Delaware Department of Transportation

Roadside Vegetation Establishment and Management Manual

Enhancing Delaware Highways

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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.

DelDOT is committed to reducing pesticide use in their transportation rights-of-way. By implementing an integrated roadside vegetation management manual, DelDOT will select the management strategy that best reduces negative environmental impact in a cost effective manner.

Purpose of the DelDOT Establishment and Management Manual

Maintaining roadsides for safety and aesthetics is important to DelDOT, 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.

Purpose of the DelDOT Establishment and Management Manual

- DelDOT 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

- 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, DelDOT is committed to adopting alternative strategies for vegetation control that minimize the need for herbicides.

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 DelDOT 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 DelDOT 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.
- DelDOT 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 DelDOT roadside vegetation managers and agents employed by DelDOT. 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

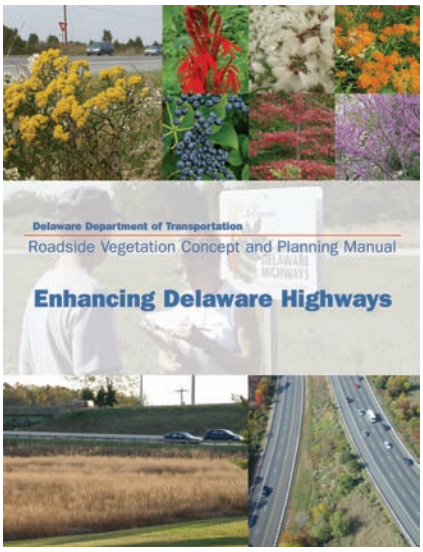
The *Enhancing Delaware Highways* program is based on IRVM philosophy, consequently, the public needs to understand the reasons for roadside vegetation management in relation to functional roadway objectives, surrounding land use, the overall ecosystem, natural processes and applied technologies. The 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

Audience

- Roadside vegetation managers
- Contractors
- Designers and planners

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.

Roadway limitations

- Follow clear zone guidelines in DelDOT Road Design Manual.
- Consider roadway shading, debris, and damage to vegetation from winter maintenance chemicals when locating vegetation.
- Follow lines of sight guidelines in DelDOT 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).

Soil and water conditions

- 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

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 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-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

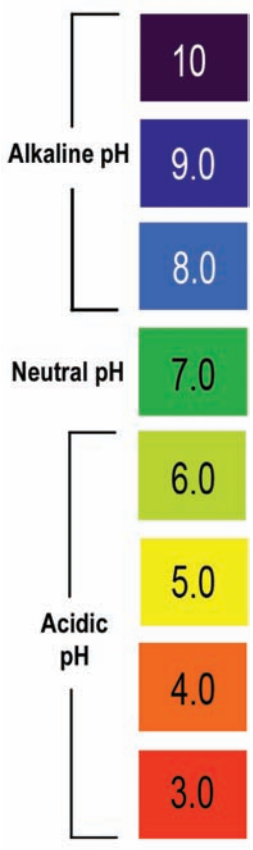
Regional-ornamental approach

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.



pH scale

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 DelDOT Road Design Manual, Chapter 6, DelDOT 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.

Erosion control

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

Contamination

- 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.

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 DelDOT 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.

Conserving indigenous plant communities

- 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 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

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.

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 DelDOT 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

Removing undesirable vegetation

- 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.

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

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, DelDOT 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 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.

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
Lot Number: W067642 Test Date: 05/03

Pure Seed	Variety	Germination
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 indiangrass 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 Marliss 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 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.

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.

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.

DelDOT 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 (*Echinocloa 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	*Festuca trachyphylla*	100.6 lbs/A	113 kg/ha
Perennial rye	*Lolium perenne*	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)	*Festuca arundinacea*	160 lbs/A	180 kg/ha
Perennial rye	*Lolium perenne*	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	*Lolium multiflorum*	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	*Echinocloa* 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	*Festuca arundinacea*	70%	35 lbs
Creeping red fescue	*Festuca rubra rubra*	20%	10 lbs
Annual ryegrass	*Lolium mulitflorum*	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	*Festuca trachyphylla*	100.6 lbs/A	113 kg/ha
Perennial rye	*Lolium perenne*	10.7 lbs/A	12 kg/ha
Redtop	*Agrostis alba*	5.3 lbs/A	6 kg/ha
Winter rye	*Secale cereale*	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	*Agrostis alba*	40 lb/A	45 kg/ha
Creeping bentgrass	*Agrostis palustris*	25 lb/A	28 kg/ha
Sheep fescue	*Festuca ovina*	35.6 lb/A	40 kg/ha
Rough bluegrass	*Poa trivialis*	25 lb/A	28 kg/ha
Winter rye *	*Secale cereale*	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	*Festuca longifolia* and *Festuca trachyphylla*	55%	27.5 lbs
Creeping red fescue	*Festuca rubra rubra*	35%	17.5 lbs
Annual ryegrass	*Lolium mulitflorum*	10%	5 lbs

Low growing turf

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

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

Perennial forbs for appropriate moist to wet sites:

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

Sedges and rushes and for wet sites:

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

Perennial forbs for drier sites:

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

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.

Warm-season grasses such as little bluestem, indiangrass 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 culitpack 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.

Mixed grass and forb meadows

- 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.

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.

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

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 truax 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

Methods of seeding

- 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.

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, DelDOT 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

Sodding

- 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.

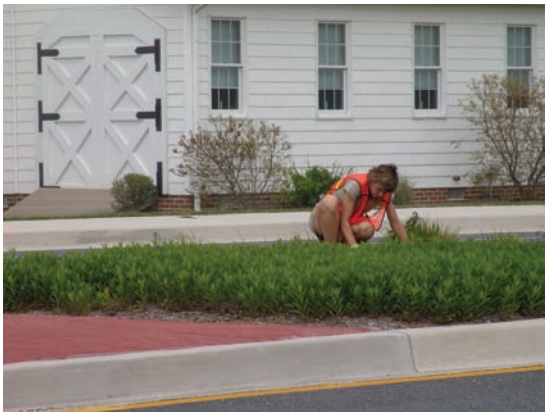
Aromatic aster quarts are planted at 18” spacing on a median in Dewey Beach.

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.

Plugging

- Keep plugs moist and protected during planting.
- Plant plugs in spring or early fall when adequate rainfall in 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.

Bare-root planting

- 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.

Container-grown planting

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.

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

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.

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 DelDOT (Sec 738, DelDOT 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:

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

Inspection

- 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 DelDOT 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.)*

Contract growing

- 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, DelDOT 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 DelDOT 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^3
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 DelDOT 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 DelDOT Standard Construction Detail (E-9).

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

Mulching

- 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 DelDOT 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.

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 over-winter 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 woody plantings, especially in shaded areas.

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

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.

Landscape beds

- 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.

Irrigation

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

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.

Replacement

- 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.