development runoff hydrology by allowing storm runoff to infiltrate into the landscape rather than routing urban runoff directly into the storm sewer.

Landscaping can be used to help minimize directly connected impervious area, which can both reduce required runoff treatment volumes (the “water quality capture volume”) and provide water quality benefits such as filtering pollutants from runoff. Green Industry professionals need to understand sound design practices associated with LID, as well as understand special maintenance requirements that may be needed on such properties.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

Basic Practice Guidelines

Landscape-related LID practices include a variety of engineered stormwater BMPs (also called Integrated Management Practices) that are specifically designed and located to minimize the quantity of urban runoff and improve its quality. Representative LID BMPs are summarized in Table 1. The remainder of this BMP fact sheet focuses on a relatively small-scale infiltration-based practice commonly described as porous landscape detention or a bioinfiltration cell. However, proponents of LID emphasize that LID is a design philosophy that incorporates many design considerations. Porous landscape detention is just one tool in the LID toolbox. Of paramount importance for any stormwater-related feature is the protection of the public safety, health and welfare. This should be kept in mind during planning, design, installation and maintenance. Those designing LID sites should recognize that it may be necessary to combine traditional stormwater management facilities for flood control with LID techniques in order to meet local government stormwater runoff criteria.



Porous landscape detention in an Aurora parking lot. (Photo Courtesy of Michelle Delaria, CASFM photo database, http://www.casfm.org/stormwater_committee/)

Table 1. Representative LID Practices and Functions

(Note: the general descriptions below are NOT design criteria; instead, they are brief descriptions to increase awareness regarding the practices.)

Practice and Description	Considerations/ Implications for Green Industry Professionals
<p>Porous Landscape Detention (PLD) (also called bioretention cells, infiltration planters and rain gardens): An engineered vegetated landscape area underlain by a sand bed, often equipped with an underdrain pipe, that receives runoff from site development. A shallow surcharge area above the vegetation allows temporary storage of a runoff design volume (typically called the water quality capture volume) and then gradually infiltrates into the underlying sand filter prior to infiltrating into the ground or exiting via an underdrain pipe.</p>	<p><i>See more detailed discussion of Porous Landscape Detention based on Urban Drainage and Flood Control District (UDFCD) criteria following this table.</i></p> <p>Check local government requirements for setbacks of PLD from building foundations.</p> <p>Removal of PLD from an existing development or modification of design specifications is not allowed.</p> <p>Proper maintenance of PLD features is essential to their long-term function.</p> <p>Proper design, installation and maintenance of the growing media and filter layers are essential to avoid clogging and standing water. Be sure to follow local design criteria to avoid these problems.</p>
<p>Contained Planters/Rain Gardens: These landscape features are similar to porous landscape detention except they are typically fed by roof downspouts or direct precipitation and are constructed in above-ground structures (planters) with underdrains to the ground surface. A variation on the rain garden is a tree planter in ultra urban areas.</p>	<p>Plants selected for rain gardens should be relatively self-sustaining, with minimal needs for supplemental irrigation, fertilizer, pesticides, etc.</p> <p>Appropriate soils and planter sizing are important to the long-term health of the plants.</p>
<p>Porous/Permeable Pavement: Porous or permeable pavement enables parking lot, street and driveway runoff to infiltrate into the ground rather than runoff into the gutter. Various forms of this practice include modular block pavement, cobblestone block pavement, reinforced grass (turf rings) pavement, poured porous concrete pavement, porous asphalt pavement and others. Also see UDFCD 2007 or Ferguson (2005).</p>	<p>When designing hardscape features as part of landscape, consider permeable materials that enable infiltration into the soil.</p> <p>UDFCD provides design criteria for several types of porous pavement appropriate for the metro Denver area.</p>

Practice and Description	Considerations/ Implications for Green Industry Professionals
<p>Replacement of Roadside Curb/ Gutter with Grass Ditches: Rather than immediately routing runoff from roads into the storm sewer, which increases runoff rates and volumes, grass ditches or swales can be used to convey road runoff.</p> <p>Some adaptations of this practice use a slotted curb and gutter or curb cuts to route runoff to the grass swale or ditch.</p>	<p>Lawn care professionals may maintain roadside ditches. Since these ditches drain to rivers, streams and other waterbodies, it is important to carefully apply or minimize use of fertilizers, pesticides and herbicides. Sediment may accumulate in roadside ditches, particularly after winter sanding, requiring shoveling and disposal of sediment to maintain the ditch capacity.</p> <p>If erosion or gullying is identified, it should be corrected as soon as possible through implementation of a variety of erosion and sediment control measures (e.g., erosion control logs and/or mats, check dams, revegetation, etc.)</p> <p>Vegetated roadside ditches in Colorado may also be affected by snow removal practices. See the <i>Snow Removal</i> BMP for more information.</p>
<p>Disconnected Downspouts: Rather than connecting roof downspouts directly into storm drains, they should be daylighted to the ground surface in areas that maintain positive drainage away from building foundations.</p>	<p>Downspouts can be directed towards planting beds and other landscape features that benefit from the additional runoff. While disconnecting downspouts is fundamental to reducing directly connected impervious area, it is also essential to be mindful of potential problems that moisture from roof downspouts in the backfill zone around building foundations can cause, especially in areas with soil that have potential for swelling. Roof downspouts should be directed to discharge to pervious areas that do not have the potential to cause foundation moisture problems. This can often be accomplished by using downspout extenders. Recommendations contained in the development's geotechnical reports should be followed.</p>
<p>Vegetated or Grass Swales (also called biofilters): Vegetated swales provide natural conveyance of stormwater providing filtering and</p>	<p>Grass swales should be maintained in healthy condition by proper irrigation, mowing, fertilization and weed control to</p>

Practice and Description	Considerations/ Implications for Green Industry Professionals
<p>some infiltration of stormwater runoff. Typical swales in Colorado are shallow grass-lined channels with relatively wide, flat bottoms designed for shallow flow near the source of storm runoff. Some communities have also implemented modifications to grass swales as “vegetated street swales” that incorporate a combination of porous landscape detention and traditional swale features. These facilities are typically narrow depressions that have vegetated surfaces underlain by a rock trench and geotextile fabric. Other variations of this practice include swales with wetland vegetation. See the City of Portland or the Low Impact Development Center for examples.</p>	<p>maximize the filtering role of the grass and to reduce potential for erosion (i.e., avoid bare patches of soil).</p> <p>Proper soil amendment to enable infiltration and plant rooting should be implemented. In some cases, soils must comply with engineered design criteria.</p> <p>Depth and sideslopes of swales should be designed with public safety in mind.</p> <p>During installation, be sure to comply with engineering specifications for the swale design.</p> <p>UDFCD provides design and maintenance criteria for grass swales. Also see the <i>Turf Management BMP</i> for other maintenance guidelines.</p>
<p>Vegetated or Grass Buffers: Grass buffers, sometimes called biofilters or buffer strips, are vegetated areas designed to accept sheet flow provided by flow spreaders which accept flow from an upstream development. Vegetation may take the form of grasses, meadows, forests, etc. The primary mechanisms for pollutant removal are filtration, infiltration, and settling.</p>	<p>Maintenance of buffers includes maintenance of irrigation systems, appropriate mowing and periodic sediment removal.</p> <p>Fertilizer and herbicides should be used only to the extent necessary to maintain plant health and controls weeds.</p> <p>UDFCD provides design criteria for grass buffers.</p>
<p>Green Roofs: Green roofs, also known as vegetated roof covers, eco-roofs or nature roofs, are multi-beneficial structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall. They are constructed of a lightweight soil media, underlain by a drainage layer, and a high quality impermeable membrane that protects the building structure. The soil is planted with a specialized mix of plants that can thrive in the harsh, dry, high temperature conditions of the</p>	<p>Experience with green roofs in Colorado is currently limited. The new EPA headquarters has a green roof that is being monitored. Green Industry professionals involved with design, installation and maintenance of green roofs should recognize special considerations will likely be required for plant selection, irrigation, maintenance and other factors.</p>

Practice and Description	Considerations/ Implications for Green Industry Professionals
<p>roof and tolerate short periods of inundation from storm events. See the LID website (www.lidstormwater.net/greenroofs/greenroofs_home.htm) or the Green Roof (www.greenroofs.com/) for more information.</p>	
<p>Infiltration Facilities: A variety of infiltration facilities may be incorporated such as infiltration trenches, sand filters, infiltration basins, percolation trenches and dry wells.</p>	<p>UDFCD provides guidance on these BMPs.</p>
<p>Minimizing Directly Connected Impervious Area: This is a site layout and design consideration that breaks up the flow of runoff across impervious surfaces by incorporating permeable, landscape oriented features.</p>	<p>UDFCD provides guidance on minimizing directly connected impervious area.</p>
<p>Preserve Natural Features: During the site design process, natural features providing significant water quality and environmental functions such as wetlands, riparian corridors and other multiple-benefit natural landscape features may be preserved.</p>	<p>Natural features preserved at a site will have different landscape maintenance requirements than traditional, manicured lawn areas. Ask the owner for guidance on such areas. Maintenance may be limited to infrequent mowing, weed control and pruning.</p>
<p>Tree Planting/Preservation: Trees intercept rainwater in their canopy and reduce the water running off from a site. Additionally, the shading effect of trees can help to reduce water temperatures in runoff.</p>	<p>Generally, large trees with small leaves are most effective at intercepting rainfall.</p> <p>Some communities such as Portland, OR have implemented aggressive tree planting goals and offer development tree credits toward stormwater treatment requirements when trees are planted as part of development. Also see www.caseytrees.org/programs/planning-design/gbo.html for study results in the Washington, D.C. area.</p> <p>(Tree planting credits are not considered by UDFCD at this time.)</p>

Practice and Description	Considerations/ Implications for Green Industry Professionals
<p>Preservation of Soils with High Infiltration Capacity and/or Use of Soil Amendment to Improve Infiltration: LID designs may set aside areas with soils with high infiltration capacity (Type A and B soils) to facilitate infiltration of development-generated site runoff. Alternatively, LID designs may incorporate soil amendment to improve infiltration, based on the results of soil tests.</p>	<p>If soils with high infiltration rates are being protected at a development site, keep heavy machinery off of the area to avoid soil compaction during development.</p> <p>If design plans call for soil amendment to improve infiltration, follow specifications for soil amendment.</p> <p>Topsoil removed from graded areas can be stockpiled for later use on a site.</p>



Aurora parking lot runoff directed to a grass swale through a slotted curb (left). Bioswale in a Colorado Springs parking lot (right). (Photos Courtesy of Michelle Delaria, CASFM photo database, http://www.casfm.org/stormwater_committee/).

Porous Landscape Detention (“PLD” or Bioretention Cell)

1. UDFCD (2007) provides a detailed design procedure, design details, and design spreadsheet that address the following design elements for PLD: basin storage volume based on a 12-hour drain time, surface area and maximum water quality capture volume (WQCV) depth, sand/peat media specifications for growing media, granular sub-base and underdrain requirements, and impermeable membranes (for use in Type D soils) or geotextile liners. These design criteria are not repeated herein and can be downloaded from the UDFCD website (www.udfcd.org).
2. Vegetation selected for PLDs in Colorado may be either irrigated bluegrass or natural grasses with shrub and tree plantings. UDFCD recommends that the PLD’s infiltrating surface be vegetated with drought tolerant native grass species that do well in sandy soils. A PLD provides a natural moisture source for vegetation, enabling green areas to exist with reduced

irrigation needs. Table 2 lists recommended seed mix for sites that will not be irrigated after the vegetation has been established and includes wildflower seed to provide a more natural and diverse appearance. All seed needs to be well mixed, broadcast seeded, followed by hand raking to cover seed, followed by an application of 800 lbs/acre¹ of Biosol to improve germination. The seeded area should be hydromulched with 2,500 lbs/acre of virgin wood fiber hydromulch and 150 lbs/acre of organic tackifier. If standing water or snow/frozen ground are present, then seeding should be delayed until these conditions subside.

3. Do not use trees and shrubs on the flat surface of the PLD because roots can damage geotextile liners and will interfere with restorative maintenance. Tree and shrubs may be used on sideslopes if they are placed at least 6 inches above the flat surface and have geotextile liners placed between them and the flat PLD surface.
4. Do not use sod in PLD installations.
5. If the PLD surface will be irrigated, do not place sprinkler heads on the flat surface. If the seed mix in Table 2 is used, be sure to reduce the water applied according to the needs of the plants.
6. PLD facilities should not be placed close to building foundations or other areas where expansive soils are present, although a properly designed and installed underdrain and impermeable liner may ameliorate some of this concern. The use of downspout extensions that direct roof runoff to PLD areas at adequate distances from building foundations and backfill zones is another alternative.
7. PLD facilities remove pollutants in stormwater through settling, filtering, adsorption and biological uptake of constituents. Additionally, infiltration and evaporation reduce runoff volumes. Installation at sites with naturally moderate to high infiltration rates (Type A or B soils) may be less expensive than facilities located in Type C and D soils, where more extensive engineered features (e.g., underdrains and liners) are required. Percolation tests at a depth equal to and deeper than the bottom depth of the PLD are needed to determine what types of engineered features are required.

¹ Most PLD facilities are several hundred square feet to a few thousand square feet in size, accepting drainage from areas less than one acre. The application rate is given in terms of acres for simplicity and should not be confused with facility size.

Table 2. UDFCD-recommended Seed Mixes for PLD

COMMON NAME	SCIENTIFIC NAME	VARIETY	PLS Lbs per Acre	Ounces per Acre
Sand bluestem	Andropogon hallii	Garden	3.5	
Sideoats grama	Bouteloua curtipendula	Butte	3	
Prairie sandreed	Calamovilfa longifolia	Goshen	3	
Indian ricegrass	Oryzopsis hymenoides	Paloma	3	
Switchgrass	Panicum virgatum	Blackwell	4	
Western Wheatgrass	Pascopyrum smithii	Ariba	3	
Little bluestem	Schizachyrium scoparium	Patura	3	
Alkali sacaton	Sporobolus airoides		3	
Sand dropseed	Sporobolus cryptandrus		3	
* Pasture Sage	Artemisia frigida			2
* Blue aster	Aster laevis			4
* Blanket flower	Gaillardia aristata			8
* Prairie coneflower	Ratibida columnifera			4
* Purple prairieclover	Dalea (Petalostemum) purpurea			4
Sub-Totals:			27.5	22
Total lbs per acre:				28.9

8. Maintenance of PLD during the first year includes temporary irrigation and mowing to control annual weeds. Mowers should be rotary and the tractor small enough not to rut the soil and damage the vegetation. If needed, spot treat with approved herbicides to control noxious weeds. Be sure to reseed bare areas after the first growing season.
9. Routine maintenance following the first growing season includes replacement of mulch in the spring and fall. By removing and disposing of old mulch, sediment accumulation in the PLD can also be removed, prolonging the life of the structure. Clogging of the facility with silt and eroded clay soils is a possible problem to keep in mind.
10. Typical opportunities for incorporating PLD into a site include parking lot islands/medians, street medians, roadside swale features, and site entrance or buffer features. PLD sites typically receive drainage from relatively small areas such as a single lot or parking area. A slotted curb opening or curb cut into a depressed landscape area is often a key sign that the landscape is engineered to provide stormwater benefits. When landscape maintenance crews encounter such features, they should consult with the property owner regarding any special maintenance considerations and should not “re-landscape” or remove such facilities.

Regional, Industry or Sustainability Considerations/Adaptations

1. For porous landscape detention and other landscape-based stormwater management practices, owners and/or local governments may require that a maintenance log be completed to document and track maintenance at stormwater facilities. This may be a regulatory requirement under the local government or Colorado Discharge Permit System (CDPS) stormwater discharge permits.

2. Warranties or landscape bonds may be required for vegetation installed in stormwater facilities following planting. Under such requirements, plants that do not survive must be replaced.
3. Rainwater harvesting is a LID BMP that is advocated in some parts of the country, but which is not legally permissible in Colorado under most conditions. See the *Irrigation Water Sources BMP* for a discussion of this issue in Colorado.
4. LID techniques are consistent with several sustainability principles such as “valuing all water on the site” and “maintaining or regenerating healthy hydrologic processes.” Runoff is treated as a site resource, rather than a waste product targeted for quick disposal. By directing runoff through vegetated areas, plants can take advantage of natural rainfall and runoff pathways, and downstream water bodies benefit from reduced runoff rates, volumes and pollutants.
5. LID practices should be identified early in the site development planning process for the most creative implementation and to ensure compliance with local drainage criteria, since some LID practices are new approaches that may not have fully defined design criteria in some communities.



Providing proper soil amendment to enable infiltration of runoff is a LID technique, unlike this photo where infiltration is not occurring below turf (left). The U.S. EPA Region 8 headquarter in Denver has installed a green roof that includes drought tolerant vegetation and drip irrigation (right). (Photos from EPA Region 8 website: <http://www.epa.gov/region8/greenroof/>).

Key References

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Revegetation of Drainageways

Description

Establishing a robust vegetation cover is critical to the proper functioning of engineered drainage structures such as grass-lined channels, detention basins, retention ponds and wetlands. Vegetation serves multiple purposes, including stabilizing structures to prevent excessive erosion and removing pollutants from stormwater. Because of the semi-arid nature of Colorado’s climate, prevalence of introduced weeds and variety of soil types, prompt implementation of a revegetation plan is critical if revegetation is to be successful.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	
ALCC	X	ISA	X
CALCP	X	RMSGA	X
CNGA		GCSAA	X

This BMP has been adapted directly from the Urban Drainage and Flood Control District’s Storm Drainage Criteria Manual, Volume 2, “Chapter 12 Revegetation” (UDFCD 2001).

Basic Practice Guidelines

When landscaping engineered drainage facilities, Green Industry professionals should work closely with the engineer responsible for the facility design. A planting plan should be developed and followed that addresses soil bed preparation; plant species, types and sizes to be used; planting methods; mulching and fertilization; and a planting schedule. The basic practice guidelines below are categorized according to plant selection, site preparation, seeding and planting and maintenance.

Plant Selection

1. The form(s) of vegetation and species used should be adapted to the soil and moisture conditions and use of the area (e.g., conveyance of flow, side slopes, etc.). The bottom, side slopes and areas immediately adjacent to a facility have differing moisture regimes that should be taken into consideration. Different plant forms (e.g., grasses, shrubs and trees) may also be limited to specific areas to enable proper functioning of the facility. For example, planting trees and shrubs along the bottom of a channel can reduce the hydraulic capacity of the channel, increase maintenance requirements and cause the plugging of downstream bridges and culverts when uprooted by higher flows.
2. Native, perennial species should be used to the extent possible.
3. Use of plant species requiring irrigation and high maintenance should be avoided except along maintained park settings or where other uses dictate such maintenance.
4. Sod-forming grasses are preferred over bunch grasses.
5. Use containerized nursery stock for wetland, tree and shrub plantings to the extent feasible.

6. The Urban Drainage and Flood Control District recommends that wetland plantings should not include cattails because they tend to proliferate and out-compete other wetland species. If plants are to be purchased, it is more desirable to select a variety of wetland species that will flourish such as sedges, rushes, etc., if cattails are not initially introduced. (Note: other resource agencies may have different recommendations regarding cattails.)
7. Maintenance requirements should be considered in plant selection (e.g., tall grasses should not be used in urban areas unless regular mowing will occur).
8. Live stakes, willow bundles and cottonwood poles should be obtained from local or on-site sources, whenever possible.

Site Preparation

9. All areas to be planted should have at least 6 inches of topsoil suitable to support plant growth. Native topsoil should be stripped and saved for this purpose whenever a site is graded.
10. The upper 3 inches of the soils in areas to be seeded should not be heavily compacted and should be in a friable condition. An 85 percent standard proctor density is acceptable.
11. When necessary, soil amendments should be added to correct topsoil deficiencies (e.g., soil texture, pH or percent organic matter). (If topsoil and native seed mixes are used, fertilizer is often not needed.)
12. Fertilizer and other amendments should be used if specified by a soil analysis. Slow-release (controlled-release) type fertilizers should be used to reduce weed growth and protect water quality. Fertilizer should be worked into soil during seedbed preparation.

Seeding and Planting

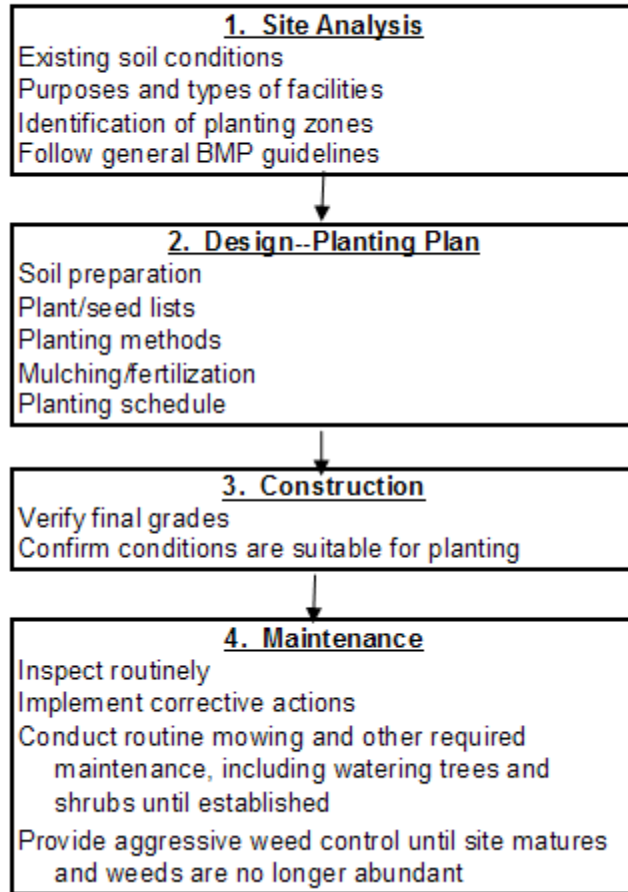
13. Seed mixtures should be sown at the proper time of year specified for the mixture.
14. Seed should be drill seeded, whenever possible. Broadcast seeding or hydro-seeding may be substituted on slopes steeper than 3(H):1(V) or on other areas not practical to drill seed.
15. Seeding rates should be doubled for broadcast seeding or increased by 50 percent if using a Brillion drill or hydro-seeding.
16. Broadcast seed should be lightly hand-raked into the soil.
17. Seed depth should be ¼ to ½ inch for most mixtures.
18. All seeded areas should be mulched and the mulch should be adequately secured.
19. If hydro-seeding is conducted, mulching should be conducted as a separate, second operation.

- 20. All containerized nursery stock should be kept in a live and healthy condition prior to installation.
- 21. Containerized trees and shrubs should be installed properly to ensure success.
- 22. Live stakes, poles and willow bundles should be installed when dormant (late winter and early spring) according to the planting details provided by the UDFCD (2001).
- 23. Beaver protection should be provided for trees and shrubs for species known to be attractive to beavers if beavers are known to be in the area.

Maintenance

- 24. Sites should be routinely inspected following planting to implement follow-up measures to increase success. Immediate attention to a problem (e.g., weed infestation, failure of seed to germinate) can prevent total failure later.
- 25. Access to and grazing on recently revegetated areas should be limited with temporary fencing and signage while plants are becoming established (normally the first year).
- 26. Weed infestations should be managed using appropriate physical, chemical or biological methods as soon as possible. When using chemical weed control, only herbicides with aquatic labeling should be applied.
- 27. Stakes and guy wires for trees should be maintained. Dead or damaged growth should be pruned.
- 28. Beaver protection cages should be used around tree plantings.
- 29. Mulch should be maintained by adding and redistributing mulch, as necessary.
- 30. Areas of excessive erosion should be repaired and stabilized.
- 31. Planted trees and shrubs should be watered as needed year round until established.

Revegetation Process Flow Chart
(Source: UDFCD 2001)



Regional or Industry Considerations/Adaptations

1. See local Colorado State University Extension office, the Natural Resources Conservation Service or other local government recommendations for seed mixes and revegetation species.

Key References

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Riparian Buffer Preservation

Description

Preserve wide, undisturbed natural riparian areas along streams. These buffers help protect water quality by filtering pollutants, sediment and nutrients from runoff and aid in flood control, streambank stabilization and stream temperature control.

Basic Practice Guidelines

1. Protect and retain existing riparian vegetation whenever possible. Consider enhancing the existing buffer area by planting site-appropriate, native plants. Make the natural riparian area an integral part of the site design.
2. Clearly mark the riparian area to be protected on landscape plans. Generally, when landscaping in a riparian area, do not clear existing vegetation, disturb soil by grading or stripping, or fill in these areas. Exceptions may include removal of dead/diseased vegetation, stream restoration and stabilization activities, installation of stormwater BMPs, etc.
3. Plan site drainage so that the hydrology of the riparian buffer area is maintained.
4. Restore natural vegetation in riparian areas whenever possible when it has been disturbed by development.
5. Check local regulations for buffer setback requirements, typically ranging from 25 feet to more than 100 feet. Features such as erodable soils, unstable streambank conditions, steep slopes, presence of a wildlife migration corridor, poor vegetative cover, property usage involving hazardous materials, etc., may warrant larger setbacks. Permits may be required to disturb land within the setback requirement.
6. Clearly specify landscape maintenance practices that are acceptable within buffer zones. For example, the use, storage and application of pesticides are generally not appropriate for these areas, with a few exceptions such as spot spraying of noxious weeds. Landscape maintenance equipment (e.g., mowers) should not be maintained in these areas.
7. Manage the riparian buffer canopy to maintain maximum vigor of the overstory and understory.

Regional or Industry Considerations/Adaptations

1. Land development in the Rocky Mountains is occurring rapidly. Because of the terrain associated with this mountainous area, most of the development occurs along valley floors. This growth pattern focuses development around streams, rivers, wetlands and lakes. Without adequate planning and management, development around these water features can degrade water quality, water quantity (pre-development hydrology) and riparian habitat. Preserving undeveloped riparian corridors in high mountain valleys is an important

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	
ALCC	X	ISA	X
CALCP	X	RMSG	
CNGA		GCSAA	X

commitment to help protect water quality and aquatic life.



Preservation of wide, undisturbed riparian corridors helps to protect water quality.

Source: Wright Water Engineers, Inc.

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Employee Education

Description

Educate Green Industry employees on water quality and water conservation practices.

Basic Practice Guidelines

1. Educate employees on turf, plant and water management practices that conserve water and protect water quality. Explain the environmental benefits provided by properly designed, installed and maintained landscapes and appropriate and efficient irrigation systems in production and holding yards.
2. Train employees to identify irrigation problems (e.g., broken hoses, etc.) and designate an employee (or employees) to verify and correct irrigation problems. This is applicable to all industry segments.
3. Provide bilingual educational materials, as needed.
4. Provide easy-to-read guidance sheets for field use that include water conservation and water quality topics.
5. Encourage employees to obtain and maintain professional certifications and licenses appropriate to each industry. Representative examples include: certified pesticide applicator; certified nursery professional; certified irrigation designer, contractor, or manager; certified landscape irrigation auditor, etc. Ensure that employees know when licenses and certifications are mandatory by law for certain activities (e.g., applying restricted-use pesticides). See Appendix I for a list of representative certification and training programs.
6. Encourage employees to take continuing education courses to stay up-to-date with the state-of-the-practice and to obtain region-specific practice guidelines and information.
7. Encourage active participation in local, state, regional and national Green Industry organizations to keep up with current water efficiency technology and trends.
8. Make water conservation a priority for employees. A water conservation awareness campaign and incentive program can be helpful in changing attitudes and actions.
9. Emphasize the importance of always reading labels on fertilizers, pesticides and other chemicals and following the directions. Employees must be properly trained and educated on chemical usage. Employees should know where Material Data Safety Sheets (MSDSs) are and be familiar with commonly used chemicals as required under the Community Right-to-Know laws.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

10. Emphasize proper installation of and regular maintenance of irrigation systems—proactive maintenance is more cost-effective than repair or treatments required due to poor irrigation systems.
11. Mandate that employees follow the requirements of relevant permits, local ordinances and health and safety regulations (e.g., Occupational Safety and Health Administration).

Regional or Industry Considerations/Adaptations

1. Region-specific considerations should be incorporated in the local certification courses.

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Public Education

Description

Model and teach water conservation and water pollution prevention to all consumers of green industry products.

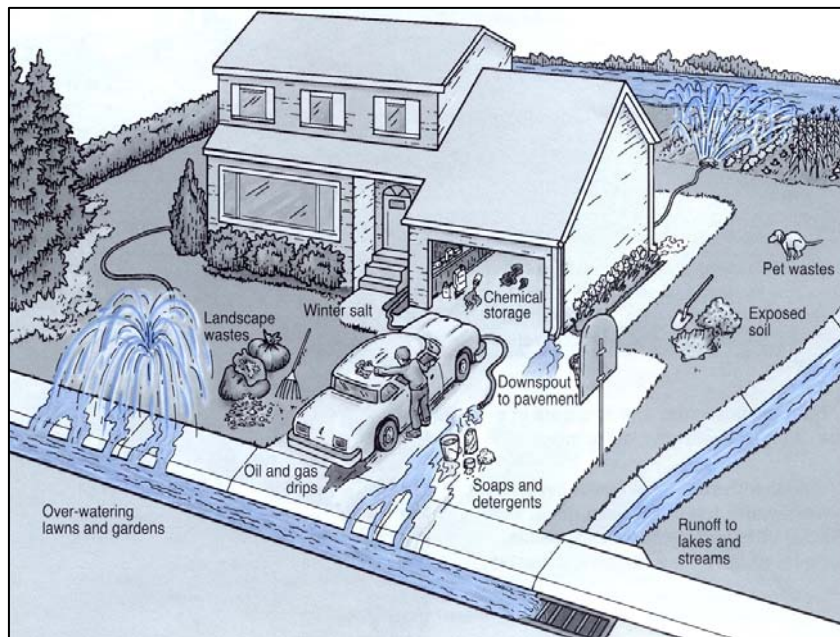
Basic Practice Guidelines

Green Industry professionals have the opportunity to model water conservation and water quality protection practices to the public through their actions and through distribution of educational materials. Following these basic public education guidelines is a list of references that are readily accessible and already in a form appropriate for the general public.

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

1. Set the example for the public by implementing the GreenCO BMPs and demonstrating that practices that conserve water, use water efficiently and protect water quality result in attractive landscapes providing environmental benefits and cost saving, in many cases.
2. Distribute water conservation and water quality protection information through a wide range of media including the internet, nurseries and garden centers.
3. Educate the public on the many environmental and aesthetic benefits of landscaping.
4. Emphasize the value of conservation-oriented watering practices and the benefits of Xeriscape to clients and customers. For example, clearly communicate the basic principle that proper irrigation saves water, money and promotes healthier plants. Also let clients know that Xeriscape “doesn’t have to be ugly” or grass-less. Turf has its place in Xeriscaped landscapes and provides water quality benefits when properly maintained.
5. Provide technical assistance to the public in converting existing landscapes into those that incorporate Xeriscape principles.
6. Provide education to customers and the public regarding the benefits of establishing a water budget and adjusting irrigation practices to fit the water budget (and therefore meeting the needs of the plants.)
7. Actively participate in educational programs focused on water conservation and water quality protection. Examples may include speaking in schools, distributing videos and brochures, hosting Xeriscape demonstration projects, etc. Nurseries and garden centers can provide displays featuring Xeriscape demonstration gardens or hands-on demonstrations on creating Xeriscape landscapes.
8. For lawn care professionals, offer clients a water audit service to improve efficiency of water use. This would include evaluating sprinkler systems for proper coverage, replacing damaged heads, realigning heads, teaching owners how to program their controllers, preparing watering schedules based on weather conditions, etc.

9. Cooperate with other agencies on local ordinance development, public workshops, garden tours, videos, newsletters, events, etc.
10. Educate new owners of irrigation systems on how to operate them. At a minimum, owners should know how to run the controller and change watering times and duration (minutes) based on weather and seasonal conditions. Irrigation contractors should provide owners with proper scheduling guidelines and techniques and an "as-built" drawing of the irrigation design that specifies the location and specifications of all application devices, pipelines, wiring, control valves, back-flow prevention devices and rain shut-off equipment.
11. When communicating with the public, be properly educated about the water requirements of plants and recommend plants with lower water requirements. Don't be fooled by marketing campaigns touting low-water usage or native plants without the data to back up their claims.
12. Emphasize the fact that reading the label when applying pesticides, herbicides and fertilizers is critical—over-application and misuse of these chemicals can harm plants and damage the water quality in streams and lakes.
13. Emphasize the critical importance of proper ground preparation prior to planting and laying sod. Many new homeowners have "basement topsoil" left to work with and may not understand how important it is to properly amend this soil to facilitate efficient water usage and healthy lawns.
14. Consider establishing displays, signage, information brochure distribution shelves, or pilot-demonstration test sites for the purposes of effective public education.



Green Industry professionals can help to educate the public on measures to conserve water and minimize pollution.

Source: Colorado Nonpoint Source Council/U.S. Environmental Protection Agency.

Industry Websites

American Nursery and Landscape Association (ANLA) Website: www.anla.org.

American Society of Landscape Architects (ASLA) Website: www.asla.org.

Associated Landscape Contractors of Colorado (ALCC) Website: www.alcc.com.

Colorado Association of Lawn Care Professionals (CALCP) Website:
www.lawncarecolorado.org/.

Colorado Nursery and Greenhouse Association (CNGA) Website: www.coloradonga.org

Garden Centers of Colorado (GCC) Website: www.gardencentersofcolorado.org.

Golf Course Superintendents Association (GSAA) Website: www.gcsaa.org/.

GreenCO Website (including water budgeting calculator): www.greenco.org.

International Society of Arboriculture (ISA) Website: www.isa-arbor.com/.

International Society of Arboriculture, Rocky Mountain Chapter (ISA/RMC) Website:
www.isarmc.org.

Professional Landcare Network (PLANET) Website: <http://www.landcarenetwork.org>.

Rocky Mountain Sod Growers Association (RMSGGA) Website:
www.rockymountainsodgrowers.com.

X-Rated® Gardening Website: www.xratedgardening.com/.

Colorado State University Extension Resources

Colorado State University Extension Drought Task Force Website: www.drought.colostate.edu/.

Colorado State University Extension Gardening On-line Website:
www.ext.colostate.edu/pubs/garden.

Colorado State University Extension Planttalk Colorado Website: www.ext.colostate.edu/ptlk.

Colorado State University Extension, Soils Program Website:
www.extsoilcrop.colostate.edu/Soils/pub.htm.

Colorado State University Extension Tri-River Area, Western Slope Gardening Website:
www.westernslopegardening.org/

Colorado State University Turfgrass Program Website: csuturf.colostate.edu/.

Colorado Water Resources Research Institute Website: cwrri.colostate.edu.

Other Resources

Colorado Department of Local Affairs. 2004. *Water Efficient Landscape Design Model Ordinance*. Website: www.dola.state.co.us/smartgrowth/. Denver, CO: Colorado Department of Local Affairs, Office of Smart Growth.

Colorado Springs Utilities Xeriscape Website: www.csu.org/xeri.

Colorado Water Conservation Board Website: www.cwcb.state.co.us.

Colorado WaterWise Council Website: coloradowaterwise.org/.

Denver Botanic Gardens and Colorado State University Extension Plant Select® Website: www.plantselect.org.

Denver Public Library Xeriscape Information Website: www.denver.lib.co.us/dpl/news/xeriscape.html.

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Irrigation Association Website (including irrigation BMPs): www.irrigation.org.

Irrigation Training and Research Center, Cal-Poly State University, San Luis Obispo, California Website: www.itrc.org.

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Northern Colorado Water Conservancy District Website (including multiple resources for irrigation scheduling): www.ncwcd.org/.

Save Our Shade Website: saver.denverwater.org/saveourshade.asp.

Trees Are Good Website: www.treesaregood.com/.

Turf Resource Center Website: www.turfgrassod.org.

Urban Drainage and Flood Control District. 1996. Clear Choices for Clean Water Series: Managing Your Construction Site, Caring for Your Lawn and Garden, and Managing Your Household Waste. (www.udfcd.org). Denver, CO: UDFCD.

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www.epa.gov/greenskapes/.

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Regulatory Awareness

Description

A variety of local, state and federal environmental regulations impact landscaping and nursery operations. Green Industry professionals should be aware of these regulations and comply with their requirements.

Basic Practice Guidelines

Green Industry professionals should be aware that environmental regulations apply to a variety of activities. See Appendix C for a list of specific regulations with contact information. Potential regulatory issues include the following:

1. Pesticide Application, Handling and Disposal—state and federal regulations mandate specific requirements and certifications for those applying, handling and storing pesticides. Regulations also exist for reporting spills of these chemicals.
2. Riparian Buffer Zones—local regulations may limit disturbance of riparian areas along streams or near wetlands. This is typically in the form of a “setback” requirement, which may vary considerably (e.g., 25 to 200 feet) based on local conditions.
3. Wetlands—Section 404 of the federal Clean Water Act restricts the dredging and filling of jurisdictional wetlands. Consult with the local U.S. Army Corps of Engineers prior to initiating any activity that affects wetlands.
4. Stormwater Management/Erosion and Sediment Control—the Phase II stormwater regulations require a discharge permit for construction activities disturbing one acre or more. Local permits may also be required for land disturbance. Landscape contractors should work with the general contractor and/or civil engineer to ensure that requirements of state and local permits are met, particularly with regard to erosion and sediment control during construction. Additionally, permanent engineered stormwater management facilities (e.g., retention ponds, wetlands, infiltration basins) may be required aspects of landscape design.
5. Groundwater Protection—Particularly in areas overlying shallow groundwater, regulations may exist that require special precautions when applying chemicals or including ponds as part of landscape and stormwater management features (e.g., retention ponds, detention ponds, infiltration basins). Many pesticide labels prohibit application over or near shallow water tables.
6. Noxious Weeds—State and county regulations are in place regarding control of noxious weeds. (See www.ag.state.co.us/DPI/weeds/weed.html for a complete listing of such weeds and to contact the county weed coordinator.) Several species of noxious weeds, although available for purchase, are legally prohibited in ornamental landscapes.
7. Water Rights—Always check with the landowner to ensure that adequate water

BMP Type			
Design			X
Installation			X
Maintenance/Operations			X
Green Industry Relevance			
ASLA	X	GCC	X
ALCC	X	ISA	X
CALCP	X	RMSGGA	X
CNGA	X	GCSAA	X

supplies/water rights are in place prior to installing water or irrigation-dependent landscape features. The Colorado State Engineer's Office administers water rights under the "prior appropriation" doctrine in Colorado.

8. Landscaping Ordinances—Some local governments in Colorado have landscaping ordinances in place, which specify the types of landscaping and irrigation practices that are acceptable. Before designing a landscape or irrigation system, check with local authorities to determine applicable requirements. Guidelines associated with these ordinances may be helpful in selecting appropriate plant species for a site.
9. Backflow Prevention—Backflow prevention devices are required for irrigation systems to prevent cross-contamination of municipal water supplies. See the Colorado Unified Plumbing Code for guidance.
10. Cross-connection Controls—Cross-connection controls are required for irrigation systems using reclaimed or non-potable water.
11. Fire—Local fire departments may prescribe landscape practices near fire hydrants and in fire-prone areas.
12. Wildlife—Local "overlay" districts may affect landscaping with regard to certain wildlife species. Additionally, some habitats may be protected through the federal Endangered Species Act and the Migratory Bird Treaty Act, as administered by the Colorado Division of Wildlife and the U.S. Fish and Wildlife Service. Contact these agencies for specific information.
13. Utilities—Landscaping must conform to local requirements with regard to utilities such as power line rights-of-way and locating underground utilities prior to excavation.
14. Other—A variety of other regulations may exist that do not directly pertain to water resources (e.g., air regulations, public safety, frontage setbacks) and are not included in this list.

Regional or Industry Considerations/Adaptations

1. Local regulations may vary and should be considered prior to landscaping activities. Mountain areas where sensitive streams (e.g., trout fisheries) are present or areas that are particularly drought-prone may have stricter regulations than some Front Range communities.

Key References

See Appendix C for a detailed list of references and contacts.

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Glossary¹

Note: For terms with common acronyms or units of measure, the Irrigation Association convention is used identifying the acronym in [] and common units of measure in { }. This glossary is intended to provide definitions of terms that may not be familiar across Green Industry segments, but is not an all-inclusive glossary. For more detailed information on a broader range of terms, see the Colorado State University Extension website (www.ext.colostate.edu/) for horticultural terms, the Irrigation Association website (www.irrigation.org) for irrigation related terms or the U.S. Environmental Protection Agency (www.epa.gov) for stormwater management terms and practices.

accelerated soil erosion: The increased migration and movement of soils on land surfaces that occurs as a result of human activities. (UDFCD 1999).

aeration: Aerating a lawn means supplying the soil with air, usually by poking holes in the ground throughout the lawn using an aerator that extracts plugs of soil. It reduces soil compaction and helps control thatch in lawns while helping water and fertilizer move into the root zone. Also called **core cultivation** (CSU Extension, Plantalk Colorado).

agronomic rate (in the context of reclaimed water application): The rate of application of reclaimed water and associated nutrients to plants that is necessary to satisfy the plants' nutritional and watering requirements, while strictly minimizing the amount of nutrients that run off to surface waters or which pass below the root zone of the plants. (CDPHE 2007).

alkaline soils: Soils with a pH above 7.2. In Colorado, soils with moderate to high alkalinity (pH above 7.5) need to be managed by increasing the organic matter, using organic mulches, and light frequent irrigation. Plants are less tolerant of dry soil conditions when the pH is high. (CSU Extension).

allowable depletion [AD] {in.}: The amount of total plant available water (PAW) that is to be depleted from the active plant root zone before irrigation is applied. (IA Water Mgt Committee 2001).

alternative turf: Grasses used for lawn or field/meadow purposes other than bluegrass or a bluegrass/fescue blend.

¹ Definitions in this glossary have been compiled from several key references and websites including: the Irrigation Association (IA) (www.irrigation.org), Colorado State University (CSU) Extension (<http://www.ext.colostate.edu/>), Colorado Revised Statutes (<http://198.187.128.12/colorado/lpext.dll?f=templates&fn=fs-main.htm&2.0>), Denver Water Quality Management Plan (www.denvergov.org), Urban Drainage and Flood Control District, (UDFCD) Volume 3 <http://www.udfcd.org/usdcm/vol3.htm>, Colorado Water Quality Control Division <http://www.cdphe.state.co.us/wq/>, U.S. Environmental Protection Agency (EPA) website glossaries <http://www.epa.gov/ednrrmrl/main/gloss.htm> and http://cfpub.epa.gov/npdes/glossary.cfm?program_id=0, the Low Impact Development website: <http://www.lowimpactdevelopment.org/school/glossary.html>.

annual: A plant with a life cycle that lasts for only one year. Its life cycle begins with the germination of the seed, then the plant blooms, producing the next generation of seed, after which the parent plant dies.

available water holding capacity [AWHC]{in. water per in. soil}: Ability of the soil to retain water. Also see **field capacity**, **permanent wilting point**, and **plant available water**. (IA 2006).

backflow prevention device [BPD]: Safety device which prevents the flow of water from the water distribution system back to the water source. (ASAE 1998, as used by IA Water Mgt Committee 2001).

balled and burlapped (B&B): Established in the ground and dug with a portion of the root system and undisturbed soil immediately around the roots.

Best Management Practice [BMP]: A voluntary practice that is designed to reduce water usage and protect water quality. BMPs are reasonably economical, practical, and sustainable, and maintain a healthy, functional landscape without exceeding the water requirements of the landscape. (Adapted from IA Water Mgt Committee 2001). BMPs are also used in stormwater quality management under the Federal Clean Water Act.

biofilter: A Low Impact Development term describing dense vegetation designed to filter stormwater runoff. Also see definition of **grass buffer** and **grass swale**.

biological control or management: The use of an organism to disrupt the growth of noxious weeds or control pests. (Colorado Noxious Weed Act).

bioretention: A Low Impact Development term, also sometimes called a rain garden, biofilter or porous landscape detention, that is based on onsite retention of stormwater through the use of vegetated depressions engineered to collect, store, and infiltrate runoff. (www.lowimpactdevelopment.org).

biosolids: A byproduct of municipal sewage treatment that may be used in commercially available compost. Biosolids are assigned “grades” according to quality, with Grade 1 biosolids having the lowest heavy metal, pathogen, and salt content.

BMP: Best Management Practice. (See definition above.)

buffer strip: Strips of grass or other erosion resistant vegetation located between a waterway and an area of more intensive land use. Also see definition of grass buffer.

buffer zone: A designated transitional area around a stream, lake, or wetland left in a natural, usually vegetated state so as to protect the waterbody from runoff pollution. Development is often restricted or prohibited in a buffer zone.

caliper: The measurement in diameter of a tree trunk measured 6 inches above the ground for trees up to 4 inches in size and 12 inches above the ground for larger sizes.

canopy: The tree cover in an urban setting. Canopy size is an important determinant of a city's heat island reduction potential.

cation exchange capacity [CEC] {meq/100 g or g/g}: The clay and organic components of the soil have a negative charge. As a result of these charges, positively charged ions (cations) such as hydrogen H⁺, potassium K⁺, ammonium NH₄⁺, calcium Ca²⁺, magnesium Mg²⁺, aluminum Al³⁺, etc. may be held at the surface of the clay or organic particles and exchanged with other ions in the solution or with ions at the plant root's surface. This ability of a soil to hold cations is termed its **cation exchange capacity** (CEC). Since many cations are plant nutrients, the cation exchange capacity is a measure of the soil's ability to hold such nutrients. Expressed in milliequivalents per 100 grams or per gram of soil (or other exchangers such as clay). (CSU Extension, Tri Rivers Area 2007).

check valve, spring: A spring-loaded valve located in a lateral or at the base of a sprinkler that prevents water from draining through the sprinkler lowest in elevation after the irrigation cycle is completed. Sometimes called an "anti-drain valve". (IA Water Mgt Committee 2001).

chemical control or management: The use of herbicides, pesticides or plant growth regulators to disrupt the growth of noxious weeds or to control pests. (Colorado Noxious Weed Act).

Clean Water Act: Legislation that provides statutory authority for the National Pollutant Discharge Elimination System (NPDES) program; Public law 92-500; 33 U.S.C. 1251 et seq. Also known as the Federal Water Pollution Control Act. Also see **Colorado Discharge Permit System**.

climate change: A term sometimes used to refer to all forms of climatic inconsistency. Because the Earth's climate is never static, the term is properly used to imply a significant change from one climatic condition to another. In some cases, **climate change** has been used synonymously with **global warming**. Scientists, however, tend to use **climate change** in the wider sense to include both human-induced and natural changes in climate.

Colorado Discharge Permit System [CDPS]: The State of Colorado's system of permitting discharges (e.g., stormwater, wastewater) to "Waters of the State" that corresponds to the federal **National Pollutant Discharge Elimination System (NPDES)** permits under the Federal Clean Water Act.

commercial pesticide applicator: Any person, other than a private applicator, who engages in the business of applying pesticides for hire or operating a device for hire that is designated as requiring licensure for use under the Colorado Pesticide Applicator's Act (Colorado Pesticide Applicator's Act).

constructed wetland basin: A constructed wetland basin 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.

container grown: Grown and marketed in a container.

containerized stock: Grown in the ground and subsequently dug with a soil ball (described as “balled and processed” by ANSI Z60.1) or bare root (described as “process balled” by ANSI Z60.1) and placed in a container until sold.

controller or irrigation controller: An automatic timing device used to remotely control valves or heads (valve in head) according to a set irrigation schedule. (IA Water Mgt Committee 2001).

crop coefficient [Kc]{dimensionless}: A numeric value that relates reference crop evapotranspiration (typically grass reference ET [“ET_o”]) to the actual characteristics of the crop being grown. The crop coefficient value assumes a healthy crop, actively growing, without stress, and with optimum soil moisture. (adapted from IA 2006).

cultural controls or management: The methodologies or management practices that favor the growth of desirable plants over noxious weeds, including maintaining an optimum fertility and plant moisture status in an area, planting at optimum density and spatial arrangement in an area, and planting species most suited to an area. Cultural controls can also be used to control pests. (Colorado Noxious Weed Act).

cultural practices: Plant care practices such as proper watering, mulching, and fertilizing.

cycle {minutes or hours}: The operating duration of one or more valves for one irrigation start time. (IA Water Mgt Committee 2001).

deciduous: A plant with foliage that is shed annually.

deficit irrigation practice: Irrigation water management strategy where the plant root zone is not filled to field capacity or the plant water requirement is not fully met. (IA Water Mgt Committee 2001).

detention: The storage and slow release of stormwater from an excavated pond, enclosed depression, or tank. Detention is used for pollutant removal, stormwater storage, and peak flow reduction. Both wet and dry detention methods can be applied.

distribution uniformity, lower-half [DU_{LH}]{%}: A measure of the uniformity of applied irrigation water over an area. The average of the lowest fifty percent of measurements divided by the overall average measurement, gathered through the use of catch cans, commonly used to evaluate the coverage of one or more sprinklers. (IA Water Mgt Committee 2001). This value is used for scheduling landscape irrigation.

distribution uniformity, lower-quarter [DU_{LQ}]{%}: The average of the lowest twenty five percent of measurements divided by the overall average measurement, gathered through the use of catch cans, commonly used to evaluate the coverage of one or more sprinklers or drip systems. (IA Water Mgt Committee 2001). This value is used to measure system performance.

distribution uniformity [DU]{%}: The measure of the uniformity of applied irrigation water over an area. (ASAE 1998, as adopted by IA Water Mgt Committee 2001).

drip line: A hypothetical vertical line extended downward from the tips of the outermost branches of a tree or shrub to the ground.

drip/trickle/micro irrigation: Method where water is applied at, or below, the soil surface and at low pressure and low volume. (IA 2006).

drought: A period of dryness, especially when prolonged, that causes extensive damage to crops or prevents their successful growth. (Webster 1981; IA 2006).

earth disturbance: A human-made change in the natural cover or topography of land, including all grading, cut and fill, building, paving and other activities, which may result in or contribute to soil erosion or sedimentation of the “Waters of the State”. (UDFCD 1999).

effective rainfall [R_e]{in.}: The amount of total rain that is actually stored in the root zone and available for use by the plant. Some rainwater does not reach the soil profile because it is held in mulch or turf thatch or because it runs off. Some water may percolate below the root zone and be lost, depending upon the intensity and duration of the rain event and the water content of the soil prior to the rain event. (Scheduling 1999; IA 2006).

efficiency, irrigation system [E_s]{%}: The amount of irrigation water that is beneficially used by the plant, divided by amount of irrigation water applied, times 100. (ITRC, CIM-AG 1992)

electrical conductivity [EC_w or EC_s] {dS/m; mmho/cm; μ mho/cm}: The ability of the solution to carry a current is called electrical conductivity. EC may be reported in the context of irrigation water quality (EC_w) or soil quality (EC_{sw}) or (EC_e) soil extract, Also see **saline soils.**

erosion: The process by which the ground surface is worn away by action of wind, water, gravity, or a combination thereof.

ETo: Grass reference **evapotranspiration**, see definition for **evapotranspiration (ET)**.

eutrophication: Excessive levels of phosphorous, nitrogen, and other nutrients in waterbodies, leading to a decrease in oxygen levels. Often characterized by excessive growth of algae and aquatic vegetation and deteriorated water quality.

evapotranspiration [ET] {in./ time period}: Combination of water transpired from vegetation and evaporated from the soil and plant surfaces. (ASAE 1998).

evergreen: A plant with foliage that persists and remains green year-round.

exchangeable sodium percentage [ESP]: The degree of saturation of the soil exchange complex with sodium.

fabric: Refers to a porous geotextile fabric installed underneath mulch to retard the growth of weeds into and from the soil.

field capacity [FC]{in./in.}: Depth of water retained in the soil after ample irrigation or heavy rain when the rate of downward movement of water due to gravity has substantially decreased

(usually one to three days after irrigation or rain). Field capacity is one tenth to one third bar of soil moisture tension. (Doorenbos & Pruitt 1977). Also see **permanent wilting point** and **plant available water**. (IA 2006).

filter strip: Grassed strips situated along roads or parking areas that remove pollutants from runoff as it passes through, allowing some infiltration and reduction of velocity.

floodplain: An area adjacent to a watercourse, which is subject to flooding as the result of the occurrence of the 100-year event.

flow rate [Q]{gal/min, gpm, gph, cfs}: Volume of water per unit time, such as discharge from an irrigation sprinkler or emitter; or flow into a lateral. (IA 2006).

flow sensor: A device that measures the rate of liquid flow or the total accumulated flow. (IA Water Mgt Committee 2001).

gear drive sprinkler: Sprinkler containing gears as part of its rotational drive mechanism. (IA 2006).

global warming: The gradual rise of the Earth's surface temperature. Global warming is believed to be caused by the “greenhouse effect” and is responsible for changes in global climate patterns and an increase in the near-surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of greenhouse gases.

grading: Stripping, excavating, filling, and/or stockpiling soil to shape land area for development or other purposes.

grass buffer: A stormwater BMP with uniformly graded and densely vegetated area of turf grass. This stormwater BMP requires sheet flow to promote filtration, infiltration, and settling to reduce runoff pollutants.

grass swale: A stormwater BMP with 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.

graywater: Household wastewater generated on site, such as rinse water, washing machine discharge, or bath water, that does not include toilet or dishwashing water.

green roof: A vegetated roof that can be used to treat precipitation and/or provide detention. Green roofs require an engineered structure that can support soils, vegetation, and loads associated with rainfall, snow, people, and equipment. Key components include a waterproof membrane, root barrier, drainage layer, soil/growing medium, irrigation system, and plants.

greenway: A linear open space or corridor composed of native vegetation. Greenways can be used to create connected networks of open space that include traditional parks and natural areas.

groundcover: Living plant material that grows low to the ground, usually under 24 inches in height, often of a spreading nature and typically available in small pots for planting. Does not include annuals, weeds, turf grasses, herbaceous perennials, mulches, or tree canopy.

hardscape: Impervious surfaces within the landscape, such as concrete walkways or brick paving. (IA Water Mgt Committee 2001).

head-to-head spacing: Spacing of sprinkler heads so that each sprinkler throws water to the adjacent sprinkler. (IA 2006).

herbaceous plants: Plants with non-woody stems. Their above-ground growth usually dies back in winter in the temperate zone, even in cases where the herbaceous plants in question are perennials.

historical evapotranspiration [historical ETo]: A multiple-year average of recorded historical reference ETo data from a weather station or evaporative pan in a given geographic location. This value is typically a monthly average of the specific month in a given multi-year time frame. This value, when corrected for plant species characteristics, can be used as a baseline to evaluate the expected water needs of a landscape planting in that geographic area. (IA 2006).

hydrozone: Grouping of plants with similar water (and environmental) requirements for irrigating with one or more common station/zone valves. (Weinberg and Roberts 1988; IA Water Mgt Committee 2001). Also see **microclimate**.

impact drive: Sprinkler which rotates using a weighted or spring-loaded arm which is propelled by the water stream and hits the sprinkler body, causing movement. (Rain Bird 1997; IA 2006) Also called a **rotor**.

impervious area: A hard surface area (e.g., parking lot or rooftop) that prevents or retards the entry of water into the soil, thus causing water to run off the surface in greater quantities and at an increased rate of flow relative to the natural landscape.

infiltration rate (intake rate) {in./h}: The dynamic rate at which irrigation water applied to the soil surface can move into the soil profile. The rate typically declines rapidly after an initial period of surface hydration. This value depends to a great extent on the texture of the soil and whether the soil is overly compacted. (IA Water Mgt Committee 2001).

in-ground fabric bag: A method used to grow trees in the ground using a specially designed fabric bag to restrict root spread.

integrated pest management (IPM): The practice of using targeted biological, chemical, cultural, and physical measures to manage pests while minimizing or eliminating the use of chemical pesticides. Also see **plant health care**.

irrigation audit: Procedure to collect and present information concerning the uniformity of application, precipitation rate, and general condition of an irrigation system and its components. (IA Water Mgt Committee 2001).

irrigation contractor: Any person who is in the business of installing, repairing, or maintaining landscape irrigation systems. (IA Water Mgt Committee 2001).

irrigation design: Drawings and associated documents detailing irrigation system layout, and component installation and maintenance requirements. (IA Water Mgt Committee 2001).

irrigation designer: Any person who is in the business of designing irrigation systems (IA 2006).

irrigation interval [IN]{days}: The number of full days between irrigation applications. (IA Water Mgt Committee 2001).

irrigation run time: See **run time**.

irrigation schedule: Set of data describing when irrigation should be applied for each zone and how much irrigation water should be applied. The irrigation schedule includes the duration and frequency that each zone should run based on the precipitation rate for each zone the water needs of the plants in that zone and soil conditions. Irrigation schedules change throughout the growing season.

irrigation water management, landscape: Process of comparing landscape irrigation water usage to an expected amount, and then making improvements to the landscape, irrigation system or schedule to achieve irrigation objectives. (IA Water Mgt Committee 2003).

irrigation water requirement, base [IWR_{base}]{in./period}: The amount of irrigation water (in inches) required to meet the supplemental water needs of the landscape. The irrigation water requirement includes the plant water requirement plus an extra amount to account for non-uniformity and other irrigation losses. (IA Water Mgt Committee 2003).

irrigation water requirement, gross [IWR_{gross}]{in./period}: The total applied irrigation water, some of which enters the root zone and adds to the soil moisture balance, and some of which is lost to evaporation, runoff, deep percolation, wind drift, leaks or overspray outside the target area. (IA Water Mgt Committee 2003).

irrigation water requirement, net [IWR_{net}]{in./period}: That portion of the applied irrigation water that is stored in the root zone and adds to the soil moisture balance so as to meet the **net plant water requirement (PWR_{net})**. It is also known as the **supplemental irrigation water requirement**. (IA Water Mgt Committee 2003).

irrigation: The intentional application of water for purposes of sustained plant growth. (IA Water Mgt Committee 2001).

landscape architect/designer: A professional who has successfully completed formal study or training in the field of landscape architect/design, culminating in certification, licensing, or degree.

landscape contractor: Any person who is in the business of constructing, installing, and/or maintaining turf, trees, or ornamental plant material and associated hardscaping in an urban environment. (IA Water Mgt Committee 2001).

landscape water allowance, landscape water allotment, landscape water allocation [LWA]{ccf, gallons}: A volume of water allocated to the entire landscape area for some period of time. This allowance is established by the water purveyor for the purpose of ensuring equitable supply of water resources. Also see **water adjustment factor**. (IA Water Mgt Committee 2003).

landscape water requirement [LWR]{ccf, gallons}: A volume of water that is necessary for the landscape to be healthy and functional. (IA Water Mgt Committee 2003).

lateral: The pipe installed downstream from the control valve on which the (sprinkler heads or) emission devices are located. (Rain Bird 1997; IA 2006). Also, water delivery pipeline that supplies irrigation water from the main line to sprinklers or emitters. (ASAE 1998; IA 2006).

leaching requirement [LR] {in., mm}: Quantity of irrigation water required for transporting salts through the soil profile to maintain a favorable salt balance in the root zone for plant development. (ASAE 1998; IA 2006).

leaching: Removal of soluble material from soil or other permeable material by the passage of water through it. (ASAE 1998; IA 2006).

Leadership in Energy and Environmental Design (LEED): The U.S. Green Building Council's Leaders in Environmental Design certification program. (www.usgbc.org).

local native plant: A population or ecotype of native plant species that was grown from genetically local plant materials (Colorado Native Plant Society).

Low Impact Development [LID]: The integration of site ecological and environmental goals and requirements into all phases of urban planning and design from the individual residential lot level to the entire watershed (www.lowimpactdevelopment.org). LID uses engineered landscape features to help approximate predevelopment site hydrology.

management allowable depletion [MAD] {%}: The percent of total plant available water (PAW) that can be depleted from the active plant root zone before irrigation is applied. (IA Water Mgt Committee 2001).

master valve: Valve used to protect the landscape from flooding in case of a ruptured main or malfunctioning downstream valve. The master valve is installed on the mainline after the backflow preventer (in some systems). (Rain Bird 1997; IA 2006).

matched precipitation rate: System or zone in which all the heads have similar precipitation rates is said to have matched precipitation rates. (Monroe 1993).

mechanical control or management: Methodologies or management practices that physically disrupt plant growth, including tilling, mowing, burning, flooding, mulching, hand-pulling, hoeing, and grazing. (Colorado Noxious Weed Act).

media filter: A stormwater BMP that is based on a filter containing sand, compost, sand peat, or perlite and zeolite designed to filter constituents (particulates, oil, bacteria, or dissolved metals) out of stormwater runoff as it passes through the filter.

microclimate: A portion of a landscape characterized by environmental conditions that may differ from the typical site condition to a degree that the plant ET will differ from the expected ET for the site. Examples of conditions that might create a separate microclimate include reflected heat, breezeways, wind exposure, topography (slope), shading, or even a large rock. (Adapted from IA Water Mgt Committee 2001).

minimizing directly connected impervious areas [MDCIA]: A variety of runoff reduction strategies based on reducing impervious areas and routing 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. Also see **Low Impact Development**.

moisture sensor: Device that monitors or measures soil water content or tension. (IA Water Mgt Committee 2001)

MS4: Municipal Separate Storm Sewer System, see below.

mulch: a non-living organic or inorganic material such as bark, rock, or stone materials typically in a loose condition, used in the landscape industry to cover bare ground. Mulch will provide a protective covering around plants, retard erosion, retain soil moisture, reduce weeds, and maintain soil temperatures.

Municipal Separate Storm Sewer System (MS4): A publicly owned conveyance or system of conveyances that discharges to waters of the United States and is designed or used for collecting or conveying stormwater, is not a combined sewer, and is not part of a publicly owned treatment works (POTW; i.e., wastewater treatment plant).

Municipal Stormwater Permit: An NPDES permit issued to municipalities to regulate discharges from municipal separate storm sewers for compliance with EPA regulations.

National Pollutant Discharge Elimination System (NPDES): The national program under Section 402 of the Clean Water Act for regulation of discharges of pollutants from point sources to waters of the United States. Discharges are illegal unless authorized by an NPDES permit.

native plant: A plant species that occurs naturally in a particular region, state, ecosystem and habitat without direct or indirect human actions. (Federal Native Plant Conservation Committee 1994).

nonpoint source pollution: Water pollution caused by irrigation, rainfall or snowmelt moving both over and through the ground and carrying with it a variety of pollutants associated with human land uses. A nonpoint source is any source of water pollution that does not meet the legal definition of point source in section 502(14) of the Federal Clean Water Act. (www.lowimpactdevelopment.org).

non-potable water: Water used for purposes other than human consumption that is not treated to potable water standards. This includes water from ditches, lakes, ponds, or the reclaimed treatment system.

noxious weed: An alien plant (a plant that is not indigenous to Colorado) or parts of an alien plant that have been designated by rule as being noxious or has been declared a noxious weed by a local advisory board, and meets one or more of the following criteria: (a) aggressively invades or is detrimental to economic crops or native plant communities; (b) is poisonous to livestock; (c) is a carrier of detrimental insects, diseases, or parasites; (d) the direct or indirect effect of the presence of this plant is detrimental to the environmentally sound management of natural or agricultural ecosystems. (Colorado Noxious Weed Act).

nozzle: Final orifice through which water passes from the sprinkler or emitter to the atmosphere. (Rain Bird 1997; IA 2006).

NPDES: National Pollutant Discharge Elimination System, as described above.

number of cycles: Number of cycle starts (number of repeat cycles including the first cycle) to be applied to the station/zone per irrigation event. (IA Water Mgt Committee 2001).

ornamental tree: A tree of smaller size than a large shade or evergreen tree, often providing variety and interest by flower display, attractive fruit or fall color. Examples of ornamental trees are crabapple, aspen, hawthorn, and similar species.

perennial: An herbaceous plant that blooms and produces seed for each year, exceeding two years. A short-lived perennial lives for approximately 3 to 5 years. Long-lived perennials are likely to live much longer and can remain for over 20 years.

perlite: A common inorganic amendment used in potting soils and planter mixes. Perlite is made from heat expanded volcanic rock. It is used to increase pore space and has a low water holding capacity. (CSU Extension, Master Gardener Program).

permanent wilting point [PWP] {in./in.}: The amount of water in the soil, at or below which the plant may permanently wilt and not recover. Permanent wilting point is defined as fifteen bars of soil moisture tension. Also see **field capacity** and **plant available water**. (IA Water Mgt Committee 2001).

permeability: The ability of a material to allow the passage of a liquid, such as water through rocks or soil. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas impermeable material, such as clay, does not allow water to flow freely. Permeability is usually expressed in inches/hour to describe the rate at which water moves downward through the saturated soil.

pest: Any insect, rodent, nematode, fungus, weed, or other form of terrestrial or aquatic plant or animal life or virus, bacteria, or other microorganism (except viruses, bacteria, or other microorganisms on or in living humans or in other living animals) which the commissioner or the administrator of the EPA declares to be a pest. (Colorado Pesticide Applicator's Act).

pesticide: Any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest or any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant; except that the term "pesticide" shall not include any article that is a "new animal drug" as designated by the United States food and drug administration. (Colorado Pesticide Applicator's Act).

plant available water [PAW] {in.}: The amount of water held within the root zone after gravitational drainage has ceased, less the amount of water that adheres tightly to soil particles. Commonly expressed as $PAW = (FC - PWP) \times RZ$ where FC = amount of water (in. of water per in. of soil) held in the root zone at field capacity, PWP = amount of water (in. of water per in. of soil) held in the root zone at the permanent wilting point, and RZ = root zone depth (in.). Also see **field capacity**, **permanent wilting point** and **available water**. (IA Water Mgt Committee 2001).

plant health care [PHC]: A six-component prescriptive care program for landscapes. It addresses tree selection, cultural practices, fertilizing, pruning, cabling and bracing, and Integrated Pest Management (IPM). The term was coined by the International Society of Arboriculture to more clearly define IPM techniques as they apply to tree care and landscape maintenance. PHC is a holistic approach to landscape management. The primary objective is to grow healthy plants and in so doing minimize the impact of pests. (Colorado State Extension).

plant water requirement [PWR] {in./day, in/week, etc.}: Amount of water used by a plant as computed by $PWR = ETo \times Kc$, where ETo is the grass reference evapotranspiration and Kc is the plant-specific crop coefficient (also sometimes called K_L or landscape coefficient). Also see **evapotranspiration and crop coefficient**. (Adapted from IA Water Mgt Committee 2001).

porous landscape detention: Porous landscape detention is a stormwater quality management technique consisting of a low lying vegetated area underlain by a sand bed with an underdrain. Also see **rain garden**.

porous pavement and pavers: Alternatives to conventional asphalt that utilize a variety of porous media, often supported by a structural matrix, concrete grid, or modular pavement, which allow water to percolate through to a sub-base for gradual infiltration.

potable water: Water from any source which has been investigated by the health agency having jurisdiction, and which has been approved for human consumption. It can be used as a source of

irrigation water, but once water enters an irrigation system (and passes through the backflow device) it is no longer considered potable. (Cross Connection 1988).

precipitation rate [PR] {in./h}: Rate at which a sprinkler system applies irrigation water. Also known as the **application rate**. (IA Water Mgt Committee 2003).

pressure regulating valve: Valve designed to automatically provide a preset downstream pressure in a hydraulic system. (IA 2006).

pressure regulator: Device which maintains constant downstream operating pressure (immediately downstream of the device) that is lower than the upstream pressure. (Rain Bird 1997)

rain shut-off device, rain sensor, rain switch: A device that causes the irrigation controller to suspend or override an irrigation cycle or that opens the circuit to a valve or set of valves when a preset amount of rain occurs. Ideally, the device will also override the irrigation cycle as long as rain is withheld in the root zone and is available to the plants. A soil moisture sensor may be considered a rain shut-off device if the sensor overrides or suspends an irrigation cycle based on the conditions above. (IA Water Mgt Committee 2001).

rainwater harvesting: The process of intercepting stormwater runoff and putting it to beneficial use, typically following storage in a rain barrel or cistern. The act of intercepting and diverting rainwater is generally a violation of Colorado Water Law, unless water rights are in place for this purpose.

reclaimed water: Wastewater that has received secondary treatment by a domestic wastewater treatment facility and such additional treatment to enable the wastewater to meet the standards for approved uses, either restricted or unrestricted use.

record drawing: Set of construction plans, mylar film, or computer file, including the original irrigation design and noting all design deviations. These drawings should also show the location of all major underground components, dimensioned from permanent features as-built (IA Water Mgt Committee 2001).

reference evapotranspiration [ET_o]{in./period}: Grass reference ET_o is the rate of evapotranspiration from an extensive surface of cool-season grass cover of uniform height of 12 centimeters, actively growing, completely shading the ground, and not short of water. (FAO 1998; ASCE 1990). A related term is ET_r, which is alfalfa reference ET, which is the rate of evapotranspiration from an extensive surface of alfalfa or very similar agricultural crop of uniform height of approximately 50 centimeters, actively growing, completely shading the ground, and not short of water. (Wright 1982; Allen et al. 1989; Walter et al. 2000; ASCE 1990). Typically, ET_r is 10 to 30 percent greater than ET_o; therefore, when referencing ET data, care should be taken to select the proper reference ET data set.

restoration: Human activity that results in the return of an ecosystem to a close approximation of its condition prior to disturbance.

retention pond: A stormwater BMP, also called a wet pond, consisting of a permanent pool of water designed to treat runoff by detaining water long enough for settling, filtering, and biological uptake.

riparian area: Vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding.

root collar: The transition zone between the stem and root at the ground line of a tree or seedling. Also called a **root crown**.

root flare, trunk flare: Interchangeable terms for the area of transition between the vertical stem and structural roots at the base of the tree's stem or trunk. The "flare" develops over time as the tree grows and may not be evident on young trees.

root zone [RZ]{in., ft}: The depth of the soil from which the crop roots extract water and nutrients. (USDA 1993).

rotor: Sprinkler that rotates, but may more specifically refer to a gear driven sprinkler, or an impact driven sprinkler. (IA 2006).

run time [RT]{minutes, hours}: Length of time to operate an individual station/zone for a single irrigation event. Can also be the run time of the station/zone for the entire month or other time period. (IA Water Mgt Committee 2001).

runoff [RO]{in.}: Portion of irrigation or rainwater that leaves the target area, primarily due to slope or the precipitation rate exceeding the soil infiltration (intake) rate. (IA Water Mgt Committee 2001).

runoff reduction practices: Strategies to reduce runoff peaks and volumes from urbanizing areas, employing a practice generally termed **minimizing directly connected impervious areas (MDCIA)**.

saline soils: Soils containing large amounts of water-soluble salts that inhibit seed germination and plant growth. The salts are white, chemically neutral, and include chlorides, sulfates, carbonates and sometimes nitrates of calcium, magnesium, sodium and potassium. Salinity is measured by passing an electrical current through a soil solution extracted from a saturated soil sample. The ability of the solution to carry a current is called **electrical conductivity (EC)**. (CSU Extension).

salts or soluble salts: The soluble salts in soils are mostly combinations of the cations (+ charged ions) sodium, calcium, magnesium and potassium, and the anions (- charged) bicarbonate, chloride and sulfate. When dissolved in water, these compounds dissociate (separate) into their respective cations and anions. For example, calcium sulfate (gypsum) will dissociate into calcium cations and sulfate anions. (CSU Extension, Tri Rivers Area 2007).

sediment: Soil, sand, and materials washed from land into water, usually after rain. Sediment can destroy fish-nesting areas, clog animal habitats, and cloud water so that sunlight does not reach aquatic plants.

shade tree: Deciduous trees of large size, generally 30 feet or more in height when mature.

sheet flow: The portion of precipitation that moves initially as overland flow in very shallow depths before eventually reaching a stream channel.

shrub: A plant that typically retains branches all the way to the ground level; does not include evergreen trees with the exception of upright junipers.

slope: Angle of land measured in horizontal distance necessary for the land to fall or rise one foot, expressed by horizontal distance in feet to one vertical foot.

slotted curbs: Curbs with slots or cut-out areas that allow stormwater to flow away from the curbed pavement into an adjacent landscape or turf area. These can reduce excessive concentration of flows and associated erosion problems.

“smart” controller: Irrigation clocks that automatically adjust irrigation duration and frequency in response to environmental changes based on sensors and weather information. At installation, the controller is programmed based on site-specific landscape and irrigation system characteristics to enable automated adjustment of the system as weather conditions change.

soak time [ST_{cycle}]{minutes}: The amount of time that applied irrigation water is allowed to soak into the soil between cycle starts (i.e., exclusive of the run time). (IA Water Mgt Committee 2003).

sodic soils: Soils with a high sodium (Na) content, as measured by the exchangeable sodium percentage (ESP). If a soil is sodic, a brownish-black crust sometimes forms on the surface due to dispersion of soil organic matter. (CSU Extension).

sodium adsorption ratio [SAR]: A ratio of sodium, magnesium and calcium that is used to express the relative activity of sodium ions in exchange reactions with soil. When the SAR exceeds a certain level (e.g., 10 for most woody plants) the exchangeable soil sodium would be toxic to the plant. (CSU Extension, Tri Rivers Area 2007).

soil amendment: Any material added to the soil to improve its physical properties, such as water retention, permeability, water infiltration, aeration and structure. The goal is to provide a better environment for plant roots. (CSU Extension).

soil moisture balance [SMB]: The amount of moisture in the soil as the sum of effective rainfall and net irrigation amounts less plant evapotranspiration amounts. Also called soil water balance.

soil moisture depletion, soil water depletion [SMD] {in.}: The difference between the **field capacity** and the actual amount of water within the **root zone**.

soil moisture reservoir {in.}: The amount of water in the root zone between the limits of **field capacity** and the **permanent wilting point**.

soil moisture sensor: See **moisture sensor**.

soil probe: A soil coring tool that allows an intact soil core to be removed from the soil profile for examination. (IA Water Mgt Committee 2001).

soil texture class: Soil classification defined by the relative amounts of sand, silt or clay in a particular soil.

soil texture: The size and shape of individual soil particles such as sand, silt, or clay. Soil texture largely determines the amount of water that can be stored in a soil as well as the soil **infiltration rate** and **permeability**.

soil water deficit, soil water depletion, soil moisture depletion [SMD]{in.}: Depth of water required to bring a specific depth of soil to field capacity at a particular time. (ASAE 1998). Preferred term **soil moisture depletion**. (IA 2006).

Spill Prevention Control and Countermeasure Plan (SPCC): A plan prepared by a facility to minimize the likelihood of a spill and to expedite control and cleanup activities should a spill occur.

spray head: Sprinkler head that does not rotate (IA 2006). Also called a fixed spray head.

sprinkler irrigation: Type of irrigation using mechanical devices with nozzles (sprinklers) to distribute water through the air by converting water pressure to a high velocity discharge stream or streams. (IA 2006).

station: An individual output from an irrigation controller that operates electric valves or relays. See zone.

streetscaping: Physical amenities added to the roadway and intersections, including lighting, trees, landscaping, art, surface textures and colors, and street furniture.

structural roots: Woody roots relatively large in diameter, giving characteristic form and shape to a root system.

structural stormwater BMPs: Devices that are constructed to provide temporary storage and treatment of stormwater runoff.

sustainable development: Development that meets the needs of the present without compromising the ability of the future to meet its own needs. Also: Development that maximizes efficiency and functionality of systems while minimizing the consumption of precious resources.

thatch: The layer of dead turfgrass tissue between the green vegetation and the soil surface.

tilth: The soil's general suitability to support plant growth or more specifically to support root growth. Tilth is technically defined as "the physical condition of soil as related to its ease of tillage, fitness of seedbed, and impedance to seedling emergence and root penetration." (CSU Extension Master Gardener Program).

top dressing: A prepared soil mix added to the turf surface; usually incorporated into the soil by raking or irrigating. (CSU Extension, Tri Rivers Area 2007).

turf: Refers to a grouping of grasses that grow in very close proximity to form a living surface at the ground plane. Turf is generally an area of the ground plane intended to be/or could be walked on and when regularly mowed, forms a dense growth of leaf blades and roots.

underdrain: A perforated pipe, typically 4 to 6 inches in diameter placed longitudinally at the invert of a bioretention facility for the purposes of achieving a desired discharge rate. Removes water from saturated soil.

urban heat island effect: A measurable increase in ambient urban air temperatures resulting primarily from the replacement of vegetation with buildings, roads, and other heat-absorbing infrastructure. The heat island effect can result in significant temperature differences between rural and urban areas.

valve: Device to control flow.

velocity, water {fps}: The rate at which water moves through the system (pipe). (Monroe 1993).

vermiculite: A common inorganic amendments used in potting soils and planter mixes that is made from heat expanded silica (mica). It is used to increase pore space and has a high water holding capacity. (CSU Extension, Master Gardener Program).

water budget [V_{IWR}]{ccf, gallon}: Volume of irrigation water required to maintain a functional, healthy landscape with the minimum amount of water over a given length of time. This volume of irrigation water is equivalent to the base irrigation water requirement. (IA Water Mgt Committee 2001).

water quality capture volume [WQCV]: The quantity of stormwater runoff that must be treated in stormwater quality BMPs in Denver. 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. In simple terms, this quantity is about half of the runoff from a 2-year storm. See the Urban Drainage and Flood Control District (www.udfcd.org) for more information.

water right: A legally enforceable right to use water under Colorado Water Law. Colorado water law is based upon the doctrine of prior appropriation or "first in time - first in right", and the priority date is established by the date the water was first put to a beneficial use. Colorado

water law is contained in the State Constitution Article XVI Sections 5 and 6 and in the Colorado Revised Statutes, Sections 37, Articles 80 through 92.

(<http://www.blm.gov/nstc/WaterLaws/colorado.html>).

watering window {h}: The hours and days of the week available for irrigation to be completed. Site uses and local statutes may limit the time and days on which irrigation can occur. (IA Water Mgt Committee 2001).

watershed: The geographical area which drains to a specified point on a water course, usually a confluence of streams or rivers (also known as drainage area, catchment, or river basin).

wetlands: Areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

xeriscape: A landscaping approach that promotes water conservation by implementing seven principles: planning & design, limiting turf areas, selecting and zoning plants appropriately, improving the soil, using mulches, irrigating efficiently, and conducting appropriate maintenance. The term was originally coined by Denver Water.

zone or sprinkler zone: A sprinkler zone is a group of pipelines, with sprinkler heads attached, controlled by a manual or electric valve. The valve provides water to all of the sprinkler heads fed by that zone. (CSU Extension, Tri Rivers Area 2007). Also called a block, or lateral. A station is part of the irrigation controller.

**Green Industry
Best Management Practices (BMPs)
for the Conservation and Protection
of Water Resources in Colorado:
*Moving Toward Sustainability***

Appendices

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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 (2007) *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:

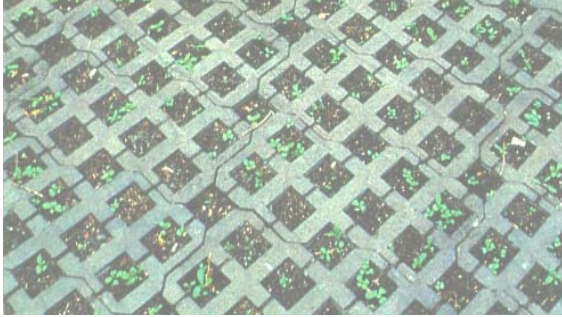
- Level 1. The primary intent is to direct the runoff generated by impervious surfaces to flow over grass-covered areas, and to provide sufficient travel time so as to encourage the removal of suspended solids before runoff leaves the site, enters a curb and gutter, or enters another stormwater collection 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.		
Landscaping 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	303-692-3539 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	303-692-3500 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 Liuzzi	303-692-3588 Michael.liuzzi@state.co.us
Minimal Wastewater from Industrial Facilities (MINDI)	For facilities discharging wastewater of small volume or over a short time period which are amenable 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	303-692-3539 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/weeds/weed.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	Oil Inspectors Section Colorado State Oil Inspection 303-620-4300 (TEL) oil.cdle.state.co.us
Colorado Pesticide Applicator's Act	Restricted use of pesticides and pesticide applicator training	Chemical application in industrial, commercial or agricultural use	Colorado Department of Agriculture	www.colorado.gov/ag 303-239-4140 (TEL) 303-239-4177 (FAX) www.dora.state.co.us/plumbing 303-894-2300 (TEL) 303-894-2310 (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	
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.cdphe.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.cdphe.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.cdphe.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 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

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.

Enter your Data in the White Areas

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



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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? <input type="checkbox"/> Yes
Enter Xeriscape Area	0	sq.ft.	
Or Total Area	0	sq.ft.	OK

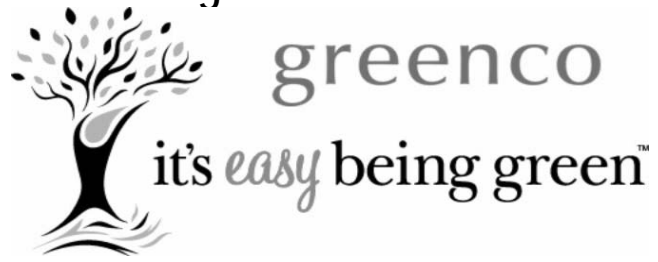
3 Total Water Budget

Water Restriction	0	% Target
* 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
2a. Acres to Sq.Ft. Calculator:		0.00	Mar	0.00	12,690	12,500
	Acres	4.00	Apr	4.00	24,700	24,500
Enter Acres	<input type="text" value="2.00"/>	4.95	May	4.95	25,620	25,500
	sq.ft.	6.20	Jun	6.20	28,990	29,000
	87,120	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

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	<input type="text" value="1"/>	Persons
Low Flow Plumbing?	<input type="text" value="Yes"/>	
Gallons Per Home Per Day		55

2 Landscape Water Consumption Estimate

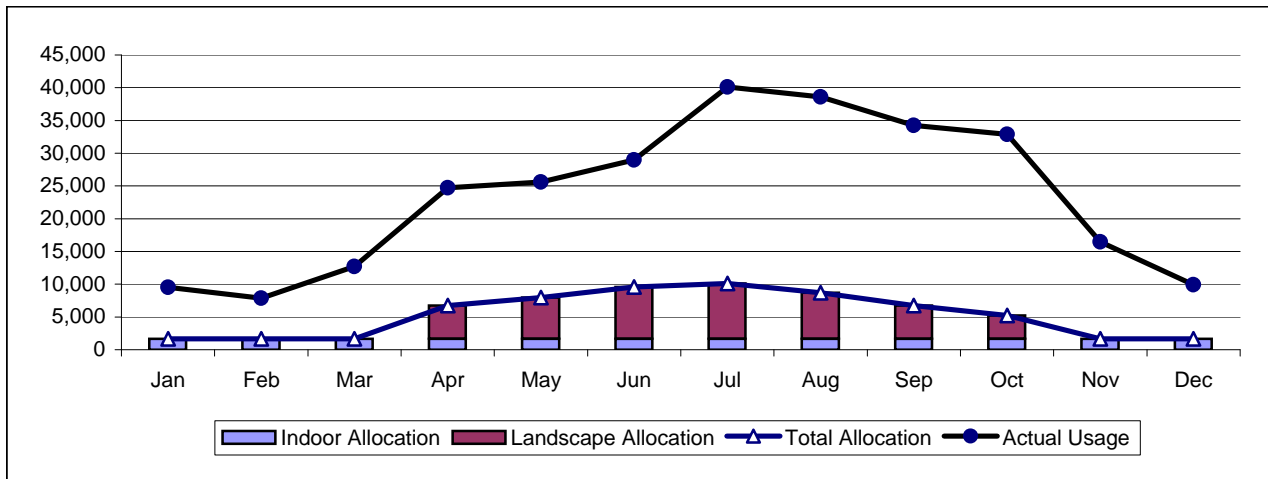
Turf Area	<input type="text" value="1,000"/>	sq.ft.	Automatic Sprinklers? <input type="text" value="Yes"/>
Shrubs/Ground cover Area	<input type="text" value="1,500"/>	sq.ft.	
Xeriscape Area	<input type="text" value="0"/>	sq.ft.	
Or Total Area	<input type="text" value="0"/>	sq.ft.	

OK

3 Total Water Budget

Restriction Budget	<input type="text" value="0"/>	% Target
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* 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

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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 ET_o. Each species' crop coefficient (Kc) is a percentage of ET_o.

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 (ET _o = cool season turfgrass)	Approximate Irrigation Requirement for Metro-Denver Front Range Locations ¹
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_o in terms of inches per week and inches per month. Actual application rates will be affected by climate conditions.

Table 2

**Approximate Monthly and Weekly Irrigation Application Rates in Inches
for Metro Denver Area**

Month	100% ET_o		75% ET_o		50% ET_o		25% ET_o		0% ET_o	
	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% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
 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	ST	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	ST	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	ST	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	L	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	ST	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	ST	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	ST	L	39	L	9	L	9	L	57
Amelanchier laevis	Serviceberry, Allegheny	ST	M	28	L	4	L	4	L	36
Amelanchier lamarckii	Serviceberry, Lamarck	ST	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	ST	M	27	L	6	L	5	L	38
Amorpha canescens	Leadplant	S	VL	31	VL	6	VL	1	VL	38

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

Estimated Water Usage for Plant: VL=Very Low < 25% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
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 fruticosa	False Indigo	S	L	25	L	5	L	4	L	34
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 barnebyi	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	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	S	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 stellerana '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
Arunco diocis	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 carniolica	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		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

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

Estimated Water Usage for Plant: VL=Very Low < 25% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
 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 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
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	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	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	L	1	H	2	H	19
Belamcanda chinensis	Lily, Blackberry	P	L	14	M	1	L	1	L	15
Bellis perennis	Daisy, English	A P	M	10	M	1	M	1	M	11
Bellium minus	Daisy, Miniature Mat	P	M	10	M	1	M	1	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 gladwynensis '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
Bergenia cordifolia	Bergenia, Heart-Leaved	P	M	21	L	2	L	1	M	23
Berlandiera lyrata	Chocolate Flower	P	L	20	VL	3	L	1	L	24
Betula 'Crimson Frost'	Birch, Crimson Frost	ST	H	25	H	4	M	4	H	33
Betula fontinalis /occidentalis	Birch, Native River	ST	H	34	M	6	M	6	M	46
Betula jacquemontii	Birch, Himalayan White	ST	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	1	M	2	M	13
Brassica oleracea	Ornamental Cabbage or Kale	A	M	14	M	1	M	3	M	17
Bromus inermis	Smooth Brome	TU	L	10	VL	1	M	3	L	14
Browallia speciosa	Bush Violet	A	M	11	M	1	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	1	L	1	L	6
Calendula officinalis	Calendula	A	M	19	M	1	L	2	M	22
Callicarpa 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	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
Calylophus hartwegii fendleri	Sundrops, Fendler's	P	L	18	VL	6	L	1	L	25
Calylophus serrulatus	Shrubby Evening Primrose	P	L	4	L	1	L	1	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	L	1	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	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	1	L	1	L	23
Campsis x tagliabuana	Trumpet Vine	P V	L	13	L	1	L	1	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 buchananii	Sedge, Leatherleaf	P	M	12	M	2	M	1	M	14
Carex comans	Sedge, New Zealand Hair	A	M	4	M	1	M	1	M	4
Carex conica	Sedge, Dwarf	P	M	4	M	1	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	1	M	1	M	5

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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 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
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		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 Bower	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
Convallaria 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

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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
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
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	ST	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	ST	M	23	H	4	M	3	M	30
Cornus mas	Dogwood, Cornelian Cherry	ST	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	ST	M	23	M	5	M	4	M	32
Cornus sericea (stolonifera)	Dogwood, Redosier	S	M	23	M	3	H	4	M	30
Cornus stolonifera 'Kelseyi'	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	ST	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	ST	L	40	L	8	L	6	L	54
Crataegus arnoldiana	Hawthorn, Arnold	T	M	12	L	2	L	2	L	16
Crataegus chrysocarpa	Hawthorn, Fire Berry	ST	L	13	L	3	L	3	L	19
Crataegus crus-galli	Hawthorn, Cockspear	ST	L	40	L	7	L	5	L	52
Crataegus crus-galli 'Inermis'	Hawthorn, Thornless Cockspear	ST	L	37	L	6	L	5	L	48
Crataegus douglassii	Hawthorn, Douglas	ST	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	ST	L	28	L	6	L	4	L	38
Crataegus phaenopyrum	Hawthorn, Washington	ST	L	40	L	7	L	4	L	51
Crataegus punctata	Hawthorn, Thicket	T	L	9	L	1	L	1	L	10
Crataegus rivularis	Hawthorn, River	ST	M	16	L	3	L	3	L	22
Crataegus succulenta	Hawthorn, Colorado	ST	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	1	L	7
Dalea purpurea	Clover, Purple Prairie	P	L	14			M	1	L	15
Daphne cneorum	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
Dasyliiron 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 deltoides	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

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

Estimated Water Usage for Plant: VL=Very Low < 25% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
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
Dianthus plumarius (lumznitzer)	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 integerrima '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
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	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	L	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
Eleagnus 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	Eyonymus, 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

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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
Fragaria virginiana glauca	Strawberry, Scarlet	P	L	6			M	1	M	7
Fraseria 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
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 krebiana 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	1	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	M	2	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

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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	ST	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
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	V	M	14	L	2	L	2	M	18
Hydrangea anomala petiolaris	Hydrangea, Climbing	S	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 (kaempheri)	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	Sweetspire	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	ST	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	ST	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	ST	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	ST	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
Kerria japonica 'Pleniflora'	Kerria, 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 thunbergii	Japanese Bush-clover	P	L	6					L	6
Leucanthemum x superbum	Daisy, Shasta	P	M	29	M	1	M	2	M	32

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

Estimated Water Usage for Plant: VL=Very Low < 25% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
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
Lewisia cotelydon	Bitterroot	P	L	9	L	1	L	2	L	12
Leymus arenarius 'Glaucia'	Grass, Blue Lyme	P	L	8					L	8
Liatris punctata	Gayfeather, Native	P	L	25	L	2	L	2	L	29
Liatris pycnostachya	Gayfeather, Thickspike	P	L	13					L	13
Liatris 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
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 Bluelea	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 Tartar	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 B	V	M	15	L	1	L	1	M	17
Lonicera x heckrottii 'Goldflame'	Honeysuckle, Goldflame	P S V	M	24	L	2	L	2	M	28
Lonicera x xylosteoides	Honeysuckle, European Fly	S	L	19	L	4	L	3	L	26
Lunaria annua	Money Plant	A	L	9					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 chalconica	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 pattersonii	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 fremontii	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	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

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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
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
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 lavestigatum '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 Mountain'	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 miyabeum	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

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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 virans	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
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
Petrophytum 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 virginialis	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	ST	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	ST	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	ST	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	ST	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	L	L	26	L	7	L	11	L	44
Pinus densiflora	Pine, Tanyosho	ST	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	ST	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 Scru	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 Orienta	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	M	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 abertii	Vine, Silver Lace	P V	L	22	L	2	L	2	L	26
Polystichum polyblepharum	Fern, Tassel	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, Soixland	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

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

Estimated Water Usage for Plant: VL=Very Low < 25% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
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
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, Woolly	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 neummanniana	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
Potentilla pensylvanica	Cinquefoil, Prairie	P	L	9					L	9
Potentilla species	Cinquefoil, Creeping	GCP S	L	25	L	5	L	4	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	M	1	H	3	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	1	M	1	M	6
Prunella grandiflora	Self-Heal	P	M	8					M	8
Prunella laciniata	Lacy Self-Heal	P	L	14	L	2	M	1	L	17
Prunus americana	Plum, American	S T	L	41	L	8	L	7	L	56
Prunus armeniaca	Apricot	T	M	28	L	7	L	4	M	39
Prunus avium	Cherry, Sweet	T	M	25	L	6	L	3	M	34
Prunus besseyi	Cherry, Western Sand	S	L	36	L	6	L	5	L	47
Prunus cerasifera	Plum, Cherry	T	M	30	L	6	L	4	M	40
Prunus cerasus	Cherry, Sour	T	M	23	L	4	L	2	M	29
Prunus fruticosa	Cherry, European Dwarf	S	M	11	L	2	L	2	L	15
Prunus glandulosa 'Rosea Plena'	Almond, Pink Flowering	S	M	23	L	3	L	2	M	28
Prunus maackii	Chokecherry, Amur	T	M	30	L	4	L	4	M	38
Prunus maritima	Plum, Beach	T	M	6	L	1	L	1	M	8
Prunus nigra 'Princess Kay'	Plum, Princess Kay Canadian	T	M	28	L	4	L	3	M	35
Prunus padus	Mayday Tree	T	M	28	L	5	L	5	M	38
Prunus pensylvanica saximontana	Cherry, Pin	S	M	11	L	1	L	1	M	13
Prunus pesica	Peach	T	M	23	M	4	L	2	M	29
Prunus sargentii	Cherry, Sargent	T	M	14	L	3	L	3	M	20
Prunus serrulata 'Kwanzan'	Cherry, Kwanzan Japanese Flow	T	M	15	M	3	M	3	M	21
Prunus subhirtella 'Pendula'	Cherry, Weeping Spring	T	M	13	M	3	L	2	M	18
Prunus tenella	Almond, Dwarf Russian	S	L	14	L	4	L	3	L	21
Prunus tomentosa	Cherry, Nanking	S	L	29	L	4	L	3	L	36
Prunus triloba	Rose Tree of China	S	M	17	L	4	L	2	M	23
Prunus virginiana 'Shubert'	Chokecherry, Canada Red	S T	M	42	L	8	L	8	L	58
Prunus virginiana melanocarpa	Chokecherry	S	L	32	L	5	L	7	L	44
Prunus x 'Snow Fountains'	Cherry, Weeping White	S	M	10	L	2	L	2	M	14
Prunus x americana 'Toka'	Plum, Toka	T	M	16	M	3	L	4	M	23
Prunus x cistena	Plum, Purple-Leaf	S T	M	38	L	8	L	5	M	51
Prunus x domestica 'Stanley'	Plum, Stanley Prune	T	M	19	L	2	L	2	M	23
Pseudotsuga menziesii	Fir, Douglas	S T	M	35	L	6	L	10	M	51
Psilostrophe tagetina	New Mexico Paper Flower	P	VL	11	L	1	L	1	VL	13
Ptelea trifoliata	Ash, Wafer	T	L	27	L	5	L	4	L	36
Pulmonaria 'Roy Davidson'	Bethlehem Sage, Roy Davidson'	P	M	14					M	14
Pulmonaria rubra 'Redstart'	Lungwort, Redstart	P	M	11	M	1			M	12
Pulmonaria saccharata	Bethlehem Sage	P	M	13					M	13
Pulsatilla patens	Pasqueflower, Lavender	P	L	13			L	2	L	15
Pulsatilla vulgaris	Pasqueflower, European	P	L	18	L	2	L	3	L	23
Purshia tridentata	Bitterbrush Antelope	S	VL	22	VL	4	VL	6	VL	32
Pyracantha angustifolia	Firethorn, Narrowleaf	S	M	19	L	3	L	2	L	24
Pyracantha coccinea	Firethorn, Scarlet	S	L	22	L	4	L	2	L	28
Pyrus calleryana	Pear, Ornamental	T	M	32	L	3	L	3	M	38
Pyrus communis	Pear, Orchard	T	M	18	L	4	L	4	M	26
Pyrus fauriei	Pear, Korean Wild Pear	T	L	11	L	4	L	4	L	19
Pyrus ussuriensis	Pear, Ussurian	T	L	24	L	6	L	5	L	35
Quercus acutissima	Oak, Sawtooth	T	M	12	M	3	L	2	M	17
Quercus alba	Oak, White	T	M	25	L	5	L	2	M	32
Quercus bicolor	Oak, Swamp White	T	L	31	L	5	L	3	L	39
Quercus coccinea	Oak, Scarlet	T	M	23	L	4	L	2	M	29
Quercus ellipsoidalis	Oak, Northern Pin	T	M	17	L	4	L	2	M	23
Quercus gambelii	Oak, Gambel	S T	L	42	VL	9	VL	6	VL	57
Quercus imbricaria	Oak, Shingle	T	M	15	L	2	L	1	M	18
Quercus macrocarpa	Oak, Bur	T	L	39	L	6	L	4	L	49
Quercus muehlenbergii	Oak, Chinkapin	T	L	16	M	3	L	2	L	21
Quercus palustris	Oak, Pin	T	M	24	M	3	L	2	M	29
Quercus phellos	Oak, Willow	T	M	13	L	2	L	2	M	17
Quercus prinus	Oak, Chestnut	T	M	13	L	3	L	2	M	18
Quercus robur	Oak, English	T	M	30	L	5	L	3	M	38
Quercus rubra	Oak, Northern Red	T	M	30	L	5	L	3	M	38
Quercus shumardi	Oak, Shumard Oak	T	M	21	M	3	L	2	L	26
Quercus turbinella	Oak, Shrub Liveoak	S	VL	13	L	2	L	2	VL	17
Quercus undulata	Oak, Wavyleaf	T	L	16	L	2	L	2	L	20
Ranunculus gramineus	Buttercup, European	P	M	9			M	1	M	10
Ranunculus repens	Creeping Buttercup	P	M	15			H	1	M	16
Ratibida columnifera	Coneflower, Prairie	P	L	26	VL	3	L	2	VL	31

**Appendix E
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Estimated Water Usage for Plant: VL=Very Low < 25% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
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
Rhamnus catharticus	Buckthorn, Common	S	L	29	L	3	L	2	L	34
Rhamnus frangula 'Asplenifolius'	Buckthorn, Glossy Cutleaf	S	M	19	L	4	L	3	L	26
Rhamnus frangula 'Columnaris'	Buckthorn, Tall Hedge	S	L	26	L	5	L	2	L	33
Rhamnus saxatile	Buckthorn, Rock	S	L	10	L	2	L	2	L	14
Rhamnus smithii	Buckthorn, Smith's Alder	S	L	16	VL	5	L	2	L	23
Rheum rhabarbarum	Rhubarb	P	M	20			M	1	M	21
Rhododendron	Rhododendron	S	H	19	M	4	M	2	H	25
Rhus aromatica	Sumac, Fragrant	S	L	24	L	5	L	4	L	33
Rhus glabra	Sumac, Smooth	S	L	28	L	6	L	4	L	38
Rhus lanceolata	Sumac, Flameleaf	S	L	8	L	4	L	3	L	15
Rhus microphylla	Sumac, Little Leaf Desert	S	VL	12	L	4	L	3	VL	19
Rhus trilobata	Sumac, Three-Leaf	S	VL	33	L	6	VL	7	VL	46
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	ST	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 globulariifolia	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	Pearwort	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	ST	H	32	H	6	M	4	H	42
Salix alba vitellina	Willow, Russian Golden	ST	H	23	M	5	M	6	H	34
Salix amygdaloides	Willow, Peach Leaf	ST	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	ST	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

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Estimated Water Usage for Plant: VL=Very Low < 25% ETo; L=Low 25%-50% ETo; M=Medium 50%-75% ETo; H=High >75% ETo
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
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	ST	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
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 kamtschaticum	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	ST	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	ST	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	ST	M	24	M	3	M	4	M	31
Sorghastrum nutans	Grass, Indian	P	L	19	L	2	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, Vanhouttei	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

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

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

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

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

**Appendix F
Historical Grass Reference ET Data**

Mean Daily Historical Grass Reference ET (ETo inches-- Calculated Using Kimberly-Penman Method)

Historical reference ETo data are useful for irrigation scheduling. The ETo values must be adjusted by a crop coefficient (Kc), irrigation efficiency and effective precipitation to properly schedule irrigation application.

Percent values provided beneath the ETo (in/day) values can be used in conjunction with "Percent Adjust key" function on irrigation controllers to promote seasonal adjustment of irrigation application rates.

Frequency days are provided as a suggested maximum frequency (i.e., "no more frequent than"), since both duration and frequency should be adjusted when scheduling irrigation. Unless sandy soil conditions are present, the most water efficient irrigation practices are typically "deeply, but infrequently." Allowable watering frequency is controlled by the water provider in some communities.

Example: In Akron, CO in May, for a Kentucky bluegrass lawn mowed at 3 inches (Kc = 0.9) and an irrigation efficiency of 85%, the irrigation controller would be set to apply 0.48" every 3 days, for a total of 4.96" for the month. Equation: (ETo*Kc)/IE x Frequency = Irrigation Application Rate (inches on day applied).

This value would be adjusted downward based on effective precipitation, which for irrigation scheduling purposes can be assumed to be 70% x Precipitation (inches). So, if 1 inch of rain occurs in May, then the total monthly irrigation need would be adjusted to 4.26" to account for 0.7 inches of effective precipitation. (The 70% is a general rule of thumb derived from the Blaney-Criddle calculations.)

Data Source	Period of Record	Station	April	May	June	July	August	September	October	Seasonal Total (in/season)
Denver Water	(2003-2007)	Metro Denver Area	0.15	0.19	0.23	0.24	0.20	0.16	0.13	39.19
		Percent Adjust	61%	77%	94%	100%	82%	65%	54%	
		Frequency Days	3	3	2	2	2	3	4	
CoAgMet	(2005-2007)	Akron	0.11	0.16	0.20	0.24	0.24	0.13	0.11	35.91
		Percent Adjust	46%	66%	83%	100%	99%	54%	46%	
		Frequency Days	4	3	2	2	2	4	4	
CoAgMet	(1996-2007)	Ault	0.15	0.19	0.23	0.23	0.20	0.15	0.09	37.56
		Percent Adjust	63%	83%	98%	100%	85%	64%	41%	
		Frequency Days	3	2	2	2	2	3	5	
CoAgMet	(2002-2007)	Avondale	0.17	0.22	0.27	0.28	0.23	0.19	0.11	44.97
		Percent Adjust	63%	81%	99%	100%	82%	68%	40%	
		Frequency Days	3	2	2	2	2	3	5	
CoAgMet	(1997-2007)	Blanca	0.18	0.24	0.30	0.26	0.23	0.20	0.13	47.00
		Percent Adjust	58%	81%	100%	86%	75%	65%	42%	
		Frequency Days	3	2	2	2	3	3	5	
CoAgMet*	(2000-2007)	Boulder	0.14	0.18	0.21	0.22	0.19	0.15	0.10	36.39
		Percent Adjust	64%	82%	95%	100%	86%	68%	45%	
		Frequency Days	3	2	2	2	2	3	4	
CoAgMet	(2002-2007)	Briggsdale	0.15	0.21	0.27	0.29	0.26	0.17	0.11	44.66
		Percent Adjust	53%	72%	92%	100%	90%	59%	37%	
		Frequency Days	4	3	2	2	2	3	5	
CoAgMet	(2001-2007)	Burlington North	0.15	0.22	0.28	0.31	0.25	0.21	0.14	47.77
		Percent Adjust	50%	73%	93%	100%	83%	67%	45%	
		Frequency Days	4	3	2	2	2	3	4	
CoAgMet	(1994-2007)	Burlington South	0.16	0.21	0.27	0.29	0.25	0.21	0.14	46.79
		Percent Adjust	55%	72%	92%	100%	86%	72%	47%	
		Frequency Days	4	3	2	2	2	3	4	
CoAgMet	(2003-2007)	Center	0.16	0.23	0.27	0.24	0.20	0.18	0.11	42.42
		Percent Adjust	62%	85%	100%	89%	76%	66%	42%	
		Frequency Days	3	2	2	2	3	3	5	
CoAgMet	(2003-2007)	Center #2	0.17	0.23	0.26	0.23	0.19	0.17	0.11	41.59
		Percent Adjust	65%	86%	100%	89%	74%	63%	41%	
		Frequency Days	3	2	2	2	3	3	5	
CoAgMet	(1991-2007)	Cortez	0.15	0.19	0.26	0.24	0.20	0.15	0.10	39.12
		Percent Adjust	58%	76%	100%	93%	77%	58%	40%	
		Frequency Days	3	3	2	2	3	3	5	
CoAgMet	(1995-2007)	Delta	0.16	0.22	0.27	0.27	0.23	0.18	0.12	44.19
		Percent Adjust	59%	81%	100%	97%	83%	67%	44%	
		Frequency Days	3	2	2	2	2	3	5	
CoAgMet	(1995-2007)	Dove Creek	0.17	0.25	0.32	0.30	0.24	0.19	0.12	48.46
		Percent Adjust	54%	78%	100%	93%	75%	58%	37%	
		Frequency Days	4	3	2	2	3	3	5	
CoAgMet	(2000-2007)	Eastern Adams Co.	0.16	0.22	0.28	0.26	0.21	0.17	0.11	43.34
		Percent Adjust	59%	80%	100%	93%	77%	62%	40%	
		Frequency Days	3	2	2	2	3	3	5	
CoAgMet	(1992-2007)	CSU Fruita Expt.	0.16	0.24	0.31	0.30	0.24	0.18	0.10	46.67
		Percent Adjust	53%	76%	100%	96%	77%	57%	34%	
		Frequency Days	4	3	2	2	3	4	6	

Appendix F
Historical Grass Reference ET Data

Data Source	Period of Record	Station	April	May	June	July	August	September	October	Seasonal Total (in/season)
CoAgMet	(1992-2007)	Fort Collins ARDEC	0.14	0.18	0.23	0.24	0.20	0.16	0.11	38.64
		Percent Adjust	58%	74%	94%	100%	80%	66%	46%	
		Frequency Days	3	3	2	2	2	3	4	
CoAgMet	(1992-2007)	Fort Collins AERC	0.13	0.16	0.21	0.22	0.18	0.13	0.09	34.05
		Percent Adjust	58%	73%	94%	100%	80%	61%	39%	
		Frequency Days	3	3	2	2	3	3	5	
CoAgMet	(1992-2007)	Fort Lupton	0.13	0.17	0.22	0.24	0.19	0.15	0.10	36.93
		Percent Adjust	55%	73%	94%	100%	81%	64%	44%	
		Frequency Days	4	3	2	2	2	3	5	
CoAgMet	(1995-2007)	Fort Morgan	0.14	0.19	0.25	0.26	0.21	0.16	0.11	40.19
		Percent Adjust	55%	73%	96%	100%	83%	63%	41%	
		Frequency Days	4	3	2	2	2	3	5	
CoAgMet	(2005-2007)	Fowler	0.13	0.17	0.22	0.23	0.18	0.14	0.10	35.49
		Percent Adjust	56%	73%	94%	100%	80%	62%	42%	
		Frequency Days	4	3	2	2	2	3	5	
CoAgMet	(1993-2007)	Grand Junction	0.14	0.21	0.28	0.27	0.22	0.15	0.09	42.11
		Percent Adjust	52%	76%	100%	98%	79%	55%	33%	
		Frequency Days	4	3	2	2	3	4	6	
CoAgMet	(1992-2007)	Greeley	0.14	0.19	0.23	0.24	0.19	0.14	0.09	37.34
		Percent Adjust	60%	80%	99%	100%	80%	61%	38%	
		Frequency Days	3	3	2	2	3	3	5	
CoAgMet	(1997-2007)	Haxtun	0.15	0.21	0.27	0.27	0.22	0.18	0.12	43.44
		Percent Adjust	55%	76%	100%	100%	79%	65%	43%	
		Frequency Days	4	3	2	2	3	3	5	
CoAgMet	(2005-2007)	Heartstrong	0.17	0.19	0.26	0.24	0.19	0.16	0.11	40.31
		(2005-2007) Percent Adjust	63%	73%	100%	92%	72%	59%	40%	
		Percent Adjust	3	3	2	2	3	3	5	
CoAgMet	(2001-2007)	Holly #1	0.18	0.24	0.29	0.32	0.27	0.23	0.17	52.28
		Percent Adjust	58%	75%	90%	100%	86%	73%	55%	
		Frequency Days	3	3	2	2	2	3	4	
CoAgMet	(2000-2007)	Hoehne	0.18	0.23	0.28	0.28	0.23	0.18	0.12	45.72
		Percent Adjust	66%	82%	100%	100%	82%	66%	43%	
		Frequency Days	3	2	2	2	2	3	5	
CoAgMet	(1998-2007)	Hotchkiss	0.14	0.20	0.26	0.24	0.20	0.14	0.09	39.28
		Percent Adjust	56%	79%	100%	94%	78%	54%	35%	
		Frequency Days	4	3	2	2	3	4	6	
CoAgMet	(1991-2007)	Holyoke	0.16	0.20	0.26	0.25	0.21	0.18	0.13	42.22
		Percent Adjust	61%	78%	100%	97%	80%	69%	49%	
		Frequency Days	3	3	2	2	2	3	4	
CoAgMet	(1991-2007)	Idalia	0.16	0.21	0.27	0.28	0.23	0.20	0.13	44.98
		Percent Adjust	56%	74%	97%	100%	83%	70%	46%	
		Frequency Days	4	3	2	2	2	3	4	
CoAgMet	(1996-2007)	Kirk	0.14	0.19	0.25	0.26	0.22	0.18	0.17	43.29
		Percent Adjust	55%	74%	98%	100%	86%	70%	64%	
		Frequency Days	4	3	2	2	2	3	3	
CoAgMet	(1992-2007)	Kersey	0.15	0.20	0.26	0.26	0.21	0.17	0.12	42.22
		Percent Adjust	59%	77%	99%	100%	82%	65%	45%	
		Frequency Days	3	3	2	2	2	3	4	
CoAgMet	(2005-2007)	Las Animas	0.17	0.21	0.27	0.28	0.23	0.19	0.12	44.97
		Percent Adjust	60%	74%	96%	100%	84%	67%	44%	
		Frequency Days	3	3	2	2	2	3	5	
CoAgMet	(2005-2007)	La Junta	0.18	0.22	0.29	0.29	0.22	0.17	0.12	45.32
		Percent Adjust	61%	76%	100%	99%	78%	61%	40%	
		Frequency Days	3	3	2	2	3	3	5	
CoAgMet	(1998-2007)	Lamar #1	0.17	0.23	0.30	0.34	0.29	0.24	0.15	52.63
		Percent Adjust	51%	67%	88%	100%	84%	69%	44%	
		Frequency Days	4	3	2	2	2	3	5	
Denver Water*	(2005-2007)	Littleton	0.13	0.19	0.25	0.20	0.19	0.15	0.10	37.15
		Percent Adjust	54%	78%	100%	83%	77%	62%	40%	
		Frequency Days	4	3	2	2	3	3	5	
CoAgMet*	(2000-2007)	Longmont	0.13	0.16	0.20	0.19	0.17	0.13	0.08	32.40
		Percent Adjust	65%	80%	100%	95%	85%	65%	40%	
		Frequency Days	3	3	2	2	2	3	5	
CoAgMet*	(2000-2007)	Loveland	0.13	0.17	0.20	0.20	0.18	0.14	0.08	33.63
		Percent Adjust	65%	85%	100%	100%	90%	70%	40%	
		Frequency Days	3	2	2	2	2	3	5	
CoAgMet	(1992-2007)	Lucerne	0.16	0.21	0.27	0.28	0.23	0.18	0.13	44.36
		Percent Adjust	58%	75%	98%	100%	83%	66%	46%	
		Frequency Days	3	3	2	2	2	3	4	

**Appendix F
Historical Grass Reference ET Data**

Data Source	Period of Record	Station	April	May	June	July	August	September	October	Seasonal Total (in/season)
CoAgMet	(1992-2007)	Olathe	0.15	0.20	0.26	0.24	0.18	0.14	0.09	38.69
		Percent Adjust	56%	78%	100%	91%	70%	53%	35%	
		Frequency Days	4	3	2	2	3	4	6	
CoAgMet	(2002-2007)	Paoli	0.15	0.21	0.28	0.30	0.24	0.19	0.12	45.92
		Percent Adjust	51%	71%	92%	100%	79%	64%	39%	
		Frequency Days	4	3	2	2	3	3	5	
CoAgMet	(1992-2007)	Peckham	0.16	0.21	0.27	0.28	0.23	0.18	0.13	44.67
		Percent Adjust	57%	74%	97%	100%	82%	65%	45%	
		Frequency Days	4	3	2	2	2	3	4	
CoAgMet*	(2000-2007)	Pueblo	0.17	0.21	0.25	0.22	0.18	0.16	0.12	40.03
		Percent Adjust	68%	84%	100%	88%	72%	64%	48%	
		Frequency Days	3	2	2	2	3	3	4	
CoAgMet	(1992-2007)	CSU Rocky Ford Expt.	0.18	0.24	0.29	0.28	0.22	0.17	0.12	46.03
		Percent Adjust	62%	81%	100%	95%	76%	58%	40%	
		Frequency Days	3	2	2	2	3	3	5	
CoAgMet	(2002-2007)	San Luis	0.17	0.23	0.28	0.25	0.21	0.17	0.11	43.01
		Percent Adjust	60%	82%	100%	88%	74%	59%	40%	
		Frequency Days	3	2	2	2	3	3	5	
CoAgMet	(1998-2007)	Towaoc	0.17	0.25	0.33	0.32	0.25	0.20	0.13	50.54
		Percent Adjust	51%	76%	100%	96%	76%	60%	39%	
		Frequency Days	4	3	2	2	3	3	5	
CoAgMet	(1993-2007)	Vineland	0.16	0.21	0.25	0.23	0.18	0.15	0.12	40.03
		Percent Adjust	65%	84%	100%	91%	71%	61%	47%	
		Frequency Days	3	2	2	2	3	3	4	
CoAgMet	(1996-2007)	Wray	0.15	0.20	0.24	0.22	0.18	0.15	0.10	38.19
		Percent Adjust	62%	84%	100%	91%	74%	60%	43%	
		Frequency Days	3	2	2	2	3	3	5	
CoAgMet	(1991-2007)	Yellow Jacket	0.15	0.21	0.28	0.26	0.21	0.16	0.10	42.02
		Percent Adjust	55%	76%	100%	95%	76%	59%	38%	
		Frequency Days	4	3	2	2	3	3	5	
CoAgMet	(2003-2007)	Yucca House	0.15	0.23	0.29	0.27	0.21	0.16	0.11	43.16
		Percent Adjust	53%	77%	100%	93%	72%	54%	37%	
		Frequency Days	4	3	2	2	3	4	5	
CoAgMet	(1996-2007)	Yuma #2	0.16	0.21	0.26	0.25	0.20	0.16	0.11	41.62
		Percent Adjust	62%	78%	100%	95%	75%	62%	42%	
		Frequency Days	3	3	2	2	3	3	5	

Compiled from CoAgMet weather station (<http://www.coagmet.com/>) data at the Colorado Climate Center by Austin Clifford and Troy Bauder, Colorado State University Extension, February 2008.

Denver Water data provided by Phil Segura, June 2008. Annual total based on monthly averages is 38.45 inches. Value reported in table is based on daily averages.

CoAgMet or Denver Water sources with * * * notation calculated by Larry Lesser, GreenCO Committee Participant, 2008.

Notes and Disclaimers

The values reported in this table are gross grass reference ET (E_{T0}) values. For water budgeting purposes, these values are reduced by effective precipitation and adjusted by crop coefficients and irrigation efficiency estimates in order to develop a water budget for supplemental irrigation needs. Several different methods can be used to calculate historical reference ET, which may result in varying estimates of ET. The Kimberly-Penman Method was used for development of this table.

The period of record for each site varies significantly. For example, periods of record that include drought years will have higher ET values than those without drought periods.

These values are useful for general planning purposes with regard to water budgeting, but should not be used for detailed water rights analysis, which requires more detailed analysis.

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Appendix G: Pre-Audit Checklist

Pre-Audit Sprinkler Check Level 1

(Individual Logo)

Date	Evaluator		
Customer Name	Account #		
Address:	Phone		
Irrigated Area (sq ft.)	Efficient Technology		
Avg. Root Depth (in.)	Rain Sensor: Yes No	Backflow: Yes No	

Current Program

Current Watering Days: Su M T W Th F Sa	# Days Between Watering:								
Water Adjustment by %	Spring			Summer				Fall	
Start Times	# 1		# 2			# 3		# 4	
Station Number	1	2	3	4	5	6	7	8	9
Head Type: <u>R</u> otor, <u>S</u> pray, <u>D</u> rip, <u>H</u> ose									
Minutes of Run Time									

Site Inspection

Plant Type: <u>A</u> nnu <u>a</u> ls, <u>P</u> erennials, Cool Season Turf, <u>W</u> arm Season Turf									
Plant Quality: <u>A</u> cc <u>e</u> ptable, <u>U</u> nacc <u>e</u> ptable									
Sloped Area: <u>Y</u> es <u>N</u> o									
Exposure: <u>S</u> un, <u>S</u> Hade, <u>P</u> artial									
Soil <u>C</u> ompaction / <u>T</u> hatch: Need to Aerate									
Soil Type: <u>C</u> lay, <u>L</u> oam, <u>S</u> and									

Observed Problems

Station Number	1	2	3	4	5	6	7	8	9
Sprinklers									
<u>B</u> roken / <u>L</u> eaking <u>V</u> alve or <u>P</u> ipe									
Broken <u>H</u> eads / <u>N</u> ozzles									
Mixed Heads (rotors & spray on same zone)									
<u>T</u> ilted Heads / <u>S</u> unken Heads									
Spray: <u>M</u> isdirected, <u>O</u> Bstructed or <u>O</u> verspray									
Incorrect Nozzles <u>A</u> rc / <u>R</u> adius									
Clogged <u>N</u> ozzle or <u>F</u> ilter									
Low Head Drainage									
<u>M</u> isting / <u>H</u> igh or <u>L</u> ow Pressure									
Drip Irrigation									
Emitter <u>M</u> issing / <u>B</u> roken									
Tubing <u>P</u> inched, <u>B</u> roken, <u>N</u> ot Connected									
Missing Filter									
Pressure Regulator <u>M</u> issing, Ma <u>L</u> functioning									

Blank cell = no problems observed.

Comments

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Appendix H: Salt Tolerances of Various Plants

(Source: Swift, C. 1997. Salt Tolerance of Various Temperate Zone Ornamental Plants, Colorado State University Extension, Tri-River Area.)

Several BMPs in this Manual discuss salt-related impacts to plants. These include the Snow Removal, Irrigation Using Nonpotable Water, Turf Management, and Soil Amendment, among others. While a variety of measures may be implemented to reduce salt related impacts originating from soil or irrigation water conditions, in some cases, selection of salt tolerant plants may be a key part of the solution. The plant list below identifies the salt tolerances of some common Colorado plants based on a literature review and personal experiences of nurserymen in Western Colorado's Tri River Area and is suggested as a guide when recommending trees, shrubs, vines and herbaceous plants for salty sites. The tolerance values below are based on soil tests reported as electrical conductivity in millimhos/centimeter (mmhos/cm), which is equivalent to deciSiemens/meter (dS/m). Check your local CSU Extension Office for the most up-to-date or regionally specific plant lists. This plant list was developed by Curt Swift, CSU Extension and is subject to periodic revision. Comments on this list may be submitted to cswift@coop.ext.colostate.edu.

Deciduous Trees

High Tolerance; up to 8 mmhos/cm

Acer plantanoides; Norway Maple
Aesculus hippocastanum Common Horsechestnut
Ailanthus altissima; Tree of Heaven
Amelanchier canadensis; Shadblow
Crataegus crus-galli; Cockspur Hawthorn
Elaeagnus angustifolia; Russian Olive; possibly up to 10 mmhos
Gleditsia triacanthos; Honeylocust
Quercus alba; White Oak
Quercus robur; English Oak
Quercus rubra; Red oak
Robinia pseudoacacia; Black Locust
Ptelea trifoliata; Wafer Ash

Moderately High Tolerance; up to 6 mmhos/cm

Acer negundo; Box-elder
Acer ginnala; Amur maple
Betula lenta; Sweet Birch
Betula populifolia; Grey Birch
Betula alleghaniensis; Yellow Birch
Betula papyrifera; Paper Birch
Fraxinus americana; White Ash
Populus alba; White Poplar
Populus deltoides; Eastern Cottonwood

Populus grandidentata; Large-toothed Aspen
Populus nigra; Lombardy Poplar
Populus tremuloides; Trembling (Quaking) Aspen
Prunus padus; European Bird Cherry
Prunus serotina; Black Cherry
Prunus virginiana; Choke Cherry
Salix alba `Tristis`; Golden Weeping Willow
Salix alba `Vitellina`; Golden Willow
Salix nigra; Black Willow
Sophora japonica; Japanese Pagoda Tree
Ulmus pumila; Siberian Elm

Moderate Tolerance; up to 4 mmhos/cm

Catalpa speciosa; Northern Catalpa
Celtis occidentalis; Hackberry
Celtis reticulata; Netleaf hackberry
Cercis occidentalis; Western Redbud
Fraxinus anomala; Singleleaf Ash
Fraxinus excelsior; European Ash
Fraxinus pennsylvanica; Green Ash
Ginkgo biloba; Maidenhair Tree
Koelreuteria paniculata; Goldenrain Tree
Maclura pomifera; Osage-Orange
Pyrus species; Pear
Ulmus americana; American Elm

Slight Tolerance; up to 2 mmhos/cm

Quercus palustris; Pin Oak
Malus species and cultivars; Apple and Crabapple

Sensitive or Intolerant

Acer rubrum; Red Maple
Acer saccharinum; Silver Maple
Acer saccharum; Sugar Maple
Cercis canadensis; Eastern Redbud
Juglans nigra; Black Walnut
Plantanus acerifolia; London Plane
Sorbus aucuparia; European Mountain-Ash
Tilia americana; American linden
Tilia cordata; Littleleaf Linden

Coniferous Trees

High Tolerance; up to 8 mmhos/cm

Juniperus chinensis; Pfitzer juniper
Picea glauca `densata'; Black Hills Spruce
Pinus mugo; Mugho Pine
Pinus nigra; Austrian Pine

Moderately High Tolerance; up to 6 mmhos/cm

Pinus ponderosa; Ponderosa Pine
Pinus thunbergiana; Japanese Black Pine
Thuja occidentalis; American Arborvitae

Slight Tolerance; up to 2 mmhos/cm

Picea albies; Norway Spruce
Pinus strobus; Eastern White Pine
Pinus sylvestris; Scot's Pine
Pseudotsuga menziesii; Douglas Fir
Taxus cuspidata; Japanese Yew

Sensitive or Intolerant

Abies balsamea; Balsam Fir
Pinus resinosa; Red or Norway Pine
Tsuga canadensis; Canadian Hemlock

Shrubs

Very High Tolerance; Up to 10 mmhos/cm

Atriplex canescens; Fourwing Saltbush

Atriplex convertifolia; Shadscale Saltbush
Atriplex corrugata; Mat Saltbush
Atriplex nuttalli; Nuttall Saltbush
Atriplex nuttalli cuneata; Castle Valley Clover
Atriplex nuttalli gardneri; Gardner Saltbush
Baccharis emoryi; Emory Baccharis
Baccharis glutinosa; Seep-Willow
Ceratoides lanata; Common Winterfat
Chrysothamnus Greenei; Greene Rabbitbrush
Chrysothamnus linifolius; Flaxleaf Rabbitbrush
Ephedra species; Mormon Teas
Ephedra torreyana; Torrey Ephedra
Kochia americana; Greenmolly Summercypress
Sarcobatus vermiculatus; Black Greasewood

High Tolerance; up to 8 mmhos/cm

Caragana arborescens; Siberian Peashrub
Chrysothamnus albidus; Alkali Rabbitbrush
Cytisus scoparius; Scotch Broom
Elaeagnus commutata; Silverberry
Elaeagnus multiflora; Cherry Elaeagnus
Euonymus japonica; Spindle Tree
Halimodendron halodendron; Salt-tree
Hippophae rhamnoides; Sea Buckthorn
Juniperus chinensis; Pfitzer Juniper
Lonicera tatarica; Tatarian honeysuckle
Rhamnus cathartica; Common Buckthorn
Rhus trilobata; Squawbush
Rhus typhina; Staghorn Sumac
Rhamnus frangula; Glossy Buckthorn
Shepherdia canadensis; Buffaloberry
Spiraea vanhouttei; Van Houtte Spirea
Symphoricarpos albus; Snowberry
Syringa amurensis japonica; Japanese Tree Lilac
Syringa vulgaris; Common Lilac
Potentilla fruticosa `Jackmanii'; Jackman's potentilla

Moderately High Tolerance; up to 6 mmhos/cm

Artemisia frigida; Fringed Sagewort
Artemisia spinescens; Bud Sagebrush
Artemisia tridentata; Basin Big Sagebrush
Buxus microphylla; Japanese Boxwood
Chrysothamnus nauseosus; Rubber Rabbitbrush
Chrysothamnus visci diflorus; Douglas Rabbitbrush
Ephedra nevadensis; Nevada Mormontea
Forsythia x intermedia; Showy Border Forsythia
Juniperus communis; Common Juniper
Philadelphus coronarius; Sweet Mockorange
Purshia glandulosa; Desert Bitterbrush
Pyracantha fortuneana; Pyracantha
Rhus glabra; Smooth Sumac
Rhus trilobata; Skunkbush Sumac; Three-leaf Sumac
Shepherdia rotundifolia; Roundleaf Buffaloberry
Spirea `Froebel's'; Froebel's spirea

Slight to Moderate; up to 4 mmhos/cm

Artemisia cana; Silver Sagebrush
Berberis fremontii; Fremont Barberry
Robinia neo-mexicana; New Mexican Locust
Rosa woodsii; Wood's Rose
Salix exigua; Coyote Willow

Slight Tolerance; up to 2 mmhos/cm

Chaenomeles speciosa; Flowering Quince
Ligustrum vulgare; Common Privet
Rosa rugosa; Rugosa Rose; may be slightly tolerant
Viburnum opulus; High Bush Cranberry

Sensitive or Intolerant

Cornus racemosa; Grey Dogwood
Cornus stolonifera; Red-osier dogwood
Rosa; Rose

Vines

High Tolerance; up to 8 mmhos/cm

Lonicera tataricum `Zabelii'; Zabel's Honeysuckle
Parthenocissus quinquefolia; Virginia Creeper; Woodbine

Slight Tolerance; up to 4 mmhos/cm

Lonicera japonica; Japanese Hall's Honeysuckle

Flowers

High to Moderate; 6 to 8 mmhos/cm

Aquilegia micrantha; Cliff Columbine
Machaeranthera xylorrhiza; Common Woody Aster
Psilostrophe bakerii; Paperflower
Stanley pinnata; Prince's Plume; a good indication that the soil is high in selenium

Moderate Tolerance; 4 to 6 mmhos/cm

Fallugia paradoxa; Common Apache
Oenothera caespitosa; Tufted Evening Primrose
Sphaeralcea coccinea; Scarlet Globemallow
Yucca elata Soaptree; Yucca
Yucca glauca; Small Soapweed

Slightly Tolerant; 2 to 4 mmhos/cm

Argemone species; Prickly Poppies
Calochortus species; Mariposa Lilly
Chrysopsis villosa; Hairy Goldenaster
Gallardia pennatifida; Cutleaf Blanketflower
Mentzelia species; Blazing Stars
Physaria australis; Twinpod

Grasses and Other Ground Covers

High tolerance; 14 to 18 mmhos/cm

Agropyron elongatum; Tall Wheatgrass
Agropyron smithii; Western Wheatgrass
Distichlis; Saltgrass

Elymus triticoides; Beardless wildrye
Lotus corniculatus; Birdsfoot trefoil
Puccinellia; alkaligrass
Sporobolus airoides; Alkali sacaton

Moderately High; 8 to 12 mmhos/cm

Bromus marginatus; Mountain brome
Lolium perenne; Perennial ryegrass
Melilotus alba; White sweet clover
Melilotus officinalis; Yellow sweet clover
Trifolium fragiferum; Strawberry clover

Moderate; 4 to 8 mmhos/cm

Agropyron cristatum; Crested Wheatgrass
Agropyron riparium; Streambank
Wheatgrass
Agropyron trachycaulum; Slender
Wheatgrass

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Arrhenatherum elatium; Tall meadow
oatgrass
Bromus inermis; Smooth brome
Buchloe dactyloides; Buffalograss
Dactylis glomerata; Orchardgrass
Elymus giganteus; Mammoth wildrye
Elymus junceus; Russian wildrye
Festuca arundinacea; Tall Fescue
Medicago sativa; Alfalfa
Phalaris arundinacea; Reed Canarygrass

Low Salt Tolerance

Alopecurus pratensis; Meadow foxtail
Festuca rubra; Red fescue
Festuca elatior; Meadow fescue
Poa pratensis; Kentucky Bluegrass
Trifolium pratense; Red clover
Trifolium repens; White clover

Appendix I: Continuing Education

Appendix I
Continuing Education and Certification Programs

Practice Area	Professional Organization	Training & Certification	Websites
Greenhouse	Colorado Nursery and Greenhouse Association	CGG: Certified Greenhouse Grower	www.coloradonga.org
Irrigation	Irrigation Training and Research Center at CalPoly	Various irrigation-related courses; see website for current course offerings and schedule	www.itrc.org
Irrigation	Irrigation Association	CGIA: Certified Golf Irrigation Auditor	www.irrigation.org/
Irrigation	Irrigation Association	CLIA: Certified Landscape Irrigation Auditor	www.irrigation.org/
Irrigation	Irrigation Association	CID: Certified Irrigation Designer	www.irrigation.org/
Irrigation	Irrigation Association	CIC: Certified Irrigation Contractor	www.irrigation.org/
Landscape Architect	Colorado State Board of Landscape Architects	Colorado Licensed Landscape Architect	www.dora.state.co.us/la/
Landscape	PLANET	CLT: Certified Landscape Technician (with 5 core tests in Softscape Installation, Hardscape Installation, Turf Maintenance, Ornamental Maintenance, and Irrigation)	www.alcc.org and www.landcarenetwork.org
Landscape	PLANET	CLP: Certified Landscape Professional	www.alcc.org and www.landcarenetwork.org
Landscape	PLANET	CLT-I: Certified Landscape Technician–Interior	www.alcc.org and www.landcarenetwork.org
Landscape	PLANET	COLP: Certified Ornamental Landscape Professional	www.alcc.org and www.landcarenetwork.org
Landscape	PLANET	CTP–CSL: Certified Turfgrass Professional–Cool Season Lawns	www.alcc.org and www.landcarenetwork.org
Nursery	Colorado Nursery and Greenhouse Association (CNGA)	CCNP: Colorado Certified Nursery Professional	www.coloradonga.org
Pesticides	Colorado Department of Agriculture	Colorado Dept. of Agriculture Commercial Pesticide Applicator	www.colorado.gov/cs/Satellite?c=Page&cid=1167928159784&pagename=Agriculture-Main%2FCDAGLayout
Snow Removal	Snow & Ice Management Association (SIMA)	CSP: Certified Snow Professional	www.sima.org/
Trees	International Society of Arboriculturists (ISA)	ISA Certified Arborist	www.isa-arbor.com/
Trees	International Society of Arboriculturists (ISA)	ISA Certified Arborist/ Utility Specialist	www.isa-arbor.com/
Trees	International Society of Arboriculturists (ISA)	ISA Certified Arborist/ Municipal Specialist	www.isa-arbor.com/
Trees	International Society of Arboriculturists (ISA)	ISA Certified Tree Worker/Climber Specialists	www.isa-arbor.com/
Trees	International Society of Arboriculturists (ISA)	ISA Board-Certified Master Arborist	www.isa-arbor.com/
Trees	American Society of Consulting Arborists (ASCA)	Registered Consulting Arborist	www.asca-consultants.org
Other Green Industry Related:			
Erosion/Sediment Control	CPESC, Inc.	CPESC: Certified Professional in Erosion and Sediment Control	www.cpesc.org/
Erosion/Sediment Control	CPESC, Inc.	CESSWI: Certified Erosion, Sediment and Stormwater Inspector	www.cpesc.org/
Stormwater Quality	CPESC, Inc.	CPSWQ: Certified Professional in Stormwater Quality	www.cpesc.org/
Certification Programs for Landscapes, Products or Programs			
Green Building	Built Green Colorado	Built Green University (training for the Built Green Checklist)	www.builtgreen.org/
Green Building	U.S. Green Building Council & Green Building Certification Institute	LEED AP: Leadership in Energy and Environmental Design Accredited Professional	www.gbci.org/
Water Conservation/ Efficiency	EPA WaterSense	WaterSense program certifies both products and professionals	www.epa.gov/WaterSense/
Other Professional Organizations Serving as Resources to the Green Industry			
All Areas	Colorado State University Extension	CSU Extension provides courses and information on all aspects of the Green Industry. Contact either the central headquarters or the county-based offices for information on a variety of topics	www.ext.colostate.edu/
Irrigation	Northern Colorado Water Conservancy District	Sponsors annual field day in September. Good source of information on irrigation technology and water conservation.	www.ncwcd.org
Irrigation	American Society of Irrigation Consultants	Provide a forum wherein irrigation design professionals can meet to exchange information and advance skills and techniques in irrigation design, installation and product application.	www.asic.org/
Plant Selection	Colorado Native Plant Society	Native plant lists for Colorado	www.conps.org
Pond Installation	International Pond Contractors Association	Proper pond installation	www.ipcca.com

Appendix J: Industry Checklists

- Associated Landscape Contractors of Colorado (ALCC)
- Colorado Association of Lawn Care Professionals (CALCP)
- Colorado Nursery and Greenhouse Association (CNGA)
- Garden Centers of Colorado (GCC) for In-house and Public Contact

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ALCC Reminder Checklist for Best Management Practices (BMPs)

<p>Water Management & Irrigation System Care</p> <ul style="list-style-type: none"> <input type="checkbox"/> Are you applying adequate water during establishment and adjusting the irrigation once plants are established? <input type="checkbox"/> Are you regularly checking, adjusting and repairing all irrigation systems to ensure systems are performing at optimum levels? <input type="checkbox"/> Are you managing and modifying the system to respond to changes and seasonal requirements of water needs? <input type="checkbox"/> Are you aware of the updates on the water saver Web site? <input type="checkbox"/> Do your water management practices prevent erosion? <input type="checkbox"/> Are you minimizing pollution to all stream ways and buffer zones? <input type="checkbox"/> Have you considered regional soil conditions when determining watering requirements? <input type="checkbox"/> Are you calculating the water needs of all landscaped areas and adjusting appropriately? 	<p>Education</p> <p>Employees</p> <ul style="list-style-type: none"> <input type="checkbox"/> Do you have water management training programs? <input type="checkbox"/> Do you encourage and promote all industry certifications? <input type="checkbox"/> Do you understand and refer to the manufacturers' specifications? <input type="checkbox"/> Are you aware of state and county regulations for noxious weeds? <input type="checkbox"/> Are your employees educated about the material safety data sheets (MSDS) and OSHA regulations? <p>Public</p> <ul style="list-style-type: none"> <input type="checkbox"/> Are the environmental landscape benefits discussed with the end user? <input type="checkbox"/> Are you explaining the benefits of the seven principles of Xeriscape? <input type="checkbox"/> Are you working with your customers to find rebates and other incentive programs? 	<p>Installation and Erosion Control</p> <p>Erosion Control</p> <ul style="list-style-type: none"> <input type="checkbox"/> Are you protecting drainage ways from runoff and repairing/stabilizing areas with excessive erosion? <input type="checkbox"/> Are you aware of and in compliance with all storm water construction permit regulations? <input type="checkbox"/> Are you mulching seeded areas as appropriate when the slope requires it? <input type="checkbox"/> Are you properly storing and protecting top soil and amendments? <input type="checkbox"/> Are you properly protecting trees and other plant material to be retained on site? <p>Landscape Installation</p> <ul style="list-style-type: none"> <input type="checkbox"/> Is the site properly prepared for the arrival of materials? <input type="checkbox"/> Are you performing a soil analysis and properly amending and fertilizing prior to planting or laying sod? <input type="checkbox"/> Are you planting seed at the appropriate time of year and mulching all seeded areas? <input type="checkbox"/> Are you maintaining all nursery stock so it remains healthy prior to installation? 	<p>Maintenance & Turf Care</p> <ul style="list-style-type: none"> <input type="checkbox"/> Are you fertilizing according to label requirements and turf needs? <input type="checkbox"/> Do you have regular turf maintenance schedules? <input type="checkbox"/> Are you mowing turf to proper height to maximize moisture? <input type="checkbox"/> Are you leaving grass clippings on the turf and keeping clippings out of the gutters? <input type="checkbox"/> Are you practicing IPM on a regular basis for both turf and plant care? <input type="checkbox"/> Do you mark all sprinkler heads prior to aeration? <input type="checkbox"/> Are you aerating 1-2 times per year to improve nutrient and water intake? <input type="checkbox"/> Are you replenishing mulch beds to the proper depth? <input type="checkbox"/> Are you regularly checking, adjusting, and repairing the irrigation system?
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Review these reminders regularly to ensure industry BMPs are followed.



Associated Landscape Contractors of Colorado
Professionals Grounded In Excellence

ALCC • 1873 S. Bellaire St., Suite 920 • Denver, CO • 80222
Phone: 303 757-5611 • Fax: 303 757-5636 • www.alcc.com

ALCC Reminder Checklist for Best Management Practices (BMPs)

<p>Snow Removal</p> <ul style="list-style-type: none"> <input type="checkbox"/> Do you regularly plan out areas for snow storage? <input type="checkbox"/> Do you have any necessary permit required for snow management and disposal? <input type="checkbox"/> Are you aware of and protecting any streams and wetlands prior to plowing? <input type="checkbox"/> Do you follow all de-icing instructions for human and plant safety? <input type="checkbox"/> Are you maintaining plants throughout the year, so they're not affected by de-icing chemicals? 	<p>Codes, Inspections, Regulations</p> <ul style="list-style-type: none"> <input type="checkbox"/> Do you verify all landscape ordinances? <input type="checkbox"/> Do you obtain all proper permits and licenses before starting work? <input type="checkbox"/> Do you verify water restrictions in the different municipalities in which you work? <input type="checkbox"/> Are all appropriate inspections performed? <input type="checkbox"/> Are you checking and following all code requirements? <input type="checkbox"/> Are you reviewing all the local, state and federal regulations for water reclamation? 	<p>Irrigation Design</p> <ul style="list-style-type: none"> <input type="checkbox"/> Is the irrigation system designed for maximum efficiency and distribution uniformity? <input type="checkbox"/> Are you considering microclimates, grading, drainage, hydraulics, etc., during the design process? <input type="checkbox"/> Are you specifying properly sized equipment to maximize efficiency and maintain proper pressure? <input type="checkbox"/> Are you using recycled or non-potable water to the greatest extent possible? <input type="checkbox"/> When planning a system using reclaimed water, do you account for existing soil, plants and efficiency? 	<p>Sustainability</p> <ul style="list-style-type: none"> <input type="checkbox"/> Are you using the seven Xeriscape principles as often as possible? <input type="checkbox"/> Are you designing, installing and maintaining the landscape based on the 9 general principles for sustainability? <input type="checkbox"/> Are you recycling and composting, when possible?
<p>Landscape Design</p> <ul style="list-style-type: none"> <input type="checkbox"/> Are you using the design BMPs? <input type="checkbox"/> Do your designs meet all local code requirements? <input type="checkbox"/> Are you designing based on sound landscaping practices, Xeriscape principles, and drainage in the overall landscape? 	<p>Plant Care</p> <ul style="list-style-type: none"> <input type="checkbox"/> Do you regularly review your plant maintenance requirements? <input type="checkbox"/> When working with existing trees, are you protecting all the root zones when necessary? <input type="checkbox"/> Are you aware of different soil types on the properties you work? <input type="checkbox"/> Are you frequently dead heading and removing dying plants and weeds? 	<p>Pesticides, Fertilizers and Other Chemicals; General Safety</p> <ul style="list-style-type: none"> <input type="checkbox"/> Are you following manufacturer directions for applying chemicals? <input type="checkbox"/> Are you reviewing all safety practices and material safety data sheets (MSDS)? <input type="checkbox"/> Do you have proper record keeping of all pesticides that are applied to your properties? <input type="checkbox"/> Do you properly handle and dispose of all pesticides to minimize safety and health risks? <input type="checkbox"/> Are you following all OSHA requirements? <input type="checkbox"/> Do you regularly inspect and maintain your equipment? 	<p style="text-align: center;">For detailed information, please refer to the 2008 edition of the Best Management Practices manual, located online at www.greenco.org</p>

Colorado Association of Lawn Care Professionals (CALCP): Industry Checklist

- Follow regular maintenance practices: check fertilizer, herbicide and pesticide labels for appropriate application practices and conditions; check calibration of fertilization equipment with each use especially when changing blends or products; follow manufacturer's directions on all labels; keep grass & fertilizers off pavement and concrete; triple rinse herbicide containers before disposal; carry MSDS & PPE in all vehicles; conduct winter watering as needed; perform weekly preventive maintenance on equipment; sharpen blades & check oil in machines daily; winterize equipment before storage per manufacturer's instructions.
- Herbaceous plant care: prepare soil with organic amendments, group plants with similar water needs, select plants with lower water requirements, fertilize when needed, regularly maintain mulch, water efficiently and comply with watering restrictions, where applicable.
- Follow irrigation efficiency guidelines: adjust irrigation duration and frequency throughout the growing season to meet the water needs of the plants; use drip methods in bed areas and for shrubs and trees; and winter water trees and shrubs. Avoid light, frequent applications of water; instead water less frequently and more deeply.
 - Use high quality system and replace worn parts as needed.
 - Develop and adjust irrigation schedule based on water needs of plants, soil types, slope, exposure, etc.
 - Design: uniform coverage, avoid run-off, check pressure, flow and velocity of water flow for type of equipment used, use pressure regulators where needed.
 - Installation: follow design criteria, test system, set zone schedules, explain system operation to end user.
 - Maintenance: check, adjust & repair system regularly, prevent watering hard surfaces, check backflow device, conduct winterization and spring activation, check sensors regularly, check plant health regularly and adjust accordingly. Particularly for large parcels, conduct water efficiency audit periodically.
 - Manage system for efficient use: reset schedule as needed per ET rates and weather conditions.
- Irrigation technology: know best current technology (e.g., smart controllers, rain and wind shut-off devices, soil moisture sensors), test manually periodically and remember to reset to auto control, train end-user, know how much water needs to be applied to meet plant requirements.
- Irrigation efficiency audits: learn proper procedure for irrigation efficiency audits; conduct pre-audit to correct existing deficiencies such as damaged equipment.

- Follow sustainable practices where possible: plant/locate trees to reduce indoor heating/cooling needs, keep equipment well maintained, replace damaged plant material, use solar power for outdoor lighting/water features when possible.
- Tree & woody plant care: select plants appropriate for climate, area & exposure; plant according to proper depth; water as needed for good health, especially until established and during dry periods; inspect for insect or disease damage; prune to maintain health and shape; protect during construction so as not to damage roots.
- Tree preservation: assess possible damage, avoid root damage as much as possible, protect tree with fencing, monitor health during & after construction, treat injuries immediately.
- Snow removal: use mechanical approaches where feasible; do not pile snow on plants, use care with de-icing chemicals around plants. In areas with heavy de-icing chemical usage, flush soil with water if needed in the spring to decrease impacts on vegetation.
- Low Impact Development: be aware of special maintenance requirements for Low Impact Development features such as porous landscape detention areas, planters/rain gardens, porous/permeable pavement, grass ditches, grass swales, grass buffers, and green roofs. Do not alter drainage associated with these features, which may involve temporary ponding following storms.

Checklist Release Version 1.0, Prepared by CALCP Volunteer Committee, 2008.

Colorado Nursery and Greenhouse Association (CNGA) BMP Checklist for Production, Distribution and Holding Areas

<u>TASK VERIFICATION DATE</u>			<u>TASK</u>	<u>CURRENT BMP</u>
_____	_____	_____	Group plants (hydro-zoning) that have similar water needs	#30 - Production Practices
_____	_____	_____	As inventory is sold, consolidate plant material to maximize benefit of water used	#31 - Water Mgmt for Nurseries...
_____	_____	_____	Use a quality soil mixture that retains moisture and optimum growth without requiring multiple daily watering	#31 - Water Mgmt for Nurseries... #30 - Production Practices
_____	_____	_____	Train workers to identify irrigation problems, i.e., broken hoses, etc.	#37 - Education of Employees
_____	_____	_____	Designate employee to verify and correct irrigation problems	#37 - Education of Employees
_____	_____	_____	Adjust irrigation system timers for the appropriate season	#30 - Production Practices
_____	_____	_____	Repair or replace broken or leaking hoses, pipes, sprinkler heads, & valves	#30 - Production Practices
_____	_____	_____	Schedule annual irrigation audit to identify current and potential problems	#30 - Production Practices
_____	_____	_____	Plug sprinkler heads & emitters that are no longer watering plants	#30 - Production Practices
_____	_____	_____	Upgrade irrigation equipment to improve efficiency as possible	#30 - Production Practices
_____	_____	_____	Use moisture-retaining materials for storage on above ground B&B stock	#30 Production Practices
_____	_____	_____	Use shrink wrap on B&B trees to save water	#30 Production Practices
_____	_____	_____	When designing B&B storage areas, place more drought tolerant species on southern and western sides and the less tolerant species on the northern and eastern sides of the storage areas	#30 Production Practices
_____	_____	_____	Keep plant material free of weeds to avoid competition for water	#30 Production Practices
_____	_____	_____	Use or upgrade to automatic irrigation systems whenever possible	#30 Production Practices
_____	_____	_____	Use appropriate plant material to create a natural wind break for your growing area	#30 Production Practices

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Garden Centers of Colorado: Industry Checklist for General In-house Practices

General Water Resource & Conservation Practices for Landscapes

- See ALCC and CNGA BMP checklists for help.

General Water Resource & Conservation Practices for Nurseries, Greenhouses and Growers

- See CNGA BMP checklist for help.

Education of Employees

- Offer employer training on BMPs at appropriate times
- Make all employees aware of BMPs

Education of the Public

- Make employees aware of resource information to assist general public with questions

Fertilizer/Herbicide/Pesticide Application/Storage & Disposal

- Apply fertilizer, herbicides/pesticides to store inventory as needed to maintain quality of material
- Know appropriate spill clean up procedures

Herbaceous & Woody Plant Care/Selection/Placement

- Hydrozone plants for water/light needs and water appropriately
- Prune/deadhead as needed to maintain healthy appearance of plant materials
- Inspect plant shipments on arrival for insects/diseases and isolate/treat if necessary

Irrigation Efficiency

- Use shut off on all hoses
- Avoid water waste in every instance
- Hydrozone plants for water and light needs

Irrigation System Design/Installation/Maintenance

- See CNGA checklist for in-house water/irrigation BMPs

Landscape Design/Maintenance

- See ASLA and ALCC checklists for BMPs

Lawn Aeration, Lawn Waste Disposal/Composting, and Mowing

- Be aware of basic practice guidelines for these BMPs

Mulching

- Demonstrate use of various types of mulch for customers to see

Regulatory Awareness

- Review Regulatory Awareness BMP

Soil Amendment/Ground Preparation

- Prepare and have available a list of resources for city/county ordinances

Water Budgeting

- Review Water Budgeting BMP and understand general concepts

Xeriscape

- Train employees to understand ET and how it applies to watering plants/and other applications
- Review/recommend 7 steps of Xeriscape with employees
- Encourage tie-in sales with every purchase

Checklist Release Version 1.0, Prepared by GCC Volunteer Committee, May 2008

Garden Centers of Colorado: Industry Checklist for Public Contacts

General Water Resource & Conservation Practices for Landscapes

- Review and recommend following the 7 steps of Xeriscape
- See individual BMPs for specific detail

General Water Resource & Conservation Practices for Nurseries, Greenhouses and Growers

- See CNGA checklist

Education of Employees

- See GCC in-house checklist

Education of the Public

- Lead by example in the store displays, display gardens, watering techniques, plant placement, etc.
- Have on-hand educational materials and distribute correct information for BMP practices, etc.

Fertilizer/Herbicide/Pesticide Application/Storage & Disposal

- Read and follow product labels
- Review product knowledge and sell appropriate fertilizers/herbicides/insecticides for customer needs

Herbaceous & Woody Plant Care/Selection/Placement

- Provide signage to educate customers on plant needs
- Recommend right plant for right place
- Direct customers to appropriate educational resources

Irrigation Efficiency

- Water deeply at appropriate intervals according to plant needs: avoid frequent, shallow watering

Irrigation System Design/Installation/Maintenance

- Refer customer to irrigation consultants

Landscape Design/Maintenance

- Refer customers to landscape consultant/specialists

- Review product knowledge and recommend/sell appropriate products for landscape maintenance: soil amendments, fertilizer, tools, blade sharpening, aeration services, mulch, etc.

Lawn Aeration

- Recommend core aeration twice a year (spring & fall) for healthy turf

Lawn Waste Disposal/Composting

- Leave cores/clippings on lawn
- Recommend composting yard debris when possible

Mowing

- Recommend mowing height of 2-1/2" to 3"
- Leave clippings on lawn
- Maintain mowing equipment so as not to damage blades

Mulching

- Encourage use in plantings, containers, baskets for water conservation

Regulatory Awareness

- Refer customer to appropriate city/county ordinances or other source of this information

Soil Amendment/Ground Preparation

- Demonstrate, recommend and encourage soil amendment/ground prep with all plant purchases

Water Budgeting

- Suggest websites such as: planttalk.org, watersaver.org, GreenCO.org (water budgeting procedures & ET explanation), and others

Xeriscape

- Know and be able to explain 7 steps of Xeriscape to customers
- Direct customer to educational materials/websites such as Denver Water and GreenCO BMPs
- Distribute GCC's x-rated brochures

Checklist Release Version 1.0, Prepared by GCC Volunteer Committee, May 2008