



**Delaware Department of Transportation**

Roadside Vegetation Establishment and Management Manual

# Enhancing Delaware Highways



**Delaware Department of Transportation**

---

Roadside Vegetation Establishment and Management Manual

## **Enhancing Delaware Highways**

**Written, edited and prepared by:**

Susan Barton, University of Delaware

Rick Darke, Rick Darke LLC

Gary Schwetz, Delaware Center for Horticulture

Glossary by: Anne Lucey, University of Delaware

Graphic Design by: Carrie Finnie

Produced under contract with the  
Delaware Department of Transportation,  
Carol Ann Wicks, Secretary

April 2009



# Acknowledgements

The *Enhancing Delaware Highways* project is a joint venture between the Delaware Department of Transportation (DeIDOT), the Delaware Center for Horticulture (DCH) and the University of Delaware (UD). Project leaders are Susan Barton, University of Delaware, Gary Schwetz, Delaware Center for Horticulture and Rick Darke, Rick Darke Inc. Valann Budischak serves as project administrator.

**The following people contributed to the production of this manual.**

Eugene Rosan, Roadside Environmental Supervisor  
Marianne Walch, Environmental Scientist, DeIDOT Stormwater Quality Program  
Randy Cole, Environmental Program Manager I  
Steve Gantz, proprietor, All Seasons Landscaping  
Brian O'Neill, proprietor, Weeds Inc.

Copyright statement

Text copyright DeIDOT, April 2009.

Photography by Rick Darke, Susan Barton and Gary Schwetz, individually copyrighted.

Cover photographs copyright Rick Darke.

# Table of Contents:

## **10 Introduction**

- 10** DeIDOT Roadside Vegetation Policy
- 10** Purpose of the Establishment and Management Manual
- 12** Integrated Roadside Vegetation Management Program
- 13** Environmental Stewardship and Public Perception
- 17** Audience
- 17** Goals and Objectives

## **20 Establishing Vegetation**

- 20** Establishing Vegetation Introduction
- 21** Site Conditions
  - 21** Roadway limitations
  - 21** Soil and water conditions
    - Soil compaction **21**
    - Soil pH **24**
    - Lack of topsoil **24**
    - Erosion control **25**
    - Contamination **25**
    - Drainage issues **26**
- 26** Site Preparation
  - 27** Conserving indigenous plant communities
    - Plant community inventory **27**
    - Weed control in plant communities **28**
    - Selective removal of vegetation (editing) **28**
  - 29** Removing undesirable vegetation
    - Removal strategies **29**
    - Removal methods **30**
- 33** Soil preparation
  - Grading **33**
  - Topsoil **34**
  - Soil amendment/nutrition **35**



		Tillage <b>36</b>
		Site preparation equipment <b>37</b>
<b>37</b>	Case study examples of site preparation	
<b>40</b>	Establishment Using Seed	
<b>40</b>	Seed characteristics	
		Purity <b>40</b>
		Inert matter <b>40</b>
		Weed seeds <b>40</b>
		Other crop seed <b>40</b>
		Germination <b>40</b>
		Pure live seed (PLS) <b>40</b>
		Variety <b>41</b>
		Cleaned seed <b>41</b>
		Certified seed <b>41</b>
		Provenance <b>41</b>
		Seed dormancy <b>42</b>
		DeIDOT standard specifications <b>42</b>
<b>42</b>	Vegetation types established by seed	
		Temporary cover <b>42</b>
		Regularly mowed turf <b>43</b>
		Low growing turf <b>44</b>
		Grass meadows <b>45</b>
		Mixed grass and forb meadows <b>47</b>
<b>49</b>	Methods of seeding	
		Broadcast seeding <b>49</b>
		Hydroseeding <b>50</b>
		Drill seeding <b>51</b>
		Topdressing <b>53</b>
<b>53</b>	Establishment Using Vegetative Material	
<b>53</b>	Types of vegetative material	

	Sod	53
	Plugs	53
	Bare-root plants	54
	Container-grown plants	54
	Balled and burlapped plants	54
<b>54</b>	Methods of planting	
	Sodding	54
	Plugging	55
	Bare-root planting	57
	Container-grown planting	58
	Balled and burlapped planting	59
	Tree spading	60
<b>61</b>	Plant aquisition	
	Inspection	61
	Contract growing	62
<b>63</b>	Mulching	
<b>63</b>	Seeded sites	
	Straw mulching	63
	Cereal grain straw	63
	Salt hay mulch	63
	Bonded fiber matrix	63
	Soil retention blanket mulches	64
<b>65</b>	Landscape beds	
<b>67</b>	Irrigation	
<b>68</b>	Design and Stakeout of Landscape Planting Projects	
<b>69</b>	Replacement	
<b>71</b>	<b>Managing Vegetation</b>	
<b>71</b>	IRVM Objectives	
<b>72</b>	Roadside Features	
<b>72</b>	Guardrails	

<b>74</b>	Medians
<b>75</b>	Roadsides
<b>75</b>	Beds
<b>77</b>	Stormwater best management practices
<b>78</b>	Stormwater mitigation sites
<b>81</b>	Design Approaches
<b>81</b>	Regional
<b>82</b>	Regional-ornamental
<b>82</b>	Fully ornamental
<b>83</b>	Vegetation Reduction Techniques
<b>83</b>	Discontinued mowing or release
<b>84</b>	Editing
<b>84</b>	Cutting back
<b>85</b>	Mowing
	Routine mowing <b>85</b>
	Periodic mowing <b>87</b>
	Equipment <b>88</b>
<b>89</b>	Pruning
<b>89</b>	Reasons for pruning
<b>90</b>	Pruning tools
<b>90</b>	Pruning techniques
	Natural target pruning <b>90</b>
	Pruning sequence <b>91</b>
	Pruning timing <b>92</b>
	Complete removal <b>92</b>
	Cutback <b>92</b>
<b>94</b>	Trash Accumulation
<b>95</b>	Weeds
<b>95</b>	Weed classification
	Plant type <b>95</b>



	Life cycle	96
	Aggressive nature or legal status	96
<b>98</b>	Weed Control	
<b>98</b>	Control methods	
	Cultural	99
	Biological	100
	Mechanical	101
	Chemical	102
<b>104</b>	Herbicide safety	
<b>106</b>	Herbicide use	
<b>106</b>	Herbicide mode of action	
	Contact herbicides	106
	Systemic herbicides	106
<b>107</b>	Herbicide selectivity	
	Nonselective herbicides	107
	Selective herbicides	107
	Plant factors	107
	Application factors	108
	Environmental factors	108
<b>109</b>	Herbicide formulations	
	Liquids or aqueous suspensions	109
	Emulsifiable concentrates	110
	Solutions	110
	Liquified gases	110
	Wettable powders	110
	Water dispersable granules and dry flowables	110
	Soluble powders	111
	Granules	111
<b>112</b>	Application equipment	
	Conventional sprayers	112

	Backpack sprayers <b>112</b>
	Rope-wick applicators <b>112</b>
	Controlled droplet applications <b>112</b>
	Granular spreaders <b>113</b>
	Gravitational drop spreaders <b>113</b>
	Mechanically fed drop spreaders <b>113</b>
	Centrifugal or rotary spreaders <b>113</b>
	Equipment calibration <b>114</b>
	Cleaning and care of equipment <b>116</b>
<b>117</b>	Calculating application rates
<b>118</b>	Additional application methods
	Stem cutting <b>118</b>
	Basal bark treatment <b>118</b>
	Bare ground vegetation control <b>118</b>
<b>119</b>	Spray drift control
<b>121</b>	Specific recommendations
	Invasive woody plants <b>121</b>
	Meadows <b>121</b>
	Stormwater ponds <b>122</b>
	Wetland mitigation sites <b>122</b>
<b>122</b>	Sensitive areas
<b>123</b>	Product policies
<b>124</b>	Fertilization
<b>124</b>	Turf
<b>124</b>	Trees and shrubs
<b>124</b>	Lime
<b>126</b>	Problems
<b>126</b>	Insect and disease
<b>126</b>	Cultural problems
	Compaction <b>126</b>

	Excess mulch	126
	Trunk, bark, branch and root damage	126
	Supports, wire, twine and tree wrap	126
	Salt damage	127
	Soil grade changes	127
<b>127</b>	Diagnosing problems	
	Root flare	127
	Crown dieback	127
	Abnormal leaf size	127
	Trunk scars	128
	Yellow foliage	128
<b>129</b>	Record Keeping	
<b>129</b>	DeIDOT forms	
<b>130</b>	Inventories	
<b>130</b>	Guardrails	
<b>130</b>	Existing stormwater system	
<b>130</b>	Noxious and invasive weeds	
<b>131</b>	Training Program	
<b>132</b>	Glossary	
<b>139</b>	Literature Cited	
<b>140</b>	Appendix A – Herbicides How-to Information	
<b>141</b>	Appendix B – Pesticide Application Daily Report Form	
<b>142</b>	Appendix C – Selected Weed Species Control Recommendations	
<b>144</b>	Appendix D – SOPs from DeIDOT – handling spills; calibration; spray mixes	
<b>145</b>	Appendix E – Structural Soil	
<b>146</b>	Appendix F – Modular Paving	
<b>151</b>	Appendix G – Herbicides Approved for Use on DeIDOT Rights of Way	
<b>155</b>	Appendix H – References	



# Introduction

## **The Delaware Department of Transportation Roadside Vegetation Policy**

The Delaware Department of Transportation is dedicated to conserving and enhancing regionally indigenous vegetation in the State's transportation rights-of-way. Regionally native plants are valued for their adaptation to the region and its climate, ability to control erosion, support of biodiversity, provision of wildlife habitat and contribution to the regional sense of place. Roadside vegetation strategies strive to utilize plant succession processes to achieve self-sustaining native plant communities that are cost effective to maintain, environmentally sound, scenic and unique to the State of Delaware.

DeIDOT is committed to reducing pesticide use in their transportation rights-of-way. By implementing an integrated roadside vegetation management manual,

DeIDOT will select the management strategy that best reduces negative environmental impact in a cost effective manner.

## **Purpose of the DeIDOT Establishment and Management Manual**

Maintaining roadsides for safety and aesthetics is important to DeIDOT, Delaware government and Delaware residents. A healthy roadside environment reduces maintenance needs and costs, preserves the road surface, provides safety for vehicles and travelers, maintains good public relations, and improves the overall driving experience.

*Enhancing Delaware Highways (EDH)* is a direct response to a need to develop an integrated and sustainable roadside vegetation management program for the Delaware Department of Transportation. For the past 50 years or more, mowing and herbicides have been the predominant methods used to manage nationwide roadside vegetation. New environmental laws, reduced budgets, and increased public interests necessitate finding more environmentally sensitive methods, incorporating new technologies, incurring lower maintenance costs, and finding cost-effective alternatives to today's methods of management of roadside vegetation. Sustaining native roadside vegetation requires a shift from traditional management based upon repetitive maintenance routines to progressive



management based upon routines that evolve in response to changing habitat conditions.

Selective removal of undesirable plants is conducted as needed. As trees grow and shade increases, the population of shrubs and perennials will evolve.

Integrated Roadside Vegetation Management (IRVM) uses a decision-making process to implement best management practices (BMPs) for roadside vegetation management. IRVM principles maintain that establishing and managing roadside vegetation in the most sustainable manner relies on blending the natural processes of each site with available resources and the design objectives for that site. The first publication of *EDH, The Concept and Planning Manual*, was developed in part to promote integration of vegetation management in the planning, design and construction phases of highway development. This Establishment and Management Manual explains in detail the necessary steps to establish sustainable roadside vegetation, and manage that vegetation in an environmentally sound, aesthetically pleasing, and fiscally responsible manner.

Integrated roadside vegetation management contributes greatly to biological diversity, preserves biological heritage, and provides attractive roadsides that positively reflect local landscape character.



Although traditional mowing will keep this median and on-ramp right-of-way looking like this indefinitely, it requires expenditures of time and fossil fuel that are unnecessary and does not allow for any evolving diversity or enrichment of the roadside habitat.



The right-of-way adjacent to this I-95 on-ramp includes a routinely mowed narrow strip, a broader area mowed yearly to maintain visibility and a large area where woody and herbaceous vegetation has been allowed to regenerate.



By evaluating the existing conditions on roadsides, decisions about preserving and managing vegetation can be made.



When roadside vegetation decisions are integral to the planning, design and construction processes, sustainable vegetation can be incorporated.

- DeIDOT is committed to reducing pesticide use, increasing biodiversity and reducing negative environmental impacts of roadside vegetation management by adopting an Integrated Roadside Vegetation Management (IRVM) approach.
- *EDH, The Planning and Concept Manual* promotes integration of vegetation management in the planning, design and construction phases of highway development.

## **Integrated Roadside Vegetation Management Program (IRVM)**

Integrated Roadside Vegetation Management has been endorsed as an accepted operational standard by the 1996 Task Force of the National Roadside Vegetation Management Association (NRVMA). In the 1997 how-to manual prepared by the Task Force, IRVM is defined as a process for maintaining roadside vegetation that integrates: (1) the needs of local communities and highway users; (2) knowledge of plant ecology (and natural processes); (3) design, construction, and maintenance considerations; (4) government statutes and regulations; and (5) technology. The IRVM process weighs these needs and resources against available cultural, biological, mechanical, and chemical pest control methods to economically manage roadsides for safety plus environmental and visual quality. The benefits of IRVM planning and programming reach from safety, economics, flexibility, and appearance to improved environment and public relations.

The *EDH* program gives emphasis to the First State's regional native vegetation, accentuating the diverse and attractive array of trees, shrubs, grasses and wildflowers that offer interest throughout the region's distinct seasons. Roadside landscape management based

upon these local natural resources provides visual pleasure while contributing to awareness of Delaware's biological heritage and regional pride of place. Delaware is well known for its parks, gardens, and nature preserves, and roadsides managed for beauty and conservation contribute to the positive impression of the First State, indirectly supporting tourism and economic development.

Though Delaware is a small state, the thousands of acres held in roadside rights-of-way constitute major preserves of public open space, which is otherwise diminishing rapidly due to commercial and residential development. Traditional roadside vegetation management based upon regular mowing minimizes visual and biological diversity and ignores the potential for positioning these lands as preserves of regional biodiversity. Management strategies outlined in this manual are designed to blend horticultural techniques for attractive and efficient roadside landscapes with ecological principles of population dynamics. The result will be visually appealing habitats that preserve Delaware's native flora and fauna. Additional benefits are a reduction in maintenance costs, primarily through decreased mowing, and minimized use of herbicides through alternative strategies for vegetation control.



Diverse habitats ranging from upland woods to wetlands often flank Delaware's transportation corridors. Each supports a distinct ecological community.



Native Pinxter azaleas flower in the shrub layer of an oak woodland along Route 1.



Open water fringed with native rushes and grasses meets a moist woodland along Route 72.

## Environmental Stewardship and Public Perception

Roadside landscapes managed for economic efficiency and environmental responsibility will in some situations present an appearance distinctly different from traditional designs dependent upon high-maintenance exotic plants and routine use of toxic herbicides. A multifaceted program for educating the driving public about the benefits of new designs is an essential part of the management strategy. An effective program building upon Delawareans' pride of place will result in acceptance of roadside management strategies and will

also cast the Department of Transportation in the admirable role of a major steward of the First State's legacy of natural resources. Most state departments of transportation have close ties to the public and political community of their state and have responded to the wishes of the public when appropriate.

Public education is a critical component of any highway vegetation program. Observers note the exceptional beauty of annual plantings during the first year, but don't understand the economic or environmental costs associated with maintaining such plantings. Regionally representative plantings may take two or

- IRVM is defined as a process for maintaining roadside vegetation that integrates:
  - the needs of local communities and highway users
  - knowledge of plant ecology (and natural processes)
  - design, construction, and maintenance considerations
  - government statutes and regulations
  - technology
- Roadside acreage provides an important resource of public open space that can serve as preserves of regional biodiversity.
- Enhancing the management ethic of IRVM, DeIDOT is committed to adopting alternative strategies for vegetation control that minimize the need for herbicides.

IRVM

## Delaware Speaks Out Survey Results

(% of respondents selecting 1-5; low appeal to high appeal)

Scene	Low Appeal (1)	(2)	(3)	(4)	High Appeal (5)
Mowed grass	3	5	19	40	31
Unmowed grass	55	22	11	5	3
Billboards	47	23	22	3	1
Industrial sites	51	24	17	3	2
Office complexes	3	8	32	34	19
Wooded areas	8	2	16	41	36
Wetland area	3	7	25	35	27
Open meadow	1	3	21	37	35
Colorful flowers	1	1	9	29	57
Shrub thickets	2	4	21	33	38

more years to realize their full potential. Educating the public or users of the natural area is often necessary to gain acceptance.

A Delaware focus group survey conducted in 1999 derived the following conclusions about public opinion.

1. Colorful and diverse plantings could replace annual cosmos plantings. Scenes that had color, either from flowers or fall foliage, were more attractive and more effective at reducing highway monotony than their counterparts with no color other than green.

2. Mowed grass was viewed as the least effective at reducing highway monotony. Other researchers (Billings, 1990) have found that plantings other than mowed turf provide aesthetic variety and break up highway monotony.

3. Distinct lines or masses within the landscape achieved order. Scenes with order were rated as attractive and effective at reducing highway monotony. This is consistent with the findings of

Ulrich (1986), who found that coherence (a sense of order) was an excellent predictor of scene preference.

4. Scenes with a natural look were viewed as less expensive to maintain and more effective at reducing highway monotony. Davis and Schimalfenig (1999) found that the public has a high interest in efficient maintenance; therefore it is not surprising that there was an appeal expressed for natural, easy to maintain scenes.

Delaware Speaks Out, a statewide Cooperative Extension survey conducted in 1999 revealed that Delawareans notice the impact of roadside plantings. Respondents believe plantings along the roadside have a moderate, significant or major impact (58%) on short trips but more impact (78% responded with moderate, significant or major impact) for long trips (one hour or more). Colorful flowers (57%), shrub thickets (38%), wooded areas (36%) and open meadows (35%) were rated as having high appeal more frequently than other types of roadside scenes.



Mowed turf, the default vegetation along Delaware roadsides, was rated as moderately attractive.



An unmowed roadside received the lowest rating from survey respondents.



Unmowed turf with a mowed edge was rated as attractive as fully mowed turf.

A Comprehensive Mail Survey of 1200 Delawareans (57% response rate) supports the conclusion that color is a desirable attribute for roadside vegetation. Color does not need to come exclusively from flowers; fruit and foliage provide attractive roadside color. In fact, respondents are somewhat more supportive of colorful displays from trees and shrubs (83%) than from flowers in highway medians (67%). This may be due to the perceived cost of maintaining median plantings of flowers.

Mowed turf is the default vegetation along Delaware roadsides. Survey respondents rated a fully mowed turf infield moderately attractive and much better than the unmowed roadside (received the lowest rating). But, an unmowed roadside with a mowed edge received the same rating as the fully mowed infield. Respondents agreed (72%) that all turfgrass areas should be mowed regularly, but half (50%) also agreed with allowing grasses to reach a meadow height with edges that are kept neatly mowed. An additional 29% of respondents were neutral about this practice, so only

19% of respondents disagreed with the practice of mowing an edge.

No one specific vegetation type or management method will please all drivers in all situations. But, responses to this survey indicate DeIDOT should reduce expenditures on mowing by mowing only a strip of vegetation adjacent to the road and allowing the rest of the right-of-way to grow to meadow height. While there is some concern for keeping spending in check, there is also significant support for using varied state and federal funding to beautify roadsides with colorful trees, shrubs and perennial flowers. More intensively planted areas can be reserved for highly visible locations when traffic is slower and drivers can appreciate plantings, such as at gateways to communities or towns and intersections. Delawareans expressed a desire for Delaware roadsides to maintain a sense of place by using vegetation that matches the native flora of the region. Roadsides should be managed and a sense of order maintained.



Enhancing Delaware Highways signs draw attention to locations exemplifying environmentally sound and cost effective planting and management practices.



Once DeIDOT roadside designers and vegetation managers understand the preferences of the traveling public they will be better able to make decisions concerning roadside design and management. A 2005 survey by The National Cooperative Highway Research Program found that mechanical control of roadside vegetation is the preferred method on 90% to 100% of roadsides of

responding states. Delaware, as with other states, has historically relied heavily on mowing for roadside vegetation control. An IRVM program can help change this routine practice. In many cases simply ceasing blanket mowing and substituting the mowing of an edge only will result in a cost effective, environmentally sound and aesthetically pleasing roadside.

## Environmental Stewardship and Public Perception

- Public education is a critical component of any highway vegetation program.
- Colorful, diverse plantings with an appropriate sense of order are desirable and believed to reduce roadside monotony as compared to mowed turf.
- DeIDOT should reduce expenditures on mowing by mowing a strip of vegetation adjacent to the road and allowing the rest of the right-of-way to grow to meadow height.

## Audience

The Establishment and Management Manual is primarily designed as a tool for DeIDOT roadside vegetation managers and agents employed by DeIDOT. This includes landscape installation contractors, Departmental roadside crews, temporary seasonal employees, contract maintenance crews, district specialists for vegetation management, maintenance engineers, and other administrators. The research-based rationales presented in the manual will also prove useful in communicating the challenges and opportunities of roadside landscape management to designers, consultants, local community stakeholders and other decision-makers whose business is occasionally integrated with vegetation management activities. This group includes landscape architects, engineers and highway maintenance personnel.

## Goals and Objectives

The *Enhancing Delaware Highways* program is based on IRVM philosophy, consequently, the public needs to understand the reasons for roadside vegetation management in relation to functional roadway objectives, surrounding land use, the overall ecosystem, natural processes and applied technologies. The dominant philosophy is an appreciation for the beauty present in a self-sustaining, low maintenance roadside plant community. The taxpayer benefits from lower life-cycle maintenance costs, less negative environmental impact, and attractive and sustainable naturalistic roadsides.

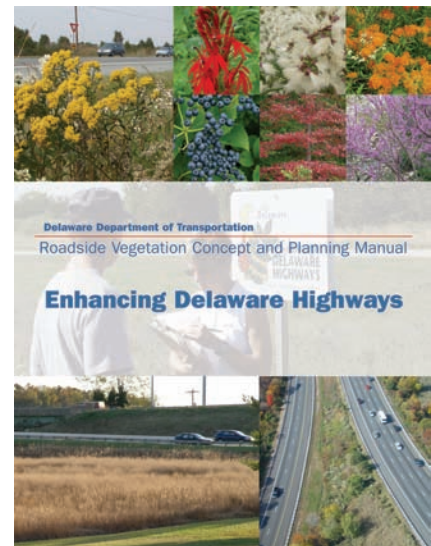
This manual works in conjunction with the *Enhancing Delaware Highways Roadside Vegetation Concept and Planning Manual* (C & P manual). These two tools are integral to the development and application of appropriate design approaches and maintenance strategies. With the C & P manual, designers factor in

- Roadside vegetation managers
- Contractors
- Designers and planners

Audience



the varying priorities of visual appeal, regional conservation and economics and use the matrix tool provided to select the most appropriate approach for any given location. Illustrated exercises are provided to demonstrate the process of applying the matrix to actual projects. Other tools included in the C & P manual that may be useful to roadside vegetation managers are charts to guide appropriate plant selection, a table of estimated installation and maintenance costs, an illustrated appendix of recommended plants and a glossary of terms.



C & P Manual

## Goals and Objectives

- Delaware drivers will be guided to discover the beauty present in self-sustaining, low maintenance roadside plant communities.
- The EDH C & P manual will be used to select design approach and plant choices that will dictate feasible establishment and management practices for each site.
- The EDH E & M manual outlines the establishment and management procedures.



Delaware residents and travelers entering Delaware from Pennsylvania are greeted by a regionally appropriate gateway planting along I95.

### **Short-term IRVM goals and objectives:**

- Identify and implement pesticide reduction strategies.
- Conduct risk assessment on roadside chemicals.
- Develop annual work plan and timetable for implementation.
- Reduce maintenance costs.
- Manage vegetation for highway safety.
- Outline vegetation removal strategies and determine appropriate chemical use.
- Identify undesirable situations and develop procedures for prevention and correction.
- Collect existing data and manage inventories.
- Identify and enforce no-spray zones in environmentally sensitive areas.
- Develop procedure for public notification.
- Fulfill noxious weed control requirements.

### **Long-term IRVM goals and objectives:**

- Enhance the scenic quality of Delaware's roadsides.
- Provide self-sustaining, diversified vegetation communities.
- Research new methodologies.

### **Best Management Practices for roadside vegetation include:**

- Use integrated construction and maintenance practices.
- Establish sustainable vegetation.
- Develop a mowing policy and improved procedures.
- Control noxious and invasive weeds.
- Develop an integrated roadside vegetation management plan.
- Develop a public relations plan.

# Establishing Vegetation

## Introduction

Establishment practices are determined in large part by the design approach (see sidebar, pgs. 22–23). Practices described in this manual include site preparation, plant selection and planting.

Site preparation usually involves removing some vegetation, either selectively or completely, to eliminate undesirable species, introduce aesthetic order, or accommodate new plantings. Modifications of environmental conditions may range from minimal grading and soil amendment to complete alteration of the hydrology and topography, (e.g., wetlands creation on a previously dry site).

Plant selection is determined by design; however, well conceived design objectives take aesthetic goals, budgetary concerns, ease of establishment and maintenance needs into account. Seed may be the ideal material and if so, the

seed mix and planting rates must be determined. For other applications, vegetative material may be most appropriate, and if so, variables include size, and whether material used will be plugs, or container-grown, bare-rooted, or balled-and-burlapped plants.

Successful planting involves appropriate timing and installation methods. Timing varies with the nature of the material being planted. Some material can be planted almost anytime, such as stabilizing cover crops planted by seed. Other material, such as warm-season grasses or bare root woody plants may require very precise timing. Installation methods vary depending upon whether the plant material is seed, plugs, container grown, bare root or balled and burlapped.

## Introduction

- Removal of existing species may be necessary to eliminate noxious and invasive species, introduce aesthetic order, or provide space for the introduction of new plants.
- Soil, moisture and grade may require modification to provide required growing conditions.
- Appropriate design takes plant selection and establishment into account.
- Seed and vegetative methods of establishing methods of establishing plant have unique advantages and requirements.
- Successful planting involves appropriate timing and installation methods.

- Follow clear zone guidelines in DeIDOT Road Design Manual.
- Consider roadway shading, debris, and damage to vegetation from winter maintenance chemicals when locating vegetation.
- Follow lines of sight guidelines in DeIDOT Road Design Manual and C & P Manual.
- Select appropriate trees for use under utility lines.
- Call Miss Utility before digging holes to plant trees or shrubs.

## Site Conditions

### Roadway limitations

The establishment and planting process should include a final review of whether or not the sight line, utility and clear zone requirements are being met. Substitutions of plant material must be evaluated for both aesthetic, cultural and roadway limitations.

### Soil and water conditions

**Soil compaction** – Roadsides are often highly compacted from vehicular, pedestrian and construction traffic. Compacted soils are low in oxygen and poorly drained. Plants growing in compacted soil typically suffer from restricted root growth. Strategies for improving growing conditions in compacted soils include limiting traffic, core aeration, radial trenches; and a variety of new urban forestry soil management techniques such as structural soil (Appendix E) and cantilevered and modular pavement support systems (Appendix F).

- Compacted soils have low oxygen, poor drainage and result in restricted root growth.
- To cope with compacted soils, limit traffic, core aerate, trench radially or install new urban forestry soil management techniques such as structural soil and cantilevered and modular pavement support systems.

## Design Approaches

There is a continuum between ecologically-based regional design and ornamental, primarily decorative design; however for practical purposes three general approaches have been identified: the regional approach, the regional-ornamental approach and the fully ornamental approach. For greater detail in determining the application of these approaches, see EDH C & P Manual, Landscape Planning Process, pgs 64-69, 89-106.



Regional approach

intervention allows for considerable natural growth and propagation of native plant species on site. This approach is appropriate for large-scale sites where cultural conditions are suitable (or suitable with minor modification) for Delaware native species, and where the installation and maintenance budget is minimal. It is particularly appropriate in areas where the Delaware native flora remains a significant part of the local context. Low to moderate visibility sites including extended highway margins, broad median strips, and larger highway infields are examples where the regional approach might be selected.

### Regional approach

Plant selection is restricted to Delaware native species. The design intent is to develop attractive, naturalistic landscapes based directly on the regional ecology: the dynamics, patterns, colors and cycles of Delaware's native plant communities. There is a minimal level of intervention, just sufficient to create and maintain an aesthetic order that can be appreciated on a large scale. Though not intended to fully replicate native plant communities, regional plant associations and dynamics are conserved and enhanced, and the low level of

### Regional-ornamental approach

Plant selection is restricted to Delaware native species plus other North American native species that reflect the general character of Delaware's native flora. The design intent is to develop ornamental landscapes inspired by the regional colors, patterns and cycles of the native Delaware landscape, but is not necessarily based upon plant community dynamics. There is a moderate level of intervention, sufficient to create and maintain an aesthetic order that is noticeable and attractive on a medium-to





Regional-ornamental approach



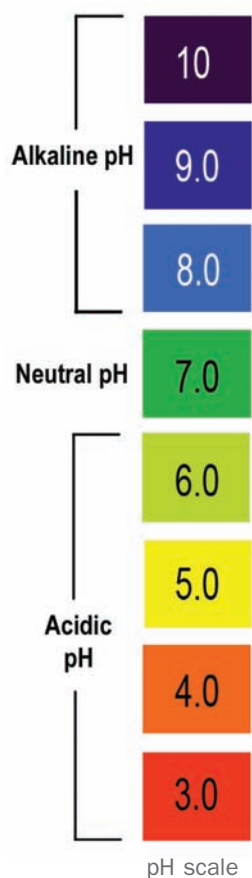
Fully ornamental approach

large-scale. The designs rely on well-defined groupings and masses to create ornamental impact, using regional plant associations when practical to suit this purpose. This approach is appropriate for medium-to large-scale sites where cultural conditions are suitable (or suitable with moderate modifications) for a mix of Delaware and North American native species, and when the installation and maintenance budget is moderate. It is appropriate in areas where the Delaware native flora is a modest to minimal part of the local context. Moderate to high visibility sites including larger traffic islands, highway infields, and city and community gateways are examples where the regional-ornamental approach might be selected.

### **Fully ornamental approach**

Plant selection is unrestricted. Design intent is to create highly ornamental garden-like landscapes based primarily on visual impact and functionality, not necessarily related to the colors, patterns and cycles of the native Delaware landscape. If site conditions are suitable and aesthetic requirements are met, regional flora should be given preference.

There is a high level of intervention and maintenance, sufficient to create and maintain a highly ordered aesthetic that is attractive on a small to medium scale, and evident even when viewed at close range. The designs rely on well-defined groupings and masses to create ornamental impact based upon qualities of color, texture and form. This approach is appropriate for small-to medium-scale sites where the desire for a neat, highly ornamental appearance exceeds the capacity of the native and regional flora, and/or where the cultural conditions on the site are so heavily impacted that they severely limit the choice of native or regional species. It is appropriate in areas where the Delaware native flora is a minimal or nonexistent part of the local context. Well-defined, small-scale, high visibility sites including traffic islands and parking lots are examples where the fully ornamental approach might be selected. Due to the relatively high installation and maintenance cost of this approach, community sponsorship or assistance may be an important component in the cost-effective management of these sites. Mowed turf falls in this category since cool-season turf is not native and the maintenance cost is high.



**Soil pH** – Soil pH is the relative acidity or alkalinity of a soil. The majority of Delaware’s indigenous flora grows best in the slightly acidic (pH 6.0 – 6.5) soils most commonly found in the state. In that range, nutrient availability is ideal and beneficial microorganisms thrive.

Increased acidity (pH lower than 5.0) can result in toxic conditions due to excessive availability of certain micronutrients such as aluminum and manganese. Amend excessively acid soils with lime to increase pH. Human activity such as construction and development typically modify pH. Building materials (e.g., stucco, mortar and concrete) raise the pH, creating alkaline conditions. This is especially pronounced in urban environments. High pH often reduces nutrient availability. Amend alkaline soils with sulfur to reduce pH. In roadside environments, it is often most cost effective to measure pH and select plants

that tolerate the existing conditions, rather than to make extensive modifications. Some fill soil along roadsides may be so acidic that it completely prevents plant growth. In those cases modification is necessary.

**Lack of topsoil** – Topsoil is often removed from roadsides during construction and what remains is often subsoil low in nutrients and organic matter. Lack of topsoil can be limiting when trying to establish woody vegetation. Many Eurasian weed species thrive on richer organic soils. Native warm-season grasses and perennial forbs are often better adapted and therefore favored when soil is low in organic matter and nutrients. Subsoil has low fertility and fewer weed seeds, so it may limit the growth of opportunistic weeds and invasive species and favor tough native species.

### Soil pH

- Selecting plants that tolerate existing soil conditions is the most cost effective approach.
- Existing conditions are sometime so extreme they require modification. In highly acid fill situations add lime to raise pH before planting. In highly alkaline conditions add sulfur to lower pH.

### Lack of topsoil

- Lack of topsoil may limit the establishment of woody shrubs and trees.
- Low fertility subsoil may favor the growth of native warm-season grasses and forbs, reducing weed and invasive species competition.



This cool-season grass mixture is not deeply rooted enough to prevent erosion.



The deep, spreading roots of colonizing shrubs like sumac stabilize even a steep slope.



White crust on soil in the vegetation-free zone is an indication that salt is a contaminant flowing from this drain pipe.

**Erosion control** – Vegetation is the most cost effective and visually gratifying means of erosion control. Appropriate vegetation must be chosen to stabilize the soil surface both temporarily and permanently to prevent stormwater erosion and sedimentation activity. Existing vegetation on the construction site should be preserved where practical. If this is not possible, vegetation should be re-established using grasses, forbs and woody plants. The deep rooted nature of warm-season grasses and woody vegetation is often ideal for preventing slippage on steeper slopes. The Department’s landscape policy requires the use of native species as much as possible. See DeIDOT Road Design Manual, Chapter 6, DeIDOT ES2M Design Guide and DNREC Erosion Control and Sediment Control Handbook for further guidance.

**Contamination** - Pollutants emitted and leaking from vehicles are washed from the roadway into roadside soils causing contamination that is often toxic to vegetation. The most common contaminant is salt, which is used on the roadside during winter months. Under ideal drainage conditions, salts are leached from the soil by spring rainfall. However, in poorly drained sites and in sites where roadside drain systems concentrate runoff, salt accumulation is often a serious problem. Extreme contamination may require re-engineering of drain systems; however, in moderately salt-contaminated soils salt tolerant plants offer a means of vegetating sites.

- Preserving existing vegetation is often the most effective means of erosion control.
- Re-establish vegetation promptly after construction using native species whenever possible.

### Erosion control

- Observe existing vegetation patterns to determine potentially contaminated sites.
- Test soils for salt content prior to planting.
- Salt tolerant plants may survive even in contaminated soils.

### Contamination



Misuse of the mower attachment opens bare soil, which is now subject to erosion and colonization by seeds of invasive plants.



Hydroseeded low fescue and masses of colonizing sumac (in straw mulched areas) provide a mix of stabilizing plants.



**Drainage issues** – Properly designed roadside vegetation enhances the environment while working in concert with engineered drainage systems required to maintain the integrity of the travel surface. Plantings must not interfere with adequate drainage according to road base design standards (see AASHTO Policy on Geometric Design of Highways and Streets, Chapter 4, Cross Section Elements). In the context of drainage, roadside vegetation serves two sometimes overlapping purposes. One is to provide a stabilizing cover on slopes lining drainage ways. The second is to facilitate infiltration and recharge to reduce the water entering the system.

Traditional engineering has relied upon mowed cool-season turf to cover draining surfaces. While such turf can provide reliable cover, it does little to slow the flow of water or facilitate infiltration. Modern environmental concerns are motivating a

shift away from strategies of concentration and rapid removal of stormwater towards strategies for dispersal and greater infiltration and recharge using vegetative means. Many types of vegetation are capable of providing reliable surface cover while simultaneously promoting recharge, and are therefore preferable to mowed turf. While some routinely mowed turf is necessary to meet aesthetic goals and provide necessary access, a minimum of the roadside surface and drainage ways should be planted and maintained in this way. Drainage ditches should be designed to accommodate vegetation that aids infiltration. Plants adapted to periodically moist or wet conditions typical of drainage ditches and swales are a diverse and ecologically important group.

No matter what permanent plant material is chosen to cover roadside slopes and drainage ditches, it is important to establish some type of cover promptly after construction or regrading work is completed. For this reason temporary or annual cover crops are often planted at the same time as the intended permanent vegetation. Subsequent maintenance procedures must avoid scarring or exposing bare soil, especially on slopes.

### Site Preparation

Whether vegetation will be established by seeding or planting of individual plants, proper site preparation is perhaps the most critical step in the development of durable vegetative cover. Thorough site

- Follow guidelines for drainage outlined in AASHTO Policy on Geometric Design of Highways and Streets, Chapter 4, Cross Section Elements and Chapter 6 of the DeIDOT Road Design Manual.
- Use mowed turf sparingly since it does little to encourage ground water recharge.
- Design drainage ditches to accommodate vegetation that aids infiltration.
- Establish protective vegetative cover immediately following construction and maintained with care.

preparation begins with an inventory of existing conditions. It may involve the conservation of existing vegetation and it typically requires removal of weed populations and preparation of the soil.

Conserving indigenous plant communities

Long term maintenance may be reduced by conserving desirable existing plant communities. A healthy and diverse community of site-adapted, locally indigenous plants can discourage the establishment of weed species. Conservation of these communities may also be the most efficient strategy for preserving biological diversity and aesthetic appeal.

**Plant community inventory** – The first step in evaluating the ecological stability and habitat quality of a site is to perform a thorough inventory of existing species and growing conditions. Vibrant, high quality communities typically exhibit a high level of indigenous species diversity. A dominant presence of invasive exotic species is typical of a marginal or failing community. Such failure is usually due to degradation of the habitat in combination with the increased presence of propagules of exotic species.



A young oak and native azalea were part of the piedmont community preserved in this woodland edge by the intersection of Route 273 and Bala Road.



Beach plum is flowering in a healthy coastal plain community in Seashore State Park.



Wetlands provide homes for important plant and animal species.





Oaks and maples were part of the plant community found along I-95 in Wilmington.



Spraying herbicide on the honeysuckle along Wyoming road at this time of year would damage desirable trees. But honeysuckle will stay green after native trees have lost their leaves, providing an opportunity for effective control.

The process and checklists for site inventory are described in the EDH C & P Manual.

#### **Weed control in plant communities -**

It is often possible to control undesirable species within an otherwise healthy community. In some cases, mechanical means such as repeated mowing or cutting may be sufficient to eliminate undesirables. In most cases, chemical intervention is necessary. Herbicides can be selectively targeted toward undesirables by manipulating the timing and formulation. For example, multiflora rose and Japanese honeysuckle, two undesirable exotic species, maintain green leaves and stems later into the fall and produce new growth earlier in the spring than most native species. Treatment at this time with a non-selective herbicide will not harm dormant native vegetation. Many undesirable exotic herbs such as lesser celandine and garlic mustard emerge early in spring before indigenous herbs and can be controlled at this time with a non-selective herbicide. Selective herbicides may also be useful. A broadleaf herbicide will control broadleaved weeds in desirable

grasses. Conversely, a grass herbicide will control undesirable grasses in a broadleaf community.

#### **Selective removal of vegetation**

**(editing)** - In some cases conserving the existing plant community and removing exotics will result in an attractive landscape. In other cases, editing the conserved vegetation further may be desirable to introduce a greater level of visual order and a more pleasing aesthetic. The editing technique is defined on pages 75-77 of the EDH C & P Manual as “evaluate existing vegetation and



Sassafras clusters are marked to be saved, while grape vines and multiflora rose will be removed.

- Begin with an inventory of existing vegetation and site conditions.
- Saving healthy native plant communities is often the most effective way of reducing long term maintenance, conserving biological diversity and providing a desirable aesthetic.
- Selectively control undesirable species in healthy plant communities with timing and selective herbicides.
- Editing conserved vegetation may be necessary to introduce a greater level of visual order and a more pleasing aesthetic.

identify opportunities to introduce aesthetic order by highlighting individual specimens or plant groups through the process of removing other vegetation.”

#### Removing undesirable vegetation

**Removal strategies** - Controlling or removing undesirable vegetation is a critical step in proper site preparation. The removal process varies with the type of undesirable vegetation on the site and with the type of vegetation that is to be established. Some sites may need to be totally cleared, and this may involve the removal of significant woody vegetation as well as the herbaceous ground layer. Other sites may only require control of herbaceous vegetation, such as cool-season turf.

Research has shown that warm-season grasses and perennial forbs cannot be seeded effectively into a dense

An aerial photo clearly shows the difference in vegetation three years after seeding this Milford bypass. Glyphosate was used to remove all vegetation from the midpoint to the left prior to seeding with a warm-season grass mixture. From the midpoint to the right, seed was planted into an existing layer of closely mowed cool-season turf. Warm-season grass is thriving on the left, while the right side remains primarily cool-season turf.

mat of existing vegetation. Removing all existing vegetation is necessary if the site will be seeded. Perennial plugs or container-grown plants may be planted in a low sparse mix of existing vegetation but generally do best when all existing vegetation is removed prior to planting. When planting woody trees and shrubs, allowing the existing ground layer of vegetation to remain may be the most efficient means of keeping the ground covered, although selective weed control may be necessary.

Not all weeds require removal; some are ephemerals that only occur in areas where soil remains open due to regular disturbance. These innocuous species may be annual or perennial and include such common weeds as queen anne’s lace, pokeweed, evening primrose, and foxtail grasses. These will not persist once





a durable vegetative cover is established, and therefore the most efficient approach is to direct resources toward developing that cover quickly.

In contrast, some weed species, usually perennial herbs and woody plants, are persistent even in an established cover of desirable vegetation. These must be eliminated before planting occurs, and they will typically require additional control during the establishment period and even after the permanent cover is in place. Examples include crown vetch, multiflora rose, Japanese honeysuckle, tree-of-heaven, Oriental bittersweet, porcelain berry, Japanese stilt grass, phragmites, autumn olive, and callery pear. Four persistent species are designated as noxious weeds in Delaware: Canada thistle, Johnsongrass, burr cucumber and giant ragweed. Delaware legally mandates that noxious weeds be prevented from going to seed or reaching a height greater than 24 inches.

Since every site is different it is advisable to conduct an inventory prior to implementing weed control. Also, experience has proven that some sites are more prone to weeds than others. Sites formerly planted with “wildflower mixes” typically have more diverse and persistent weed populations than sites formerly planted in cool-season turf. Multiple treatments may be necessary for

especially persistent weeds. It may be necessary to extend treatments through multiple seasons, and in extreme cases involving woody plants such as tree-of-heaven, the process may take more than one year. Even though this may considerably delay planting, it is always more cost effective than planting prematurely, before persistent weeds are controlled.

**Removal methods** – Removal methods vary depending upon the existing vegetation and the vegetation being established.

*Cool-season turf* – cool-season turf is best eliminated with one application of the non-selective systemic herbicide glyphosate (commercially branded as Roundup Pro® and others). This herbicide will be most effective if the turf is mowed to a height of six inches or less prior to application. Unmowed turf requires considerably more herbicide and often requires multiple applications for complete control. Some weeds often present in



It is illegal to allow Canada thistle to bloom in Delaware.

cool-season turf will not be adequately controlled with glyphosate and will require the use of additional herbicides.

Two of the most common are nutsedge and crown vetch. Nutsedge can be controlled with halosulfuron-methyl (commercially branded as Sedgehammer®). Crown vetch can be controlled with clopyralid (commercially branded as Transline® or Lontrel®). These products can be mixed with glyphosate in the initial application. The opportunity to continue application of selective herbicides to remove persistent weeds varies with the vegetation being established. For example, when warm-season grasses are being established it is possible to continue use of selective broadleaf herbicides to control plants such as crown vetch. Conversely, when plantings exclusively of forbs are being established, it is possible to continue use of selective grass herbicides to control undesirable grasses.

*Mixed forb and grass cover* – When existing vegetation is a mix of forbs (broadleaved herbaceous plants) and grasses that is not regularly mowed and has attained a height greater than six inches, herbicides should be applied without mowing. Initial herbicide recommendations are the same as for cool-season turf (see above). The resulting dead vegetation may require mowing prior to new planting. This may be necessary for aesthetic reasons and to allow good seed/soil contact and allow sunlight to



cool-season turf has been eliminated with glyphosate to prepare this bed for planting.



Broadleaved weeds in a planting of warm-season grasses can be controlled with selective herbicides.



A broadleaved herbicide was used to kill broadleaved weeds and leave the switchgrass unharmed.



An herbicide that is selective for grasses can be used to control weedy grass seedlings among aromatic asters.



When a thicket of undesirable woody vegetation covers the site, trunks and stems must be removed by mechanical means. Once the site is cleared, resprouts can be treated chemically as needed.



reach newly planted plugs. For precise fully ornamental planting beds, use a combination of pre-emergent and post-emergent herbicides to remove existing weeds and prevent new weed seeds from germinating. Imazapic (commercially branded as Plateau®) can be used in combination with glyphosate when establishing warm-season grasses and forbs. Glyphosate and imazapic are complimentary because glyphosate controls vegetation growing at the time of application but provides no residual control. Imazapic has both post- and pre-emergent action and provides residual control. A number of warm-season grasses and legumes tolerate imazapic. The following forb species (see label for a complete list) are labeled as tolerant of imazapic: New England aster (*Aster novae-angliae*), black-eyed susan (*Rudbeckia hirta*), purple coneflower (*Echinacea purpurea*), lance-leaved coreopsis (*Coreopsis lanceolata*), and garden phlox (*Phlox drummondii*). Note that switchgrass (*Panicum virgatum*), an important warm-season grass, will be damaged by imazapic.

**Woody species** – Vegetation to be cleared from a site often includes woody species. A variety of chemical and mechanical methods of removal may be

employed (see DeIDOT Maintenance Work Standards 1110.0-1140.0).

**Brush control by foliage and stem treatment** – Control brush 3 feet in height or less during the growing season with an over the top application of 2,4-D plus triclopyr (commercially branded as Garlon 3A®) or ammonium salt of fosamine (commercially branded as Krenite S®). Remove dead vegetation with a boom ax.

**Remove trees** – Remove designated trees within the ROW by methods as established by the American National Standards Institute (ANSI A300). Chip all portions of tree up to six inches diameter in brush chipper and pick up all portions of tree in excess of six inches diameter and remove from site to acceptable



Woody plants treated with herbicides must be physically removed to prepare the site for future planting.



disposal area. Removal and pruning of trees should be performed only by qualified tree personnel\*.

Remove and stump treat woody plants – Cut and remove designated woody plants; leave stump height not to exceed 10 inches; remove cut material from site to acceptable disposal area; and treat stump with appropriate chemical herbicide to prevent regrowth such as triclopyr (commercially branded as Garlon 4® or Pathfinder II® ) mixed with oil and dye.

Basal treatment and removal – Spray basal bark of undesirable woody plant with appropriate herbicide, such as triclopyr (commercially branded as Garlon 4® or Pathfinder II® ) mixed with oil and dye. Later remove and dispose of dead vegetation in an appropriate manner.

Clear tree trunks – Remove vines and brush growth away from the base of tree trunks and remove twining and climbing vines from the branches and canopy of

trees being careful not to damage the desirable trees. When trees are heavily infested with vines, it is best to cut and stem treat vines without removing them from the tree canopy. Allow the dead vines to fall from the tree canopy over time during a natural weathering process.

\* Qualified tree personnel are persons who, through related training and on-the-job experience, are familiar with the processes and hazards of pruning, trimming, repairing, maintaining, or removing trees and with the equipment used in such operations, and have demonstrated ability in the performance of the special techniques involved as defined in the American National Standard for Tree Care Operations (ANSI A300). Contract tree removal is only performed by persons who are licensed and insured.

#### Soil preparation

**Grading** - Grading is primarily employed to achieve the desired elevation and proper drainage. It can also create

- Remove all existing vegetation using glyphosate prior to establishing vegetation from seed.
- Plugs or container- grown perennials generally do best when existing vegetation is removed prior to planting.
- Consider leaving the existing ground layer when planting woody trees and shrubs.
- Persistent weeds may require multiple applications of systemic herbicide.
- Base weed control methods on an inventory of weed species present and species to be planted.
- Augment glyphosate with preemergent and/or selective herbicides on precise fully ornamental planting beds.

## Removing undesirable vegetation

Proper reshaping of the land during roadway construction will result in desirable growing conditions for vegetation.



highly efficient desirable vegetation. Such plants are often more competitive against persistent weeds in poorer soil conditions. Lower horizon soils are typically free of weed seeds.

Aronia are planted on a shelf to take advantage of the natural accumulation of water from the upper slope.



conditions suitable for a wide variety of plantings and plant communities.

Standard grading practices prescribe topsoil removal prior to grading (Sections 202, 732, 733, DeIDOT Standard Specification). Standard topsoil replacement stipulates salvaged topsoil or imported topsoil be subsequently distributed to a minimum depth of six inches over the site after grading and prior to seedbed preparation. The seedbed should be firmly packed, but not compacted. Driving a tracked vehicle across the topsoiled area is a common method of firming seedbeds. Traditional roadside revegetation practices utilize high quality topsoil because most ornamental plantings benefit from the higher organic content and nutrient levels. In some instances, topsoil replacement is not necessary. Soils from lower horizons often have sufficient nutrients to support the growth of warm-season grasses and other

**Topsoil** - If topsoil replacement is utilized, it is critical that the soil source is guaranteed high quality and free of contaminants, particularly noxious or invasive plant matter or weed seeds. If topsoil is to be stockpiled, it must be hauled and stored in a proper manner to prevent degradation of structure and content. Avoid handling at improper moisture or temperature conditions and avoid exposure to contaminants.

*Final grade* - The final step in soil preparation is the removal of roots, rocks, trash, and other debris from the surface layer. All rock and foreign debris three inches or larger should be removed from medians and shoulders, and from ditch



Care must be taken to separate soils containing noxious weed seeds from relatively clean soils. Contaminated soils should be buried during the regrading process. Clean soils can be applied on the surface to provide growing medium for new plantings.



When soil contaminated with weed seeds is reused on the surface, major infestations of noxious weeds can result requiring considerable control efforts.

cut or fill slopes that have a 3:1 or flatter gradient. The soil may be screened of foreign matter for highly visible or ornamentally treated areas such as gateway medians, rest areas, and roadside parks.

#### **Soil amendment and nutrition –**

Although soils on some sites are suitable for the intended vegetation without modification, other soils require modifications to pH, fertility or tilth.

*Sampling* – Take one or more soil samples to thoroughly evaluate soil characteristics before planting a site. Agronomic soil analysis labs (e.g., University of Delaware Soils Lab) can identify soil texture, nutrient content and soil pH. A percolation test can be performed to identify poorly drained sites. If percolation is poor, soil modification or wet tolerant plants should be specified.

*pH* – On roadside sites in Delaware, the most common correction needed is raising a low soil pH. Untreated soils tend to become more acidic with time and roads are sometimes constructed with soil from unknown sources. cool-season turfgrass grows best in a pH of 6.0 to 6.5. If the existing soil pH is low, add

lime prior to planting turf. It is much easier to correct a low pH when the lime can be tilled into the upper 4 to 6 inches of soil. warm-season grasses and native forbs will tolerate lower pH soils (4.5 to 6.0), so if they are the desired vegetation, no modification may be required. Extremely acid soils will require liming to grow any type of vegetation.

If pH is too high, add sulfur. High pH is often a problem in urban soils. Building materials elevate pH and make essential nutrients such as iron unavailable.

*Fertilization* – Since excess fertility often promotes weed growth it is important not to add any more fertilizer than is necessary. The vegetation most often requiring supplemental fertilizer is cool-season turf. When establishing cool-season turf, apply enough fertilizer to correct phosphorus and potassium deficiencies and apply approximately one pound of nitrogen for every 1000 square feet of seeded area.

*Organic amendment* - Some soil amendments may be beneficial when reclaiming highly disturbed sites. Organic materials provide slow release nutrients and humus to start the process of

rebuilding topsoil in disturbed areas. Soils with higher organic content are more capable of imbibing and retaining moisture and are less prone to compaction, which is one of the most common causes of planting failure in urban environments and roadsides.

**Tillage** – Plants establish most readily in friable soils that allow proper air and water infiltration. Many soils have sufficient tilth for plant establishment. However, construction often results in compacted conditions that require additional tillage. Since tillage can bring weed seeds to the surface, it should be used only when necessary. Drill seeding is a technique that avoids the need for broad tillage.

*Primary tillage* – If tillage is required, tilling to a depth of three to eight inches is

normally sufficient. This can be accomplished with a chisel plow or heavy disc pulled behind a tractor. If deeper tillage is required, a subsoiler or mole plow can be used to reach depths of 24 inches. Compaction during the grading process can be reduced by mounting a ripper directly behind the bulldozer used for grading.

*Secondary tillage* – Secondary tillage is often necessary to break up soil clods larger than one inch in diameter and to provide a smooth planting surface. Use a disc, harrow, chain drag, cultipacker, or rototiller/rotovator. Hand operated equipment can be used for smaller or less accessible sites. Secondary tillage can also serve to eradicate sprouted weeds up to planting time. In order to prevent compaction, avoid tillage when soils are extremely wet.

## Soil preparation

- Consider grading as a means of creating specialized conditions for plant growth.
- Many durable, efficient indigenous plants will tolerate soils from lower horizons, making the addition of topsoil unnecessary.
- If the addition of topsoil is necessary, ensure that it is free from weed seeds and other contaminants.
- Sample the soil to determine pH, nutrient levels and percolation.
- Modify the pH to suit the species being planted (cool-season turf – 6.0-6.5; warm-season grasses and native forbs – 4.5-6.0).
- Apply fertilizer (1 lb N/1000 square feet) to establish cool-season turf.
- Add organic matter to improve the aeration and moisture retention of compacted soils.
- Avoid tillage if possible to reduce weed seed germination.
- Till highly compacted soils to provide an adequate seed bed or planting environment.



*Steep slopes and ditches* – Steep slopes often require special tillage equipment and techniques. Slopes greater than 3:1 can be chained, grooved, trenched, or punctured to provide pockets, ridges, or trenches in which seeding materials can lodge. Exercise extreme care on shoulders and slopes of ditches to maintain the graded cross section that existed before tillage began.

Case study examples of site preparation

The following two case studies illustrate the development of two sites from site evaluation to maturity.

Case Study 1:



The roadside slope at the White Clay Creek Park Office is viewed by commuters and park visitors and provides an opportunity to showcase Delaware’s Piedmont flora.

**Site preparation equipment -**

The types of equipment used for site preparation for vegetation establishment include:

Specialized use	Equipment
tillage	chisel plow, ripper, subsoiler/mole plow, harrow, disc, chain drag, cultipacker, rototiller/rotovator, tractor
grading	backhoe, bulldozer, track loader
clearing	brush hog, boom ax, backhoe, bulldozer, track loader
chemical treatment	spray truck, backpack sprayer



Vegetation on the site included introduced Norway maples and indigenous red maples, sassafras, viburnum, and spicebush. Remnants of an English ivy planting covered part of the bank and climbed some of the trees.



Desirable trees and shrubs were tagged for preservation. Norway maples were removed and the ground layer was treated with glyphosate.



Stump sprouts of Norway maples were treated the following season prior to new plantings.



Red maples and serviceberry were planted at the top of the slope and shrubs, including witch hazel and viburnum were planted in between and below them.



A low fescue mix was seeded to stabilize the slope and suppress weed growth.



Further stabilization of the slope was accomplished by planting hayscented fern plugs.



The following season, dense clusters of hayscented fern began to cover the slope suppressing the potential growth of aggressive weeds such as garlic mustard, bittersweet and Japanese stilt grass.

By the fall of 2008, the site exhibits attractive fall color and a well-covered slope, resistant to erosion.





## Case Study 2:



The backdrop for the gateway site to the City of Newark was an unattractive thicket of multiflora rose and other invasive plants. An inventory of the site revealed several desirable trees worth saving. The majority of the shrubby vegetation required removal; however the root systems of desirable sumacs were left intact to allow regrowth after the site was cleared.



This image shows the site with trees that were retained and small newly planted sweet gum trees.



Five years later the slope is completely revegetated with preserved trees, resprouted sumacs, and maturing sweet gum trees.



The gateway site is now backed by an attractive wooded slope, welcoming travelers to Newark.

## Establishment Using Seed

Seeding is the cost most effective means of establishing many types of herbaceous (non-woody) vegetation on larger sites. It generally requires more extensive site preparation than needed for establishment using vegetative material.

### Seed characteristics

Seed varies widely in character and quality. Understanding the following terms is necessary for selecting seed with the appropriate characteristics and for choosing between different seed sources. Most of this information can be found on the seed analysis tag.

**Purity** denotes the percentage of specified seed and does not include other seeds or inert matter.

**Inert matter** is the non-viable material such as sand, stones, sticks, dirt, chaff,

broken seeds, and vegetative materials. These materials do not increase yield.

**Weed seeds** are specified as percentage of the total weight. Weed seeds may be present but only in very low percentages. Objectionable and noxious weed seed percentage should be zero or near zero.

**Other crop seed** refers to seed other than the specified seed and is given as a percentage of the total weight. Choose seed with a near zero percentage of other crop seed.

**Germination** is the percentage of pure seed that will produce normal plants when planted under favorable conditions.

**Pure live seed** (PLS) is the percentage of specified seed that will germinate and can be determined by multiplying the pure seed percentage by the germination percentage and dividing by 100. For example, you have a lot of seed with 95.5 percent pure seed and 93 percent germination. The pure live seed is 88.82 percent. Pure live seed is the best gauge

Sample analysis tag

Formula L Mixture		Test Date: 05/03
Lot Number: W067642		
<u>Pure Seed</u>	<u>Variety</u>	<u>Germination</u>
34.46%	Silverlawn Creeping Red Fescue	85%
27.34%	Discovery Hard Fescue	85%
27.32%	Rescue 911 Hard Fescue	85%
9.98%	Annual Ryegrass	93%
0.88%	Inert Matter	
0.02%	Weed Seed	Net Weight: 50L
0.00%	Other Crop Seed	(22.68 KG)



of real value and should be used when choosing between seed.

**Variety** refers to the cultivated variety of the species. For example 'Discover' and 'Rescue 911' are varieties of hard fescue.

**Cleaned seed** has had the nonviable material (chaff) removed from the seed. This is generally done through processes of screening, debearding or dehulling. Many native warm-season grasses including big bluestem, little bluestem and indiagrass have awns or beards attached. Removing these beards permits the seed to pass more easily through a mechanical seeding device such as a conventional grain drill. A carrier may still be required to prevent lodging over the seed cup or plugging in the seed tubes or shoe. While debearding improves handling quality, it also increases seed cost. Specialized seed drills made by Truax, Miller, Great Plains and Marlist are designed to handle bearded seeds and often do not require the use of carriers. Whether or not a seed is debearded will affect the pounds of seed needed in a project. For example, there are approximately 165,000 clean seeds in one pound of undebearded big bluestem seed and 190,000 clean seeds in one pound of debearded big bluestem seed.

**Certified seed** has been inspected and conforms to rigorous standards set by certifying authorities, which vary from state to state. Certified seed is generally the highest quality seed available. It has traditionally been available for cool-season



Indiangrass has fluffy awns that necessitate seeding with specialized drill seeders or debearding in order to use conventional mechanical seeders.



warm-season grass seed can be purchased from a reliable seed source, or it can be collected locally to ensure the proper provenance.

turfgrasses, and is increasingly becoming available for native warm-season grasses and perennial forbs. In Delaware, certified seed must include name and location of certified seed grower, origin and date of harvest, seed germination statement, and certified weights of each species.

**Provenance** refers to origin or source and when speaking about plants it denotes where the specific plant material in question evolved. As plants evolve under different conditions, they develop unique ecotypes. Ecotypes are fixed genetic subdivisions within the range of a species that have similar characteristics such as growth habit, time of maturity and height. Plants of local provenance are often genetically best suited to local growing conditions. Provenance affects winter hardiness, drought tolerance and heat tolerance. Although there is a trend toward local production, most purchased

seed is grown or harvested in the West. To insure local provenance, collect mature seed or have seed contract grown in your area. If you collect your own seed, wait until significant quantities of ripe seed are present. Indicators of harvest readiness include: 1) seeds are full-sized; 2) seed coats are changing color; 3) stems are dry and not nourished by the roots; and 4) the earliest formed seed is dropping.

**Seed dormancy** – Not all seed is ready to germinate when purchased. Many seeds are dormant when acquired and require a period of cold temperatures (either natural or controlled cold stratification) and/or time in the ground to break dormancy. Seed planted in late spring may not germinate until the following spring because it has required the natural cold period provided by winter. warm-season grass and perennial forb meadows take at least 2-3 years to become established, in part because of dormancy requirements. Although some research suggests the need for cold stratification diminishes as seeds age, the

general recommendation is to provide cold treatment. This can be accomplished by purchasing pre-chilled seed or by insuring that seed will have a natural exposure to a prolonged cold period prior to anticipated germination. Purchasing seed with a proven germination percentage is one way of ensuring that dormancy requirements have been met.

#### **DeIDOT Standard Specifications**

(Sec 737) includes the following requirements for purchased seed:

- no more than one-year old
- free of mold, insect and disease
- of known origin
- collected and/or grown in the region
- at least 60 percent germination
- 95 percent purity

#### Vegetation types established by seed

**Temporary cover** – Soil stabilization quickly following construction or disturbance is necessary to prevent erosion. This is often best accomplished by the use of quick-to-establish grasses

### Seed characteristics

- Calculate percentage of pure live seed (PLS) and use this to select seed and choose between different seed sources.
- Select seed with proven performance in your area. When possible select seed of known local provenance.

### Temporary cover

- Use quick-to-establish grasses to provide immediate soil stabilization and prevent erosion following construction or disturbance.

- Seed regularly mowed cool-season turf from late summer to early fall (August 15 – October 1).

such as Canada wild rye (*Elymus canadensis*), annual barnyardgrass (*Echinochloa crus-galli*), winter ryegrass (*Secale cereale*) and annual ryegrass (*Lolium multiflorum*). Seed mixes and application rates can be employed to ensure germination and establishment during most of the year. Such grasses will temporarily blanket the surface and help stabilize the soil. Unless they are followed or mixed with more durable species, another strategy for keeping the ground covered must be implemented.

These plants are often included in seed mixes with more durable perennial species, acting as nurse crops and providing conditions necessary for the slower-to-establish long-term species.

**Regularly mowed turf** – A high percentage of pure seed is required for establishing a regularly mowed turf of cool-season grasses. The best time to establish cool-season turf in Delaware is late summer to early fall (August 15 –

October 1). Soil temperatures are warm enough to promote rapid seed germination, natural rainfall is usually sufficient, cooler air temperatures develop as the newly germinated turf begins to grow, and annual weed competition is greatly reduced compared to spring. If spring seeding must be performed, it should be done before the end of April to avoid injury from summer heat and dryness. cool-season turfgrass can be seeded later in the growing season, but successful establishment will depend upon the ability to apply water throughout the first growing season. In an effort to conserve resources and to enhance sustainable practices, the trend in Delaware is to move away from turfgrass mixes designed for regular mowing on roadsides and medians and to substitute low growing mixes that require only occasional mowing. Regularly mowed turf is still planted in subdivisions and is present on many existing roadsides and medians.

*Delaware: Permanent grass seeding – subdivision- OLD SPEC*

Common name	Scientific name	Quantity (lb/A) (bulk seed)	Quantity (kg/ha) (bulk seed)
Hard fescue blend	<i>Festuca trachyphylla</i>	100.6 lbs/A	113 kg/ha
Perennial rye	<i>Lolium perenne</i>	10.7 lbs/A	12 kg/ha

*Delaware: Permanent grass seeding – subdivision- PROPOSED NEW SPEC*

Common name	Scientific name	Quantity (lb/A) (bulk seed)	Quantity (kg/ha) (bulk seed)
Turf type-tall fescue (no K31 permitted)	<i>Festuca arundinacea</i>	160 lbs/A	180 kg/ha
Perennial rye	<i>Lolium perenne</i>	20 lbs/A	22.4 kg/ha



Delaware: Temporary grass seeding – dry ground

Common name	Scientific name	Quantity (lb/A) (bulk seed)	Quantity (kg/ha) (bulk seed)
Annual ryegrass	<i>Lolium multiflorum</i>	40 lbs/A	45 kg/ha

\* For spring and fall seeding add winter rye (*Secale cereale*) 65 lb/A (73 kg/ha)

Delaware: Temporary grass seeding – wet ground

Common name	Scientific name	Quantity (lb/A) (bulk seed)	Quantity (kg/ha) (bulk seed)
Annual barnyardgrass/ Dutch millet	<i>Echinochloa</i> spp.	40 lb/A	45 kg/ha

\* For spring and fall seeding add winter rye (*Secale cereale*) 65 lb/A (73 kg/ha)

Pennsylvania Formula D – dry mix

Common name	Scientific name	Quantity by weight	Quantity (lbs/1000 sq.
Tall fescue	<i>Festuca arundinacea</i>	70%	35 lbs
Creeping red fescue	<i>Festuca rubra rubra</i>	20%	10 lbs
Annual ryegrass	<i>Lolium multflorum</i>	10%	5 lbs

Delaware: Permanent grass seeding – dry ground

Common name	Scientific name	Quantity (lb/A) (bulk seed)	Quantity (kg/ha) (bulk seed)
Hard fescue blend	<i>Festuca trachyphylla</i>	100.6 lbs/A	113 kg/ha
Perennial rye	<i>Lolium perenne</i>	10.7 lbs/A	12 kg/ha
Redtop	<i>Agrostis alba</i>	5.3 lbs/A	6 kg/ha
Winter rye	<i>Secale cereale</i>	65 lbs/A	73 kg/ha

\* For late spring to mid-summer seeding, delete redtop and winter rye and replace with Korean lespedeza (*Lespedeza stipulacea* now *Kummerowia stipulacea*) 4.5 lbs/A (5 kg/ha)

**Low growing turf** – Although most cool-season turf is mowed frequently, fescue mixes are available to establish low growing turf that requires mowing only a few times each year. The most frequently used low fescue mix is called PA Formula L. Timing and seeding methods are similar to those for regularly mowed turf.



PA Formula L mix provides a relatively uniform cover on the White Clay Creek State Park Office slope and does not require routine mowing.



Delaware: Permanent grass seeding – wet ground

Common name	Scientific name	Quantity (lb/A) (bulk seed)	Quantity (kg/ha) (bulk seed)
Redtop	<i>Agrostis alba</i>	40 lb/A	45 kg/ha
Creeping bentgrass	<i>Agrostis palustris</i>	25 lb/A	28 kg/ha
Sheep fescue	<i>Festuca ovina</i>	35.6 lb/A	40 kg/ha
Rough bluegrass	<i>Poa trivialis</i>	25 lb/A	28 kg/ha
Winter rye *	<i>Secale cereale</i>	65 lb/A	73 kg/ha

\* For late spring to mid-summer seeding, delete winter rye.

Pennsylvania Formula L – low mix

Common name	Scientific name	Quantity by weight	Quantity (lbs/1000 sq.)
Hard fescue mixture	<i>Festuca longifolia</i> and <i>Festuca trachyphylla</i>	55%	27.5 lbs
Creeping red fescue	<i>Festuca rubra rubra</i>	35%	17.5 lbs
Annual ryegrass	<i>Lolium multiflorum</i>	10%	5 lbs

- Seed low growing cool-season turf from late summer to early fall (August 15 – October 1).

Low growing turf

**Grass meadows** – Grass meadows are best established from warm-season grasses, which provide long-lived, long-term, low-maintenance vegetative cover. warm-season grasses start growing late in the spring season, grow best when temperatures are between 80 and 90°F, and flower in the fall. They are deeply rooted and often more heat and drought tolerant than cool-season grasses. Most warm-season grasses suitable for meadow purposes are taller than cool-season grasses typically reaching 3 to 6 feet in height.

Many warm-season grasses have dormancy requirements and will not germinate the first year they are planted unless dormancy has been satisfied during seed preparation or they are planted early enough in the spring to

satisfy dormancy. Purchasing seed with a guaranteed germination percentage ensures at least some germination the first year.

Most warm-season grass stands do not fully mature until the third or fourth growing season. Though they are more competitive against weeds than most perennial forbs, germinated seedlings require sun for best growth and must have protection from taller weeds during the first year or two of establishment.

Seeding in late May through June generally gives best results, however fall planting is sometimes viable since dormant seed will receive a natural cold-wet stratification over winter and will be ready to germinate the following spring. Problems may arise if some seed



Switchgrass has become the dominant species in this highway median on Route 1.



Over the years, Indiangrass has out-competed the perennial forbs that were once a significant component of this I95 cloverleaf.

germinates in the fall. Such seedlings may be lost due to frost heaving, predation by wildlife, and/or competition from early spring weeds. In EDH research plots, spring seeding has consistently resulted in a better stand of perennial forbs and warm-season grasses than fall dormant seeding. Spring seeding provides the opportunity to use a broad spectrum herbicide such as glyphosate to control winter annuals and other weeds that flourish in early spring.

Seeding rates for warm-season grasses are much lower than cool-season grass rates. Seeding rates vary depending on species and seeding method. Drilling is the most efficient method and requires fewer seeds per acre than broadcasting or hydroseeding. The following seeding recommendations are for Pure Live Seed (PLS), not bulk pounds per acre.



The foreground of this test plot demonstrates complete control of weeds by Plateau®.

### **Switchgrass**

- 6-8 lbs. PLS/ac. drilled
- 8-10 lbs. PLS/ac. broadcast or hydroseeded

### **Indiangrass, big bluestem or little bluestem**

- 8-10 lbs. PLS/ac. drilled
- 10-12 lbs. PLS/ac. broadcast or hydroseeded

### **EDH Median Seed Mix (for 12,000 sq. ft.)**

- *Panicum virgatum* 'Cave-in-Rock'  
Qty: 2.5 PLS lbs.
- *Rudbeckia hirta* Qty: 0.75 PLS lbs.
- *Elymus canadensis* –  
Qty: 2.5 PLS lbs.

Mixed seeding may be done to provide a more diverse meadow. The varying adaptability of mixed grasses also may increase the likelihood that suitable cover is established. When switchgrass is included in mixes it eventually tends to dominate. Since taller grasses tend to shade shorter grasses, when creating mixes it is best to group plants of similar height.

- Seed warm-season grasses from late May through June.
- Use Pure Live Seed (PLS) when calculating lbs./ac. required.
- Control tall weeds to allow light to reach small warm-season grass seedlings during the first year or two of establishment.
- Allow 2-3 years for the establishment of warm-season grass meadows.

The following mix is designed to be used with Plateau® herbicide, which will control broadleaf and annual grass weeds. It should be drilled at a rate of 12 lbs.

PLS per acre:

25% little bluestem Fort Indiantown Gap

PA ecotype

25% big bluestem

25% Indiangrass PA ecotype

25% side oats gama

#### Mixed grass and forb meadows –

warm-season grasses are the backbone of most meadow seed mixes, however incorporating perennial forbs can provide desirable color and textural interest. On moist to wet sites, a number of sedges and rushes can also add to aesthetic appeal and habitat diversity. Traditional mixes incorporate a great diversity of grass and forb species in the hope of including plants that will be adapted to different microclimates on a particular

#### Warm-season grasses appropriate for the varying conditions found along Delaware roadsides:

Scientific Name	Common Name
<i>Andropogon gerardii</i>	Big bluestem
<i>Andropogon glomeratus</i>	Bushy beardgrass
<i>Andropogon gyrans</i>	Beardgrass
<i>Andropogon ternarius</i>	Silver bluestem
<i>Andropogon virginicus</i>	Broomsedge
<i>Bouteloua curtipendula</i>	Sideoats grama
<i>Dichanthelium clandestinum</i>	Deertongue grass
<i>Elymus canadensis</i>	Canada rye
<i>Eragrostis spectabilis</i>	Purple lovegrass
<i>Panicum amarum</i>	Coastal panic grass
<i>Panicum virgatum</i>	Switchgrass
<i>Saccharum brevibarbe</i>	Bent-awn plumegrass
<i>Saccharum coarctatum</i>	Bunched plumegrass
<i>Schizachyrium scoparium</i>	Little bluestem
<i>Sorghastrum nutans</i>	Indiangrass
<i>Sporobolus heterolepis</i>	Prairie dropseed
<i>Tridens flavus</i>	Redtop
<i>Tripsacum dactyloides</i>	Eastern gamagrass

#### Perennial forbs for appropriate moist to wet sites:

Scientific Name	Common Name
<i>Asclepias incarnata</i>	Swamp milkweed
<i>Asclepias tuberosa</i>	Butterfly weed
<i>Aster novae-angliae</i>	New England aster
<i>Aster puniceus</i>	Purplestemmed aster
<i>Bidens polylepis</i>	Tickseed sunflower
<i>Eupatorium coelestinum</i>	Mistflower
<i>Eupatorium dubium</i>	Joe-pye weed
<i>Eupatorium fistulosum</i>	Hollow Joe-pye weed
<i>Eupatorium perfoliatum</i>	Common boneset
<i>Eupatorium serotinum</i>	Late-flowering thoroughwort
<i>Hibiscus moscheutos</i>	Marsh mallow
<i>Lobelia cardinalis</i>	Cardinal flower
<i>Lobelia siphilitica</i>	Great blue lobelia
<i>Mondarda didyma</i>	Bee balm
<i>Monarda fistulosa</i>	Wild bergamot
<i>Rudbeckia laciniata</i>	Cutleaf coneflower
<i>Typha angustifolia</i>	Narrowleaf cattail
<i>Typha latifolia</i>	Broadleaf cattail
<i>Verbena hastata</i>	Blue vervain
<i>Vernonia noveboracensis</i>	New York ironweed





Moist conditions in this swale have allowed Joe-pye weed to thrive.



Deliberately naturalized in appropriately moist habitat, this population of marsh mallows in a highway infield along I95 now perpetuates itself by self sowing.

site. EDH research has shown that even when many species are planted only a few actually become established. Excessive diversity in the mix is not cost-effective.

Seed mixes should be tailored to site conditions. Moist to wet sites generally support a greater species diversity. The following plants have proved to be suitable

for establishment by seeding on Delaware roadsides.

Including annuals in the mix can contribute to flowering interest, especially in initial years. Since annuals require open ground if they are to continue through self seeding, they generally diminish as perennial species become more established. A new meadow with conspicuously flowering annuals may result in expectations of floral displays that are not sustainable in mature meadows. Despite this, annuals such as *Rudbeckia hirta* can provide desirable cover and interest during the period when warm-season grasses are becoming established.

**Sedges and rushes and for wet sites:**

Scientific Name	Common Name
<i>Carex stricta</i>	Tussock sedge
<i>Glyceria obtusa</i>	Blunt mannagrass
<i>Juncus effusus</i>	Soft rush
<i>Scirpus cyperinus</i>	Woolgrass

**Perennial forbs for drier sites:**

Scientific Name	Common Name
<i>Asclepias tuberosa</i>	Butterfly weed
<i>Aster novae-angliae</i>	New England aster
<i>Coreopsis lanceolata</i>	Lance-leaved coreopsis
<i>Eupatorium hyssopifolium</i>	Hyssop-leaved thoroughwort
<i>Liatris spicata</i>	Blazing star
<i>Oenothera speciosa</i>	Evening primrose
<i>Penstemon digitalis</i>	Beardtongue
<i>Silphium laciniatum</i>	Compassplant
<i>Solidago juncea</i>	Early goldenrod
<i>Solidago nemoralis</i>	Gray-stem goldenrod
<i>Solidago rugosa</i>	Rough-leaf goldenrod



Warm-season grasses such as little bluestem, indiagrass and switchgrass share this dry meadow with flowering perennial forbs.



### **A typical forb/warm-season grass**

#### **mix:**

5 lbs. PLS/ac. forbs

5-10 lbs. PLS/ac. warm-season  
grasses



Black-eyed Susan (*Rudbeckia hirta*) reseeded itself and provided attractive floral displays for several years before the warm-season grasses became dense enough to prevent yearly seed germination.

When formulating a seed mix for mixed grass and forb meadows, begin by establishing the ratio of grasses to forbs (for example 60:40) and then select the species complement. Since individual seeds vary tremendously in size and weight, the pounds per acre will vary dramatically between light and heavy seeded species. For example, the seeds of butterflyweed are minute but heavy (67,000 seeds/lb) and are seeded at a rate of 27 lbs/ac; little bluestem is light (260,000 seeds/lb) and is seeded at a rate of 8 lbs/ac.

#### Methods of seeding

Seed can be broadcast, applied with a hydroseeder or drilled. Each of these methods offers advantages for specific applications. In all cases, good seed/soil contact is critical for germination. Cultipacking firms the soil using a light roller. It is most common to cultipack

following seeding to press the soil tighter around the seeds, thus improving contact and ultimately improving seed germination. If soils have been tilled or disturbed just prior to seeding, it is advisable to cultipack prior to seeding.

**Broadcast seeding** – If soil is exposed due to construction then broadcast seeding can be done after cultipacking. If seeding is to be done on an undisturbed site with existing vegetation, that vegetation must be killed, and the soil must be exposed using a mechanical method such as a harrow or chain drag.

Cultipacking is usually accomplished with equipment designed specifically for this purpose. On sloped sites it may be advantageous to cultipack using a tracked bulldozer which is driven up and down the slope. The cleat marks both increase seed/soil contact and reduce the likelihood of erosion and seed loss.

- Seed warm-season grasses and perennial forbs from mid-spring to early summer.
- Use seed of proven performance under local conditions.
- Use Pure Live Seed (PLS) when calculating lbs./ac. required.
- Select species based upon site moisture conditions.
- Allow 2-3 years for the establishment of warm-season grass and perennial forb meadows.
- Color from flowering annuals is not sustainable in mature meadows.

### **Mixed grass and forb meadows**

Mechanical seed spreaders are designed for broadcasting clean seeds without beards or fluff. They do not work well with the bearded seed that is typical of many warm-season grasses. Broadcasting bearded or fluffy seeds requires incorporation in an organic carrier such as composted sawdust, mushroom compost, or composted yard waste and different methods of spreading. The carrier ensures even distribution of seed, provides a good environment for seed germination, and reduces weed competition by shading the soil surface. Carriers containing excessive quantities of nitrogen will promote weed growth and should be avoided. One advantage to the broadcast method is that it is practical and cost effective for both small and large planting sites. On small sites, it can be accomplished with a wheelbarrow and hard rake, and on large sites a manure spreader is most efficient.



For small areas, seed is mixed with a moist carrier and spread using a wheelbarrow and hard rake.

After seeding, various methods of finishing the site will increase seed/soil contact and thus germination. For seed broadcast without a carrier the site should be worked over to cover the seed with 1/4 inch of soil. This may be done with a rake or for larger sites with a weighted metal sheet pulled by a small tractor. The standard recommendation to increase seed quantity when broadcast seeding (without a carrier) vs. drill seeding can be negated if the site is cultipacked or track-driven after seeding. Seed broadcast in a carrier does not require additional finishing, however rolling can increase seed /soil contact.

**Hydroseeding** – Hydraulic seeding or hydroseeding is a method of distributing seed in a slurry that is sprayed onto the prepared soil with a motorized pump and a hose or gun tower. The slurry most commonly consists of seed, mulch, and a



For larger areas, a manure spreader can be used to distribute the moist medium and seed mixture.



The red line indicates the area that was broadcast seeded with a carrier; the balance of the median is comprised of plots seeded with a trax drill or hydroseeded. The broadcast seeded plot is almost completely filled in with switchgrass. Switchgrass is growing in the drilled and hydroseeded plots but the cover is not as complete.



Kiln-dried sawdust provided an effective broadcast medium. One year after seeding, black-eyed Susan and switchgrass seedlings blanket this median strip with almost no weeds.

tackifier suspended in water in a large tank with an agitation system. Hydroseeding equipment can spray 200 feet or more, making this method ideal for distributing seed over sites that are too steep to drive over or are otherwise inaccessible. The success of hydroseeding depends upon conditions being adequate to keep the mulch and seed moist for several weeks, so it is important to hydroseed during times of year when rainfall is likely. In the absence of rainfall, irrigation will be necessary.

The standard hydroseeding method works well for cool-season turf, which germinates relatively rapidly. Since the seed of warm-season grasses often takes quite a while to germinate, there is a danger of the mix drying out, shrinking, and pulling the seed away from the soil before it can germinate. For such seed it is best to use a two-step process, first distributing the seed in a slurry with just enough fiber mulch for marking purposes (300 lb/ac.). Once this dries, a second application consisting only of mulch and tackifier is applied at a rate of 900 lb/ac.

When practical, use a roller, cultipacker with tines raised, or track-type bulldozer to enhance seed/soil contact. Like broadcasting, hydroseeding has an advantage over drill seeding in that it is practical and cost effective for both small and large planting sites.

**Drill seeding** – This method employs planting equipment that has disk-type furrows that open the soil and drill the seed at a metered rate to a specified



Large areas, especially slopes can be conveniently seeded from the roadside edge.





Capable of handling various size seeds, a Truax drill delivers seeds into a planting furrow, providing good seed/soil contact.



Seed boxes in a Truax drill separate fluffy seeds and small seeds to provide even distribution.

depth. The drilled row is then covered and packed with an assembly attached to the back of the planter. Because this equipment provides accurate seeding rates, it is more efficient and allows the use of less seed per acre. It is also more versatile and can be used to seed into residual vegetative material or sparse live vegetation.

Drill seeders are most efficient on larger, flatter sites because they have a relatively wide turning radius and because proper metering of the seed depends upon the seed boxes being more than 1/4 inch full at all times.

Standard drill seeders work best with clean, relatively large seed of similar size (e.g. corn). They are not designed to handle the fluffy, bearded seed common to many warm-season grasses or the tiny seeds of many perennial forbs. For such seeds, specially designed drills (e.g. Truax) are necessary. These drills have separate seed boxes, each designed to handle seeds of different size and characteristics (e.g. fluffy seed and small seed). They are also designed to minimize plugging of seed passages by bearded seed and to ensure consistent delivery of seed at calibrated rates.

## Methods of seeding

- Broadcast seeding – the simple dry distribution of seed often mixed with a carrier such as sawdust to improve dispersal.
- Hydroseeding – distributing seed with a paper mulch through a stream of high pressure water.
- Drill seeding – the placement of seed in a shallow trench created by a disc.

**Topdressing** – Weed growth on newly seeded beds can be reduced by the use of sterile topdressings prior to seeding. The topdressing suppresses germination of surface weed seeds by blocking sunlight. Suitable topdressings include clean quartz sand or fine, granular subsoil. The topdressing must be applied thinly since a thick layer will reduce the effectiveness of the drill seeder.

### **Establishment Using Vegetative Material**

Although typically more costly than establishment using seed, establishment using vegetative material is the only choice for some types of herbaceous plants and nearly all woody plants. The higher cost is often justified by the more immediate impact and/or by design requirements for accurate placement.

#### Types of vegetative material

**Sod** – typically consists of cool-season grass turf grown and cut specifically for the quick establishment of turf areas. Sod is primarily used on roadsides where an instant cover is needed to stabilize slopes or make other disturbed sites presentable. Typical roadside applications include bridge approaches, areas under guardrails, and small highly visible areas, such as strips between sidewalk and curb.

**Plugs** – are young herbaceous plants grown to small size in specialized flats with individual cells for each plant. Plugs are available in different cell sizes and shapes. For example, 72's (flats with 72 cells) contain very small plants with small soil volumes in cells that are 1.5 x 1.5 x 2.5 inches. 32's (flats with 32 cells) contain larger plants with cell soil volumes that are 2.25 x 2.25 x 3 inches. Deep plugs, for

- Choose appropriate method of seed dispersal based on site size, slope, and type of seed being planted.
- Although broadcast seeding can be done without a carrier, the use of a carrier enhances germination and reduces weed problems.
- Hydroseeding is the best method for steep slopes or inaccessible sites.
- cool-season grasses, including low fescue mixes may be hydroseeded in one step. Separate hydroseeding and hydromulching works best for warm-season grasses, which must be kept moist for longer periods.
- Though it is only practical on larger, flatter sites, drill seeding using specialized drills (e.g. Truax), is the most accurate and cost effective method of planting warm-season grasses and other seeds which are either fluffy or of unusual size.
- Use sterile topdressing before drill seeding to reduce weeds.

#### **Methods of seeding**

Plugs are removed from the flat and spaced on site for immediate planting.



example deep 38's (flats with 38 cells) have cells with greater depth (2.25 x 2.25 x 5 inches). Larger, deeper plugs are generally called "landscape plugs."

Although the smallest sized plugs are usually intended as starter plants for nursery production, they can be a practical highly cost-effective means of establishing warm-season grasses under ideal conditions. Because small plugs are especially vulnerable to drying out and to frost heaving, larger landscape plugs are most reliable for direct planting on landscape projects.

**Bare-root plants** – are field grown, usually woody plants harvested with a root mass that is devoid of soil. Bare-root plants are harvested and transplanted while in a dormant state. If roots are kept moist, their establishment success rate is usually very high. Since bare-roots plants can be transported without heavy soil around their roots, they are less expensive than balled and burlapped plants. Unfortunately, the time schedules associated with roadside vegetation projects often prohibit the use of bare root plants.

**Container-grown plants** – are grown in artificial media within a container. This production method is increasingly used for woody plants and herbaceous perennials. Care must be taken to avoid purchasing pot-bound container plants or, especially in the case of woody species, to avoid purchasing plants with circling roots. Small trees or shrubs with circling roots may grow well initially but are likely to succumb to girdling by their own roots as they mature.

**Balled and burlapped (B & B) plants**– are field-grown, typically woody plants harvested with a root mass and surrounding soil contained by burlap. The burlap may be biodegradable natural fiber or nylon, which will not biodegrade and must be removed before planting.

#### Methods of planting

**Sodding** – (Sec 736, DeIDOT Standard Specifications) - is a method of transplanting mature turf to a site to provide immediate cover. Sod can be transplanted at any time of year, provided adequate moisture can be maintained. Frozen or extremely wet conditions may prohibit sod installation.

Extreme care should be taken when transplanting sod to prevent it from becoming too dry. Ideally, sod should be installed within 24 hours after it has been harvested. Temporary storage, not lasting more than three days, is permissible



during fall and winter months provided the sod is kept in a shaded area.

Soil preparation for sodding should be similar to that for seeding (see site preparation page 26). Raise or lower the soil level so that when sod is laid the finished grade will be flush with the roadway. If the soil is dry, water prior to installation.

Sod is normally installed by hand. Each piece of sod must be packed tightly against the edge of the adjacent piece. Install sod with the long edge perpendicular to the slope and stagger pieces so the short edges do not line up. On especially steep slopes, anchor sod with 1" x 1" x 12" wooden stakes or U-shaped sod pins driven flush. After sod is placed and staked, it should be tamped or rolled to ensure good soil contact.

After installation, irrigate thoroughly, moistening soil to a depth of 6 to 8 inches. Sod must be irrigated regularly (as often as daily) after planting until roots grow into the surrounding soil.

**Plugging** – Plant plugs in well-prepared sites (see site preparation page 26) where all the existing vegetation has been killed. Keep plugs moist and protected while in transit and on the site prior to planting.

Plant warm-season grass and herbaceous perennial plugs in mid- to late-spring after the ground has warmed sufficiently for good root growth, but while adequate rainfall can still be expected. Avoid plug planting in the late fall, when alternate freezing and thawing can result in heaving of plugs that have not been fully established.

Twelve- to 18-inch spacing is recommended for most species planted from plugs. Closer spacing provides more immediate cover and reduces the amount of weed control necessary. Wider spacing covers a larger area with the same number of plugs, however weed control between plugs will be required for a longer time.

Planting holes should be dug to the depth of the plug root mass. Plant each plug so the top of the root mass is level

- Transplant sod at any time of year unless the ground is frozen or too wet.
- Install sod soon after harvest and keep cool and moist during short-term storage.
- Water soil prior to installation if dry.
- Pack adjacent sod pieces tightly together.
- Irrigate thoroughly after installation.

## Sodding

Aromatic aster quarts are planted at 18" spacing on a median in Dewey Beach.



with the surrounding soil. Since soil volumes are small, water within 30 minutes after planting to re-wet the plug and settle the soil around the plug. Mulch after planting with salt hay or weed-seed-free compost to keep the soil moist and reduce weed competition.

During the first year, asters and grasses grow rapidly and begin to fill the median.



Plugs are more expensive than seeding but much less expensive than container plants. They are most appropriate for planting relatively large areas in which the positioning of plants must be fairly precise. Plugs can be used in combination with seeding to define edges or create patterns within plantings. To create well-defined patterns within a meadow, it is important to ensure that the background matrix is stable and weed-free before planting plugs. Once the area is covered with a consistent stand of desirable grasses and/or forbs, add plugs as desired.

When asters emerge the following spring, the ground is almost completely covered.



With a dense cover, only occasional weeding is required.



- Keep plugs moist and protected during planting.
- Plant plugs in spring or early fall when adequate rainfall is expected.
- Implement weed control strategies during plug establishment.

**Bare-root planting** – Bare-root plants are less expensive than plugs, container-grown plants or B & B plants. However, since they can dry out very rapidly they require precise handling. They can be a highly cost-effective method of establishing street trees. Small herbaceous bare-root plants can often be used in place of plugs when they are available. Bare-root seedlings are often most cost-effective and practical for wetland mitigation projects.

Bare-root plants generally must be planted while dormant. Damaged or desiccated roots should be removed before planting.

For street tree planting, use bare-root plants that have been soaked in hydrophyllic gel to keep roots moist during transit and planting. Dig holes to the depth of the root system. In each hole, build up a cone of soil and distribute roots over it. Refill holes, firming backfill soil around the roots. Water thoroughly.

Special tools needed to install large quantities of bare-root seedlings on

mitigation projects are a planting bag and planting bar (or dibble). The planting bag is a moist canvas bag used during the planting process to prevent root systems from drying out. The dibble has a triangular blade 12 inches long, 4 inches wide, and one inch thick and is used to dig the planting hole.

**The following guidelines should be used to install bare-root seedlings:**

1. Insert the dibble into the soil to a depth of approximately 10 to 12 inches and pull the handle toward the operator.
2. Remove the dibble and insert the seedling into the hole. Be sure the roots of the seedling are enclosed in the hole.
3. Insert the dibble approximately two inches behind the seedling to create a second hole. Push the handle of the bar forward toward the seedling to firm the soil around the roots eliminating air pockets.
4. This second hole, called the compaction hole, is left open after planting to allow for a water retention area.

- Consider bare-root plants as cost-effective alternatives to plugs, container-grown plants and B & B plants whenever it is possible to provide precise handling.
- Keep plants cool and roots moist in transit and during planting.
- Plant bare-root plants while dormant.
- Plant seedlings using a dibble to create the planting hole and a second hole, which aids water retention near the seedling.





The top of the root mass of this black-eyed Susan is planted slightly higher than it was growing in the container.



When an auger is used to dig holes, the sides must be roughed up to encourage roots to grow into the surrounding soil.

### **Container-grown planting –**

Containerized plants may be planted at any time the ground can be worked. Since supplemental irrigation is rarely available on roadside projects, it is best to plant in spring or fall when consistent rainfall is expected. Earlier planting times increase the likelihood that plants will become established before summer's typical hot and dry conditions. While most plants perform well with fall planting, certain species produce little root growth in the fall and should be planted in the spring. These species include but are not limited to magnolias, tulip poplar, most evergreens, oaks and flowering dogwood.

Container trees and shrubs are usually planted in lightweight artificial media and are often pot-bound. Since container trees have 100 percent of their original root system, some of those roots may be disturbed during planting without harming the plant. Follow general planting procedures described for balled and burlapped plants.

### **The following procedure should be used for planting container plants:**

1. Dig a rough-sided, saucer-shaped planting hole that is 2 to 3 times wider than the container and only deep enough to plant the tree/shrub at the same depth or slightly higher than it was growing in the container. If the site is poorly drained, the root mass should be 2 to 4 inches above the surrounding soil.
2. Break up circling roots to promote root growth into the surrounding soil and remove as much of the artificial medium as possible, either by teasing the roots apart or by washing the medium away with a hose.
3. Backfill with the soil removed from the hole. First, backfill two-thirds of the hole and then add water to eliminate air pockets. Continue backfilling and watering until the hole is filled. Create a ring of soil approximately four inches high and three to five feet in diameter around the base of the plant to retain water.

- Plant trees and shrubs in early spring or fall to reduce the need for supplemental water.
- If project schedules necessitate late spring or summer planting, allow for supplemental watering.
- Remove artificial medium and loosen circling roots on container plants.

**Balled and burlapped planting** – Since balled and burlapped trees and shrubs are harvested with a relatively small percentage of their root systems, it is critical to maintain the integrity of the root ball during handling. Always handle balled and burlapped trees by the root ball—not the trunk.

Nurseries usually dig balled and burlapped plants while dormant and store them for planting when the ground can be worked. But, as with container plants, it is best to plant in the spring or fall when consistent rainfall is expected..

Smaller trees establish more quickly than larger (and often more expensive) trees. A larger-caliper (trunk diameter) tree (such as 3- to 4-inch caliper) takes several years to recover from transplant shock. A 1 1/2 – to 2-inch caliper tree establishes more quickly and often grows at a rate

that will surpass the 4-inch caliper tree before the larger tree recovers from shock.

**The following procedure should be used for planting balled and burlapped plants:**

1. Dig a rough-sided, saucer-shaped planting hole that is 2 to 3 times wider than the root ball and only deep enough to plant the tree/shrub at the same depth or slightly higher than it was growing in the nursery. If the site is poorly drained, the root ball should be 2 to 4 inches above the surrounding soil.

2. Gently place a balled and burlapped tree/shrub into the planting hole to avoid breaking the root ball.

3. Cut and remove all twine from the trunk. Once the ball is in the hole, gently slide the burlap out or cut away as much as possible. Treated or synthetic burlap and tree bags must be removed completely. For trees in wire baskets, cut and remove wire (at least top two circles).

4. Backfill with the soil removed from the hole. First, backfill two-thirds of the hole and then add water to eliminate air pockets. Continue backfilling and watering until the hole is filled. Create a ring of soil approximately 4 inches high and 3 to 5 feet in diameter around the base of the plant to retain water. On slopes, the ring should be open at the upper portion so that surface water will be directed into the ring.



Large holes are hand dug for balled and burlapped Eastern red cedars.



Semi-circular mulch barriers at the base of these red maples capture rainwater from the upper slope and direct it to the root area where it can slowly infiltrate.

At planting, prune only dead or injured branches. Newly planted trees need as many leaves as possible for photosynthesis required to provide energy for new root growth. Remove any tree wrap that was used to protect the tree during transit. Once planted, tree wrap only harbors insects and undesirable moisture that may rot tree bark. Don't fertilize trees at planting. Wait until the second year to avoid burning new roots.

Most trees do not need staking. If trees are large, top heavy, planted in a very windy area or require protection in a tough urban environment, staking may be necessary. Stake trees properly by

hammering two tall stakes or three short stakes into the ground beyond the root ball area. Secure the tree with flexible strapping and allow 1 inch of play in the straps to help the tree develop a strong trunk and root system. Remove the stakes and strapping after 4 to 6 months, since forgotten stakes often girdle trees.

After planting, irrigate to soak the entire root system. Provide additional water at least once every five days during dry conditions until the plants are established.

**Tree spading** - Tree spades can be used to dig and move large trees. Vermeer Models TS-84 through TS-20 hydraulic spades, or an approved equal are specified by DeIDOT (Sec 738, DeIDOT Standard Specifications). When using a tree spade, the root structure of each plant is transplanted as a conical shaped earthen core cut by the hydraulically-operated cutter blades. The spade should be located so the blades are positioned equidistantly from the trunk(s) or stem(s) of the plant being transplanted.

## Balled and burlapped planting

- Always handle balled and burlapped trees by the root ball—not the trunk.
- Plant trees and shrubs in early spring or fall to reduce the need for supplemental water.
- Plant smaller trees (1- to 1 1/2- inch caliper) whenever possible since they establish more quickly.
- Only stake trees when necessary and be sure to remove stakes once established to avoid girdling.



Plant acquisition

**Inspection** - Nursery stock should be inspected before acceptance on the job site. The following conditions should be met.

- Plants should be healthy, shapely and well-rooted.
- Roots should not show evidence of being restricted or deformed.
- Stems or trunks of trees should show no evidence of having been cut, broken, mutilated or constricted by plant ties or supports.



A healthy, well-shaped tree will never develop from the dense congested branching on this redbud; this tree should be rejected when or before it reaches the job site.

- Plants should be free from insects, pests, and disease and should be acquired only from inspected nurseries.

**Plants should be rejected if the following defects or damage are evident:**

<b>Defect or damage</b>	<b>Description</b>
<i>Decay</i>	Evidence of decayed tissue on plant trunk, branches or twigs
<i>Sunscald or sunburn</i>	Cambium tissue or bark damage
<i>Mechanical damage/ bark abrasions</i>	Damage to cambium tissue
<i>Frost cracks</i>	Splits in bark or wood
<i>Disease</i>	Evidence of abnormal growth of leaves, twigs, fruit, bark, discoloration of leaves and bark or sap discharge
<i>Insect damage</i>	Evidence of borer holes into bark or wood or insect eggs or larvae
<i>Other damage or injury</i>	Evidence of branch and twig dieback, dry buds or dead leaves
<i>Improper pruning</i>	Evidence of improper stubs left on trunk branches or twigs or removal of excessive branches which will leave the plant asymmetrical or non-uniform in plant density
<i>Girdling roots</i>	Evidence of roots growing in a damaging, encircling configuration
<i>Improper habit of growth</i>	Nonstandard growth patterns for single or multiple stem plants, non-typical for their plant genus, species or varieties
<i>Sheared plants</i>	Sheared evergreen trees or shrubs not representative of full foliated, natural growth plants

- Inspect plants delivered to the job site and reject if they don't meet the outlined conditions or if they have a significant defect.
- Replace any plants damaged during planting operations.
- Segregate and remove rejected plants from the planting site within 48 hours.

**Contract growing** - Contract growing involves selecting a nursery (through a bid process) to grow a known quantity of plants for delivery at a specified time. This method of acquisition is sometimes necessary when quantities needed are unusually large or when the type of plants needed are not readily available from standard sources. There are some logistical challenges associated with developing a contract-growing bid within the DeIDOT bid process, however the benefits of contract growing sometimes outweigh those challenges.

**Benefits of contract growing include:**

- Guaranteed plant availability (plant type, quantity, and delivery time)
- Reduced plant cost
- More direct control of plant quality
- Development of specialty nurseries for future projects

**The following issues require resolution in order to develop a contract with a production nursery:**

- Accuracy of plant estimates in early phases of projects. *(Complete landscape design early in project.)*
- Responsibility for storage if plants

are not needed at the projected installation time. *(Include a price for storage of plants if not used by the projected installation date in the initial contract. Nurseries should be required to hold plants, but should be paid for storage.)*

- Availability of a wide variety of plants and plant types from one nursery.
- Contingency for increasing plant quantities if necessary.
- Contractor responsibility for guaranteeing plants. *(Include specifications in the contract for plant size and quality as outlined by ANLA standards. Require the landscape contractor to inspect plants and reject if necessary, and guarantee them.)*
- Variable shipping costs for the landscape contractor depending on location of the contract nursery. *(Include the cost of delivery in the nursery contract.)*

- Arrange for contract growing for unusually large quantities or when the type of plants needed are not readily available from standard sources.

## Mulching

### Seeded sites (Sec 735, DeIDOT specs)

**Straw mulching** consists of incorporating a uniform layer of straw into the soil with a studded roller. Straw mulching after seeding promotes uniform, rapid seed germination and establishment by conserving moisture, suppressing weeds and reducing the seed scattering impact of rainfall. Straw mulch protects the soil surface from the impact of rain drops, preventing soil particles from becoming dislodged. The following types of mulch are appropriate for varying slopes and other site conditions.

**Cereal grain straw** is comprised of the dry stalks of cereal plants such as barley, oats, rice, rye and wheat, which have had the grain or seed removed. It is often available baled. For use as mulch, grain straw must be dry and free of noxious weed seeds, mold, and other objectionable materials.

**Salt hay mulch** is comprised of harvested dry stalks of salt hay grass, *Spartina patens*, which grows at the edge of tidal salt marshes. It is typically free of weed seeds.

**Bonded fiber matrix (BFM)** is a hydraulically applied product composed of thermally refined long-strand wood fibers held together by a hydrocolloidal bonding agent (10% by weight). Curing time takes approximately 24 to 48 hours and rate of

application varies from 2500 to 4000 lbs/ac. based on the slope length and inclination. BFM adheres to the soil forming a continuous, 100% biodegradable, erosion-control blanket providing 100% coverage. BFM maximizes soil retention and minimizes wind and water erosion while improving seed germination. BFM should only be used on slopes flatter than 1:3 (v:h). Do not use BFM in areas of concentrated flow or in winter months (November-February).

Cereal grain straw is the most commonly used mulch for turfgrass seed establishment. It is recommended for use on level ground or gentle slopes (flatter than 1:3 (v:h)) that are accessible to tracking or crimping equipment.

Apply cereal grain or straw mulch at the rate of 4000 lb/A. The mulch layer should provide 100% coverage. The ground shall be evenly covered (approximately 2" thick) with straw strands, measuring a minimum of 6 inches in length. Anchor straw mulch to prevent it from being disturbed by the



Salt marsh hay provides coverage on a newly seeded median to conserve water, reduce weeds and prevent seed scattering.



wind, rain or mechanical disruption.  
Secure in place by crimping or tracking.

Crimping is done with a tractor-pulled crimping disk that produces parallel indentations with a minimum depth of 2 inches anchoring the mulch to the ground. On sloped sites, the disk must be driven perpendicular to the slope to minimize erosion.

Tracking is a method of anchoring mulch by driving steel-cleat track-type equipment up and down the slopes producing horizontally-oriented indentations. Cleats must be capable of pressing the mulch into the soil to a minimum depth of 1 1/2 inches.

**Soil retention blanket mulches (SRBM)** are rolled erosion control blankets. There are types used in DeIDOT projects, whose use is determined by slope rise and inclination, soil type and longevity. SRBM Types 1-5 are woven, 100% biodegradable fiber blankets that vary in material from straw-coconut to coconut fiber. Type 5 is utilized for channel bottoms. Types 6 & 7 are sometimes referred to as Turf Reinforcement Mats. They are designed to be permanent structures, handle high velocity flows and do not biodegrade. The need for types 5-7 is determined by shear stress calculations.

Shear stress = water density x slope x water height

Water density = 62.4 lb/ft<sup>3</sup>

Slope = ft/ft

Water height = ft

Determine the appropriate SRBM according to the v:h ratio of the slope and chose from the Approved Product List. Install SRBM according to manufacturer's recommendation and/or DeIDOT Standard Specification, which ever gives stricter guidance.

On slopes less than 10 feet. in vertical length, SRBMs may be installed horizontally. Provide a 6 inch overlap on parallel sections of SRBM with a staple/stake pattern of 6 inches on center on either side of the midpoint. Install SRBMs vertically with slopes exceeding 10 feet. in vertical length. Pattern staples/stakes 18 inches on center along the entire width and length of SRBM.



A fiber blanket lines this ditch on a newly constructed roadside.

For swales or ditches make the flow channel or bottom of the swale a minimum of 2 feet wide and, in most cases, install SRBM Type 5. Install a terminal trench (applied upstream) and initial trench (applied downstream). Pattern staples/stakes 18 inches on center along the entire width and length of the SRBM. Start blanket installation at the downstream end (outfall) and proceed upstream. Refer to the DeIDOT Standard Construction Detail (E-9).



Two to three inches of hardwood bark mulch is applied between newly planted redtwig dogwoods.

- Apply mulch to conserve moisture, promote uniform seed germination, and reduce erosion and weed competition.
- Use cereal grain straw, SRBM Types 1-5, or bonded fiber matrix on level ground or gentle slopes (< 1:3 v:h).
- Anchor cereal grain by crimping, tracking following DeIDOT Standard Specifications 735.
- Use SRBM Types 1,3 or 5 on slopes steeper than 1:3 (v:h).
- Use SRBM Types 5,6 or 7 on ditch/swale (concentrated flow) applications.

## Mulching

### Landscape beds

Mulching helps reduce weeds, conserves moisture, moderates soil temperatures, improves soil structure, reduces erosion and is a visual reminder to keep mowers and string trimmers away from tree trunks. Many materials make good mulches, including shredded bark and bark chunks, composted sewage sludge, one-year-old wood chips, pine needles, and composted, shredded leaves. The type of mulch selected is based on the type of plant material, the desired finished look, availability, and

cost. Shredded hardwood mulch works well in most highway situations and holds well on slopes.

Plastic sheets should not be used under the mulch because they prevent air and water from reaching plant roots. Although weed barrier fabrics allow the passage of air and water, they eventually result in weed problems. Weeds grow on the decaying mulch and root into the weed barrier becoming extremely difficult to remove.





Existing turf provides a ground cover between viburnums and clethra; mulch rings are only used around the base of newly planted shrubs.



Salt marsh hay is used as mulch between newly planted perennials.



Once perennials grow, their leaves cover the soil surface and mulch is no longer needed.



When warm-season grasses are cut back each year, the past year's leaf tissue can be allowed to fall to the ground and serve as mulch.



Apply 2 to 3 inches of mulch immediately after planting or whenever the depth of mulch on an existing plant bed becomes insufficient. Do not apply mulch so that it touches the stems of plants or trunks of trees. More than 3 inches of mulch is unnecessary and harmful to growth. Excessive mulching prevents water from reaching roots. It also encourages the undesirable growth of adventitious roots. Rodents and insects often overwinter in thick layers of mulch and feed on stems and trunks.

When undesirable vegetation is killed prior to new planting, it is often advantageous to allow the dead vegetative matter to remain, providing additional soil stabilization under the mulch.

A stable cover of desirable plants is generally preferable to the repeated use of mulch. This cover may consist of herbaceous plants or low-growing woody plants. For example, low fescue turf can be a highly effective groundcover below



Black-eyed Susans required supplemental water in the first season after planting.

woody plantings, especially in shaded areas.

## Irrigation

Properly designed and installed roadside plantings require irrigation only during the period of establishment. Irrigation is usually accomplished with a water truck that must travel to the site; however, trees are most effectively irrigated by the use of specially designed watering bags (treegator® , gatorbag® ) with capacities between 15 and 25 gallons. Bags are filled completely and water drips slowly into the root zone. Whether using a truck or bags, irrigation needs must be closely monitored, especially in the first season of growth.

- Mulch to reduce weeds, conserve moisture, moderate soil temperatures, improve soil structure, reduce erosion and provide a visual reminder to keep mowers and string trimmers away from tree trunks.
- Do not use plastic sheeting or weed barrier fabrics.
- Maintain a maximum 2- to 3-inch mulch layer around, but not touching plant stems or trunks.

## Landscape beds

- Keep new plants well watered during dry periods until plants are established (one year or more) with deep, slow watering.

## Irrigation



Plant locations are staked on site to facilitate planting by landscape contractors.

## Design and Stakeout of Landscape Planting Projects

Field personnel must adjust landscape planting plans to fit the natural topography under actual field conditions. Measure and mark individual plants and plant bed areas according to the planting plan. Install flags to designate individual plants in major planting areas. Color code flags to represent various types of plant material. For example, white flags for deciduous trees, red flags for evergreen trees, yellow flags for flowering trees, and green flags for shrubs. Parameters that must be considered while staking out a landscape planting design include: safety set-backs, sight distances, effects on mowing and drainage, utility lines, and soil conditions in the plant root zone.

Locate and mark all underground utility lines before staking out the landscape planting plan. Avoid underground utility lines during staking and relocate plants, as necessary, so utility lines are not disturbed.

Plantings should be laid out to facilitate ease of mowing, reducing the need for excessive maneuvering or hand trimming. Plantings should also be a minimum of six feet behind the ditch line in cut sections and six feet outside the shoulder break point in fill sections. Whenever possible, include plantings in beds to protect plants from mechanical damage. Beds may be mulched or seeded with low fescue to provide a groundcover between woody plantings. When following the regional design approach (C & P manual, pgs 58-59), consider releasing existing turf to serve as a groundcover to woody plantings.

### Design and Stakeout of Landscape Planting Projects

- Adjust landscape planting plans as necessary to fit actual field conditions on the site.
- Locate and mark all underground utility line and adjust plantings to avoid them.
- Group plantings in beds with outlines that facilitate ease of mowing.

## Replacement

All contracts with landscape installation and maintenance firms should be written to include replacement guarantees. Guarantees must not limit replacement to “one time.” Contracts should stipulate that the one-year plant guarantee and replacement period begins after all final landscape-related punch list items have been completed.

- Replace all plants that are dead, dying, are unhealthy and/or have lost their natural shape.
- Install replacement plants during the first growing season after the last loss has occurred – even if that season falls beyond the 1-year guarantee and replacement period.
- At the end of the 1-year guarantee and replacement period, remove all stakes, wires and other guying materials.

## Replacement







## IRVM Objectives

Integrated Roadside Vegetation Management (IRVM) objectives are the same across all roads in the First State:

1. to provide safe conditions both for motorists and for residents adjacent to the right of way,
2. to help preserve the road surface,
3. to remain in compliance with state and federal regulations,
4. to act as good land stewards in maintaining an environmentally healthy and aesthetically pleasing quality along the roadside,
5. to maintain good public relations,
6. to minimize the use of pesticides and develop alternative control strategies wherever possible (as specified by NPDES permits), and
7. to fulfill the above objectives through a program of maintenance operations that are efficient and cost effective.

Safe driving conditions are maintained by keeping vegetation far enough back from the roadside to maintain sight distance on the road ahead, especially around curves. Road signs, guardrails, and intersections must be kept clear of vegetation that would obstruct driver visibility.

Trees adjacent to the pavement may create several types of safety hazards. First, tree diameters larger than four inches are classified as obstructions because of their risk as targets for

collision, and therefore must be kept out of the “clear zone” (see DelDOT Road Design Manual, 3.3.) Second, although the canopy effect created by deciduous trees whose branches reach out over the road may be attractive, they can create undesirable risk situations. Overhead branches fall down onto the road, particularly during storms. Shaded roads stay wet and slippery, especially when covered with fallen leaves. Leaves and branches can obstruct drainage flow. Evergreens can shade the road in winter and cause icy patches.

Preservation of the road surface can also be negatively affected by shaded or wet road surfaces. The road surface is subject to disintegration when moisture is allowed to remain or pond for extended periods especially through temperature extremes that allow freeze-thaw cycles. The road surface is also damaged when plants take root in pavement cracks.

Knowing when to encourage plant growth is as important as knowing when to prevent it. In some cases vegetative ground cover should be left in place to help prevent erosion. Proper drainage along the road shoulder is necessary to prevent undermining the pavement and guardrail posts.

Abiding by State and Federal laws is an important objective of roadside vegetation management. Environmental and human safety laws to be considered include Delaware Noxious Weed law, State

pesticide regulations, County and State Erosion and Sedimentation laws, NPDES permits, Occupational Safety and Health Regulations (OSHA), and Federal Department of Transportation requirements.

Maintaining good public relations is both a moral and a practical obligation of the DOT. Plants can provide an attractive natural screen to be viewed by residents and travelers both to and from the road. Undesirable views can be screened for the benefit of travelers and buffer zones can be created by attractive complementary vegetative screens for the benefit of adjacent residents.



Trees, shrubs and herbaceous perennials welcome travelers to Delaware with a display of autumn color.

Roadsides maintained with environmental quality in mind will contribute to the pleasure and safety of the traveling public. A roadside that offers a diverse variety of natural vegetation and scenery is not only pleasing to residents and travelers but can help drivers stay alert.

## Roadside Features

### Guardrails

Guardrails are metal structures installed along highways to help prevent motorists from exiting the road surface or crossing median lines into oncoming traffic. Guardrails that do not block sight distances minimize the chance of head-on collisions. Allowing grasses or broadleaf weeds to grow up along guardrails will affect visibility. The following are appropriate management practices for vegetation around guardrails:

#### *Maintain low vegetation under guardrail –*

Low vegetation is maintained by hand trimming with hand mowers or weed eaters. Low fescue can be planted under guardrails as a groundcover requiring infrequent or no mowing.

*Weed control barriers –* These barriers are expensive and their lifespan is unknown.

## IRVM Objectives

- IRVM is an integrated management tool that uses native vegetation while reducing the use of pesticides.
- Roadside vegetation in Delaware will be managed following IRVM objectives.



DelDOT and other departments of transportation throughout the country are testing the following products for potential use under guardrails. Designers should contact the Roadside Environmental Administrator for the most current products available. Products include:

- Permeable systems such as woven fiber mats and weed prevention fabric under a 2- to 3- inch layer of rubber mulch. These systems have the advantage of not creating additional impervious highway surfaces, which may impact stormwater permitting and mitigation requirements.
- Interlocking rubber or molded plastic tiles, sized to fit typical guardrail post spacing, made from recycled materials.
- Pavement under guardrail. (Vegetation that is allowed to grow in pavement compromises pavement integrity resulting in greater weed problems.)

*Control existing vegetation with herbicides-*  
Non-selective herbicides are used to maintain bare ground below guardrails. Selective herbicides are used to control tall broadleaf plants but allow short grasses to grow. Soil residuals are used only when necessary for long term control. Low volume, low pressure spray equipment is used to apply herbicides under guardrails in a 2 1/2- to 3- foot wide zone. Spraying beyond the zone can result in erosion. Guardrails are treated once a year.



Low fescue seeded under guard rail provides a low cover that stabilizes soil but requires only infrequent mowing.



DelDOT is testing various weed control barriers for use under guard rail



Herbicides are used to control tall vegetation obstructing the guard rail.



Edges of crossovers are mowed to allow visibility for turning vehicles.



The berm between I95 and 495 has been planted with trees, shrubs and warm-season grasses. Mowing is routinely required at the base of the berm only and warm-season grasses are cut back once each year.

### Medians

Medians are areas of varying width between two directions of traffic on divided highways. Medians often consist of a shoulder, edge and swale. Medians may have a soil berm in the center. Medians can range in width from 20 feet wide to more than 100 feet wide. Medians may not contain trees greater than 4 inches in caliper unless they are behind guardrail or on an elevated berm. Medians are usually planted with turfgrass. Traditionally, medians have been mowed from pavement edge to pavement edge but this is counter to current DeIDOT policy. Any deviation from the mowing policy must be approved by the District Engineer.

#### **DeIDOT Median mowing policy:**

1. Mow entire medians when equal to or less than 40 feet wide.
2. Mow one mower width on either edge when median is greater than 40 feet wide. Mow entire median once yearly to control woody vegetation or leave unmowed and

treat woody vegetation with selective herbicides.

3. Mow edges of crossovers to allow for a sight triangle appropriate to posted speed as described in the Road Design Manual. On controlled access highways the edge of the sight triangle should be no greater than 50 feet from the edge of paved crossover.
4. Mow medians to a height of no less than 6 inches.
5. Keep woody vegetation out of drainage swales unless swales are designed to accommodate them (yearly mowing or selective herbicides).



One mower pass provides a neat appearance, while allowing the interior grasses to grow.



- Plant berms or allow natural succession to occur on berms in medians to eliminate the need to mow.

### Roadsides

Roadsides typically include five zones that might occur on either side of the pavement (back slope or cut slope, swale or ditch zone, edge or border zone, edge or border zone, approach or shoulder zone, front or fill slope). These areas vary significantly in their geomorphic characteristics from high, dry and well-drained to low, moist wetlands. Slopes vary from steep (2:1) to relatively flat (2% or less) and soils vary from relatively undisturbed to highly compacted or reconsolidated. The edge or border zone should be mowed routinely to provide a safe stopping zone for vehicles.

- Flat roadsides can be maintained with one mower width routinely mowed.
- Roadside with swales or drainage



Along I95, the roadside is mowed one mower pass beyond the swale.



Mowing neatly to the edge of the planting bed ensures an attractive appearance.



A mowed strip around this bed of switchgrass on a prominent corner in Lewes keeps the area looking neat and well-maintained.

ditches can be mowed up to the swale.

### Beds

Beds are ornamental enhancements planted on roadside or in medians that require special maintenance. Low weeds in established beds can be tolerated when desired species are tall and the planting is viewed at relatively high speeds. Beds at intersections and adjacent to sidewalks



Flowering trees along 896 are obstructed by unmowed vegetation (left) but provide an attractive spring display when turf has been properly mowed (right).



must have a higher level of weed control. Preemergent herbicides can be used in beds. It is critical to maintain a neatly mowed edge around planted beds and areas released from mowing. If unmowed grass and weeds are allowed to grow in front of desired species, the beds look poorly maintained. Perennial forb, warm-season grass or shrub bed edges can be maintained by spraying a line of non-selective herbicide (glyphosate) at the edge of the bed. A mow strip must be maintained at the edge of areas of released turf.

Low fescue turf should be planted as

a groundcover below woody plantings in beds, especially in shaded areas. When existing turf is released and allowed to serve as a groundcover to woody plantings it forms a relatively consistent groundcover growing to about one-foot tall, but it is highly competitive with the desirable woody species. For spring flowering trees, it is important to mow the ground layer in early spring (or previous fall) to appreciate spring bloom. To maintain beds as ornamental enhancements:

1. Mow to edge of bed routinely. Edge of bed should be marked yearly before the first mow of the year.
2. Provide weed control with preemergent herbicide.
3. Use selective herbicides for grass or broadleaf control depending upon composition.
4. Handweed, depending on location and prominence.
5. Mow annually if comprised of herbaceous plants.
6. Mow every 5-7 years if comprised of cutback shrubs.



Bed edges are reflagged every spring to ensure proper mowing up to the edge of the bed with the first mow. Once the area has been mowed correctly, subsequent mowing follows the established pattern and flags can be removed.

### Stormwater best management practices

Stormwater ponds are a common best management practice (BMP) along Delaware roadsides and defined by NRCS Pond code 378 as “a water impoundment made by constructing a dam or embankment or by excavating a pit or dugout”(DeIDOT Erosion & Sediment Control and Stormwater Management Design Guide section 7). A stormwater pond serves the primary purpose of absorbing stormwater runoff and improving water quality by filtering out sediments and pollutants before the water moves into local waterways. Stormwater ponds are also valuable for the plant and wildlife habitat they can support and the aesthetic value a well-designed body of water can add to a landscape. Ponds can be designed as ‘wet ponds’, which contain a fairly consistent water level or ‘dry ponds’, which may fill with water only after storm events.

“Green technology” stormwater quality BMPs include infiltration trenches, bioretention cells, and bioswales. Manufactured BMPs include filtration systems, hydrodynamic separators, and sand filters. All erosion, sediment control and stormwater management measures have been designed and installed in accordance with the latest versions of the Delaware Sediment and Stormwater Management Regulations, the DeIDOT Standard Construction Details, and the DeIDot Standard Specifications and Design Guidance for Drainage,



Ducks and other water birds frequent the stormwater pond constructed at the corner of Bala Road and 273.

### Erosion Control and Stormwater Management manuals.

In the design phase, ponds and embankments should be shaped to blend with the natural topography of a site. A low flow channel stabilized with a permanent vegetative lining system, such as turf reinforcement mat, should be used to route water between detention ponds. Included in the design should be a planned sediment disposal site and easy access routes to any areas requiring annual maintenance inspection such as hydraulic structures or manmade embankments. Seedbed preparation, seeding, fertilizing, and mulching must comply with the SCS Standards and Specifications for Critical Area Planting, Practice Code 342.

Fencing stormwater ponds is advised against because of the false sense of safety created (a fence is no obstacle to a child who wants to get to a pond, but one will certainly block rescue efforts). Fences





Extensive plantings surround and protect a stormwater pond along renovated 141 and 202.



Mowed turf is restricted to a narrow strip adjacent to the guardrail. The slope is planted with grasses and other low maintenance vegetation and serves as a buffer enhancing the habitat quality of this stormwater pond.

also create additional maintenance challenges and scar the beauty of a well-designed pond. Safety is much better addressed by incorporating an extended shallow edge at the pond's perimeter.

This submerged "bench" at the pond's perimeter should be 10 feet wide and submerged 1-3 feet below normal water level in a wet pond. Planting this shallow freshwater marsh with appropriate native vegetation will provide real beauty and excellent wildlife habitat, in addition to

limiting damage by nuisance species like Canada geese.

Do not mow up to pond's edge but leave a ten-foot wide buffer strip along the perimeter of the pond beyond the top of the pond banks. The pond banks and this landscaping buffer should be planted with low maintenance grasses, trees, and shrubs to improve aesthetics, limit maintenance needs, and improve pond ecology. Relatively flat terrain on grassed buffer strips is desirable to facilitate easy maintenance and turn around space for mowers. Avoid planting woody plants on manmade dam or embankment areas to preserve their structural integrity. Avoid mowing any slopes steeper than 3:1 (H:V). Plant species suggestions for submerged, marshy, or dry areas can be found in Section 5-7 of the DeIDOT Erosion & Sediment Control and Stormwater Management Design Guide.

Pond systems require regular maintenance. Yearly inspection is the responsibility of the NPDES section of DeIDOT. From those inspections, work orders are generated for various activities including control of invasive species, removal of trees, excess sediment removal, reseeding of eroded slopes and structural maintenance.

#### Stormwater mitigation sites

Stormwater mitigation sites are intended to reduce the negative effects that add significant quantities of



stormwater to a natural wetland has on water quality, species diversity, and overall ecosystem health. The state of Delaware does not encourage the use of existing natural wetlands for stormwater management purposes.

Road construction in a rapidly urbanizing state such as Delaware creates many acres of impervious road surface where wetlands once existed. To address this loss of natural wetland area and the stormwater management issues created, Delaware law requires that for every acre of wetland used in road construction, DelDOT must provide 2 acres of (new) wetlands. For smaller areas these new 'wetlands' are often created as roadside stormwater ponds, swales, or other drainage areas. However, the DelDOT / DNREC Memorandum of Agreement on Stormwater provides that "...where DelDOT has demonstrated it cannot provide stormwater quality management on a given project [locally], the "deficit" thus created will be mitigated at another DelDOT project, or existing road, highway, or bridge within the same watershed or another watershed determined by DNREC to be in greater need of water quality control" (1, Sec 8). The anticipated need for these stormwater mitigation sites has led DelDOT and DNREC to work together to create artificial wetland areas, thus 'banking' these sites for future mitigation needs. These constructed wetlands are spacious, formerly-dry areas engineered to drain poorly and have the primary purpose of stormwater absorption and filtration.

However, created wetlands are not able to support the same level of species diversity or the complex ecology of natural wetlands.

Expensive to create, these areas require intensive maintenance for the first 3 years to ensure establishment of appropriate vegetation. Initial establishment is most effective using nursery stock such as dormant rhizomes, containerized plants, or bare rootstock. Establishing plants at appropriate water depth is especially important. A "wetland mulch" soil taken from a natural wetland can help establish native plant species. Wetlands may also be left to 'volunteer-seed' via air or animal borne seed. However, this inexpensive method leads to the most problems with invasive species like Phragmites.

Wetland sites should not be mowed to water's edge, but should include a minimum 10 foot wide landscaped buffer strip planted with native grasses, trees, and shrubs at the water's perimeter. Inspect wetlands on a yearly basis for:

- invasive vegetation (often a persistent problem in wetlands, especially those that are 'volunteer' established),
- damage to the embankment,
- signs of oil build-up (a potential problem in wetlands fed with roadside runoff),
- level of sediment accumulation in the facility and forebay, and



Boulders enhance habitat by providing perches for wildlife in this constructed wetland.

- blockage or other damage to inlet and outlet structures.

Replace vegetation to maintain at least 50% surface area coverage (in planted wetlands only). Based on findings in yearly inspections, repair undercut or eroded areas and clean and remove debris from inlet and outlet structures as needed. Every 5 to 7 years, sediment may need to be removed from the forebay. Every 20 to 50 years, sediment may need to be removed from the wetland (potential dredging operation) if the water holding capacity has become reduced significantly, plants are "choked" with sediment, or the wetland becomes eutrophic.

## Roadside Features

- Keep guardrails free of tall vegetation using herbicides, low-growing vegetation or weed barriers, depending on the guardrail location.
- Mow one mower pass on either side of medians routinely and mow entire median once yearly to control woody vegetation (unless otherwise directed in specific locations).
- Mow flat roadsides with one mower width during routine mowing and mow roadside with swales or drainage ditches up to the swale.
- Mow up to the edge of enhancement beds during routine mowing.
- Design stormwater ponds in accordance with the latest versions of the Delaware Sediment and Stormwater Management Regulations, the DeIDOT Standard construction Details, and the DeIDOT Standard Specifications and Design Guidance for Drainage, Erosion Control and Stormwater Management manuals.
- Do not fence stormwater ponds.
- Do not mow up to stormwater pond or wetland mitigation site edges; leave a ten foot wide buffer strip along the perimeter of the pond beyond the top of the pond banks.

## Design Approaches

Design approaches as outlined in the Enhancing Delaware Highways Roadside Vegetation Concept and Planning Manual include the regional approach, regional-ornamental approach and fully ornamental approach. These approaches help determine the management technique employed to properly maintain each site.

### Regional approach

Plant selection is restricted to Delaware native species. The design intent is to develop attractive, naturalistic landscapes based directly on the regional ecology: the dynamics, patterns, colors and cycles of Delaware's native plant communities.

- Plant competition from desirable species is the primary method of weed control, but spot control of aggressive species that threaten the long-term survival of the site is also practiced.
- Supplemental watering is provided during establishment only.
- Mulch may be used around planted specimens, but the long-term ground layer will develop from seeded, planted or existing vegetation.



Switchgrass was seeded into the slope along the Milford bypass exit ramp. Along with groundsel bush and eastern red cedar, the grass provides a continual vegetative cover that suppresses weeds.





'Blue ice' bluestar, asters and 'Northwind' switchgrass were mulched after planting but have grown together and now provide a continual vegetative cover.



Traffic islands in Newark are routinely mulched and weeded to maintain a highly managed aesthetic.

### Regional-ornamental approach

Plant selection is restricted to Delaware native species plus other North American native species that reflect the general character of Delaware's native flora. The design intent is to develop ornamental landscapes inspired by the regional colors, patterns and cycles of the native Delaware landscape, but is not necessarily based upon plant community dynamics.

- Spot control of aggressive weeds on a regular basis may be employed to supplement plant competition as the primary method of weed control.
- Supplemental watering is provided during establishment and only in extreme drought conditions.
- Mulch may be used around planted specimens, but the long-term ground layer will develop from seeded, planted or existing vegetation.

### Fully ornamental approach

Plant selection is unrestricted. Design intent is to create highly ornamental garden-like landscapes based primarily on visual impact and functionality, not necessarily related to the colors, patterns and cycles of the native Delaware landscape. If site conditions are suitable and aesthetic requirements are met, regional flora should be given preference.

- Routine weed control is employed to remove most non-planted species.
- Supplemental watering is provided whenever conditions would negatively impact the visual effectiveness of the planting.
- Mulch is the typical ground layer.

## Design Approaches

- Select a design approach appropriate for each site following recommendations outlined in the Planning and Concept Manual. Design approaches provide guidance for appropriate management strategies.

## Vegetation Reduction Techniques

Vegetation along the roadsides can be reduced in a variety of ways. Turf is routinely mowed on roadsides. Mowing frequency affects the type of vegetation that develops. When mowing is discontinued, woody vegetation will become established. Woody vegetation can be managed by editing or cutting back.

### Discontinued mowing or release

Stopping routine mowing releases the desirable regional vegetation to develop through natural growth or seeding. Undesirable plants are controlled by spot treatment. A released site may require occasional intervention such as periodic mowing, editing or cutting back.

The composition of species found in an area of released turf depends primarily on the density of the original turf and species mix present in original turf cover. Dense vigorous cool-season turf stands are comprised primarily of cool-season turf even three to four years after they have been released to an annual mow regime. Sparse stands of cool-season turf will allow relatively rapid incursion of opportunistic species once an annual mowing regime is followed. When the



A neatly mowed turf edge provides contrast with taller grasses and contributes to an overall attractive appearance.



Groundsel bush, goldenrod, thoroughworts and various warm-season grasses quickly filled in an unmowed median in Seashore State Park.

existing seed bank of native species is large, desirable species establish themselves quickly (i.e. Route 1 in Seashore State Park).

A mowed edge is critical to make released turf attractive.

- Release turf areas from routine mowing whenever possible in the right-of-way. Spot spray or mow periodically to control invasive woody plants. Mow an edge routinely.

**Discontinued mowing  
or release**



Trees are marked for selective removal to maintain groves and open space adjacent to Iron Hill at the 896 exit from I95.



### Editing

Evaluate existing vegetation and identify opportunities to introduce aesthetic order by highlighting individual specimens or plant groups through the process of removing other vegetation. After editing, maintain the open areas with periodic spot weed control.

### Cutting back

Periodic cutting of woody vegetation maintains dense and healthy growth within desired height and spread parameters. Vigorous species, like sumac and sweet gum will move out from an existing wood edge when mowing is curtailed. Cutting back periodically (every 5-7 years) will create hedges of these vigorous species that are both attractive and within the requirements for safety and line of sight.



A boom ax attachment is used to cut back overgrown groundsel bush and encourage dense regrowth.

Tall, open shrubs such as groundsel bush, sumac and choke berry can be managed with a cutback procedure every 5 years to encourage regrowth into dense shrub masses.



Vigorous shrubs and trees such as sassafras and sumac can be mowed to the ground and will emerge as a solid hedge of similar height vegetation.

### **Editing**

- Edit roadsides to introduce order and a maintained appearance.

### **Cutting back**

- Cutback vigorous trees and shrubs to form dense hedges along the roadside.



## Mowing

The primary maintenance procedure required for turf is mowing. The frequency of mowing or the number of mowing cycles in a given season is regulated by the amount of turf growth. The amount of growth is dependent upon temperature, fertility, moisture status, season, and natural growth rate of the grass species.

Mowing operations should be performed when the soil and grass are dry. This helps prevent the spread of disease and injury to the turf. Grass clippings should be left to decay and release their nutrients back to the turf, thus minimizing the need for fertilizer. Grass clippings should be removed if they are heavy or thick enough to damage the turf.

Routine mowing of all roadside rights-of-way is an unnecessary management practice. Improper mowing can increase some weeds' ability to compete and degrade the plant community making the roadside more susceptible to weeds and erosion. Mow only the immediate road shoulder and where dictated by safety considerations (such as intersections, bridges, sharp curves, and farm and field entrances). A reduced mowing plan requires the ability to identify desirable and undesirable plant species, and to provide spot treatment at the proper growth cycle for undesirable species. Maps or detailed instructions may be required to show operators where to mow, depending on the specific roadside conditions.

Different types of turf management are appropriate depending on the location:

**Routine mowing** – mow the site frequently to maintain a specified height of vegetation.

Routine mowing operations are divided into two turf categories: residential-quality turf and utility turf. Residential-quality turf is located at facilities that are maintained by DelDOT—namely rest areas, welcome centers, DOT office buildings, and maintenance complexes. Utility turf is located along the roadsides and it is the majority of the turf DelDOT maintains.

Residential-quality turf should be maintained at a height of 3 inches and mowed weekly or bi-weekly. Mow community entrances as often as necessary to maintain an attractive appearance. When maintaining an area of high quality turf, grass should be mown so that no more than one-third of the leaf surface is removed with each mowing.



Residential quality turf is maintained around planted beds in Wilmington's riverfront.

Mowing of high quality turf should begin when the grass is one-third higher than the desired height. For instance, if one desires a 3-inch height, mowing should begin when the turfgrass reaches 4 1/2 inches. The number of mowing cycles varies and depends on the growth rate of the turfgrass. In most instances, weekly to biweekly mowing accomplishes the desired effect.

Maintain utility turf at a height of 6 inches. Mowing will be required approximately 8 times per year. Utility turf constitutes the majority of DeIDOT's mowed areas. In rural areas, 3:1 and steeper slopes shall not be mowed and shall be marked accordingly. Slope indicator shall be utilized on each tractor. In urban areas, some 3:1 slopes will be mowed with specially designed equipment.

*Interstates* – 8 mowings depending on growth rate. Follow median mowing guidelines (page 7). On roadsides, mow to ditchline and one mower pass on backslope. Mow entire median and specified roadside rights-of-way at the end of the growing season (late November) or in early spring if area is not likely to retain moisture. Mowing height – 6 inches

*Primary roads* – mow 6 times, on average, per growing season (April – October). Mowing height – 6 inches

*Secondary roads* – mow 4 times, on average, per growing season (April – October). Mowing height – 6 inches

*Tertiary roads* – mow 3 times per growing season (April – October). Mowing height – 6”

*Stormwater ponds* - Mow 10-foot wide access paths to all inlet and outlet structures regularly. For warm-season grasses, the previous season's stalks should be cut down to 8-12 inches in early spring (mid March), before new season's growth emerges. Do not mow up to pond's edge but leave a 10 foot buffer strip along the perimeter of the pond beyond the top of the pond banks. Mow buffer strip at the end of the growing season (late November) or in early spring, if area is accessible, to control woody invasive species. In rural settings, a single mowing per year should be sufficient. Mow between September 1 and 30 to allow for regrowth of winter cover while avoiding



When grass is allowed to grow too tall in-between mowings and is then cut short, remaining clippings contribute to an unsightly appearance. In addition, the clippings block light from the turf and can cause dead patches.

potential negative effects on wildlife such as nesting birds. In urban settings, mow once in early growing season (April 1 – June 30) and a second time during dry period (Aug 1 – Oct 31). A dry pond bottom can be mowed once a year during dry period; weekly during peak growing season (April – November).

*Wetland mitigation sites* - Mow dry grassy areas/buffer strip once per year during dry season (Aug 1 – Oct 31).

*Biofiltration swales* – If turf cover is used, mow regularly (weekly from April to November). Mow no lower than 6 inches to maintain desired design height. The vegetation height should be 2 times the depth of flow during the quality storm. The vegetation height should be specified on the plan.

*Filter strips* – Mow, annually, between September 1 and 30 to allow for regrowth of winter cover while avoiding potential negative effects on wildlife such as nesting birds. For warm-season grasses, the previous season's stalks should be cut down to 8-12 inches in early spring (mid March), before new season's growth emerges. The approved plan will specify the mow height. Filter strip vegetation should be maintained at a height of 2 times the depth of flow during the quality storm.

Regardless of the class of roadside, all intersections must be mowed at necessary intervals to provide for

adequate sight distance. Mowing shall be performed where needed to maintain sight distance, such as on inside curves, off ramps, on ramps, intersections, and private entrances.

The mowing cycle should begin before the grass reaches ten inches in height. The first mowing is most important since it will dictate the appearance of the turf throughout the balance of the year. Specific areas have specific instructions, e.g., mow one strip along fence, interiors of interchanges, or up to residential or business lawns.

Clean mowers regularly to reduce the spread of invasive plant parts, insects and disease from one mowed area to another.



Annual mowing can be conducted in late fall; however cutting growth at this time is hardest on equipment. Autumn mowing also reduces the visual appeal of the site and destroys winter cover, which is important to local wildlife.

**Periodic mowing** – mow the site annually or as necessary to discourage establishment of woody species and maintain an herbaceous composition. Annual mowing can be completed at the last mow of the season to clean up an area prior to the dormant period. Fall mowing is useful for sites that are





Grass is mowed in this median north of Odessa in late fall to allow spring bulbs to come up unimpeded.



Switchgrass begins to grow in mid-spring and covers the dying bulb foliage.

routinely wet and will be difficult to mow in early spring or if spring flowering perennials or bulbs exist at a site. Some sites contain warm-season grasses and other perennials that are attractive during the winter. If possible, allow this vegetation to remain standing throughout the winter and mow during the first mow of the following season. This technique utilizes the natural break-down of herbaceous vegetation over the winter making the areas much easier to mow in the spring.

**Equipment** - Either a rotary or flail (impact) mower can be used to mow turfgrass. Rotary mowers are useful for mowing tall grass at the end of the growing season. Rotary mowers should be rear discharge. Mower blades should be sharp to obtain the best results. Dull mower blades tear the grass blade instead of cutting it, thus reducing the quality of the turf. Grass tearing results in poor turf appearance and allows disease to enter the plant. Well-sharpened mower blades will also reduce mower vibration, lengthen mower life, and reduce fuel consumption.



The appealing apricot winter color of little bluestem is a benefit of allowing warm-season grasses to remain standing all winter.



Various mowers are used depending on the desired cut width and maneuverability required.

Repeated scraping and the resulting exposed soil provides an opportunity for weed species to germinate and take over.

- Mow residential quality turf to a height of 3 inches routinely.
- Mow utility turf (medians and roadsides) to a height of 6 inches.
- Mowing frequency is determined by growth rate and traffic volume of roadway.
- Mow intersections and inside curves, off ramps, on ramps, and private entrances as needed to maintain sight distances.
- Complete yearly mowing at the end of the growing season (November) or in early spring (if area is not prone to spring water accumulation).
- Mow stormwater ponds in rural settings once a year (August – October) and in urban settings twice yearly (April – June and August – October)
- Mow dry grassy areas/buffer strips once per year (August – October).

## Mowing

## Pruning

### Reasons for pruning

Pruning is the selective removal of plant parts for the purpose of increasing the value of the remaining plant. Tree pruning is performed for three purposes: health, structure, and safety.

**Health** – Pruning for health involves removing diseased, injured, insect-infested, or dead wood. Removing crossing and rubbing branches can eliminate abrasions that, along with dead wood, can serve as an entry point for insects and disease organisms. The removal of injured and broken limbs

encourages wound closure. Thinning the crown increases airflow and can reduce some pest problems.

**Structure** – Structural pruning enhances the natural form and character of the tree. It also reduces the likelihood of storm damage.

**Safety** - Remove branches that impact visibility (signs and roadway), could fall and cause injury or property damage, and grow into utility lines. For the most part, safety pruning can be avoided by choosing plants that won't grow beyond the space provided, and have characteristics suited to the site.



Pruning is often required along roadsides to keep utility lines clear.

### Pruning tools

Prune with sharp tools that are appropriate for the branch size. The tool choice depends on the size of branches to be pruned. Keep tools clean and sanitized to prevent the spread of disease from infected to healthy trees.

**Pruning shears** – used for branches no thicker than a pencil. There are two basic types of hand pruners. Scissors-action utilizes a curved cutting blade that slides past a broader lower blade. Anvil-action pruners feature a straight blade that cuts the branch against a small anvil or block when you squeeze the handle. Because anvil-action pruners do not make close cuts and can crush the tissues, it is best to use scissor-action pruners.

**Lopping shears** – used for branches up to 3/4 inch thick. Loppers are like scissor-action hand pruners with larger blades and long handles for better leverage.

**Pruning saw** – used for branches thicker than 3/4 inch. Pruning saws have narrow blades (for maneuverability) and coarser teeth than carpenter saws. They are designed to cut on the draw stroke (pulling the blade toward you). A bow saw can also be used, but may be more awkward to maneuver in tight areas.

**Pole pruners** – used to cut branches beyond reach. Most pole pruners have both a cutting blade and a saw. Exercise caution when using around utility wires. Pole pruners will conduct electricity if they come into contact with energized wires.

**Chain saws** – used for branches larger than 4 inches. Should only be used by trained personnel.

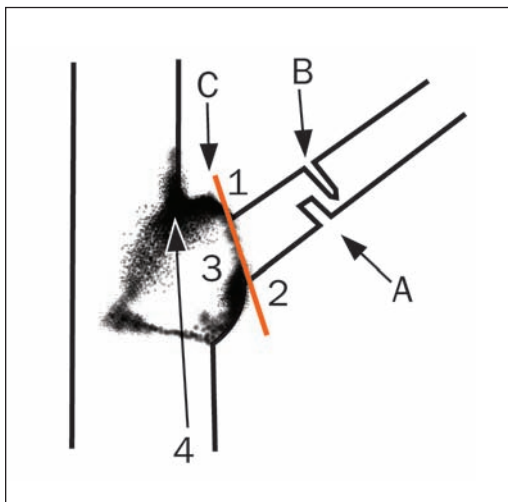
### Pruning techniques

**Natural target pruning** – Plants do not “heal” like people do. When a tree is pruned, a wound is created, causing some decay. The tree then seals or compartmentalizes the wound. However, the wound is contained within the tree forever. If the cut is made through only branch tissue, the decay will be confined to that tissue. If the cut is made through the trunk tissue, it is much more difficult for the tree to compartmentalize the wound, and the entire tree is subject to decay. Therefore, the smaller the branch is when pruned, the sooner the wound created will heal.



To locate the proper place to cut a branch, find the branch collar, which is a swelling or bulge at the underside of the base of the branch (3). If the branch collar is difficult to find, the branch bark ridge (BBR; 4) can be used to determine the proper placement for the pruning cut. The BBR is a ridge of bark that forms in a branch crotch and partially around the trunk. A proper pruning cut does not damage either the branch bark ridge or the branch collar.

A proper cut begins just outside the branch bark ridge (BBR;4) and angles down and away from the trunk of the tree (1-2). Make the cut as close as possible to the trunk, but be sure that it's outside the BBR, so that the trunk tissue is not injured.



Branches large enough to require saws should be supported with one hand while cutting. When a branch is too large to support, use three cuts to ensure the bark doesn't rip.

1. Make a small notch on the underside of the branch, outside of the branch collar to prevent the tree bark from stripping down the trunk. (A)

2. Make a cut beyond the first cut, all the way through the branch, to remove most of the weight of the limb. (B)

3. The remaining stub is cut just outside of the branch collar. (C)

Sap flow from pruning wounds is not generally harmful. Although unsightly, tree sap, gums and resins are the natural means by which trees combat the invasion by pathogens. Wound dressings may cause more harm than good. They will not stop decay or cure tree diseases. They may actually slow the tree's natural process of closing the wound surface.

**Pruning sequence-** prioritize pruning in the following order:

1. Remove diseased and dead wood.
2. Remove crossing branches that rub together and branches that grow back into the center of the tree.
3. Remove branches that form narrow-angled crotches before they become heavy enough to split the trunk below the crotch.
4. Remove suckers, water sprouts (soft, fast growing branches that usually grow vertically from large limbs or the trunk), and any branch that detracts from the natural shape of the tree.

**Pruning timing** – There is no single “best time of the year” to prune. The timing is determined by the type of plant, plant species, the reason for pruning, and desired effect. Remove dead or diseased wood anytime. Avoid pruning during the spring when trees are leafing out or when they are losing their leaves in the fall. Prune spring-flowering trees and shrubs immediately after the flowering period. Prune summer-flowering shrubs during their dormant period from mid-November to February. Prune evergreens from mid-November to mid-March. Evergreens cannot tolerate severe pruning. With newly planted trees, only remove branches damaged during the transplanting process. Wait until after a full season of growth in the new location before doing any additional pruning.

**Complete removal** – Remove all dead trees, brush, shrubs and woody vines within the legal right-of-way. Remove all trees, shrubs and woody vines in safety clear zones and drainage swales (unless designed to accommodate woody plants).

- safety clear zone - at least 30 feet from the outside edge (white line) of the travel lane.
- drainage swales - up to a maximum of 5-feet outside of the swale limits on each side

Fell and remove downed trees in a manner that will prevent injury and/or damage to remaining vegetation, structures, and people. If the potential for damage exists, carefully remove trees in

sections. Make cuts level to the ground, or to a height not to exceed 2 inches for safety reasons. Clean up all vegetative debris (wood chips). Treat live stumps, 2-inch caliper or larger, and all woody vines on the day of cutting with an appropriate herbicide. Clean the stump cut surface of all sawdust and dirt to ensure proper treatment. Repeat herbicide treatment (as directed by engineer), if suckers or sprouts develop at any time prior to the final acceptance of the work.

**Cutback** – Also known as rejuvenating, cutback is a drastic form of pruning used to manage a woody shrub border by mowing or cutting with a tractor and extended arm mower or mechanical brush hog attachment on roadsides and along embankments of woody (brush) and herbaceous (grass) vegetation at a designated frequency, leaving stubble or stump height not shorter than 6 inches and not to exceed 12 inches. Cutback is done only as directed by an engineer.



Shrubs like red twig dogwood benefit from rejuvenation pruning every other year to promote young bright red stems.

- Prune with sharp tools that are appropriate for the branch size (pruning shears for branches no thicker than a pencil; loppers for branches up to 3/4 inch; pruning saw for branches thicker than 3/4 inch).
- Prune branches following the natural target pruning procedure (i.e. do not damage the branch collar).
- Small cuts do less damage to the tree than large cuts. Prune when trees are young.
- Do not apply wound dressing or tree paint to the cut surface.
- Remove dead or diseased wood anytime.
- Correct crossing branches, branches that grow back into the center of the tree or branches that form narrow-angled crotches when a tree is young.
- Remove suckers and water sprouts that disrupt the natural shape of the tree.
- Avoid pruning during the spring when trees are leafing out or when they are losing their leaves in the fall. Prune spring-flowering trees and shrubs immediately after flowering. Prune summer-flowering shrubs from mid-November to February. Prune evergreens from mid-November to mid-March.
- Avoid topping or tipping a tree.
- Remove all dead trees, brush, shrubs and woody vines within the legal right-of-way.
- Remove all trees, shrubs and woody vines in safety clear zones and drainage swales (unless designed to accommodate woody plants).
- Make cuts level to the ground or no greater than 2 inches above ground level.
- Treat live stumps with an herbicide on the day of cutting and re-treat as necessary.
- Cutback to rejuvenate a woody shrub border.

## Pruning



## Trash Accumulation

Trash accumulation can ruin the aesthetics of any planting, yet the vulnerability of sites to trash accumulation is highly variable. A few factors should be considered so that aesthetics can be maintained without requiring an unreasonable amount of maintenance.

Primary factors influencing the potential for trash accumulation are prevailing winds, topography and the specific plants employed. Some sites are in areas where trash is prevalent and in addition some sites are the likely terminus for trash movement in the local landscape. For example, a site might be between two roadways and trash from the

top roadway may naturally sweep across the plane of the paved surface, under a guardrail and into the plantings. If the plants used in such a site are of a nature that makes it difficult to remove trash, such a site will be difficult to maintain at acceptable aesthetic levels. Some plant species are more prone to trapping trash than others. Plants with thorns, spines, or highly twiggy structure are especially likely to trap and hold trash within them, making trash removal difficult and time-consuming. Plants with smoother texture and/or plants that form an even face at the exposed edge of the planting are less likely to trap trash. If trash accumulates it will be concentrated along an easily accessed edge that facilitates easy removal.



Accumulated trash detracts significantly from an enhancement sites. The smooth texture of the blue aster would not have trapped this plastic bag, but the stem of a taller weed did.

## Trash Accumulation

- Consider potential for trash accumulation when selecting enhancement sites.
- Use appropriate plants considering the relative vulnerability of a site to accumulate trash.
- Include trash removal as part of routine landscape maintenance.

## Weeds

A weed is any plant growing in an area where it is not wanted. Plants may be considered weeds when they do one or more of the following:

- Compete with desirable plants for water, nutrients or sunlight.
- Act as contaminants in a product at harvest.
- Harbor and act as alternate hosts for pests.
- Release toxins in the soil that inhibit growth of desirable plants.
- Reduce the aesthetic value of landscape areas and rights-of-way
- Increase costs of trimming, mowing or cultivation.
- Hinder easy travel or movement.
- Clog drainage areas.
- Increase the level of fire hazard.
- Act as threats to human health (toxic plant parts).

### Weed classification

Weeds can be classified in a number of different categories based on plant type, life cycle, aggressive nature or legal status.

**Plant type** is a classification based on morphological differences between plants.

#### *Grasses have:*

- one cotyledon (seed leaf) emerging from the seed.
- narrow leaves with parallel veins.



Annual weed grasses germinate soon after planting between these two rows of chokeberry.

- a growing point at or below the soil surface; so most grasses tolerate close mowing.

Common annual grass weeds include crabgrass, goosegrass, foxtail and barnyard grass. Common perennial grass weeds include bermudagrass, johnsongrass and quackgrass.

#### *Sedges:*

- have triangular stems and three rows of leaves.
- are found in wet places (but nutsedge, the principle pest species is found in fertile, well-drained soil).

#### *Broadleaves have:*

- two cotyledons (seed leaves) emerging from the seed.
- broad leaves with net-like veins.
- growing points are at the end of each stem and in leaf axils.

Common annual broadleaf weeds include common chickweed, henbit, black medic, knotweed, purslane, lambsquarters, morning glory, pigweed, ragweed, spurge and many others. Biennial broadleaf weeds include mullein, burdock, Queen Anne's lace, yellow rocket and wild parsnip. Perennial broadleaf weeds include Canada thistle, dandelion, curly dock, bindweed, horse nettle, poison ivy, red sorrel and many others.



Although it has long been used for slope stabilization, crown vetch is now considered a persistent broadleaf weed that can plague planting sites for many years.

**Life cycle** is a useful classification when determining control methods.

*Annuals* complete their life cycle in less than one calendar year. Control strategies include preventing seed from germinating or plants from emerging each year. But annuals grow fast and produce a lot of seed, so control can be difficult. Summer annuals germinate in spring or summer, grow, set seed and die before winter. They include weeds such as cocklebur, knotweed, pigweed, lambsquarters, ragweed, crabgrass, foxtail and barnyard grass. Winter annuals germinate in fall, overwinter, mature, set seed, and die in spring or early summer. They include chickweed, henbit, shepherd's purse and cornflower. They are difficult to control because they germinate over a long period and have less aboveground competition.

*Biennials* complete their life cycle within two years. During the first year, the plant forms basal leaves (rosette) and a

tap root; the second year it flowers, matures and dies. Wild carrot, bull thistle, common mullien and common burdock are all biennials.

*Perennials* live more than two years and have a persistent root system. Most reproduce by seed and are able to spread vegetatively as well. Simple perennials spread by seed, crown buds and cut root segments. Examples include dandelion, dock plantain and pokeweed. Creeping perennials reproduce by creeping above ground stems (stolons) or below ground stems (rhizomes). Examples include red sorrel, field bindweed, wild strawberry, mouseear chickweed, ground ivy, bermudagrass, johnsongrass, quackgrass and Canada thistle.

**Aggressive nature or legal status** affects how a weed must be managed.

*Classic weeds* require consistent disturbance to become established and persist. Examples include Queen Anne's lace, pokeweed and evening primrose. These early successional species, both native and exotic, often dominate initially when an existing cool-season turf cover is removed. If desirable vegetation is established, it will out-compete these weeds in a few years and they will disappear from the mix. Classic weeds are consistent components of continually disturbed right-of-ways. Undisturbed right-of-ways that have developed into more stable native grass and forb meadows, shrub borders or forests do not provide



the conditions necessary for classic weeds to persist.

*Invasive plants* are able to replace desirable species. Invasive species can be problematic in both disturbed and established environments. The Delaware Invasive Species Council used a modified risk assessment tool to designate invasive plants as widespread and invasive, restricted and invasive, and restricted and potentially invasive.



Queen Anne's lace and chicory are classic weeds that come into an unmowed area in the first few years after disturbance. They are eventually replaced by other more permanent plants.

**Delaware Invasive Species Designations:**

<b>Widespread and Invasive</b>	<b>Restricted and Invasive</b>	<b>Restricted and Potentially-invasive</b>
Multiflora rose	Japanese barberry	Butterfly bush
Oriental bittersweet	Periwinkle	
Japanese stiltgrass	Garlic mustard	
Japanese knotweed	Winged euonymus (burning bush)	
Autumn olive	Porcelain berry	
Norway maple	Bradford pear	
Common reed	Marsh dewflower	
Hydrilla	Lesser celandine	
Mile-a-minute	Reed canarygrass	
Clematis	Honeysuckle – bush honeysuckle species	
Privet	Tree of heaven	
European sweetflag	Spotted knapweed	



Japanese stilt grass is the primary ground cover on this disturbed roadside edge in Newark.



A vigorous patch of Canada thistle must be controlled before it goes to seed.

*Noxious weeds* is a legal classification. Johnsongrass, bur cucumber, giant ragweed and Canada thistle are legally classified as noxious weeds in Delaware. It is unlawful to allow noxious weeds to set seed or exceed 24 inches in height.

*Nuisance weeds* is a legal classification. It is unlawful to grow nuisance weeds in a manner that impacts adjacent property. In Delaware, bamboo was designated as a nuisance weed. Due to an inability to enforce nuisance weed legislation, bamboo is no longer considered a nuisance weed. There are no legally classified nuisance weeds in Delaware.

## Weed Control

Weeds are controlled on roadside rights-of-way:

- To maintain the integrity of the paved surface,
- To prevent or reduce erosion,
- To provide for the safety of the traveling public,
- To provide for efficient maintenance practices,
- To maintain drainage,
- To provide beauty, and,
- To provide wildlife habitat.

### Control methods

An integrated vegetation management program (IRVM) uses a combination of mechanical, cultural, biological and chemical methods for control. In an IRVM

## Weed classification

- Weeds are categorized as grasses, sedges or broadleaves, which affects the ability to selectively control weeds in desirable plantings.
- Weeds can be annuals, biennials or perennials, which affect the timing of control measures.
- Weeds are classified as classic, invasive, noxious or nuisance, dictating different levels of required or recommended control. Specific control recommendations can be found in Appendix C.



program the least toxic alternative is always selected first.

**Cultural** - Prevention is an effective method of weed control and is best accomplished by:

1. Making sure weed seeds and reproductive plant parts are not carried onto the area via contaminated seed, water, topsoil or mulch. For example, in road construction projects, the topsoil may be contaminated with a weed such as Canada thistle. This soil should not be stockpiled and reused as topsoil on the project.

2. Preventing weeds from going to seed. Noxious weed control is based on preventing seed production to reduce the spread of those species.

3. Preventing the spread of perennial weeds that reproduce vegetatively. Mulch and topsoil are notorious for carrying perennial weed parts. Use a reliable weed-free source and do not purchase mulch, topsoil or organic matter that has been stockpiled without appropriate covering or weed control.

Many weed species require sunlight to germinate. Weed control can often be achieved with a thin covering of an organic material to prevent sunlight from reaching the soil surface. A thick cover of desirable vegetation will also prevent sunlight from reaching the soil and prevent many weed problems. For example, dense turf maintained at a height of 3-6 inches will block sunlight and dramatically reduce crabgrass germination. If turf is mowed



It is unlawful to allow a field of Canada thistle to go to seed, but it happens all the time. Preventing seed production is one of the best ways to reduce the spread of noxious weeds such as Canada thistle.



Sawdust is used as a medium to spread seed and also acts as a mulch to reduce weed seed germination in the soil below the sawdust.



Warm-season grasses, such as this Northwind switchgrass, are self-mulching. The past season's vegetation provides a dense mat that excludes light and reduces weed seed germination.



Fragrant sumac has colonized the slopes along I95 through Wilmington, creating dense stands that prevent weeds from developing.



Aromatic aster is so vigorous that few weeds are able to germinate in this Dewey Beach median planting.



Close spacing at planting allows desirable plants to cover the ground quickly and reduces the need for hand weeding in roadside plantings.



too close to the ground, the weed suppressing effect is lost.

In addition to preventing germination, desirable vegetation can provide effective weed suppression by outcompeting weed plants for nutrients and other resources. For example, a vigorous stand of a colonizing shrub such as sumac will make conditions relatively inhospitable to invasive plants. Herbaceous plants can also be effective in this way. Thick healthy turfgrass will minimize weed problems and dense stands of colonizing native plants like goldenrod, switchgrass and aromatic aster create conditions inhospitable to weeds.

**Biological** – In biological weed control, a “natural enemy,” which is otherwise harmless, is used to control the weed. Insects have been the most successful natural enemies to date. Other control agents include disease organisms, parasitic plants, rodents, fish and selective grazing by livestock. Purple loosestrife has been successfully controlled in a number of regions with an imported beetle. Mile-a-minute is potentially controllable with an introduced insect.

## Cultural control

- Cultural control is accomplished by preventing weed seeds and reproductive plant parts from contaminating growing areas.
- Reduce weed seed germination by preventing light from reaching weed seeds (mulch or dense vegetation).
- Use desirable plant competition to prevent weed incursion.



Currently pervaded by purple loosestrife, this environment could benefit from the introduction of two European beetle species (*Galerucella calmariensis* and *G. pusilla*), which have proved to be an effective biological control for some North American regions.

- Introduced insects are available for the control of some invasive weeds.

## Biological control

**Mechanical** – Mechanical control methods are the oldest methods of weed control. These include – manual weeding, hoeing, blading, grubbing, mowing, girdling, burning, flooding, mulching, cultivation and other tillage operations. Many of these methods are labor intensive and therefore expensive. Mechanical methods are still an important component of a total weed management program.

Mowing is routinely used to control woody invasive species along roadsides. Mowed strips can be used to prevent weeds outside the roadside right-of-way from spreading into managed right-of-way areas. Mowing can also be used to control classic weeds that invade new meadow plantings. Repeated mowing in the first two years of establishment will control taller classic weed species and allow shorter native grasses and perennials to become established.

Manual weeding is not practical for miles of roadside, but if feasible for specific enhancement sites. There are times when hand pulling prior to flowering and seed development can greatly reduce



The woody weed species appearing in this roadway median meadow will be controlled by this annual mowing.



Multiple mowing during the first two years of establishment allowed this meadow full of black-eyed Susan to flourish.



A mowed strip along the back edge of this plot prevents aggressive plants from growing over the fence and into the right-of-way.



a weed infestation. Manual weeding is also a technique that may be warranted during an establishment period until the desirable vegetation becomes dense enough to out-compete weeds.



Selective hand weeding in this small roadside enhancement is a practical way to remove tall broadleaf plants.

Girdling is a mechanical control technique useful for controlling established woody species. Remove phloem in a collar around the trunk. Xylem is still able to translocate to the leaves but the leaves no longer send energy back to the roots. Eventually the tree, shrub or

vine will die and may require removal. With vines, do not physically remove vines once the stems/trunks have been cut. In most situations the dead vines will be removed by natural weathering processes. Allowing this to occur is the most efficient and environmentally friendly approach to vine removal. It avoids damage to trees that may occur with mechanical removal and eliminates the need to transport and dispose of dead organic material.

**Chemical** – Chemicals used to kill, change or inhibit plant growth are called herbicides. They are “phytotoxic,” meaning injurious or toxic to plants. Pesticides are a broader group of chemicals that includes herbicides but may also target undesirable insects and disease organisms.

Herbicides can be efficient and effective tools for vegetation management and weed control; however, there are potential impacts to health and the environment. The need for herbicide and pesticide use should be minimized whenever possible by adoption of cultural, biological and mechanical control methods. Though herbicides are frequently

## Mechanical control

- Mow yearly to control woody plants in an herbaceous meadow.
- Mow 2-3 times during the first two growing seasons to control classic weeds in an establishing meadow.
- Mow strips around the periphery of a meadow or shrub planting prevent weed incursion from outside the right-of-way.
- Handpull weeds in enhancements during the establishment period or periodically when warranted.
- Girdle invasive woody trees, shrubs and vines as one method of control.



necessary in the initial stages of site development, the ultimate establishment of desirable vegetation should minimize the continuing need for their use. Minimizing risks to human health and the environment must be of primary concern when selecting and applying herbicides on Delaware roadsides. In addition DelDOT policy prohibits the use of restricted-use chemicals when managing roadside vegetation.

Herbicides are an integral part of the overall vegetation management program of the Delaware Department of Transportation. The use of herbicides is often more effective, more economical and requires less labor and equipment than the alternate methods of hand cutting and mowing. Selective herbicide use can preserve greater species diversity in roadside rights-of-way.

A survey of Delaware drivers conducted in 2005, asked how drivers feel about pesticide use on the roadside. Most (80%) respondents agreed that pesticide use should be kept to a minimum, and most (75%) disagreed with the statement suggesting pesticides be used freely to keep costs down; only 20 percent believed

that DelDOT should use no pesticides at all. Most respondents (77%) approved of using herbicides along the roadside to protect natural areas from being impacted by invasive plants.

It is the intent of this manual to provide information and guidance in promoting the safe and proper use of herbicides, thereby protecting the environment and the public health while performing indispensable highway maintenance and safety. Personnel responsible for the application of herbicides to roadside vegetation must become familiar with the fundamentals of herbicides, treatment guidelines, equipment, environmental safety and record keeping. All personnel must participate in periodic training programs and must be licensed as a certified pesticide applicator in the right-of-way category (06) and ornamental and turf category (03). Licensed operators must participate in re-certification programs that are made available to departmental personnel.

- Selective herbicide use can preserve greater species diversity in roadside rights-of-way.
- Delaware drivers do not support excessive use of pesticides but do believe herbicides are important for controlling invasive plants.
- Training personnel properly is the key to safe and proper herbicide use.

## Chemical control

**Herbicide labels include:**

uses for which the chemical is legally permitted, application rates, timing, and procedures, lists of susceptible plants, specific environmental concerns, and safety precautions and proper cleanup.

**Material Safety Data Sheets include:**

emergency telephone numbers, product ingredients, physical data, fire and explosion hazard information, reactivity data, environmental and disposal information, health hazard data, first aid procedures, handling precautions, and any necessary additional information.

Herbicide safety

**Product labels and MSDS** - Herbicides must be used in accordance with their registered label. This manual serves as a supplement to, not a replacement for, herbicide labels and Material Safety Data Sheets (MSDS). The use of any herbicide requires a thorough understanding of the information printed on the label and MSDS. Regulations affecting herbicide usage and the registration status of specific herbicide materials can change without notice.

Each herbicide varies in the hazard or danger that it presents to the user. Labels are required to contain a signal word to inform the user of the product's potential danger. Knowing the meaning of these signal words will help you determine precautions you may wish to take in addition to those on the label. The signal words are as follows:

- **DANGER** - the herbicide is highly toxic. A teaspoonful taken by mouth could kill an average-sized adult. Any product that is highly toxic orally, dermally, or through inhalation OR causes severe eye and skin burning

will be labeled DANGER. If the product is highly toxic orally, dermally, or through inhalation, it will also be labeled.

- **WARNING** - The herbicide is moderately toxic. A teaspoonful to tablespoonful taken by mouth could kill an average-sized adult.
- **CAUTION** – The herbicide is slightly toxic. An ounce to a pint taken by mouth could kill an average-sized adult.

Every label contains precautionary statements regarding hazards to humans, domestic animals, and the environment, agricultural use requirements, and recommended personal protective equipment, as well as physical or chemical hazards. These statements should be read before using the product to prevent accidents and misuse.

Herbicide labels vary in the type of protective clothing and equipment safety statements they contain. The signal words will alert you to look for these precautions. Herbicides can enter the body in three principal ways – through the mouth (orally), through the skin and eyes (dermally), and through the lungs by

inhalation. To prevent herbicides from entering the body, applicators may need to use protective clothing and equipment. As a user, your common sense and knowledge of the product should help you assess potential hazards and select the kind of protection you need.

Each herbicide label contains general cautions and precautions about the application of the product. Not all of these statements have been included in the label section of this manual. The following precautionary statements are often found and should be followed unless the label specifically states otherwise.

- Do not apply herbicides through irrigation equipment.
- Avoid spray drift onto off-target species and out of the treatment area.
- Avoid runoff to adjacent water or wetland areas.
- Do not apply more than the recommended rates and treatments over a given period of time.
- Always wear the prescribed personal protection equipment for mixing,

loading, and application.

- Where appropriate, follow all Worker Protection Standards including restricted entry intervals and protective clothing.

The only way to obtain specific information on application of a particular herbicide is to READ THE PRODUCT LABEL AND MATERIAL SAFETY DATA SHEET. For this reason, up-to-date labels and MSDS for any chemical being used should be kept at hand for reference, to be used by applicators while on the job and by specialists while planning activities. MSDS reference websites include:

[www.greenbook.net](http://www.greenbook.net)

[www.cdms.net/manuf/manuf.asp](http://www.cdms.net/manuf/manuf.asp)

- Read the product label and MSDS before using any herbicide.
- Understand the meaning of signal words (danger, warning and caution) on product labels.
- Keep MSDS sheets in appropriate vehicles.
- Refer to MSDS reference website for updates.

## Herbicide safety



### Herbicide use

To achieve maximum benefit from any herbicide program, you must select appropriate chemicals and follow proper application procedures. The way an herbicide can be used and applied depends on the characteristics of the active ingredient (ai), the chemical that does the work: whether it is absorbed by foliage or by the root system, whether it works on contact or is translocated, whether it is selective or nonselective and whether it is persistent or nonpersistent. The application timing and techniques employed will greatly affect the results. Timing depends on the stage of weed growth, weed pressure, weed and crop species, environmental conditions, soil type, and chemical characteristics of the herbicide. Choose the application technique based on the chemical activity (such as preemergence versus postemergence), treatment area, proximity of nontolerant crops, chemical formulation, and available resources.

### Herbicide mode of action

**Contact herbicides** control weeds by direct contact with plant parts and are usually applied directly to plant foliage. Contact herbicides are sometimes called “chemical mowers,” because they kill only

the plant parts contacted by the herbicide. They are most effective in controlling annual weeds, but will kill the tops of perennial weeds. Results are obtained from within a few hours to a few days and require favorable plant conditions for optimum performance. Contact herbicides are often added to root absorbed ones to speed up plant kill. A contact herbicide such as fosamine (Krenite®) can be applied in July through September to inhibit bud expansion the following spring.



Krenite® applied to this roadside edge killed the foliage it contacted.

**Systemic herbicides** are absorbed through plant foliage, shoots or roots and move throughout the plant. Foliar applied systemics are absorbed through green leaf or stem tissue. Glyphosate is an example of a foliar applied systemic that must be applied to green tissue in order to be effective. Root absorbed herbicides

## Herbicide use

- Choose the herbicide, application technique, application timing to achieve maximum benefits with minimum exposure to non-targets.



A directed spray of glyphosate was used to control Japanese stilt grass and other weeds on the roadside edge.

require precipitation to become dissolved and moved into the root zone. Residual root absorbed herbicides have a low order of solubility, and depending upon the amount applied, will remain in the soil for various lengths of time making it nonproductive for plant growth. Nonresidual herbicides rapidly break down completely in the soil and have no effect on soil productivity. Systemic herbicides accumulate in growth centers where they speed up and disorganize cell division or interfere with food production. Death of the plant occurs after a period of time, perhaps even weeks or longer following the absorption of the herbicide into the plant. Systemics comprise the majority of highway related herbicides.

#### Herbicide selectivity

**Non-selective herbicides** will kill or control almost all plants. Non-selective herbicide application may be used to control vegetation periodically in the following roadside situations:

- Bridge ends and bridges sites
- Curb, gutter and sidewalk edging
- Delineators and signs
- Drainage ditches, culvert ends
- Fences
- Guardrails overgrown with broadleaf weeds or woody plants
- Rip rap
- Under asphalt

**Selective herbicides** are those that control undesirable vegetation without seriously injuring surrounding desirable plants. Selectivity is a relative rather than an absolute characteristic and is influenced by plant factors, chemical and application factors, and environmental factors.

*Plant factors* – Plant structure, leaf shape and leaf surface affect susceptibility to herbicides. Flat, wide leaves will retain a spray solution, while the spray will bounce off narrow, vertical leaves. Waxy leaf coatings and thick hair can prevent an herbicide solution from entering a leaf. Young plants have thinner cuticles and less hair, so selectivity is often based on the weed life stage. Sometimes perennials are especially susceptible to herbicides when in the bud-to-flower stage of growth. Variation in growing points between grasses (growing point at or below ground) and broadleaf plants (exposed growing points) can be a

- Contact herbicides control only the tissue touched by the herbicide.
- Systemic herbicides are translocated throughout the entire plant.

**Herbicide mode of action**



A selective broadleaved herbicide was used to control broadleaves in this warm-season grass planting.



By using a directed spray of glyphosate, hayscented ferns were saved, while Japanese stilt grass was controlled.

way to achieve selectivity. Weeds are most susceptible to herbicides when they are seedlings or when rapid growth is taking place in another growth stage. Tough-to-control woody plants like poison ivy and multiflora rose are controlled best in late summer to early fall when they are well-established and flowering. Actively growing plants take up and translocate herbicide throughout the entire plant. Plant physiology, the chemical differences between plant species, can control selectivity.

*Herbicide and application factors* – Selectivity can be controlled by application rate (high rates are nonselective but lower rates are selective), formulation (granular vs. spray), placement and application timing. Directed sprays, wiper treatments or suspension in gel, can allow the applicator to apply an herbicide selectively to weed species without harming desirable species. The following times of application also result in selectivity:

Pre-emergent treatment – Treatment made prior to the emergence of weeds. An



A preemergent herbicide was applied early in spring, allowing the Amsonia to bloom in a relatively weed-free bed.

herbicide barrier is created that kills newly germinated weeds before they emerge.

Post-emergent treatment – Treatment is made after the weed and desirable plants emerge. These treatments must employ some method of selectivity.

*Environmental factors* – Soil placement and texture can affect herbicide activity. By placing the herbicide near the surface, you can control shallow-rooted weeds without harming deep-rooted plants. Sandy soils, clay soils and highly organic soils tie up herbicides differently and affect plant availability and therefore toxicity. Most herbicides are not effective when applied to dry soils. Some herbicides become



highly toxic when temperatures are high, causing excessive volatilization and plant injury.

## Herbicide selectivity

- Non-selective herbicides kill or control almost all plants. They can be used selectively by applying through spot treatment or applying when the weeds are susceptible and the desirable plants are tolerant of the herbicide.
- Waxy leaf coatings and dense hairs can make some plants less susceptible to herbicides.
- Younger plants (seedlings) are usually more susceptible to herbicides.
- Plants that are in a rapid growth stage are usually more susceptible to herbicides.
- Woody plants like poison ivy and multiflora rose are most susceptible to herbicides in late summer to early fall.
- Selectivity can be achieved by using lower rates of herbicides.
- Selectivity can be achieved by applying the herbicide to the weed only through spot treatment with a directed spray or suspension in a gel, or wick application when the weed is taller than the desirable plants.
- Pre-emergent herbicides are applied prior to weed emergence and control annual weeds.
- Post-emergent herbicides are applied after emergence and must be used selectively.

## Herbicide formulations

The active ingredient in an herbicide is the chemical that does the work. Active ingredients can rarely be used in their pure form. They are usually changed or mixed with inert ingredients to make them convenient to handle and safe, easy, and accurate to apply. An herbicide formulation contains the active ingredient along with a liquid or dry carrier and may also contain surfactants, emulsifiers, or other adjuvants to improve the safety or performance of the active ingredient or both.

Some formulations are ready for use. Others must be diluted with water or some other liquid carrier specified on the label. The label directions explain how to use a formulation. The most common liquid and dry formulations are discussed here.

**Liquids or aqueous suspensions (L or AS).** Some active ingredients can be produced only as a solid or, at best, a semisolid. These solids are finely ground and suspended in a minimal amount of liquid carrier (water) for a flowable

formulation (which is often about the consistency of latex paint). The fine particles in these formulations seldom clog spray nozzles, but require agitation to prevent settling in the spray tank.

**Emulsifiable concentrates (EC or E).**

An emulsifiable concentrate is a liquid formulation that can mix with water to form an emulsion (typically turns milky-white in water). Each gallon of an EC usually contains 1 to 8 pounds of active ingredient. Diluted ECs usually need little agitation in the spray tank. The carrier is generally an organic solvent. An emulsifier is added to permit mixing of the organic solvent with water. The emulsifying agents and solvents in EC formulations can damage some crops. These crops may require a different formulation of the active ingredient, such as a wettable powder or granule.

**Solutions (S).** True solutions contain a mixture of two or more substances, the solute (active ingredient) and a solvent (usually water). Those true solutions that are soluble in water require no agitation in the spray tank. Highly concentrated solutions are possible as special formulations.

**Liquified gases.** Some fumigants are gases that become liquid when under pressure. For this reason, such formulations are stored under pressure, which may be either high or low, depending on the product. These formulations are applied by:

- injecting them directly under tarps.
- releasing them under tarps, or
- releasing them into structures such as pot and equipment storage areas.

Other active ingredients remain liquid in an ordinary container but turn into a gas or vapor when or after they are applied. These formulations do not require storage under pressure. Consequently, they must be put into the soil or confined in a space before they change to a gas; otherwise, they could be lost to the air.

**Wettable powders (WP or W).** These are dry, finely ground herbicide formulations. They look like dusts, but unlike dusts they are designed to mix readily with water and most are more concentrated. They contain 15 to 98 percent active ingredient, usually in amounts of 50 percent or more. Wettable powders form a suspension rather than a true solution when added to water. To maintain this suspension, good agitation is needed in the spray tank. Compared to ECs, good wettable powders are safer to use on plants. However, dust can be a problem when mixing wettable powder formulation.

**Water dispersible granules (WDG or DG) and dry flowables (DF)** are improved versions of wettable powders. The WDG, DG and DF formulations readily pour from containers with little or no dust. Active ingredients in these formulations are expressed as a percent by weight. For

example: a Gallery 75 DF contains 75 percent isoxaben, or 75 pounds of isoxaben in every 100 pounds of Gallery 75 DF.

**Soluble Powders (SP).** Soluble powders are also dry formulations. When they are added to water, they completely dissolve to form true solutions. The mixture in the spray tank may need to be agitated for these solutions to dissolve. Once they have dissolved, no more agitation is usually needed. The amount of active ingredient in a soluble powder may be between 50 percent and 94 percent.

**Granules (G or GR).** Granular formulations are small, individual particles that are applied dry. Most are made by applying a liquid formulation of an active ingredient to inert coarse particles (granules) of some porous carrier material. Carrier materials often used are clay, ground corn cobs, or recycled newspaper. The pesticide is either absorbed into the granule, coats the outside, or both. The amount of active ingredient typically ranges from 1 to 10 percent. Granular formulations are used most often as soil treatments and are applied either directly to the soil or over plants. Granular formulations should always be applied dry. Never mix them with water. However, granules require rainfall or irrigation to activate the herbicide and to remove

excess chemicals from the foliage. Certain preemergence herbicides, such as oxyfluorfen and oxadiazon, can injure plant foliage, especially if the foliage is wet. Formulating these compounds as granules reduces the potential for foliar uptake and crop injury.

Granular formulations of preemergence herbicides can sift through dense foliage onto the soil surface, unlike liquid formulations that may adhere to foliage and prevent soil contact. Placement on the soil surface enables the herbicide to work properly and may enhance its selectivity with marginally sensitive plants. However, there are several difficulties associated with the use of granules.

- Runoff water from excess rain or irrigation may remove the granules.
- Granules may collect in the crowns of rosette-form plants or leaf bases, causing injury.
- Compared to other formulations, granules cost more per unit of active ingredient.
- The application rate is more difficult to control.
- Uniform herbicide distribution is more difficult to achieve than for sprayed formulations.

- Use an herbicide formulation most appropriate for the weed control situation.
- Read label directions for an explanation of how to use a formulation.



### Application equipment

**Conventional sprayers**, regardless of size have certain common components. Each has a tank, pressure source, pressure regulator and gauge, shutoff valve, and nozzles.

**Backpack or hand-held sprayers** are preferred when treating small areas. All the functional parts of a large sprayer can be found in these smaller sprayers, but there are some differences and limitations:

- The tank is smaller and lacks an agitator. Spray mixtures that contain wettable powder formulations require frequent shaking of the tank for agitation.
- The power-driven pump is replaced by continual positive displacement pumping, compressed air, or carbon dioxide (CO<sub>2</sub>).
- Often there is no pressure regulator other than the discretion and reliability of the operator. Applying herbicides accurately requires some level of pressure regulation, whether it is done by monitoring pressure gauges or by adding a pressure regulator to the system.
- The boom is smaller yet similar in design and function. With minor modifications most continuous-pump, compressed-air, or carbon-dioxide sprayers are satisfactory for applying herbicides to small areas (up to several acres).

For directed spraying beneath the foliage of sensitive crops, flooding nozzles can be used to direct a low-pressure spray to the lower few inches of the plant stem. On uneven terrain, these nozzles should be mounted on floating skids. Spray shields are often used in combination with directed sprays to further minimize injury from spray drift.

**Rope-wick applicators** were developed to apply herbicides to weeds that grow taller than the desired plants. Rope-wick applicators consist of a loop of rope saturated with a concentrated herbicide solution by a wicking action. The saturated rope is wiped across the tall weeds without touching the desired plant, thus preventing injury.

**Controlled droplet applications (CDA)** technology provides another option for herbicide application. The most commonly encountered CDA systems are Herbie and Micromax. The CDA system is based on releasing the spray liquid onto a spinning disk or cylinder, where it is spun to the outer edge and broken into droplets. The delivery to the outer edge of the capillary tubes, disc notches, or cylinder perforations produces droplets of more uniform size than those produced by conventional spray systems. The CDA system operates with little power and little or no pressure. Researchers claim that by using a CDA system to apply postemergence herbicides one can reduce the amount of pesticide needed because the droplets are in the best size range for

peak activity. However, additional data are needed to verify this claim.

CDA systems have a few disadvantages. Foliar penetration can be limited, especially in the gravitational types. They are unsuited to windy conditions. They make it difficult for the operator to see and direct the spray pattern. Furthermore, gravity-flow systems are particularly difficult to calibrate because slight changes to the concentration of herbicide in the spray solution will change the viscosity and flow rate through the sprayer.

**Granular spreaders.** As with sprayer application, accurately metering and distributing granular formulations is essential to achieving good weed control and minimizing plant injury. Granular spreaders distribute the herbicides in one of three ways: by gravitational drop, mechanically fed drop, and centrifugal force. All three types are available as tractor-mounted models or as smaller hand-operated spreaders.

*Gravitational drop spreaders* allow the granules to drop through an adjustable orifice. The application rate is adjusted by changing the orifice size, the travel speed, or both. Differences in size and density of the granules affect the rate of flow at any given orifice size. For example, smaller, heavier particles flow more easily than larger or lighter particles. A beater bar must be present within the chemical bin to prevent clogging and to ensure uniform

distribution to the orifice.

*Mechanically fed drop spreaders* have an orifice that can be replaced with a slotted roller or similar device that measures the volume of granules to be dropped. This method is more accurate but more expensive. The application rate can be adjusted by gearing the roller to the ground speed or by replacing the slotted roller with a roller of a different calibration.

*Centrifugal (or rotary) spreaders* drop the herbicide onto a revolving plate or oscillating arm from which it is expelled by centrifugal force. The application pattern is nonuniform; therefore, two fully overlapping passes in opposite directions are recommended. Hand-operated centrifugal spreaders should be geared so that the spinning plate revolves faster than the hand crank, reducing both operator fatigue and irregularities in swath width. Because these spreaders are versatile and highly maneuverable, they are the type most often used.

To ensure product effectiveness, do not apply herbicides when rain is likely within six hours of application. You must read the label before you mix or use any product. Add surfactant to most liquid applications to achieve best control. Allow approximately 10-14 days after application for systemic herbicides to be translocated before disturbing the site. Allow time for one application of herbicide followed by a follow-up application to control spots that were missed during the first treatment.

**Equipment calibration** – is required to apply the precise amount of herbicide.

*Calibration of large ground sprayers:*

1. Measure the output of all spray nozzles and replace any whose output varies more than 10 percent from the average output.
2. Fill the spray tank with clean water to a marked level.
3. Select throttle and gear settings for the desired speed of travel and operating pressure. Spray the water over a pre-measured distance – for example, 500 feet.

4. Measure the amount of water required to fill the tank to the original mark. This is the amount that was delivered over the spray area.

*Or follow alternate step 4.*

4. Measure the time it takes to travel the measured distance. Then collect the sprayer output for that time. You may collect the output of one nozzle and multiply that by the number of nozzles.

The volume (number of gallons) applied per acre for broadcast spray applications may be calculated as shown below.

Example: You want to treat 1 acre using a spray boom with six nozzles spaced 20 inches apart. When calibrated, the spray rig took 105 seconds to travel 500 feet. It sprayed a total of 365 ounces of water in this time. How many gallons, at this calibration, will it take to cover one acre?

**Step 1:**

Convert the number of ounces delivered to gallons using this formula:

$$\frac{365 \text{ oz}}{128 \text{ oz/gal}} = 2.85 \text{ gal}$$

**Step 2:**

Calculate the number of square feet treated during the calibration by calculating swath width and using the following formula:

**Spray swath width x distance = sq ft treated**

$$\left[ \begin{array}{l} \text{swath width} = 6 \text{ nozzles} \times 20 \text{ inch spacing} \\ = 120 \text{ inches or } 10 \text{ feet} \end{array} \right]$$

$$10 \text{ ft} \times 500 \text{ ft} = 5,000 \text{ sq ft treated}$$

**Step 3:**

The application rate is 2.85 gallons per 5,000 square feet. To convert this value to gallons per acre, use the following formula:

**$\frac{\text{Rate delivered}}{\text{area covered}} \times \text{square feet/acre} = \text{gallons per acre}$**

$$\frac{2.85 \text{ gal}}{5,000 \text{ sq ft}} \times 43,560 \text{ sq ft/acre} = 25 \text{ gal/acre}$$



If the amount applied is different from the desired rate, correct it by changing the speed or nozzle size. A change in the operating pressure has less effect on the rate of application (increasing pressure four-fold will double output) yet significantly affects spray drift. Higher pressure makes the droplet size smaller, so drift is increased and more herbicide may be sprayed off-target. Once you know the volume applied in gallons per acre, you must calculate the amount of herbicide needed to achieve the desired application rate. The following example shows how to calculate the correct rate.

*Calibration of hand-held and backpack sprayers:*

To calibrate a small sprayer, it is recommended that you use 650 feet as the calibration spray area with an 80-inch boom (four nozzles set 20 inches apart). This area is 1/10 of an acre and will simplify calculations. To calibrate the sprayer, follow these steps:

1. Fill the spray tank to a known level with water, leaving at least one-fourth of the tank empty for air compression.
2. While maintaining a steady pressure (within 5 psi), spray 650 feet (measured before-hand).
3. Refill the tank to the original level, accurately measuring the amount of water required. The number of gallons used times 10 equals the number of gallons per acre the sprayer applies at your speed of travel.

Correct application depends on the applicator walking at the same speed during calibration as during field application.

Maintaining a constant speed of travel while spraying is important. The best speed of travel is one that is natural and comfortable for the applicator. Altering a person's natural pace will typically lead to inconsistent applications. However, a cadence which is comfortable for many is a normal military cadence, which with 30-inch steps equals 3 miles per hour. Some find it helpful to use a battery operated metronome to maintain a constant pace. To practice, measure 100 feet and walk this distance carrying the sprayer. Walking this distance at a speed of 3 miles per hour should take approximately 23 seconds.

To adjust the application rate, alter the concentration of herbicide in the tank or change nozzles. Once you have established a constant cadence, do not attempt to change the rate by adjusting ground speed. Doing so will produce an uneven application. As with large sprayers, periodically check the nozzle outputs, and replace any that vary more than 10 percent from the average.

*Calibration of granular applicators:*

The procedures for calibrating a granular applicator are similar to those used to calibrate spray rigs.

1. Collect the output over a known distance and swath width. Many spreaders

are equipped with catch pans for this purpose. For others, collect the granules in a plastic bag covering the spreader orifice.

2. Adjust the spreader orifice or ground speed until the desired application rate is achieved. Maintain a constant ground speed when using hand-held equipment.

3. Since the delivery rate varies for each formulation, the calibration procedure must be performed with each chemical, preferably by the person who will make the field application.

Hand-held granular spreaders are inconsistent and each unit must be calibrated for each granule to be used.

#### **Cleaning and care of equipment.**

When spraying has been completed, excess spray solution must be disposed of properly according to the manufacturer's and governmental guidelines. When cleaning spray equipment, make certain that the chemical solution does not drain into areas of desirable vegetation or into waterways. Rinse the tank and nozzles thoroughly with water or a cleaning solution appropriate for the chemical used. Partially fill the tank and run clean water through the system for several minutes.

Many companies suggest lubricating the moving parts periodically. Consult the owner's manual for specifics. If no spraying is scheduled for some time,

remove both the pump and nozzle. Never clean nozzles with wire, knives, or other hard-surfaced objects. They can damage the nozzle, which may change the spray pattern and delivery rate. Soft wood (toothpicks), toothbrushes, or liquid solvents are recommended. Do not save worn out tips for later use. Throw them away. Keep spares of each type of tip and several diaphragm check valves in the spray unit. Prior to equipment storage over the winter season, flush tanks, boom, and hoses with several changes of water. Clean all tips and screens, dry them and store them in a lightweight oil. Antifreeze can be circulated through the system to prevent the pump from freezing or locking down if it is not used for a long period.

- Select the appropriate equipment for the formulation and application method.
- Calibrate equipment to insure the application of the precise quantity of herbicide required.
- Dispose of excess solution according to manufacturer's recommendations.
- Rinse applicator thoroughly and run clean water through system.
- Clean tips and screens and store in lightweight oil.
- Circulate antifreeze through systems when storing application equipment over the winter.

### Calculating application rates

Herbicide recommendations are made in one of two ways:

1. Amount of active chemical per unit area, such as 2 pounds of active ingredient (ai) per acre.
2. Amount of product per unit area, such as 3 quarts per acre.

The examples that follow illustrate how to calculate the amount of herbicide required to meet the recommended rate for a given area.

**Example 1:** The herbicide label shows that the product contains 4 pounds of active ingredient per gallon. The recommended application rate is 6 pounds of active ingredient per treated acre. How many gallons of product do you need to treat 1 acre?

Complete the following steps to convert from pounds of product to pounds active ingredient (ai) or vice versa. Substitute the values from the label into the following formula:

$$\frac{\text{amount of ai}}{\text{amount of formulated}} = \frac{\text{desired ai/acre}}{\text{amount of product}}$$

After setting up the formula, (step 1) cross multiply (step 2) and then divide both sides of the equation by 4 lb ai (step 3):

**Step 1:**

$$\frac{4 \text{ lb ai}}{1 \text{ gal product}} = \frac{6 \text{ lb ai/acre}}{? \text{ gal of product/acre}}$$

**Step 2:**

$$4 \text{ lb ai} \times ? \text{ gal of product/acre} = 6 \text{ lb ai/acre} \times 1 \text{ gal of product}$$

**Step 3:**

$$? \text{ gal of product/acre} = \frac{6 \text{ lb ai/acre} \times 1 \text{ gal of product}}{4 \text{ lb ai}}$$

$$= 1.5 \text{ gal of product/acre}$$

Therefore, 1.5 gallons of product contains 6 pounds of active ingredient. This amount must be accurately distributed over 1 acre.



**Example 2:** Suppose that you want to apply 4 pounds active ingredient of a 90 percent wettable powder (90W) formulation per acre. How much of the product would be required per acre?

Use the following formula to solve the problem:

$$\frac{\text{ai/acre}}{\% \text{ of ai in product}} = \text{product needed/acre}$$
$$\frac{4 \text{ lb ai/acre}}{0.90 \text{ (or 90\%)}} = 4.4 \text{ lb of product per acre}$$

Thus applying 4.4 pounds of a 90 percent wettable powder formulation per acre will produce the desired rate.

#### Additional application methods

**Stem cutting** – cut at or near ground level and treat with herbicide (such as glyphosate (Roundup® Pro) or the amine formulation of triclopyr (Garlon®) or use repeated cutting to deplete plant resources.

**Basal bark treatment** – Use herbicides that penetrate the bark of trees, especially seedlings. Spray Garlon 4® (triclopyr mixed with petroleum based oil) to a height of 12-15 inches around trunk.

**Bare ground (complete) vegetation control** – Bare ground situations may be appropriate where there is a specific reason for such a treatment. Treating the edge of pavement or vegetation encroachment within paved shoulders are good examples where bare-ground herbicide rates may be appropriate. Continuous bare ground treatment, especially on sloped areas, increases the potential for erosion and sediment loss. For those areas that receive bare-ground herbicide applications, additional spot-treatments may be necessary. Application of an excessive quantity of herbicide is not economical and may result in damage to nearby desirable vegetation. Complete control may be achieved by using Roundup® Pro at a 4 quart per acre (9.3 liters per hectare) rate.

## Calculating application rates

- Use the preceding examples to learn how to calculate the amount of product required to cover a given area.

- Stem cutting and basal bark treatment can be used to apply a small quantity of herbicide directly on the targeted plant, dramatically reducing the quantity of herbicide applied as compared to a foliar spray application or broadcast granular application.
- Bare ground control is only appropriate in limited situations and care must be taken to reduce potential for erosion.

### Spray drift control

Drift is a side effect of pesticide use associated with ground and aerial application. Drift is the uncontrolled airborne movement of spray droplets, vapors, or dusts particles, away from the intended point of application. Drift is important because of potential injury to non-target plants and animals, and the potential for producing illegal residues on non-target food crops.

Virtually every pesticide application produces some amount of drift. How much drift depends on such factors as the formulation of the material applied, how the material is applied, the volume used, prevailing weather conditions at the time of application, and the size of the application job.

Pesticide applications, which are directed upwards or made by aircraft, are the most likely to be subject to drift. Pesticide application by aircraft can result in residue problems on sites that are distant from the actual application site. Pesticides released close to the ground are not as likely to be suspended in the air as those released from a greater height or distance from the target.

Air currents very easily carry lightweight particles, especially dusts and

low volatility vegetable oils. Heavier formulations such as granules and pellets settle out of the air very quickly. High pressures and small nozzle openings produce very fine spray droplets with accompanying high drift potential. Lower pressures and larger nozzle openings produce coarser sprays with larger droplet sizes having less drift potential.

Vaporization (volatilization) increases as:

- Air and surface temperatures increase
- Relative humidity increases
- Particle or droplet size decreases
- Air movement increases

Drift control is the responsibility of the applicator. DelDOT applicators and contractors are required to use drift control agents. Drift cannot be completely eliminated, but it can be greatly reduced.

## Spray drift control

- Use as coarse a spray as possible and still obtain good coverage and control. For sprays, use a formulation that gives large diameter spray droplets (150 microns or larger). Droplet size is one of the most important factors affecting drift; however, addressing droplet size alone is not sufficient to reduce the probability of drift and potential damages.
- Don't apply pesticides under windy conditions; don't apply at wind-speeds over 10 mph.
- Use drift control/drift reduction agents. These materials are basically thickeners and are designed to minimize the formation of droplets smaller than 150 microns. They help produce a more consistent spray pattern and aid in deposition. Some of these are: LoDrift, Nalcotrol, 41-A and Nalcotrol II.
- Choose the formulation carefully. Water based sprays will volatilize more quickly than oil based sprays, however, oil-based sprays can drift farther because they are lighter, especially above 95° F.
- Apply pesticides early in the morning, when feasible; the air is often more still than later in the day.
- Don't spray during thermal inversions, when air closest to the ground is warmer than the air above it. When possible, avoid spraying at temperatures above 90-95° F.
- Use a solid cone or fan spray nozzle. These produce larger droplet sizes than hollow cone nozzles.
- Be sure you are getting the spray deposition pattern you think you are; maintain and calibrate your equipment regularly.
- Check for system leaks; small leaks under pressure can produce very fine droplets.
- Determine wind direction and take this into account in determining application timing, equipment and whether or not to make an application. The wrong wind direction can cancel out everything else you have done to reduce drift.
- For application of liquid and dry formulations, commercially available or homemade shrouds or skirts attached over or behind the application equipment can help prevent spray droplets and pesticide particles from becoming airborne.



### Specific recommendations

**Invasive woody plants** – such as Norway maple, will require stump treatment after physical removal. Both physical removal and chemical control are required for invasive vine removal on forest edges. After physical removal, follow up with chemical control of resprouts and planting of desirable colonizing species to reestablish an attractive, healthy forest edge. When patches of weeds are removed in an existing planting, the space occupied by the weed must be replanted for aesthetics and to prevent recolonization by the same or another weed.

**Meadows** – Weed control is a critical component of meadow establishment. Inspect a newly seeded meadow 4 to 6 weeks after planting to identify weed species present. For grass meadows, mow 2 to 3 times during the first year. Apply Plateau® the second year if the meadow is predominantly indiangrass (*Sorghastrum nutans*). Apply 2,4-D, dicamba and MCPP the second year if the meadow is predominantly switchgrass (*Panicum virgatum*). Another strategy is to apply glyphosate early in the season after weeds have emerged but before warm-season grasses have emerged.

In a planting comprised completely of forbs, use a grass herbicide (ethoxydim (Barricade®) or fluazifop (Acclaim®)). Several preemergent herbicides—metolachlor (Pennant Magnum®), EPTC



Bittersweet, grape and honeysuckle were controlled repeatedly and this sunny opening along Wyoming road was planted with locally indigenous shrubs to discourage recolonization by invasive vines.

(Eptam®), trifluralin (Treflan®), benefin (Balan®) and pronamide (Kerb®)—are tolerated by seeded forbs (including yarrow, coreopsis, evening primrose, black-eyed susan and goldenrod). Good to excellent preemergence control of many annual grasses and broadleaved weeds can be expected with those herbicides once desirable plants are established.



Broad leaved weeds can be controlled using a grass herbicide in a meadow sown to warm-season grasses only. Once broadleaved weeds are controlled and grasses have filled in, desirable broadleaved forbs can be added.

**Stormwater ponds.** Debris and erosion are the major stormwater facility problems. Selectively treat undesirable vegetation in buffer zones or on slopes/banks and at bottom of dry ponds. Undesirable vegetation includes invasive species in any area or woody plants growing on manmade dams or embankments. Take care when removing plants not to create erosion problems. Maintain vegetation so that hydraulic structures are easily accessed for inspection and maintenance.

In **wetland mitigation sites**, control invasive plant species annually by spot treating with a wetland-appropriate herbicide.

#### Sensitive areas

Sensitive areas along the roadside include rights of way adjacent to any body of water. DeIDOT personnel and contractors will be responsible for knowing the location of all sensitive areas. In these locations, vegetation must be managed without the use of herbicides or with only aquatic-labeled herbicides.

### Specific recommendations

- Use a combination of physical removal and stump or resprout treatment for invasive woody plants.
- Control weeds aggressively during the first three years of meadow establishment. Use selective broadleaf herbicides on grass meadows and selective grass herbicides on forb meadows.
- Control invasive woody plants around stormwater ponds and wetland mitigation sites using an herbicide appropriate for use around water.
- Follow good housekeeping practices in maintenance yards to prevent pollution and reduce the sources of contamination to stormwater facilities.

### Sensitive areas

- Know the location of all sensitive areas.
- Manage vegetation in sensitive areas without herbicides or with aquatic labeled herbicides.

## Product policies

Equipment operators employed by DeIDOT will use only herbicides approved for use in sensitive areas on any roadside right-of-way unless authorized in writing by the Roadside Environmental Administrator. DeIDOT requires all glyphosate products to have an aquatic label. Restricted use pesticides are prohibited on DeIDOT roadsides. A chart of pesticides for use on Delaware roadsides is included in Appendix G. Any new pesticides must be approved by the Roadside Environmental Administrator prior to use on Delaware roadsides.

- DeIDOT equipment operators may use herbicides approved for sensitive areas only (unless they acquire written approval).
- No restricted use herbicides will be used on Delaware roadsides.
- All glyphosate products must have an aquatic label.
- All new products must be approved by the Roadside Environmental Administrator.

## Product policies



## **Fertilization**

### Turf

Take a soil sample prior to establishing turf and correct soil fertility and pH based on soil test results. Plant nutrients are essential for turf growth. Thus, they must be present in adequate amounts in the soil for optimum turf growth. The primary nutrients – nitrogen, phosphorus, and potassium – are used by turf in large quantities, and they are the most likely to be deficient. Nitrogen gives the turf a dark green color and promotes rapid vegetative growth. Phosphorus promotes root formation, and potassium aids in translocation of food and increase disease resistance and health. Fertilize residential quality turf by applying one pound of nitrogen per 1000 square feet in September/October in the form of a complete fertilizer. Do not fertilize utility turf, unless soil tests indicate a specific nutrient deficiency.

### Trees and shrubs

Do not apply fertilizer during the first year after planting. Fertilizer may burn tender roots and promote top growth before the root system becomes well established. Fertilize as needed in subsequent years depending upon the prominence of the planting. Generally two to four pounds of a complete fertilizer per 1000 square feet per year are recommended for optimum growth, depending on the plant species. The

fertilizer is applied by broadcasting. One application may be all that is needed on mature plants, while more than one application may be required on young plants. Fertilizer should be applied before spring growth if possible. Watering after fertilization is recommended. Trees confined to small planting areas usually have a greater need for fertilizer.

### Lime

Lime is required when the soil is acidic, i.e., pH below 5.5. The pH of the soil is usually determined through soil analysis. When the soil pH is low, phosphorus and several of the micronutrients become unavailable for plant use. Lime raises the pH of the soil and, thus, the availability of those nutrients to the plant increases. Liming is important in the maintenance of a healthy turf and it should be done whenever soil test reports indicate a need for lime.

The amounts of clay and organic material greatly affect liming rates. The lime requirement increases with increasing amounts of clay and/or organic matter. The following table shows the amount of lime needed to raise the pH from 5.5 to 6.5 in soils with various textures.

Lime does not move readily through the soil. Therefore, it should be mixed well with the top 4-5 inches of soil during seedbed preparation. On established turf, a centrifugal spreader or a drop spreader is used to evenly broadcast lime and,

thus, increase its effectiveness.

Ornamental plants vary in their pH requirements. Most plants grow best if the pH is maintained between 6.0 and 7.0. Some exceptions are azaleas, camellias, pieris, and rhododendrons, which grow well in the pH range of 5.0 – 6.0.

Relationships between soil-buffer and lime requirements for target pH values of 5.5, 6.0, and 6.5 for mineral soils.			
Soil buffer pH	Lime requirement*		
	pH 5.5	pH 6.0	pH 6.5
	Mg/ha		
6.5	0	0	0
6.4	0	0.2	0.3
6.3	0	0.2	0.3
6.2	0.2	2.6	2.2
6.1	1.1	3.8	3.2
6	2	4.9	4.3
5.9	2.9	6.1	5.4
5.8	3.8	7.3	6.6
5.7	4.6	8.5	7.9
5.6	5.5	9.6	9.2
5.5	6.4	10.8	10.6
5.4	7.3	12	12
5.3	8.2	13.2	13.6
5.2	9.1	14.4	15.1
5.1	10	15.5	16.7
5	10.9	15.5	16.7
4.9	11.7	17.9	20.2
4.8	12.6	19	22
4.7	13.5	20.2	23.9
4.6	14.4	21.4	25.8
4.5	15.3	22.6	27.8
4.4	16.2	23.7	29.8
4.3	17	24.9	32
4.2	18	26.1	34.1
4.1	18.8	27.3	36.4
4	19.7	28.4	38.7
3.9	20.6	29.6	41

\*Lime requirement values to soil pH 5.5 and 6.0 were developed by Tran and van Lierop (1982), and to soil pH 6.5 by Ssali and Nuwamanya (1981).

Table developed by J.T. Sims and published in Methods of Soil Analysis. Part 3. Chemical Methods-SSSA Book Series no. 5.

- Adjust soil nutrients and pH prior to planting turf or trees/shrubs/perennials based on soil sample test results and recommendations.
- Fertilize residential quality turf in the fall.
- Do not fertilize utility turf.
- Do not fertilize trees or shrubs at planting.
- Broadcast fertilizer to promote tree and shrub growth as warranted by location of planting.
- Apply lime as needed to raise soil pH in turf areas to 6.5.
- Adjust pH prior to planting trees, shrubs or perennials.

## Fertilization

## **Problems**

### Insect and disease

There are a wide variety of insect and disease problems that could negatively impact roadside vegetation. For a complete set of fact sheets on disease and insect problems common on Delaware turf, trees, shrubs and perennials visit the Delaware Cooperative Extension Home and Landscape Horticulture website (<http://ag.udel.edu/extension/horticulture/index.htm>). Fact sheets provide pest identification and control recommendations.

### Cultural problems

Insects and disease-causing pathogens are not usually the primary reasons for trees failing even though they may be the first things that come to mind when you recognize unhealthy trees. Typically, insects and diseases are the secondary agents that attack already weakened, wounded, improperly treated, neglected or generally unhealthy trees. Healthy, vigorous trees have defense mechanisms to combat insect and disease problems. In order to maintain healthy trees in an urban environment, it is necessary to identify and avoid some basic cultural mistakes.

**Compaction** - When soil is excessively compacted, there is no room for the oxygen necessary for the health of tree roots. Eliminate traffic over the root system of trees.

**Excess mulch** - A two- to three-inch layer of mulch is sufficient. When mulch is piled upon mulch each year, roots grow into the mulch layer. Those roots are susceptible to drought stress and winter injury. Mulch can also become crusted, causing water to run off. Add mulch to maintain a two- to three-inch layer only as the old mulch decomposes. Rake the mulch periodically to break up the crust that forms, then incorporate it into the soil.

**Trunk, bark, branch and root damage-** Any damage to the physical integrity of the tree provides an entry point for insects and disease organisms. Keep lawn mowers and string trimmers away from the base of trees. Do not fasten bicycle lock chains around tree trunks. Never put nails into the tree trunk.

**Supports, wire, twine and tree wrap** - Supports, wire and twine left on newly planted trees are common causes of girdling damage. The girdling will gradually cut off the flow of water and nutrients and by the time damage becomes noticeable the tree can be near death. Tree wrap left on too long provides a haven for insects and can cause girdling. Remove all twine and tree wrap at planting and remove supports after one growing season.





Failure to keep mowers away from the base of this tree has resulted in damage that is likely to necessitate replacement.

**Salt damage** - Salt used on roads and sidewalks for de-icing will cause tree root damage. De-ice sidewalks with sand, ash or calcium chloride instead of sodium chloride or rock salt.

**Soil grade changes** - Adding or removing even a small amount of soil at the surface of the tree's root zone will damage the tree. Excess soil on top of the roots reduces the oxygen available. Since most of a tree's roots are in the top 6 inches, removal of soil also means removal of roots. Avoid grade changes greater than 2 inches. Be aware that the root system may spread far beyond the furthest branches (drip line) of the tree, typically two to three times or more.

#### Diagnosing problems

There are several signs that can help pinpoint tree problems while they are still treatable:



The root flare is clearly visible on this newly planted oak indicating that the tree is planted at the proper depth.

**Root flare** – Look to see if the tree enters the ground with a natural flare or swelling. No flare may mean soil has been filled around the tree and roots are suffocating. No flare may also mean there is a girdling root restricting food, nutrients, and water.

**Crown dieback** – Search for dead twigs or branches dying back from the tips to the trunk in the tree crown. Dead twigs and branches may mean old age, insect or disease infestation, or root injury. Crown dieback may indicate too much or too little moisture, or too much competition.

**Abnormal leaf size** – Larger or smaller leaves than normal can indicate problems. A tree that has leaves smaller than the normal size may have a root injury. Leaves that are larger than normal, especially on root suckers, can also indicate root damage.

**Trunk scars** - Partially “healed”

wounds on trunks may be signs of hidden decay. Look for ragged scars on the trunk that are not callused over. To speed callusing, remove damaged, ragged tissue carefully with a sharp knife. Coating wounds with preparations has not proven to promote healing, and coatings can trap water and provide habitat for insects and diseases that cause damage and decay.

**Yellow foliage** - The general yellowing of a leaf, often called chlorosis, can be caused by a variety of factors including insects, disease, too much moisture, cold weather, air and soil pollution, excess minerals in the soil, nutrient deficiencies, or a pH imbalance.

## Problems

- Visit the Delaware Cooperative Extension Home and Landscape Horticulture website. (<http://ag.udel.edu/extension/horticulture/index.htm>) for fact sheets on diseases and insects.
- Maintain healthy trees and shrubs by avoiding common cultural problems such as compaction, excess mulch, mower damage to trunks, girdling from wire, salt damage, and soil grade changes.
- Lack of root flare, crown dieback, abnormal leaf size, trunk scars and yellow foliage can all be signs of plant problems.

## Record Keeping

### DeIDOT Forms

A Pesticide Application Daily Report Form must be completed after each pesticide application. Forms are available on the DeIDOT intranet. Forms should be stored in the district office and must be kept for two years after the application date. Send a copy of each completed form to the Roadside Environmental Supervisor. The application information will be keyed in to a database. The herbicide database will be used to track trends in herbicide use. A sample form is found in Appendix B.

- After every pesticide application, complete a Pesticide Application Daily Report Form.
- Send a copy to the Roadside Environmental Supervisor.
- Keep a copy in the district office for two years.

## Record Keeping



## Inventories

### Guardrails

A guardrail inventory was conducted for DeIDOT by a private contractor in 2008–2009. The inventory includes all guardrail sections on DeIDOT maintained roadways throughout the state of Delaware and attribute data for each section. A field-verified inventory of all guardrail sections will include GPS locations data for the beginning and end of each section. Attribute data includes material of construction, material beneath guardrail, guardrail end treatment, guardrail to barrier connection, surrounding landscape and environmental features and landscape photos. The guardrail inventory will be included in the DeIDOT GIS database system and the NPDES Inventory Database.

### Existing stormwater system

Locations of all wet ponds, extended detention dry ponds, sand filters, filter strips, biofiltration swales, bioretention facilities, infiltration trenches and storm drains are included in DeIDOT's NPDES GIS database system and available to every DeIDOT employee.

### Noxious and invasive weeds

Locations of noxious weeds are identified by Roadside Environmental Supervisors, and control recommendations are made to prevent the flowering of noxious weeds on DeIDOT property. Pesticide application forms and the herbicide use database are used to identify sites known to contain noxious or invasive weeds. Yearly inspection by Roadside Environmental Supervisors is used to identify noxious and invasive weed sites.

The Delaware Invasive Species Council maintains a database of invasive weed locations throughout the state.

## Inventories

- The guardrail inventory includes all sections of guardrail with GPS coordinates for the beginning and end of each section as well as guardrail attribute data for each section.
- All stormwater BMPs can be found on the DeIDOT NPDES GIS database system.
- Records from previous years and yearly inspections are used to identify noxious and invasive weeds on DeIDOT rights-of-way.

## Training Program

Routine training for DeIDOT maintenance personnel is conducted on a yearly basis. Training includes information on pesticides, application techniques, calibration and equipment maintenance. Training videos on Facility and Vehicle Maintenance, Stormwater Contamination and Spill Prevention and Vegetative Control and Pollution Prevention on Public Roads and Highways are available for district personnel. Annual viewing is required by the NPDES section. Training for mowing supervisors is conducted each spring prior to the mowing season. All DeIDOT employees who apply pesticides must become Certified Pesticide Applicators in the state of Delaware. To maintain certification, all applicators must attend 8 credits of recertification programs over a three-year period. All DeIDOT applicators must attend recertification and take an internal exam each year.



Bringing DeIDOT maintenance employees to roadside plots is critical for explaining detailed instructions such as mowing regimes and herbicide treatments.

- Annual viewing of NPDES videos is required.
- Training for mowing supervisors is conducted each spring prior to mowing season.
- All DeIDOT employees who apply pesticide are certified pesticide applicators.
- All DeIDOT applicators attend yearly recertification and complete an internal exam.

## Training Program

# Glossary

**Adventitious roots** – Roots arising from an unusual or irregular location.

**Aesthetic order** – A set of design principles relating to order and beauty; especially as they relate to plants.

**Annual** – A plant that completes its life cycle in one growing season.

**Balled & burlapped plant (B&B)** – Field grown plants harvested with a root mass and soil (root ball) contained by burlap. This is a common production method for woody shrubs and trees. Not typically used for herbaceous plants.

**Bare-root plants** – Field grown woody plants harvested with a root mass that is lacking soil. Bare root plants are typically used only when plants are in a dormant state.

**Berm** – Soil or earthen embankment erected to provide protection from the elements or to act as a landscape screen.

**Best Management Practices (BMP)** – Cover a wide spectrum of management practices. Some address introduction of Integrated Roadside Vegetation Management. BMPs also refer to implemented procedures for stormwater management.

**Biennial** - A plant that completes its life cycle in two growing seasons. Biennials typically undergo vegetative growth during

the first growing season and reproductive growth during the second.

**Biodiversity** – The variety of organisms present in a given ecological community. The variety of life forms that exist in an ecosystem, including different genetic, species and natural communities.

**Biofiltration swales** – An open and gently sloping vegetated channel (minimum 6 inches grass height) designed for treating stormwater runoff.

**Broadcast seeding** – The simple dry distribution of seed often mixed with a carrier such as sawdust to improve dispersal.

**Broadleaf herbicides** – Formulation of chemicals designed to combat weeds with a broad leaf. These herbicides are to be applied directly to the leaf, a practice that requires the leaf to be visible and actively growing. Also called post-emergent control.

**Brush removal** – The process of cutting and removing woody plants by hand or mechanical means.

**Caliper** – The diameter of a tree trunk. It can be an approximate indication of age.

**Clear zone** – The total unobstructed and relatively flat area bordering the roadside that is available for safe use by disabled or out of control vehicles.



**Compaction** – The reduction or absence of air space in soil particles that results in restricted rooting depth thus causing the decrease or nutrient and water uptake by a plant.

**Container-grown plants** – Plants grown in an artificial medium within a container. This is a common practice for growing woody and herbaceous plants.

**Cool-season grass** – species of grasses that grow best in temperature ranges between 60°-70 ° F. They typically undergo summer dormancy. These species include most of the mowed turfgrasses.

**Cover crops** - A crop planted with the intention to protect the soil from erosion and to improve the soil through the addition of organic matter.

**Crimping** - Process by which straw mulch is secured to the seed bed by pulling a weighted disk across the seedbed and tucking the straw into the grooves that are created.

**Culti-packing** – Process by which soil is firmly packed to prepare a hard bed for planting thus ensuring efficient seed to soil contact.

**Cut back** - Periodic cutting of woody vegetation to maintain a dense and healthy growth pattern within certain parameters.

**Dibble** – A small hand tool used to make holes in the ground for seeds, bulbs or roots.

**Discontinued mowing** – Cessation of routine mowing that results in the release of desirable regional vegetation.

**Disturbed sites** – Sites that have had the topsoil removed or altered. Re-vegetation is essential for stabilization of the soil and to prevent weed infestations.

**Ditch lines** – The imaginary line to the bottom of a V ditch or to the back of a flat bottom ditch.

**Dormancy** – The period of a plant's life cycle when growth, development and physical activity is temporarily suspended.

**Drainage ditch** – A small or shallow depression in the land created to drain water from low-lying areas along roadsides.

**Drill seeding** – The placement of seed in a shallow trench created by a disc.

**Ecology** – The study of interactions between organisms and the environment.

**Ecosystem** – A naturally occurring system encompassing all plants, animals and micro-organisms that function in conjunction with the non-living elements of the surrounding environment.

**Editing** – The evaluation of existing vegetation and identification of opportunity to introduce aesthetic order by highlighting individual specimens or plant groups through the process of removal of unwanted vegetation.

**Embankment** – A raised mound of earth used for the purpose of supporting a roadway or to hold water back.

**Ephemeral** – Short-lived plant.

**Erosion** – The gradual breakdown or transportation of rock or soil through wind or water.

**Eutrophic** – A state in which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life and usually results in the depletion of dissolved oxygen.

**Fertility** – The quantity and quality of nutrients present in a soil system.

**Filter strips** – A vegetated area that is situated between a shallow body of water and a disturbed land or roadway with the intention of filtering runoff and sediment as well as reducing the flow and velocity of storm water.

**Forbs** – Broadleaved flowering herbaceous plants.

**Friable soils** – A soil that crumbles easily when handled. This type of soil is ideal for the root growth of most plants.

**Gateway** – entrance or exit, such as to a community, city or state.

**Germination** – The process from which dormancy is broken and plant growth emerges.

**Girdling** – The process of completely removing a strip of bark around the tree's circumference resulting in the death of the tree.

**Habitat** – The natural conditions or environment of an organism, plant or animal; the place where it is usually found.

**Herbaceous** - Any non-woody plant. A plant that dies back to the ground after each growing season.

**Herbicide** – A chemical compound designed with the intent to kill plants, specifically weeds, or to inhibit their growth.

**Humus** – Organic matter that has broken down completely in a soil while also functioning to amend the soil.

**Hydrology** – The study of movement, distribution and quality of water.

**Hydroseeding** – The distribution of seed with fiber mulch through a stream of high-pressure water.

**Innocuous species** – A species of plant or animal that is not harmful or oppressive to others.

### **Integrated Roadside Vegetation**

**Management (IRVM)** – Management process for maintaining roadsides that employs biological, cultural, mechanical and chemical pest control methods in order to efficiently manage vegetated roadsides for safety, aesthetic and environmental reasons.

**Invasive plant** - An aggressive plant that reproduces rapidly and spreads over large areas of land while stifling the growth of naturally occurring plants.

**Median** – A strip of land down the center of a road separating opposing lanes on a divided highway.

**Mulching** – Applying a protective layer of material over the soil to control weeds, prevent erosion, maintain even soil temperature and conserve water.

**Native plant (indigenous plant)** – A plant that originates in and is typical of a region. A plant that records indicate to be naturally occurring prior to colonization. For the purpose of this manual, “native plants” are native to Delaware.

**Naturalization** – The process of allowing existing soil banks to germinate and/or encroaching adjacent seed sources to take over.

**Non-selective herbicide** – A herbicide that kills all plants with which it comes in contact.

**No-spray zone** – A zone that has, by request, been authorized to be free of insecticide or chemical spray.

**Noxious weed** – A plant that is regulated by a state; it is illegal for property owners to allow these plants to go to seed or grow taller than 24 inches on their land.

**Ornamental plant** – A plant that is grown for its aesthetic qualities.

**Perennial** – A plant that lives for two or more growing seasons.

**Perennial forb** – Broadleaved herbaceous flowering plant (as opposed to the narrow-leaved grasses, sedges and rushes).

**Periodic mowing** – Mowing annually or as necessary to discourage establishment of woody species and maintain an herbaceous composition.

**pH** - A measure of acidity or alkalinity of a soil.

**Piedmont** – Area of the Eastern US characterized by the low rolling hills situated between the Appalachian Mountains and the coastal plain.

**Plant communities** – Associated plant species that form the natural vegetation of a place.



**Plugs** - Herbaceous plants grown in very small containers.

**Propagules** – Any cutting or plant part used for propagation.

**Regeneration** – A process that allows existing soil banks to germinate, and/or encroaching adjacent seed sources to take over. Proximity to natural plant communities and a diligence to remove invasive plants are necessary for success.

**Regional** - Limited to or typical of a specific area of a country. As it pertains to management strategies, a regional approach considers the local character and ecology of the place and allows for input of local citizens. To be truly regional, an application must be fitted to the local biological processes and systems, and must conform to the local knowledge of cultural and historical traditions that result from extended residence in a place.

**Regionally indigenous vegetation** – Vegetation that occurs naturally in a particular region or environment.

**Residential quality turf** – Turf maintained for aesthetic purposes.

**Restoration** - The process of improving the ecosystem health of disturbed land. Soils that are not disturbed will restore and re-vegetate without outside influence, but disturbed soils are subject to weed invasion, compromising the original ecosystem.

**Re-vegetation** – The process of returning plant cover to exposed or bare soils. Re-vegetation can occur through planting, allowing existing seed to germinate or by allowing seed from surrounding vegetation to encroach.

**Rhizome** – An underground stem that develops roots and shoots.

**Right-of-way** - A narrow strip of land along the route of a transportation corridor.

**Routine mowing** – Frequent mowing of the site to maintain a specified height of vegetation.

**Rush** – A marsh plant with slender stems.

**Sedge** – A family of plants that resemble grasses or rushes but are (distinguishable by their triangular stems).

**Seeding** - A random or informal distribution of herbaceous plants (grasses and forbs) that is economical and practical for large areas where the precise location of individual plants is not of primary importance.

**Selective herbicide** – An herbicide that kills or stunts an unwanted plant or weed while causing little or no harm to desirable species.

**Self-seeding** – Plants that come back year after year from seeds that have fallen from a plant in the area.

**Self-sustaining plant** – A plant that is able to sustain itself independently.

**Sense of place** – Can be an abstract or subjective concept. It is a place that gives us our identity in a social, topographical, historical, physical and vegetative construct.

**Soil horizon** – A layer of the soil that possesses physical characteristics that differ from the layers above and beneath.

**Stewardship** – An ethical practice that involves cooperative planning and management practices that prevent the loss, or facilitate the recovery, of ecological diversity and habitat.

**Stormwater pond** - A pond that retains a permanent pool of water and temporarily retains stormwater allowing it to filter out slowly over a period of days.

**Succession** – A series of changes that create a mature plant or animal community over time.

**Sustainability** – The ability of an ecosystem to continue to function indefinitely into the future, meeting its own needs, while not compromising the needs of future generations.

**Swale** – A low depression in the land that is designed to capture and slow water runoff facilitating its infiltration into the soil.

**Tillage** – Preparation of a soil by turning or plowing.

**Tilth** – The structure and quality of a cultivated soil.

**Topdressing** – Process of adding a thin layer of quality soil to the surface of a lawn to increase resistance to drought, improve root development, or increase infiltration.

**Transportation corridor** – a long, narrow strip of land dedicated to movement of humans and their commodities usually delineated by rights-of-way boundaries.

**Turf reinforcement mat** – A layer of protection against erosion meant to stabilize soil while reinforcing vegetation.

**Understory trees** – Layer between the shrub layer and the canopy layer. Trees in this layer generally range from 20-40 feet in height.

**Utility turf** – Turf planted for its functionality (i.e. soil stabilization or dust control) and managed at a level to maintain these functions.

**Vegetation management** – The practice of maintaining healthy ecosystems through the control and maintenance of regionally appropriate vegetation.

**Volunteer seed** – A cultivated seed that grows without having been intentionally sown or planted.

**Warm-season grass** – Grasses that grow best at warmer temperatures (ideal range is 80°–90°F). They typically begin growth late in spring. Switchgrass, Indiangrass, broomsedge and little bluestem are examples of locally indigenous warm-season grasses.

**Wetland** – An area of land whose soil is either permanently or seasonally saturated with water. Wetlands are extremely diverse ecosystems.

**Woody Plant** - A plant that has a permanent above ground structure whereas herbaceous plants die back to the ground seasonally.

**Wound dressing** - A synthetic application often applied after pruning meant to heal cuts, control decay or protect against fungus and insects. Wound dressings are not necessary as trees have the natural ability to seal their wounds.

## Literature Cited

Berger, R.L. 2005. NCHRP Synthesis 341, Integrated Roadside Vegetation Management, A Synthesis of Highway Practice, Transportation Research Board, National Cooperative Highway Research Program, Washington, DC.

Billings, C.H. 1990. "Wildflowers: Municipal field reports." *Public Works* 121 (3):106.

Davis, G.L. and J. Schimelfenig. 1999. "Consumer viewpoints on prairie grass and wildflower plantings." *Hort Science* 34(3): 531, June 1999.

Integrated Roadside Vegetation Management Program Task Force. 1997. How to Develop and Implement an Integrated Roadside Vegetation Management Program. National Roadside Vegetation Management Association, March 1997.

Ulrich, R.S. 1986. "Human responses to vegetation and landscape". *Landscape and Urban Planning* 13:29-44.



# Appendix A

## **Do's and Don't s While Applying Herbicides**

1. Read label prior to opening the container. Follow instructions and pay attention to precautions and warnings.
  2. Store products in original containers.
  3. With powdered herbicides, like Oust® and Escort® , hold the container inside the mouth of the tank and pour slowly. This will eliminate much of the dust blowing up from the tank.
  4. Do not use soil active products near desirable susceptible vegetation. In these areas use foliar applied products such as Roundup® Pro.
  5. Dispose of herbicide containers according to label recommendations or recycle. Disposal usually consists of triple rinsing the container and punching holes in it rendering it useless.
  7. All of the herbicides can be left in the tank overnight but should not be left for an extended period of time. The solution should be used up if an application is not scheduled for several weeks.
  8. Oust® and Escort® are unstable in acidic water and should not be left in the spray tank for long periods of time.
- target. The applicator may need to begin application early in the morning, in order to cover as much area as possible, before the wind velocity rises.
3. Discontinue herbicide application if rainfall is threatening. Most of our herbicides are rainfast within 1-2 hours. Postpone treatment until favorable conditions are present. Wet soil and/or foliage may yield poor results.
  4. Do not apply herbicides when ground is frozen.
  5. Avoid contaminating water in lakes or streams with herbicides that are not labeled for use in water.
  6. Use only clean water in the tank. Sand or clay particles will damage the pump, solenoids, and nozzles, and will deactivate Roundup® Pro.
  7. Clean equipment when changing chemicals. Flush with water several times and spray rinseate on the right-of-way as a typical application.

## **Application Knowledge**

1. Drive at the correct speed.
2. Discontinue spraying if wind velocity rises. Winds above 5 mph (8 km/h) may cause drift. All spraying must cease when patterns cannot be kept on



DelDOT, Division of Maintenance and Operations  
Daily Report Form  
Pesticide Application

# Appendix B

**DISTRICT:**    **EXPRESSWAYS**    **NORTH**    **CANAL**    **CENTRAL**    **SOUTH**

---

**DATE & TIME OF APPLICATION :** \_\_\_\_\_ **ROAD NO.:** \_\_\_\_\_

**LOCATION(S):**(Use reverse if necessary)

---



---

**PEST(S) TO BE CONTROLLED:** \_\_\_\_\_

---

**APPLICATOR NAME (PLEASE PRINT):** \_\_\_\_\_

**APPLICATOR CERTIFICATION NO.:** \_\_\_\_\_

**CHEMICAL INFORMATION**

PRODUCT NAME(S) \_\_\_\_\_

ACTIVE INGREDIENT(S) \_\_\_\_\_

EPA REG. NUMBER(S) \_\_\_\_\_

RATE OF PESTICIDE (OZ/GAL) or (% SOLUTION) \_\_\_\_\_

TOTAL AMOUNT OF PESTICIDE ADDED \_\_\_\_\_

TOTAL VOLUME OF MIX (WATER + PESTICIDE) \_\_\_\_\_

FINAL APPLICATION RATE (GAL/ACRE) \_\_\_\_\_

TOTAL VOLUME APPLIED \_\_\_\_\_

---

**WEATHER INFORMATION**

TEMPERATURE: \_\_\_\_\_ WIND DIRECTION/SPEED: \_\_\_\_\_

RELATIVE HUMIDITY:    HIGH    MEDIUM    LOW

**SPECIAL NOTES OR INSTRUCTIONS:** \_\_\_\_\_

---

**DEPARTURE FROM DEL D. O. T. YARD:** \_\_\_\_\_

**RETURN TO DEL D. O. T. YARD:** \_\_\_\_\_

**TOTAL APPLICATION TIME:** \_\_\_\_\_ **HOURS**

\_\_\_\_\_  
**APPLICATOR SIGNATURE**

# Appendix C

## **Selected Weed Species Control**

### **Recommendations:**

**Autumn olive** – Treat with Confront® (1/2%) and Roundup Pro® (1%) tank mixed together. Spray to wet after July 4.

**Burcucumber** – Treat with Roundup Pro®. Multiple applications will be required to get late flushes.

**Canada thistle** – Treat with Confront® (1/2%) when Canada thistle is vigorously growing prior to planting the area. Multiple applications will be needed. Roundup Pro® is weak on Canada thistle. Treat with a preemergent herbicide such as Casoron as a winter application. Or spot treat with a postemergent herbicide such as Garlon®, Roundup Pro®, or Stinger®.

**Crown vetch** – Treat with Roundup Pro® when crown vetch is vigorously growing prior to planting the area. Treat in woody plantings with a preemergent herbicide containing Goal® (such as Rout® or OH2®). Treat in herbaceous plantings with a preemergent herbicide containing Gallery®. Spot spray in existing woody plantings that are listed as tolerant on the herbicide label with an herbicide containing clopyralid (such as Lontrel® or Transline®).

**Giant ragweed** – Pre-emergent herbicides can be used to control giant ragweed. Post-emergence herbicides that provide good control include Roundup Pro®, dicamba, and 2,4-D. Broadcast

applications of Roundup Pro® at 2.0 pt/A will control plants up to six inches in height. Tank mixing 2,4-D at 1 pint/A with Roundup Pro® will also provide giant ragweed control. Pursuit® (imazethapyr) is also recommended for post emergence control of giant ragweed. Tillage is effective for control of seedlings because of their early emergence in relation to many other summer annual weeds. Tillage becomes less effective as plants become larger. Under moist soil conditions, plants may be “transplanted” and begin growing in another area. Repeated mowing will effectively reduce seed production but will not eliminate giant ragweed.

**Japanese honeysuckle** – Treat with Roundup Pro® (1%) when honeysuckle is actively growing, preferably after July 4. Treat with Confront® (1/2%) anytime. When honeysuckle is mixed with desirable species, it is possible to treat in mid-November to early winter when honeysuckle has green leaves but other plants are dormant. Mow twice a year (July and September) in established plantings to limit vegetative spread.

**Japanese knotweed** – Treat with Roundup Pro® (2%) during September and early October.

**Johnsongrass** – Treat with Roundup Pro® when Johnsongrass is actively growing. Repeated and close mowing kills Johnsongrass seedlings, prevents seed production, and reduces rhizome growth and regrowth of shoots. Sites may be

tilled where it is practical (e.g. abandoned cropland) and the exposed roots left to winter kill. Repeated tillage (e.g. 6 times at 2- week intervals during the growing season) prevents rhizome development and reduces Johnsongrass populations. Limited early season tillage, however, encourages rhizome growth by spreading pieces of the rhizomes.

**Mile-a-minute** – Control with a preemergent in March or April. After emergence, treat with Confront® (1/2%) spray to wet.

**Multiflora rose** – Treat foliage in April or May with Escort® (1 oz/acre) before most desirable species have produced leaves, or anytime rose has green leaves. Use Roundup Pro® after July 4 until leafdrop. Remove the bulk of the shrub/vine by mechanical means and treat cut stems with a systemic herbicide.

**Nutsedge** – Treat with a preemergent herbicide such as Casoron as a winter application. Or spot treat with a postemergent herbicide such as Image® or Sedgehammer® .

**Oriental bittersweet** – Cut trunks and treat with a systemic herbicide. Or tank mix Confront® (1/2%) and Roundup Pro® (1%). Spray to wet after July 4.

**Phragmites** – Treat with Rodeo® (aquatic glyphosate) in combination with an aquatic wetting agent in late summer to early fall.

**Porcelain berry** – Cut stems and treat trunks with a systemic herbicide. Or tank mix Confront® (1/2%) and Roundup Pro® (1%). Spray to wet after July 4.



# Appendix D

**SOP's from DeIDOT**

(To be added in the future)

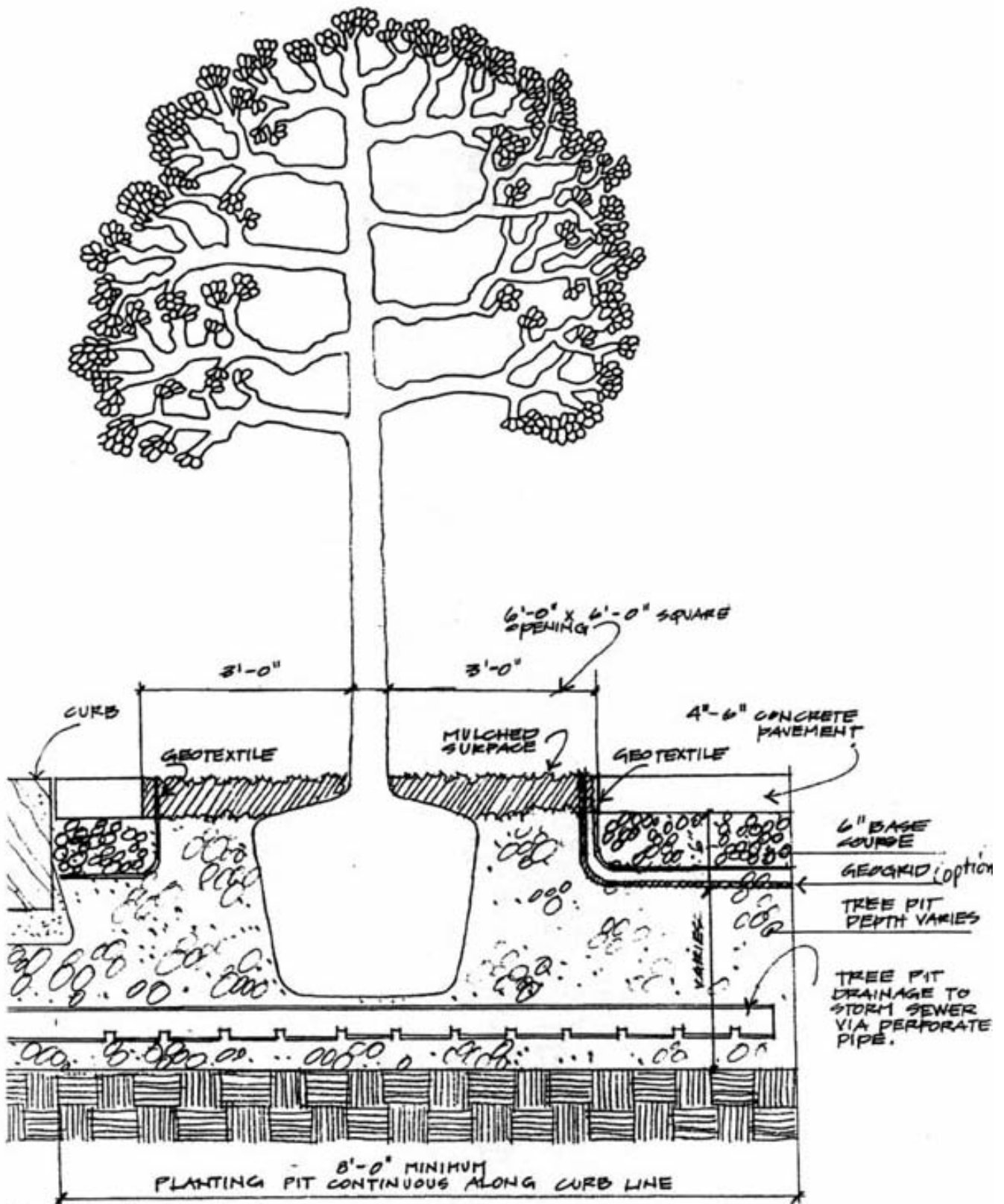


Figure 2: Elevation plan of a proposed structural soil pavement profile using the sub-base as the rooting zone.

# Appendix F

## **Modular Pavement**

### **Description**

Modular pavement comes in pre-formed modular pavers of brick and concrete. When the brick or concrete is laid on a permeable base, water will be allowed to infiltrate. Grass can be planted between the pavers, allowing structural support in infrequently used parking areas.

### **Other Terms Used to Describe**

Lattice concrete blocks  
 Monoslab concrete blocks  
 Modular brick or concrete pavers  
 Pre-cast concrete  
 Perforated pavers laid over pre-cast concrete

### **Pollutants Controlled and Impacts**

Some of the possible benefits of this practice include: removal of fine particulates and soluble pollutants through soil infiltration; attenuation of peak flows; reduction in the volume of runoff leaving the site and entering storm sewers; reduction in soil erosion; and groundwater recharge. The degree of pollutant removal is related to the amount of runoff which exfiltrates the subsoils. It may also help reduce land consumption by reducing the need for traditional stormwater management structures.

There is a potential risk to groundwater due to oils, greases, and other substances that may leak onto the pavement and leach into the ground. Pre-treatment of stormwater is recommended where oil and grease or other potential groundwater contaminants are expected.

### **Application**

#### **Land Use**

Urban, urbanizing, rural

#### **Soil/Topography/Climate**

This practice should only be used on sites with soils which are well or moderately well drained. Since subgrade soils will differ in their capacity to infiltrate and percolate water, the design of modular pavement will vary slightly based on soil type. See the "Specifications" section of this BMP.

Weather conditions will also affect frost penetration depth. This practice is not recommended for barren areas with expected wind erosion.

#### **When to Apply**

Apply when the soil, topography and climatic conditions listed above can be met.



### Where to Apply

Apply in low-volume parking lots and roads, and in high activity recreational areas like basketball and tennis courts or playground lots. The area is generally limited to 0.25 to 10.0 acres and generally serves only a small section of the watershed. This BMP can also accept rooftop and adjacent parking lot runoff.

### Relationship With Other BMPs

Subsurface Drains may collect water infiltrating the subbase of the modular pavement and route it to an Extended Detention Basin or Infiltration Basin. This may be necessary for soils having marginal infiltration capabilities. The use of subsurface drains may diminish the pollutant removal efficiency of this BMP by not allowing the water to fully exfiltrate the soil. Subsurface drains may also be installed but allowed to remain capped, acting as a backup system if the modular pavement becomes clogged.

### Specifications

#### **Planning Considerations:**

Soil tests should be conducted to determine permeability, load bearing capacity, resistance to frost heaving, swell and shrink. Soils with a permeability rating of A or B (higher permeability) are more suitable than soils with a permeability rating of C (lower permeability). Evaluate the soils and drainage area to estimate the amount of water that may enter the modular pavement, and how fast this water will percolate through the soil. Underlying soils should have a minimum infiltration rate of 0.27 in/hr, or 0.52 in/hr for full exfiltration systems.

Diversions should be placed around the perimeter of the modular pavement to keep runoff and sediment completely away from the site both before and during construction. Plan to design Diversions in conjunction with the modular pavement.

#### **Design Considerations for Various Types of Modular Paving:**

As discussed below, modular pavement comes in a variety of materials, from lattice concrete blocks to modular brick or concrete pavers. This information was derived from "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute (Tourbier and Westmacott).

**Lattice concrete blocks** are used for infrequent parking use, for lining grass swales, and for grass ramps. In parking areas, blocks should be laid on a bed of gravel or crushed aggregate (to give a sufficient capacity), and a 2-inch layer of fines and gravel. Interstices of blocks should be filled by screening with coarse sand. Spaces between blocks should be filled with coarse sand. Where the only purpose is for erosion control, blocks may be laid directly on soil and screened with topsoil. On driveways under lawns, blocks may be covered with 1-2 inches of topsoil

**Monoslab concrete blocks** result in a surface which is 25% concrete and 75% permeable soil. Blocks are of high-strength freeze/thaw resistant concrete, with both a rough and a smooth side. Lay the smooth side down for driveways, parking lawns, construction roads, erosion control, slopes banks, and waterways. Lay the rough side down for footpaths, sidewalks, bike trails, patios, malls



and tree grilles.

**Modular brick or concrete pavers** are perforated bricks, or bricks with lugs to control spacing. The brick or concrete pavers are made to a variety of specifications depending on the intended use, usually with a compressive strength of between 7,500-10,000 psi for use in areas where more wear is expected than for lattice blocks. Uses include paving around trees and dividing strips between impermeable paved surfaces. It is generally not conducive for walking. Interstices and perforations are usually kept free of vegetation.

Lay on a bed of gravel topped with 2 inches of coarse sand. The depth of the gravel will depend on the required stormwater storage capacity.

**Pre-Cast Concrete Perforated Pavers Laid over Pre-cast Concrete Lattice Blocks** can be made to a variety of specifications. A "web" opening may be in the order of 5" x 5" and 4.5" deep. The entire slab may be only 2.5 inches thick, with 0.75 inch diameter holes. These are laid on a base course of gravel of the necessary depth to provide storage capacity and 2 inches of coarse sand. This type of system is used in formal areas, especially where "warping" of large impermeable surfaces would be unsightly; also as a strip cover for French drains between areas of impermeable surface. Concrete blocks may be lifted and the web and sand filter cleaned out if the percolation rate falls.

#### **Construction Considerations:**

Where necessary, install a temporary Diversion to prevent runoff from entering the site during construction.

Install all modular pavement following manufacturer's specifications. The requirement for skilled labor for laying modular pavement may be reduced if mechanical vibrators are used for levelling uneven surfaces.

#### **After Construction:**

1. Stabilize the surrounding area and any established outlet following specifications in the Seeding and Mulching or Sodding BMPs. This will prevent sediment from entering the modular pavement.
2. Where applicable, remove temporary Diversions after vegetation is established.
3. Although snow and ice tends to melt more quickly on modular pavement, it may still be necessary to apply de-icing compounds to melt snow and ice. Do not use sand or ash because they may cause clogging of the pavement.

#### **Maintenance**

All modular pavement should be inspected several times in the first few months after construction, and at least annually thereafter. Inspections should be conducted after large storms to check for surface ponding that might indicate local or widespread clogging. If severe clogging occurs, the entire structure may have to be removed and old (clogged) filtering material replaced with new material.

Additional maintenance requirements will differ depending on the type of modular pavement selected. Follow the manufacturer's recommendations.

### **Exhibits**

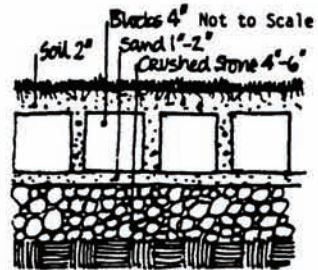
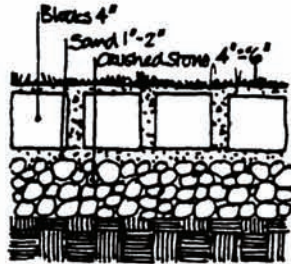
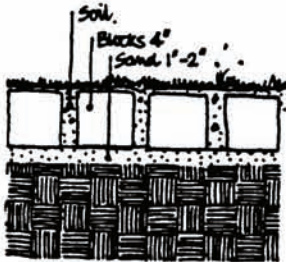
Exhibit 1: Examples of Modular Pavement. Source: "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute.

Exhibit 1

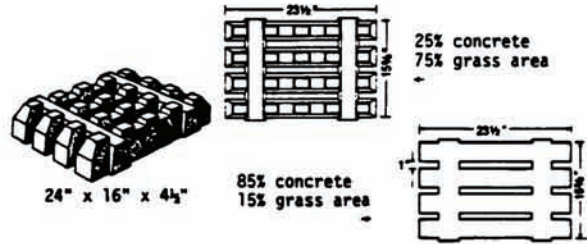
Examples of Modular Pavement



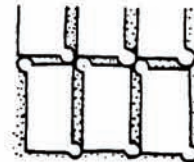
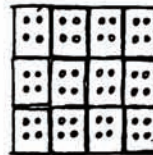
Concrete Blocks



Monoslab Concrete



Modular Brick or Concrete Pavers



Pre-cast Concrete Perforated Paver Laid Over Pre-cast Concrete Lattice Block



"Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute.



### Herbicides Approved for Use on DeIDOT Rights of Way

When making herbicide applications:

1. Always read and follow product label
2. Always use personal protective equipment when mixing, loading, and applying

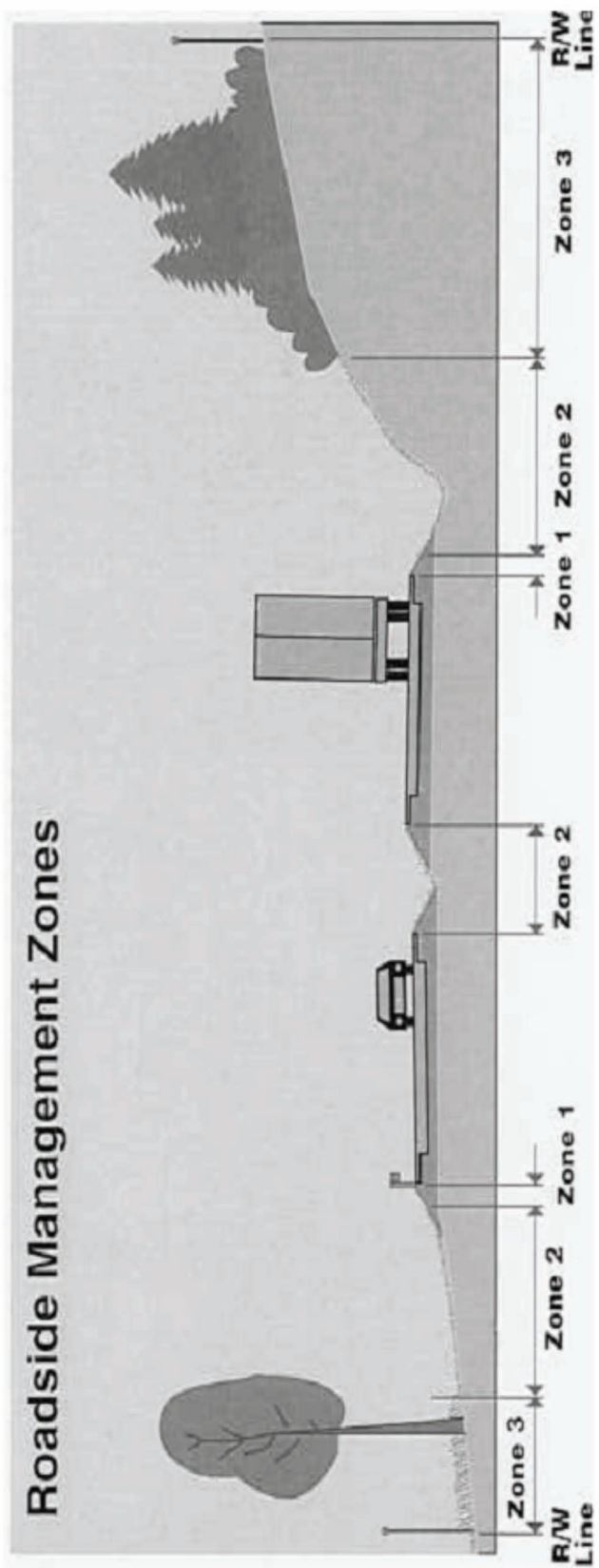
Chemical Name	Product Name(s)	Where Used	How/Why Used	Notes/Recommendation	Restrictions	Cautions
2,4-D	Weedar 64 Amine 4 Veteran 720 Curtail WeedDestroy 4 Platoon Crossbow Escalade Weedmaster SolutionSavage Weedone LV4	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Ester and acid formulations of 2,4-D may provide a good alternative to amine formulations	Amine formulations of 2,4-D are restricted for use within 60' of all water	Amine formulations cause irreversible eye damage and are highly toxic to rainbow trout. All 2,4-D products pose risks when applied near grapes and other sensitive crops
Chlorsulfuron	Telar XP Landmark XP	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Product highly effective on Canadian thistle and Horse tail	None	None
Clopyralid	Transline Curtail	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Transline is a copyralid formulation without 2,4-D	Curtail is restricted for use within 60' of all water because of 2,4D amine content	Curtail contains 2,4-D amine which causes irreversible eye damage and its highly toxic to rainbow trout
Dicamba	Vanquish Veteran 720 Veteran 10G	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Vanquish is the dicamba formulation without 2,4-D	Veteran 720 is restricted for use within 60' of all water because of 2,4-D amine content	Veteran 720 contains 2-4-D amine which causes irreversible eye damage and is highly toxic to rainbow trout



<b>Chemical Name</b>	<b>Product Name(s)</b>	<b>Where Used</b>	<b>How/Why Used</b>	<b>Notes/Recommendation</b>	<b>Restrictions</b>	<b>Cautions</b>
Dichlobenil	Norosac 4G Casoron	Ornamental planting beds	Pre-emergent weed control in ground cover beds. Post emergent control of grasses	Highly Effective for pre-emergent control of unwanted weeds in ornamentals	Restricted for use within 60' of all water	Dichlobenil is highly toxic to aquatic insects
Diflufenzopyr	Overdrive	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	None	None	None
Diuron	Karmex Diuron 4 L Diuron 80 DF	Under guardrails, on traffic control islands and around signposts	Nonselective pre-emergent grass and weed control	Cost effective weed control for	Restricted for use within 60' of all water	Highly toxic to fish
Fosamine	Krenite S	Tree and brush control in Zones 2 and 3*	Selective broadleaf treatment	Effective broadleaf tree control without visual impacts	None	None
Glyphosate	Various	Spot spray around shrub and tree planting, aquatic weed control (Rodeo Aquamaster)	Nonselective weed control	Only formulations of glyphosate labeled for use in aquatic situations are approved for use on DeIDOT roadsides	None	Avoid drift.
Imazapyr	Arsenal Habitat	Bare ground locations (guardrails, islands, signposts); brush control	Pre/post emergent, non-selective control of all vegetation	Habitat is an aquatic version of Arsenal-good alternative to glyphosate in certain cases	None	High surface runoff potential high potential to leach into ground water.
Isoxaben	Gallery 75 DF	Turf & Ornamental	Pre-emergent weed control in ground cover bed	Works well by itself or with Ronstar	Restricted for use within 60' of all water	High surface runoff potential
Metsulfuron-methyl	Escort XP Metsulfuron Methyl 60 DF	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf and conifer treatment	None	None	None
Oryzalin	Oryzalin AS Surflan AS Surflan DF	Ornamental planting beds	Pre-emergent weed control in ground cover beds	Products requires additional rinsing to thoroughly remove residues from empty container	Restricted for use within 60' of all water	Highly toxic to fish

<b>Chemical Name</b>	<b>Product Name(s)</b>	<b>Where Used</b>	<b>How/Why Used</b>	<b>Notes/Recommendation</b>	<b>Restrictions</b>	<b>Cautions</b>
Oxadiazon	Ronstar G Ronstar 50 WSP	Turf & Ornamental	Pre-emergent weed control in ground cover beds	Works well by itself or with gallery	Restricted for use within 60' of all water, gardens, plants bearing edible fruit	Highly toxic to fish
Pendimethalin	Pendulum 2G Pendulum Aqua Cap	Turf & Ornamental	Nonselective pre-emergent grass and weed control	None	Restricted for use within 60' of all water	Highly toxic to fish, high potential for loss on eroded soil
Triclopyr Amine	Garlon 3A Pathfinder II Redeem R&P	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	None	None	Irreversible eye damage
Triclopyr Ester	Garlon 4 Tahoe 4E Crossbow	Nuisance and noxious weed control Zones 2 and 3*	Selective broadleaf treatment	Works well for invert applications	Restricted for use within 60' of all water	Highly toxic to fish

\*See Roadside Management Zones, below.



# Roadside Management Zones

**Zone 1-Vegetation Free Zone:** (0 to 2 feet from pavement or as necessary.

- Provide for surface drainage
- Reduce fire potential
- Provide for visibility and maintenance of roadside hardware
- Prevent pavement breakup by invasive plants
- Provide sight distance for passing, stopping and at intersections
- Prevent the buildup of wind blown debris and winter sand at the pavement edge

**Zone 2-Operational:** (From Zone 1 or pavement edge to meet operation and maintenance needs)

- Maintain design width for vehicle recovery
- Provide sight distance for passing, stopping at interchanges and at intersections
- Maintain hydraulic capacity of ditches
- Eliminate vegetative obstructions (trees with trunk diameter of 4" or more)
- Control weeds
- Prevent erosion
- Provide wildlife habitat where compatible with roadway traffic
- Accommodate underground utilities
- Enhance visual quality

**Zone 3-Transition/Buffer:** (From Zone 2 to Right of Way line)

- Promote self-sustaining plant communities
- Blend and/or screen adjacent surroundings as necessary
- Eliminate hazard trees causing excessive shade (ice and frost potential) on the highway pavement
- Control weeds
- Prevent erosion
- Maintain and enhance visual quality
- Preserve wetlands and wildlife habitat
- Accommodate utilities
- Preserve and conserve native plants and wildflowers

AASHTO Policy on Geometric Design of Highways and Streets, 5th Edition. 2004. American Association of State Highway Transportation Officials. ISBN Number: 1-56051-263-6.  
(URL to purchase book: [https://bookstore.transportation.org/item\\_details.aspx?ID=110](https://bookstore.transportation.org/item_details.aspx?ID=110))

Barton, S.S., Darke, R. Schwetz, G. 2006. Enhancing Delaware Highways: Planning and Concept Manual. Delaware Department of Transportation. University of Delaware.

Berger, R.L. 2005. NCHRP Synthesis 341, Integrated Roadside Vegetation Management, A Synthesis of Highway Practice, Transportation Research Board, National Cooperative Highway Research Program, Washington, DC.

Delaware Sediment and Stormwater Management Regulations  
([http://www.swc.dnrec.delaware.gov/Drainage/Documents/Sediment%20and%20Stormwater%20Program/5101%20Sediment%20and%20Stormwater%20Regs\\_Rev8-06.pdf](http://www.swc.dnrec.delaware.gov/Drainage/Documents/Sediment%20and%20Stormwater%20Program/5101%20Sediment%20and%20Stormwater%20Regs_Rev8-06.pdf))

DeIDOT Erosion and Sediment Control and Stormwater Management Design Guide  
([http://www.deldot.gov/information/pubs\\_forms/manuals/es2m/index.shtml](http://www.deldot.gov/information/pubs_forms/manuals/es2m/index.shtml))

DeIDOT Road Design Manual  
([http://www.deldot.gov/information/pubs\\_forms/manuals/road\\_design/index.shtml](http://www.deldot.gov/information/pubs_forms/manuals/road_design/index.shtml))

DeIDOT Standard Construction Detail (E-9)  
([http://www.deldot.gov/information/pubs\\_forms/const\\_details/2005/pdf/e09.pdf](http://www.deldot.gov/information/pubs_forms/const_details/2005/pdf/e09.pdf))

DeIDOT Standard Specifications  
([http://www.deldot.gov/information/pubs\\_forms/manuals/standard\\_specifications/index.shtml](http://www.deldot.gov/information/pubs_forms/manuals/standard_specifications/index.shtml))

DNREC Erosion Control & Sediment Control Handbook  
([http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/New/Delaware%20ESC%20Handbook\\_06-05.pdf](http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/New/Delaware%20ESC%20Handbook_06-05.pdf))

Integrated Roadside Vegetation Management Program Task Force. 1997. How to Develop and Implement an Integrated Roadside Vegetation Management Program. National Roadside Vegetation Management Association, March 1997.

SCS Standards and Specifications for Critical Area Planting, Practice Code 342  
(<ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/342.pdf>)



