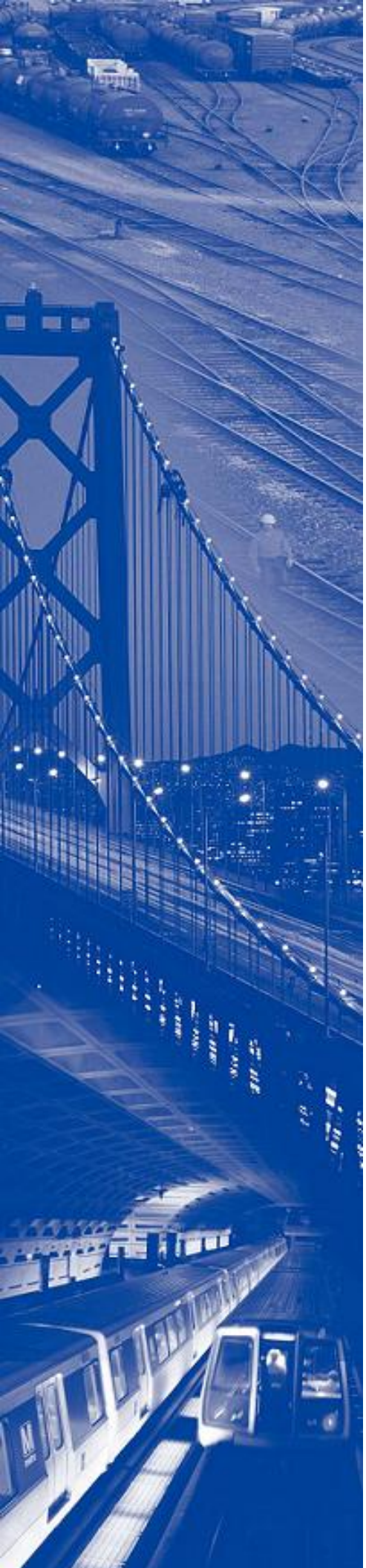

DCT 247

Guardrail Vegetation Management in Delaware

By

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February, 2013

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Project Report for

Guardrail Vegetation Management in Delaware

Prepared for

Delaware Department of Transportation

by

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Valann Budischak

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February 2013

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Guardrail Vegetation Management in Delaware

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Executive Summary:
Initiated to explore alternatives to traditional herbicide treatments under guardrail, this project evaluated

- Three herbicide formulations
  - Formulation 1 - standard DelDOT New Castle County formulation comprised of DuPont™ Karmex® DF Herbicide (Diuron), BASF Plateau (Imazapic ammonium salt) , Dow AgroSciences Accord®XRT (glyphosate), BASF Pendulum (Pendimethalin)
  - Formulation 2 - sensitive areas formulation comprised of BASF Plateau (Imazapic ammonium salt), Dow AgroSciences Accord®XRT (glyphosate), BASF Pendulum (Pendimethalin)
  - Formulation 3 - Dow AgroSciences Accord®XRT (glyphosate)
- Four weed control barriers
  - U-Teck™ WeedEnder standard installation
  - U-Teck™ WeedEnder custom installation
  - Universal Weed Cover
  - TrafFix
- Competitive vegetation
  - Low fescue
  - Zoysia seed
  - Zoysia sod
  - FlightTurf
- Hand trimming
- Pavement under guardrail.

Products were installed and treatments provided from 2008 through 2012. Data was collected approximately monthly during the growing season and the following were recorded for each plot--weed species present; a 1-5 rating assessing compliance with DelDOT guardrail standards; and a 1-5 rating of weed presence. Photographs were taken of each plot at each data collection date. Formulations 1 and 2 provided adequate control of vegetation under guardrails when applied once per year. Formulation 3 did not provide adequate control. Herbicide treatments resulted in a bare ground condition for much of the year and resulted in an unsightly edge between dead and live vegetation on the median. Weed control barriers performed differently depending upon the barrier with Universal Weed Cover providing inadequate control and U-Teck™ WeedEnder (standard or custom cut installation) and TrafFix barriers providing adequate control. Weed barriers that were not installed adjacent to the road surface, allowed a strip of vegetation to grow between the barrier and the roadway, resulting in an unacceptable condition. Low fescue was difficult to establish reliably under guardrail, but when established provided a desirable uniform cover with minimal maintenance. Zoysia did not establish from seed during the first growing season. Zoysia sod established successfully and almost entirely eliminated weeds under the guardrail and required no trimming during the first year. FlightTurf was only established at the end of the 2012 growing season. Hand trimming was required once or twice per year depending on site, weather and timing. When conducted once per year, hand trimming was the most cost effective treatment and provided a green mat of vegetation below the guardrail. Future research is planned to continue to determine the longevity of weed barrier

products, to evaluate the ability of low fescue to outcompete weeds, to monitor the competitiveness of zoysiagrass sod, and evaluate FlightTurf as alternative ground cover.

Key words – roadside vegetation management, IRVM, guardrails, herbicides, bareground, weed control barriers, low fescue, hand trim

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Disclaimers
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Introduction

Delaware's population is close to one million (917,092) and is predicted to have a GDP of 59 billion dollars in 2012 (3.5% increase from 2011). In order to support this economy and bourgeoning population, people must commute to and from work, tourists must have access to all areas of the state, goods must be transported, and citizens must be able to travel freely in a safe and timely manner. The majority of this travel is accomplished through automotive use of Delaware's roadway network. Delawareans and visitors travelled over 9 billion miles in 2010 (9,177,000,000 miles). The Delaware Department of Transportation (DelDOT) is responsible for this highway system. DelDOT is charged with the design, construction, maintenance, and operation of these roadways and roadsides which total 13,562 lane miles of roadway and 47,177 acres of roadside right-of-way. In order to fulfill its mandated duties, DelDOT is given a yearly budget of $356 million. The portion of this budget spent on maintenance activities is $57.5 million, and about 9% of this amount is spent on roadside vegetation maintenance and control.

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 (Johnson, 2000).

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. The Delaware Department of Transportation (DelDOT) is committed to reducing pesticide use in their transportation rights-of-way.

Delaware's Phase I MS4 Permit No. DE0051071 clearly states that DelDOT shall implement controls to reduce, to the maximum extent practicable, the discharge of pollutants related to the application of pesticides, herbicides, and fertilizers by the co-permittee's employees or contractors to public rights of way, parks, and other municipal property or facilities. In addition, the co-permittees shall implement programs to encourage reductions in the discharge of pollutants associated with the commercial application and distribution of pesticides, herbicides and fertilizers as described in the Application page iv-45, Part 5(iv) A6, Permit page 7, Part IIA.5 and Consent Decree page 19, Part II 21.

Many of the concerns about herbicide use relate to aquatic environments. While many roads are not adjacent to aquatic environments, older roads have ditches or closed drainage systems that are often hydraulically connected to aquatic habitats (Hill and Horner, 2005). The reasons for managing vegetation adjacent to the roadside are varied. Washington State has developed a decision framework to control vegetation removal adjacent to the road surface. Observable conditions that trigger a need to remove vegetation include frequent fire starts, ponding of runoff on the road surface, potential traffic and safety impacts from alternative practices and disruption of visual sightlines (Hill and Horner, 2005). Invasive plants found in the roadside right-of-way may also be a trigger for control. Pauchard et.al. (2004) found that roadsides are major corridors

for the dispersal of invasive non-native plant species and recommended early detection and removal to prevent the decline of quality habitat in adjacent non-roadside areas.

In some states, legislation has prompted changes in the way roadside vegetation is managed. In South Carolina, a 1991 Waste Policy Management Act requiring the South Carolina Department of Transportation to pursue the use of certain waste materials in highway construction and maintenance operations prompted a study of rubber landscape mulch and vegetation mats from waste tires. After three years, the waste tire landscaping products had not deteriorated but in unmanaged areas vegetation mats were covered with soil and grass. Initial costs of the waste tire products were considerably higher than for conventional mulch wood products (Sanders, 2000).

This project focuses on vegetation control around guardrails. A guardrail (longitudinal barrier) is a semi-rigid shoulder barrier designed to separate the driving surface from a potential hazard. Guardrails protect the traveling public, wildlife, overpass supports, and other median and roadside buildings. The area adjacent to the guardrail needs to be kept clear of vegetation in order to allow clear visibility of the barrier. Vegetation is cleared away from guardrails for several purposes including lower fire risk, improved sign visibility, more desirable roadside aesthetics, and access for inspection and maintenance (Arsenault et. al., 2008). The flow of water and maintenance of visibility are cited most frequently as the reasons for a vegetation free zone adjacent to the roadway and under guardrails. Robert Moosmann (2001) of Maine DOT explains that control of vegetation under and behind guardrails will restrict the build-up of debris, which includes sand and sediment that prevent proper sheet flow of water off the road surface. With unmanaged vegetation, rills develop behind the guardrail as water channels to points of least resistance and results in erosion (Moosmann, 2001, Glover et al., 2000). But low-growing grasses planted under guardrails have also been suggested as a means to increase biofiltration of stormwater runoff in Thurston County, Washington (Roads and Guardrails, 1997).

Literature Review

Vegetation management around guardrails can be divided into four major approaches: mechanical, cultural, biological and chemical control. Mechanical control involves the use of equipment such as mowers, hand tools, heat and manual removal of vegetation. Cultural control relies on shading, plant competition, seeding, fertilizing, mulching, and weed barriers to prevent overgrown vegetation. Biological control is the introduction of insects, disease or animals that will help reduce or control the target vegetation. Finally, chemical control is the use of herbicides.

Some states use mowing and hand trimming as their primary management tool. Mowing, while evaluated as the most cost efficient current available option in a California study (Arsenault et.al., 2008), is often not feasible because of mower size and the inability to maneuver the mowing head around and under the guardrails. Also, mowing only gives temporary control, therefore repeated mowing is necessary. Some guardrails may only get cut once every one or two years due to time constraints. Hand trimming is time consuming and labor intensive as well as dangerous because of operator exposure working between traffic and the barriers (Thurston County IVM Plan, 2012). Some states are testing alternative mechanical options such as steam

or hot foam application, infrared technology, and high pressure water application. Steam or hot foam kills tops but has no effect on roots and seed banks in the soil (Stringer, 2001). It is expensive, inefficient and subjects workers to extra risk since they are on foot to spray the undesired vegetation (Arsenault et al., 2008). Infrared technology uses radiant energy to kill unwanted vegetation. Intense heat generated by liquid propane coagulates plant proteins and bursts cell walls, killing seedling plants and destroying the tops of established vegetation. But operations are slow moving and require more than one treatment—in some reports 3-8 times/year (Arsenault et.al., 2008; Burnham et al., 2003; Edgar, 2000, Stringer 2001). High pressure water application uses water to cut or mow vegetation. When held at 3 feet above the ground, the nozzle clears most brush without disturbing the soil. But the treatment is slow, vegetation grows back quickly and workers are exposed to traffic (Arsenault et al., 2008). Burning is a mechanical method of vegetation control used in some states. In highly populated corridors, burning is not feasible but even when allowed regrowth occurs in fall (Barker and O'Brien, 1995) and air quality impacts provide an added concern (Hill and Horner, 2005).

With cultural control, a plant species is established that will compete with and suppress growth of the unwanted brush. A dense stand of low-growing plants is referred to as living mulch (Bond and Grundy, 2001). White clover was tested as living mulch but did not establish successfully enough to compete with weeds (Barker and O'Brien, 1995). Crown vetch was studied in Maine as a competitive vegetation option (LaRoche and LaRoche, 2001). Since crown vetch itself is considered an undesirable type of roadside vegetation in the mid-Atlantic, this is not an alternative for DelDOT. Where maintenance with residual herbicides has been practiced over a number of years, the lingering presence of residual herbicides may limit desirable plant growth, favoring the most aggressive and often undesirable species. Creating and encouraging stable, low-maintenance vegetation is a more permanent vegetation management strategy and should be the goal for all rights-of-way (Owens, 1999). Native plant species are especially effective in providing increased erosion control, aesthetics, wildlife habitat and biodiversity (Owens, 1999). New York is studying a mix of low growing plants for areas under guardrails, but not emphasizing the need for natives (Hill and Horner, 2005). Glover found that hard fescue provided the most effective, low-maintenance ground cover for roadsides (Glover et al., 1993). If naturally occurring low growing grasses are present in an area, or if they can be successfully established through seeding following construction or under guardrail cleaning, this is a viable option and the lowest overall under guardrail treatment (Willard et al., 2010).

Groundcover that ranked as the best plants for a variety of conditions along New York roadways were lady's mantle; pinks *(Dianthus myrtinervius* Griseb.); 'Chocolate Veil' rock geranium; 'Blue Dune' sand ryegrass (*Leymus arenarius* Hochst.); 'Walker's Low' catnip; 'Emerald Blue' creeping phlox; 'Betty Ashburner' flowering creeping bramble (*Rubus tricolor* x *R. fockeanus* Kurz); 'Golden Fleece' goldenrod (*Solidago sphacelata* Britton); lamb's ears; and 'Suffolk County' lemon thyme (Weston and Senesac, 2004). The researchers at Cornell also evaluated ten fescue (*Festuca* spp.) cultivars for weed-suppression over a two-year period in 2001 and 2002. Three cultivars, 'Oxford' (hard fescue, *Festuca ovina duriuscula* Koch.), 'Reliant II' (hard fescue), and 'Intrigue'(chewings fescue, *Festuca rubra commutata* Gaud.) received very high ratings. By the second year of the study, these cultivars suppressed weeds so well that herbicide treatment to selectively remove weeds was not generally needed (Weston and Senesac, 2004). North Carolina is promoting the use of Centipede as a competitive turf under guardrails.

Centipede's allelopathic effects should reduce the need for future herbicide applications (Yelverton and Gannon, 2003).

Mulching is another form of cultural control. A 2-3 inch layer of bark or woodchips provides erosion control (Montana DOT, 2003) and blocks sunlight (Barker and Bhowmik, 2001) preventing annual weeds from germinating. Crop residue mulch may have some allelopathic characteristics that would enhance its effectiveness (Barker and O'Brien, 1995). Wood chip and bark mulch spread to a 3 inch depth controlled weeds for one growing season, but present a costly alternative ($3,500/mile for wood chips plus labor and $4,300/mile for bark mulch plus labor) (Barker and Prostak, 2009).

Weed control mats (fiber and rubber) have been tested in some states and concerns about joint sealing and molding around guardrail posts providing an opportunity for weed growth have been identified (Hill and Horner, 2005). Washington State tested several weed barriers and found a need for annual cleaning to remove accumulation of organic and inorganic debris. Without this debris removal, the organic buildup starts to grow grass and weeds. Although prohibitively expensive for normal guardrail locations, on sites where herbicide use is restricted, weed barriers provide a viable option. WeedEnder is permeable, fire retardant and was the best performing product in Washington State trials (Willard et al., 2010). TrafFix Weed Mat is comprised of ground up, recycled tires and was the most expensive but most durable product tested. Its lack of permeability could be a problem for stormwater management (Willard et al., 2010). Universal Weed Cover was difficult to install and did not hold up well (Willard et al., 2010).

There are no available reports of significant tests of biological control on roadsides. Biocontrol research at the University of Delaware has focused on release of a weevil in highly invaded natural areas to control mile-a-minute weed (*Persicaria perfoliata*) (Hough-Goldstein et al., 2011). This strategy could have applications on the roadside for this one invasive weed, but since biocontrol is usually highly host specific, it is unlikely to be a practical solution for vegetation control on roadsides containing a wide variety of weeds.

Herbicides are considered to be the cheapest and most efficient method of vegetation control (Arsenault et al., 2008). Two applications of herbicide are often sufficient to effectively treat weeds for a season. The two treatments consist of an early pre-emergent herbicide (prevent the growth of unwanted vegetation) and then a post-emergent herbicide (treat existing vegetation) later on. Additional treatments are sometimes required in areas with dense noxious weed growth, extreme fire risk, or poor public perception. Selective herbicides specifically target certain types of vegetation, allowing desirable vegetation to grow. Residual herbicides are used for pre-emergent treatment and for total control of an area (bare ground). Non-residual herbicides treat current plant growth but do not remain in the soil for long periods of time allowing growth of desired vegetation. Herbicides are a flexible, effective, and cost efficient method for vegetation control, but there is a price to pay for these benefits.

There are also many problems with herbicide use, including environmental, health, and logistical. Herbicide spray trucks hamper traffic flow, often requiring a lane closure and causing traffic delays. Herbicide application is sensitive to weather conditions. Herbicides can't be applied on rainy or windy days. Human health risk is a concern and protective equipment must

be used by applicators. Dead vegetation after the use of herbicides can be unsightly. Bare ground herbicides can increase the risk of erosion. And bare ground herbicide application usually results in an uneven line between bare ground and living vegetation, which is also unsightly.

Herbicides are a tool in integrated vegetation management, but high ecological costs, high sociological costs and short-term, temporary benefits are prompting vegetation managers to look for alternatives. Caltrans mandated that herbicide use be reduced to 80% of 1994 levels by 2012. So far, Caltrans is having difficulty reducing herbicide use because of maintenance required to limit fire risk and the spread of noxious weeds (Arsenault et al., 2008).

Some states have tested alternative herbicides produced from plant parts or food processing by-products that have little effect on the environment once weeds are controlled. None of the products tested (corn gluten meal, citric acid, pelargonic acid, clove oil or acetic acid) provided effective weed control of roadside vegetation (Barker and Prostak, 2009).

Most states use a mixture of vegetation control methodologies. Site-specific procedures are selected rather than policy that applies to the entire state. The DOT can then utilize GIS to map populations and preserve desirable roadsides while managing undesirable vegetation. Researchers in Washington State found that strategies that worked in an arid section of the state did not necessarily work in places with more rainfall and greater vegetation pressure. The presence of noxious weed species on the adjacent roadside was also a significant factor in the effectiveness of different vegetation management strategies (Willard et al., 2010).

The first step is to decide if vegetation control is required based on surface drainage issues, subsurface drainage issues, stormwater management, pavement breakup, visibility for safety, worker safety, fire starts, landscape design, wildlife road kill, and structural deterioration of guardrails. If control is required, feasibility of alternatives (mechanical, cultural, biological and chemical) is considered. Finally, criteria can be developed to identify highly sensitive areas that warrant finding workable alternatives to conventional maintenance even if costs increase.

Materials and Methods

The Delaware Department of Transportation funded a study conducted by University of Delaware researchers to explore various methods of treating vegetation under guardrail.

In April 2008, twenty-four guardrail plots were selected on Delaware roadsides (Route 13 S between Routes 72 & 1, Route 7, and Route 13 near New Castle County Airport). Plots were selected based on the presence of guardrail with low-growing existing vegetation under the guardrail, as well as accessibility for treatment and data collection.

Treatments initially included three formulations of herbicide, two weed barriers, hand trimming, pavement, low fescue turf and a control. There were three replications of each treatment located at different sections of guardrail and split between the two sites. Over the course of the study, some treatments were removed and additional treatments added (2 additional weed barrier treatments, zoysiagrass seed and sod treatments added). Herbicide mixtures were selected based

on current DelDOT guardrail treatments. Figure 1 is a summary of all treatments used in the study.

Figure 1. Treatments under guardrails for the DelDOT study.

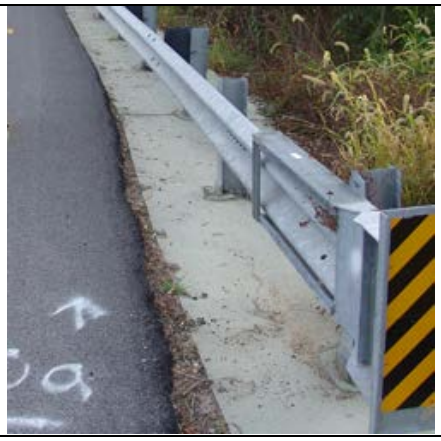
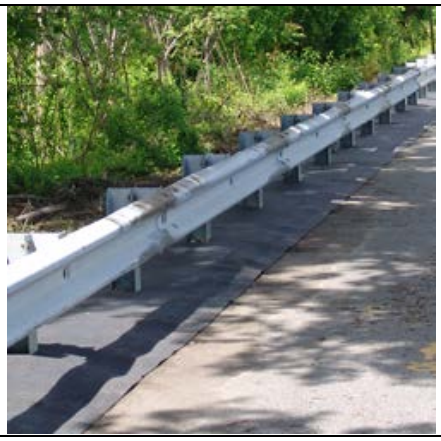
- Three herbicide formulations
  - Formulation 1 - standard DelDOT New Castle County formulation comprised of DuPont™ Karmex® DF Herbicide (Diuron), BASF Plateau (Imazapic ammonium salt) , Dow AgroSciences Accord®XRT (glyphosate), BASF Pendulum (Pendimethalin)
  - Formulation 2 - sensitive areas formulation comprised of BASF Plateau (Imazapic ammonium salt), Dow AgroSciences Accord®XRT (glyphosate), BASF Pendulum (Pendimethalin)
  - Formulation 3 - Dow AgroSciences Accord®XRT (glyphosate)
- Four weed control barriers
  - U-Teck™ WeedEnder standard installation (a permeable recycled fiber material)
  - U-Teck™ WeedEnder custom installation (a product designed to reach the road edge and accommodate variances in post width)
  - Universal Weed Cover (a semi-rigid panel made of 100% recycled plastic)
  - TrafFix (a rubber mat with 3 punched guardrail cutouts for flexible installation)
- Competitive vegetation
  - Low fescue
  - Zoysia seed
  - Zoysia sod
  - FlightTurf
- Hand trimming
- Pavement under guardrail.

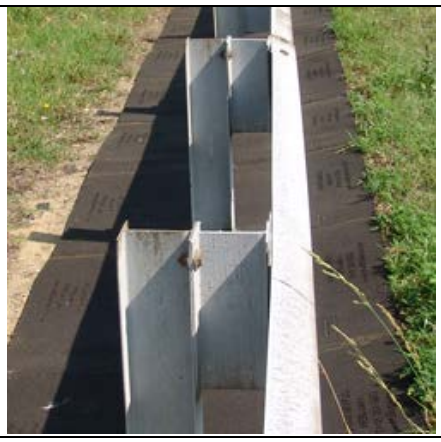
Herbicide treated plots were sprayed once during the season on 6-22-2008 by an independent contractor responsible for treating all Delaware guardrail sites. In 2009, herbicide treated plots were sprayed on 6/24/2009 by an independent contractor responsible for treating all Delaware guardrail sites. In 2010, herbicide treatments were sprayed on 6/14/2010 and were discontinued at the end of the growing season.

Initially, two weed barriers were selected for testing including U-Teck™ WeedEnder and Universal Weed Cover. U-Teck™'s WeedEnder is a permeable recycled fiber material. Universal Weed Cover is a semi-rigid panel made of 100% recycled plastic. Panels interlock around guardrail posts to form a weed barrier. Panels are threaded together with rebar. Weed barrier sites were prepared by spraying existing vegetation on 4/26/2008; cutting existing vegetation with a hand trimmer; and leveling the existing soil with a hard rake. The 4-foot standard width WeedEnder product was installed at 3 plots on 6/23/2008. The WeedEnder barrier was recaulked on 10/9/2008 due to the observation on 9/4/2008 that weeds had begun to grow through the seams. The Universal Weed Cover was installed at 3 plots on 7/31/2008. In 2011, two additional weed barrier treatments were added. Site preparation for barrier installation was conducted in fall 2010, with glyphosate treatment on 9/23/2010. In spring 2011, the

Universal Weed Cover barriers were removed and the areas raked and leveled in preparation for a new barrier installation. U-Teck™ WeedEnder added a custom cut product designed to reach the road edge and accommodate variances in post width. This product was installed at three sites on 5/5/2011. U-Teck support staff was present for the installation and used crack sealer for seams between sections of barrier and for the transition between the barrier and the road edge. TrafFix is a rubber mat with 3 punched guardrail cutouts for flexible installation. It was installed at three sites that had formerly received the Universal Weed Cover on 5/6 and 5/7/2011. At one site, an incorrect punch out for the guardrail post was used. This installation problem led to unnecessary space between the barrier and road surface. At one site, the guardrail is approximately 15 feet from the road surface, resulting in an area that cannot be covered with a barrier and must be mowed during routine mowing maintenance. At the final site a sealer was applied between the TrafFix barrier and the road surface but there was no sealer applied around the guardrail posts. In 2011, vegetation adjacent to the original installation of U-Teck™ WeedEnder was tall enough at two plots to recommend hand trimming, which was completed by DelDOT personnel on 6/21 and 6/22/2011. One plot was also hand trimmed on 9/26/2011. The U-Teck™ WeedEnder custom cut installation required hand trimming on the backside of the guardrail on 9/26/2011 at one plot. The TrafFix installation was hand trimmed on the backside of the guardrail at one plot on 9/26/2011 and at a second plot on 8/24/2011. In all cases, the hand trimming was initiated to control vegetation adjacent to the barrier.

Figure 2. Weed Barrier products tested in this project at the time of installation.

U-Teck™ WeedEnder standard cut	U-Teck™ WeedEnder custom cut
	
Universal Weed Cover	TrafFix

Three plots were selected for hand trimming. Hand trimmed plots were trimmed as needed to maintain vegetation below the top of the guardrail (Table 1). Hand trimming occurred twice in 2008 (5-29-08 and 9-9-08); once in 2009 (9/8/09) (except one plot that was also hand trimmed on 6/9/09); and once in 2010 (6/14/10). In fall 2010, when herbicide treatments were discontinued, all plots formerly treated with herbicides were designated as hand trim plots. Seven of the hand trim plots were trimmed once in 2011 (6/21/11). Two plots were hand trimmed twice in 2011 (6/21/11 and 9/26/11). In 2012, 8 plots were hand trimmed twice (6/20/12 and 9/17/12 or 9/20/12 or5/22/12 and 9/17/12 or 9/20/12) and one plot was hand trimmed three times (5/22/12, 7/18/12 and 9/17/12 or 9/20/12).

Table 1. Hand trimming for plots designated as "hand trim" in years 2008 – 2012.

Year	**# of plots**	**# of times hand trimmed**
2008	All	2
2009	All	1
2010	All	0
2011	7	1
	2	2
2012	8	2
	1	3

The pavement treatment was one location in which pavement already abutted the road surface under guardrail. This treatment was not initiated as part of this project but was evaluated as one of the treatment plots.

For the low fescue treatment, existing vegetation was controlled with glyphosate on April 26, 2008. A low fescue blend (Silverlawn Creeping Red Fescue (34.46%), Discovery Hard Fescue (27.34%), Rescue 911 Hard Fescue (27.32%) and Annual Ryegrass (9.98%)) was hydroseeded on 3 plots on April 29 and 30, 2008 into the existing material under the guardrail, which was a mixture of soil and gravel. The first seeding of the low fescue blend was unsuccessful so plots

were retreated with glyphosate. A 1-inch layer of topsoil was added to each plot and the plots were reseeded with the same seed mix on 9/9/2008.

Low fescue plots were not hand trimmed in 2008. In 2009, low fescue plots were hand trimmed on 6/9/09. In fall 2010, one of the original low fescue plots was prepped by incorporating 1-inch of compost and hydroseeded with low fescue on 10/9/2011 and 10/13/2011. Two plots that were formerly treated with Accord (glyphosate) were added as low fescue plots. One inch of compost was incorporated and low fescue was hydroseeded on 10/9/2011 and 10/13/2011. All low fescue plots were hand trimmed by DelDOT on 6/21/2011 and 6/22/2011. In 2012, 3 low fescue plots were hand trimmed twice (6/20/12 and 9/17/12 or 9/20/12) and 3 low fescue plots were hand trimmed once (6/20/12).

Table 2. Hand trimming for plots designated as "low fescue" in years 2008 – 2012.

Year	# of plots	# of times hand trimmed
2008	All	0
2009	All	1
2010	All	0
2011	All	1
2012	3	1
	3	2

Low fescue plots were spot treated with herbicides as needed in order to reduce competition during the establishment period. Low fescue plots were spot treated with Overdrive® (diflufenzopyr and dicamba) and Milestone® (aminopyralid) to control thistle and treated with a broadleaved herbicide applied on September 8, 2009. A broadleaved herbicide (Drive, Acclaim and MSL®) was applied to all low fescue plots on August 24, 2011 and another treatment (2, 4-D) was made on 2 plots on August 31, 2011. Dead vegetation following the selective herbicide treatment was hand trimmed by DelDOT on all low fescue plots except one on September 26, 2011. In 2012, three low fescue plots were treated for thistle with Milestone (0.01oz.) and MSO (0.91 oz.) once during the 2012 growing season (7/18/12 or 5/24/12 or 10/ 11/12). One plot had a recurring thistle problem and was treated for thistle four times during the 2012 growing season (5/24/12, 7/18/12, 9/20/12 and 10/11/12).

Zoysia plots were prepared for seeding or sodding by treatment with Aquaneat (3 oz) and MSO (0.48 oz) on 4/24/2012. Compadre was the zoysia cultivar used and plots were prepped by raking out existing debris, covering the soil with a ½ layer of compost. Plots were seeded on 5/18/2012. Mulch was applied through a hydroseeder after seeding. Zoysia sod plots were prepped by raking out debris and digging out the soil so the sod could be installed level with the road surface and surrounding median turf on 5/18/2012. Zoysia sod was purchased from Amazoy Farms in Delaware and was installed on 5/21/2012. Sod was watered in on 5/21/2012 and watered three more times on 5/23.2012, 5/25/2012 and 5/29/2012. In one zoysia sod plot the surrounding vegetation in the median required hand trimming on 9/17/2012 or 9/20/2012 and in another zoysia sod plant a small thistle infestation was treated with Milestone (0.01oz.) and MSO (0.91 oz.) on 7/18/2012.

The FlightTurf seed used for this project was is a mixture comprised of *Festuca rubra* var. *rubra, Festuca longifolia,* and *Festuca rubra* var. *commutata.* The Flight Turf plot was hand trimmed on 6/20/2012 and treated with Aquaneat (7/30/12). There was no other site preparation. Flight Turf was seeded by an approved Flight Turf contractor on 10/3/2012.

There was no vegetation management strategy employed on the control treatment.

Plots were observed in 2008 on 5/5/2008, 6/12/2008, 7/31/2008, 9/4/2008 and 10/8/2008. A description of existing vegetation was recorded and a photograph taken for each plot. In 2009, plots were observed on 5/18/2009, 6/24/2009, 8/17/2009 and 11/4/2009. In 2010, plots were observed on 4/29/2010, 6/4/2010, 7/920/10, 8/12/2010, 9/10/2010 and 10/29/2010. In 2011, additional data was collected for each plot at each collection date-- compliance with DelDOT guardrail standards and the weed level present. A DelDOT acceptability rating was taken as an assessment of how well the plot conformed to DelDOT's requirement of a clear guardrail on a scale of 1-5 with 1=guardrail completely obscured; 2=vegetation covering most of guardrail; 3=vegetation taller than guardrail in spots; 4=vegetation starting to grow taller than guardrail in spots; 5=no vegetation near guardrail. A weeds rating was assigned on a scale of 1-5 with 1=completely overgrown with weeds; 2=a high level of weeds present; 3=moderate weeds present; 4=a few weeds present; 5=no weeds present. Plots were observed on 5/2/2011, 6/620/11, 7/25/2011, 9/19/2011 and 10/31/2011. In 2012, plots were observed on 4/20/2012 or 4/27/2012, 6/6/2012, 7/12/2012, 8/28/2012 or 8/30/2012, 9/28/2012, and 11/11/2012 or 11/12/2012.

Results

The vegetation on the treatment sites varied somewhat between plots and throughout the seasons but was comprised of a mix of species including annual ryegrass, aster, barnyardgrass bermudagrass, bittercress, black medic, broad-leaved plantain, bush clover, Canada thistle, cattails, cheatgrass, chicory, chickweed, cornflower, crabgrass, creeping Charlie, crown vetch, dandelion, daylily, dock, fleabane, foxtail, geranium, goldenrod, henbit, Japanese honeysuckle, jewelweed, jimsonweed, lambsquarters, lespedeza, lettuce, narrow-leaved plantain, mare's tail, morning glory, mugwort, mullien, nutsedge, oenothera, oniongrass, pigweed, phragmites, pilewort, poison ivy, purslane, pussy toes, queen anne's lace, ragweed, sheep sorrel, smartweed, speedwell, spurge, sweet clover, switchgrass, tall fescue, thoroughwort and Virginia creeper.

Tree/shrub seedlings including autumn olive, black cherry, Chinese elm, empress tree, black locust, juniper, mulberry, multiflora rose, pear, sumac, tree-of-heaven, and tulip tree.

<u>Herbicide Control</u>:
Treatment with Formulation 1 (Karmex, Plateau, Accord, Pendulum) burned back vegetation after each spray application. Bermudagrass still showed some green tissue after treatment when all broadleaf plants were controlled. Bermudagrass was the first plant to start growing again after treatment (approx. one month later (1 MAT)). By spring 2009, vegetation was growing on all plots treated with Formulation 1. On two plots, vegetation was consistently below guardrail

beams with one treatment per year. On one plot, vegetation was controlled acceptably in year one. But, in year two, vegetation was only temporarily controlled and by 2 MAT vegetation was above the height of the guardrail. Due to the method of application, the edge between controlled and uncontrolled (outside guardrail zone) vegetation was irregular (Figure 3). Cost for using Formulation 1 herbicide control of guardrail vegetation was $44.92 per 100 linear feet of guardrail.

Treatment with Formulation 2 (Plateau, Accord and Pendulum) burned back vegetation after each spray application. Vegetation was completely controlled in 2008 except two phragmites that grew on one plot in September (2 MAT). In spring of 2009 a few winter annuals were present on all plots. One plot was mistakenly sprayed with Krenite in fall 2008 and cut back so it was no longer evaluated. Vegetation was completely controlled in 2009 on both remaining plots. Cost for using Formulation 2 herbicide control of guardrail vegetation was $44.20 per 100 linear feet of guardrail.

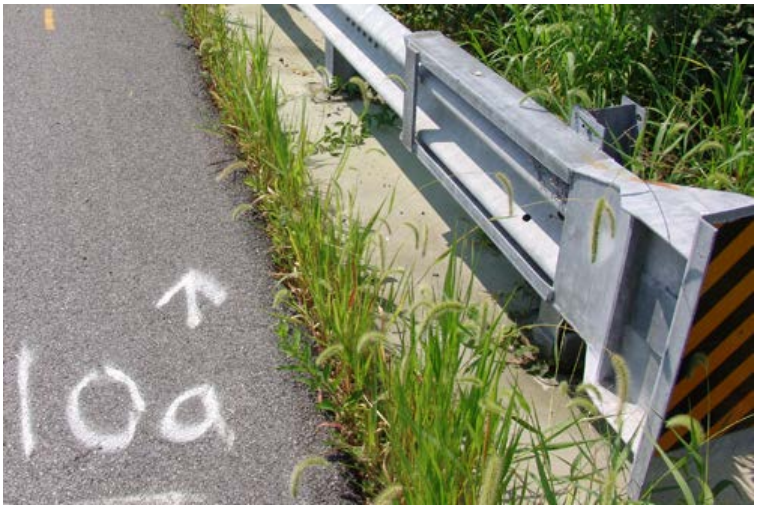
Formulation 3 (Accord) provided only partial control of vegetation after treatment. Canada thistle and nutsedge were present on one plot after treatment. By September 2008, enough weed growth occurred to consider retreatment, but the plots were not treated again in 2008. By July 2008, vegetation was at or above the top of guardrail on two plots. Vegetation was actively growing 1 MAT in 2009. Vegetation was above the guardrail on one plot by November 2009 (4 MAT). Cost for using Formulation 3 herbicide control of guardrail vegetation was $38.58 per 100 linear feet of guardrail.

Formulation 1 applied once per year kept vegetation at or below level of guardrail on all plots in 2008, and on all but one plot in 2009. Misapplication or spray drift resulted in an uneven edge between spray zone and normal vegetation that was unsightly. Formulation 2 applied once per year kept guardrail zone completely bare until the following spring and kept vegetation extremely low until the month before treatment. Formulation 3 applied once per year was insufficient to keep vegetation below guardrail.

Figure 3. Irregular edge between herbicide-treated guardrail zone and median vegetation.

Weed barrier treatments:
In several places weeds had begun to grow through seams in the U-Teck™ WeedEnder by 9/4/2008 and the barrier was re-caulked on 10/9/2008. There were low growing weeds growing over the edge of the barrier by 7/31/2008. The Universal Weed Cover barrier had weeds growing through seams by 10/8/2008. There were no weeds growing over the edge of the barrier (possibly due to its later installation). In 2009, low dead vegetation from the previous year was present on the U-Teck™ WeedEnder surface in May. Bermudagrass and crabgrass grew freely over the barrier surfaces but stayed well below the level of the guardrail. The Universal Weed Cover had seedlings growing through cracks and honeysuckle growing over the surface in May, 2009. Throughout the summer, ragweed and crabgrass grew through cracks in the barrier. By November 2009, weed growth was thick around guardrail uprights and weeds covered the surface of the barrier. By July 2010, many weeds were growing through and over the surface of the barrier. In July 2010, a few weeds were growing in organic material that had been deposited on the surface of the U-Teck™ WeedEnder barrier. The U-Teck™ WeedEnder was mottled and an unattractive color in April 2010. Some nails were popping up and the barrier was no longer flat at one plot, possibly due to water runoff from the road surface. In several plots treated with either type of barrier, there was a vegetated strip between the weed control barrier under the guardrail and the road surface. This vegetated strip grew freely throughout the season and limited guardrail visibility unless it was cut on a routine maintenance mowing cycle with the rest of the medians. If the strip was very narrow, as was the case with two plots, it did not get mowed during routine mowing and grew taller than the guardrail by July 2010 (Figure 4).

Figure 4. Strip between weed barrier and pavement allowing weed growth.



In 2011 and 2012, data was collected on U-Teck™ WeedEnder standard installation; U-Teck™ WeedEnder custom cut installation; and TrafFix barriers. U-Teck™ WeedEnder standard installation plots had vegetation growing between the barrier and road surface; bermudagrass breakthrough observed at seams (continued from previous years); and bermudagrass and crabgrass growing over the surface of barrier. The DelDOT acceptability rating for U-Teck™ WeedEnder standard plots was 3.72 and the weeds rating was 2.85 in 2011 and 3.25 and 2.80 respectively in 2012. The cost for installation of U-Teck™ WeedEnder standard installation was $1,789.52 per 100 linear feet of guardrail. Average maintenance cost was $24.00 per 100 linear feet per year, which included 1 ½ hand trims per year and no herbicide treatment.

U-Teck™ WeedEnder custom cut installation on 5/5/2011 was a much easier process than the standard product, resulting in less labor expenditure. The distance between the guardrail and the road edge varies so there was still a small amount of exposed soil at the road edge even with the custom cut product. Weed growth in this zone between barrier and road was first observed on 6/8/2011. By late summer nails holding down the barrier were starting to heave out of the ground. A few bermudagrass plants at guardrail post seams and at the road edge were growing by 7/25/2011. The DelDOT suitability rating for U-Teck™ WeedEnder custom cut was 5.0 and the weeds rating was 4.83 in 2011 and 4.87 and 4.58 respectively in 2012. The cost for installation of U-Teck™ WeedEnder custom cut installation was $2,197.54 per 100 linear feet of guardrail. Average maintenance cost was $8.00 per 100 linear feet per year, which includes 0.5 hand trims per year and no herbicide treatments.

The cost for installation of Universal Weed Cover was $$2,607.00 per 100 linear feet of guardrail. Average maintenance cost was 0 per 100 linear feet per year.

When TrafFix overlapped the road surface (one plot) there were no weeds found during 2011 or 2012. On the plots with vegetation growing between the road surface and the barrier, bermudagrass grew over the barrier surface and weeds in that zone grew taller than the guardrail by July 25, 2011. A few instances of bermudagrass growing through the seam at guardrail posts were observed starting on June 8, 2011. The DelDOT suitability rating for TrafFix plots was 4.58 and the weeds rating was 4.43 in 2011 and 4.20 and 3.83 respectively in 2012. But the one plot with appropriate conditions for ideal installation of TrafFix had a DelDOT suitability rating

of 5.0 and a weeds rating of 5.0. The cost for TrafFix installation was $2,537.17 per 100 linear feet of guardrail. Average maintenance cost was $24.00 per 100 linear feet per year, which includes 1.5 hand trims and no herbicide treatments.

A vegetation-free flat surface is required in order to install any of the weed control barrier products tested. The Universal Weed Cover barrier was cumbersome to work with, and unable to conform to road surface. The panels were bowed from shipping and were not flat at installation, but they did settle and conform to the ground over time. The rebar used to secure panels rusted by the end of 2009 and was unsightly. The U-Teck™ WeedEnder standard and custom cut products conformed to the median surface and were not readily visible from the road. The grey green color of the standard product was unattractive after 2 years on the roadside when viewed up close. The nails that heaved along the edge of the U-Teck™ WeedEnder barrier on one plot were unsightly and could pose a problem for snow plowing.

Vegetation can also penetrate seams around guardrail uprights where caulking was not applied correctly or if caulking was not used (Figure 5). The Universal Weed Cover barrier had cutouts for standard guardrail posts, not the I-beam posts used in Delaware. Therefore, weeds grew quickly in gaps present around each guardrail post. Weeds could also readily grow in joints connecting panels.

Figure 4. Bermudagrass growing around guardrail beam where caulk malfunctioned.

Vegetation grows in open soil between the road surface and barrier when the barrier cannot abut road surface. The U-Teck™ WeedEnder custom cut product was designed to address this issue. In some guardrail situations this product can abut or overlap the road surface, but in some cases the guardrail is located too far away from the road surface to make this feasible.

Low fescue:
In 2008, the low fescue seed mix did not germinate successfully. It was reseeded in September 2008. In spring 2009, low fescue was present as a sporadic cover on one plot. The annual grass in the mix was dominant on two plots in midsummer 2009. Low fescue was present on all plots but taller weeds (broadleaves and crabgrass) were more vigorous. After broadleaf herbicide application, crabgrass was still growing over top of the low fescue. Low fescue establishment was sporadic by November 2009. Low fescue established in denser colonies in shady areas of one plot.

After reestablishment of low fescue on one plot in fall 2010 and establishment of two additional low fescue plots, there was 5-10% cover, 10-20% cover or 50% cover by the end of October 2010 on the newly seeded plots. There was a good stand (65-80% cover) of low fescue on all three newly seeded plots in May 2011. By the June or July data collection dates, there was a thick stand (80% cover) on all plots, but there were some taller weeds present. The cost of establishment of low fescue plots including herbicide treatment to kill existing vegetation, grading and application of 1" of compost and hydroseeding was $444.33 for 100 linear feet under guardrail. At one site, two plots (one new and one existing) had competition from taller broadleaf weeds. After treatment with a broadleaved herbicide, those plots were hand trimmed to remove the taller dead vegetation. At the other site, the two new low fescue plots contained some broadleaf weeds and some crabgrass competing with the low fescue and were treated with broadleaf herbicide and annual grass post-emergent herbicide followed by hand trimming to remove taller dead vegetation. Average maintenance cost of the low fescue plots was $47.02/ 100 linear feet/year. This includes 1.5 hand trims and 1.25 herbicide treatments. It is projected that an herbicide treatment will be required for 3 years until the low fescue stand become thick enough to out-compete other vegetation. All low fescue plots seeded in 2010 had a thick cover of low fescue by the end of October 2011. The DelDOT suitability rating for low fescue plots seeded in 2010 was 3.37 and the weeds rating was 2.93 in 2011 and 4.20 and 3.44 respectively in 2012.

Low fescue was seeded in 2008 in late May, which is not an ideal time for seeding cool season turf. It was reseeded in September under better conditions. During the first portion of this study, low fescue did not establish significantly enough to provide a competitive cover. Reseeding of low fescue in fall 2010 was more effective, with thick stands developing by the summer of 2011. Weed competition was present during the first year after seeding and broadleaved herbicide or a combination of broadleaved herbicide and post emergent annual grass herbicide was used on plots depending on the weed pressure, resulting in a good stand of low fescue by the end of the growing season.

Zoysiagrass:

Zoysiagrass seed did not germinate in 2012. The zoysiagrass seed plots were comprised of a combination of weedy vegetation that came into the exposed soil after seeding. These plots performed most like a hand trim plot except that most of the vegetation germinated from seed in 2012 since the existing vegetation had been treated with herbicide to prepare the plot for seeding. Zoysiagrass does not germinate reliably from seed and that was evidenced in this study. Zoysiagrass seed plots had a DelDOT acceptability rating of 4.00 and a weeds rating of 2.27. The cost of establishment was $345/100 linear feet and the maintenance cost for one year was $16, which in one hand trim treatment. It is likely these plots will require at least 1.5 hand trim treatments on average in subsequent years.

Zoysia sod established successfully and had started to root into the existing soil by 6/6/2012 (the first data collection date after the sod was laid). The zoysia plot in the shade was the slowest to root in, but was completely rooted in by 7/12/2012. Zoysia sod did not grow taller than 6 inches during the first growing season. A few weeds, including foxtail and crabgrass grew at the edges of the sod. In one zoysia sod plot there was significant median planted with existing turf between the zoysia sod and the roadways. This one plot required hand trimming, but normally that would be taken care of by routine mowing of the median. By the final data collection date, 11/12/2012, the zoysia had gone dormant and turned a yellowish brown color. The DelDOT acceptability rating for zoysia sod plots was 4.93 and the weeds rating was 4.47. Zoysia sod cost $1582.28 per 100 linear feet to install and there were no maintenance costs incurred the first year.

Hand trim:
Plots were hand trimmed in late spring and early fall in 2008 and 2009. Vegetation stayed below the guardrail for about 2 months during the growing season (cut at end of May, tall by end of July) in both years. The second trimming was not performed until early September in both years. This timing kept vegetation below guardrail for the rest of the growing season. Vegetation from September until November was neat and green in the hand trimmed plots. Hand trimmed plots were kept below the level of the guardrail by only one hand trim completed in mid-June (6/14/10) in 2010. In 2011, seven hand trim plots were maintained below guardrail level with one hand trimming in mid-June (6/21/11 and 6/22/11). Two plots required hand trimming twice (6/21/2011 and 9/26/11) in 2011. Hand trimming costs varied between $17.09 per 100 linear feet when performed by DelDOT crews and $102.00 per linear feet when performed by an outside contractor. The DelDOT suitability rating for hand trimmed plots was 3.82 and the weeds rating was 3.09 in 2011 and 3.77 and 2.87 respectively in 2012.

Hand trimmed plots are not weed free, but when trimmed once or twice a year, depending upon location and weather, vegetation is maintained at or below the height of the guardrail.

Pavement:
Pavement prevented weeds from growing in front of the guardrail. Low weeds can grow from adjacent open land over the pavement but they do not grow above the height of the guardrail. Woody plants (autumn olive and sumac) growing in adjacent land began to obstruct the guardrail by November 2009.

Pavement prevents weeds from growing in the zone directly below the guardrail, but weeds are able to grow over the pavement (although not usually tall enough to provide obstruction) and woody plants on adjacent land can obstruct the guardrail eventually necessitating treatment.

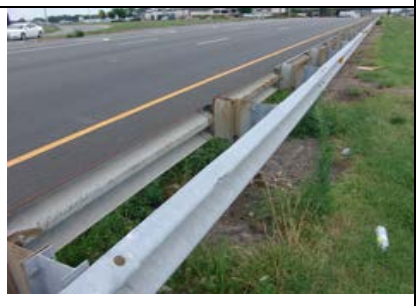
Control:
By midsummer 2008, vegetation on untreated plots was taller than the guardrail on one plot. At the end of the season, vegetation was taller than the guardrail on all plots. Winter weathering reduced the height of the vegetation on all plots. By May 2009, vegetation was at or above the height of the guardrail. In 2009, one plot was mistakenly sprayed; therefore data could no longer be valid. By late June, vegetation was tall and covering the guardrail on the control plots. Woody seedlings were prevalent in the control plots. No maintenance was performed on the control plots. In 2010, the control plots were converted to hand trim plots or used for new weed barrier treatments.

Vegetation begins to obstruct the guardrail fairly quickly and becomes problematic by early in the growing season of the second year without treatment. Since this was not acceptable for guardrail maintenance in Delaware, control plots were converted to treatment plots after two years of observation.

Table 3. DelDOT suitability rating and weeds rating summarized by treatments for 2011 (based on 1-5 Likert scale with 5=guardrail uncompromised and no weeds present).

Treatment	DelDOT suitability		Weeds	
	2011	2012	2011	2012
U-Teck™ WeedEnder standard cut	3.72	3.25	2.95	2.80
U-Teck™ WeedEnder custom cut	5.00	4.87	4.83	4.58
TrafFix	4.58	4.20	4.43	3.83
Low fescue	3.37	4.20	2.93	3.44
Zoysia sod	-	4.93	-	4.47
Zoysia seed	-	4.00	-	2.27
Hand trim	3.82	3.77	3.09	2.87

Figure 6. Photographs of each plot taken at the start of 2012.

Herbicide Formulation 1*		
Plot 2	Plot 7	Plot 17
		

Herbicide Formulation 2*		
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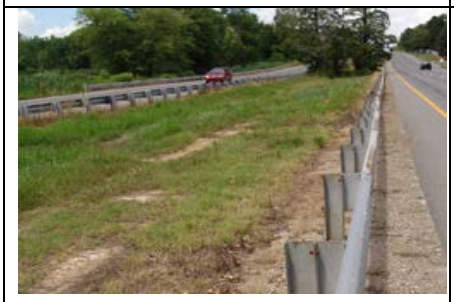		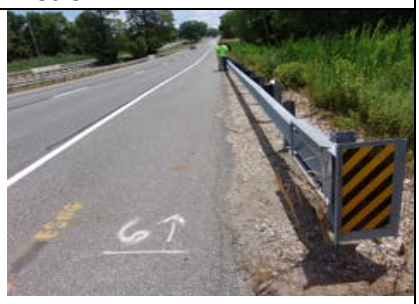
Herbicide Formulation 3*		
Plot 9	Plot 14	
		
U-Teck™ WeedEnder standard installation		
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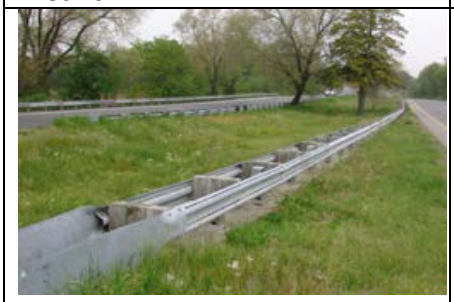	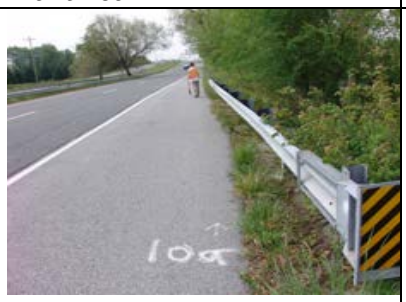	
U-Teck™ WeedEnder custom cut		
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		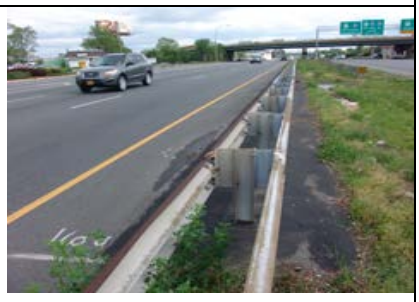

Universal Weed Cover*		
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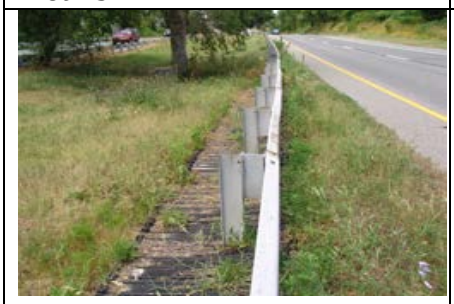
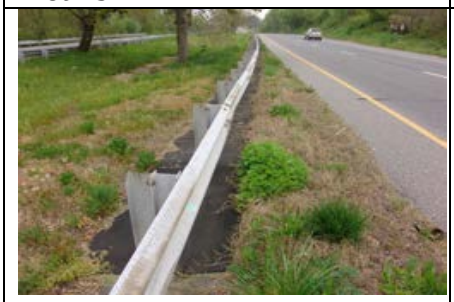
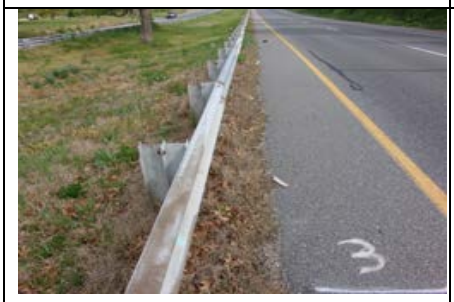
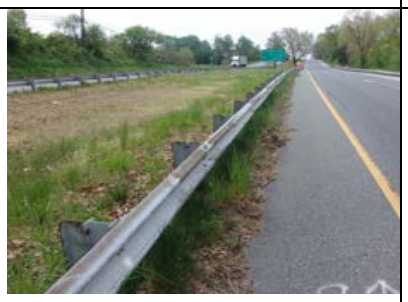
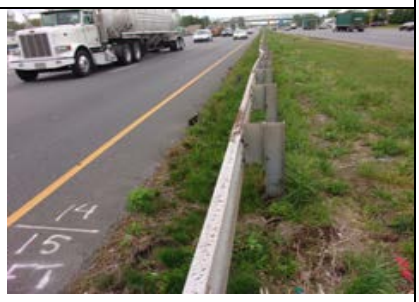
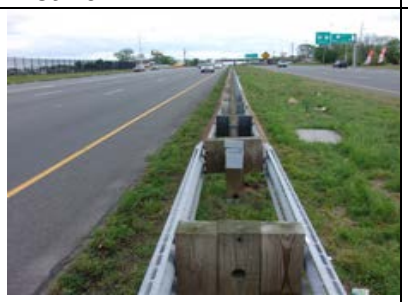
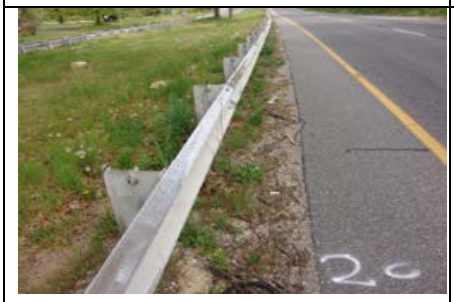
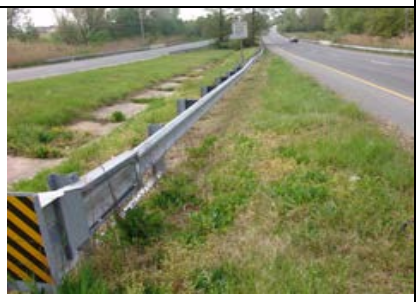
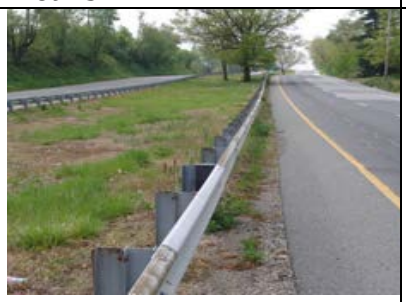
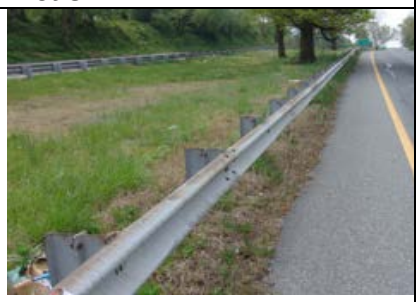
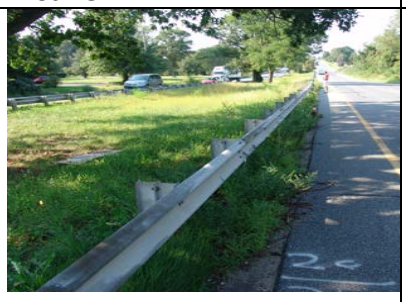
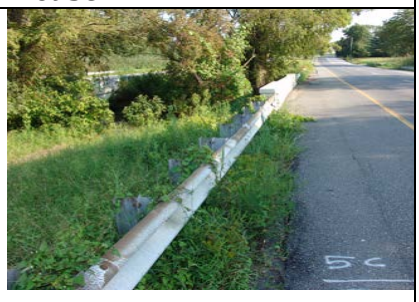
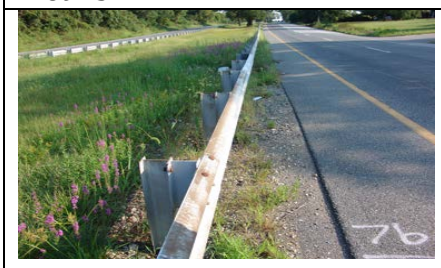
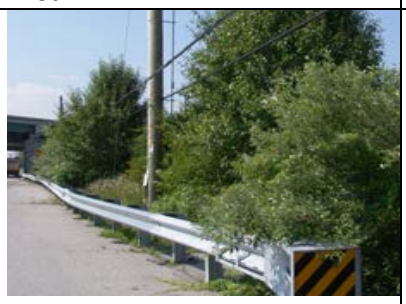
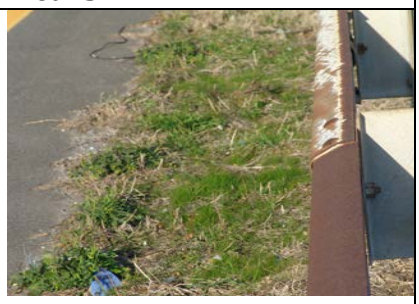
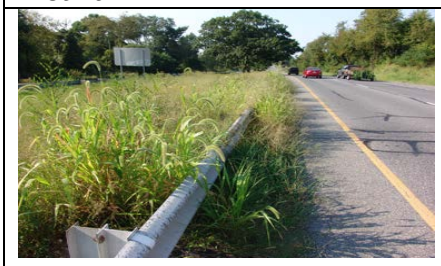
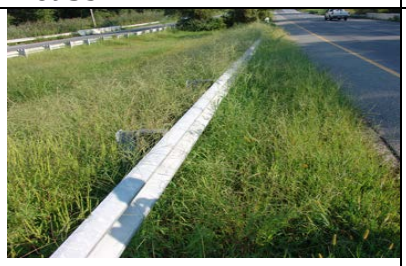
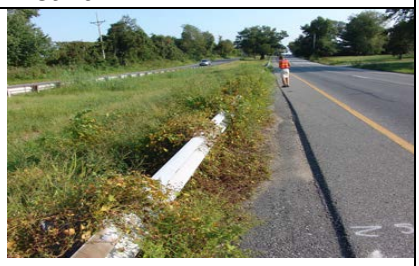
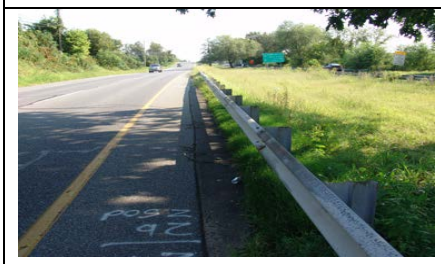
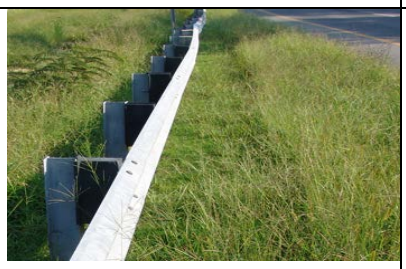
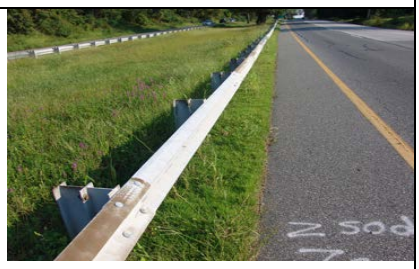
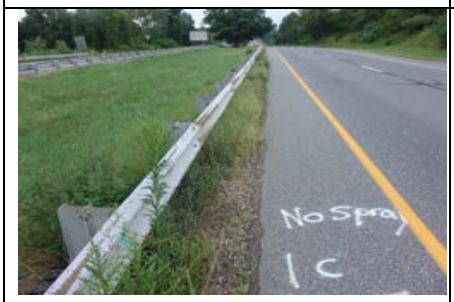
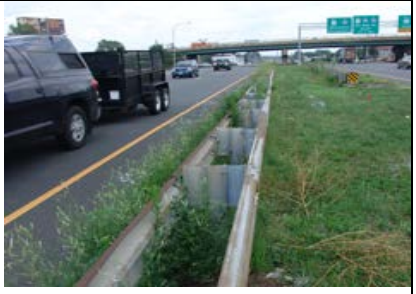
		
TrafFix		
Plot 1b	Plot 10b	Plot 18b
		
Low fescue		
Plot 3	Plot 9	Plot 14
		
Low fescue		
Plot 19	Plot 20	
		

Hand trim		
Plot 2c	Plot 4	Plot 5c
		
Hand trim		
Plot 6	Plot 7b	Plot 8
		
Hand trim		
Plot 11	Plot 15	Plot 17
		
Hand trim		
Plot 16b	Plot 2c**	Plot 5c**
		

Hand trim	Pavement *	FlightTurf***
Plot 7b**	Plot 12	Plot 15
		
Zoysia seed**		
Plot 2a	Plot 5b	Plot 7a
		
Zoysia sod**		
Plot 2b	Plot 5a	Plot 7c
		
Control*		
Plot 1c	Plot 10c	Plot 16
		

* Herbicide treatment, pavement and control photos were taken in 2010 at the completion of the herbicide treatment and control portion of the study.
**Zoysia seed, Zoysia sod, Handtrim (2c, 5c and 7b) in August 2012.
***FlightTurf photo was taken in November 2012.

Conclusions

Vegetation management is necessary to keep guardrails from being obstructed. Guardrails were still visible for the first year with no treatment but early in the growing season of the second year they were obstructed. Herbicides have been the traditional method of vegetation control in Delaware. The standard DelDOT guardrail formulation (DuPont™ Karmex® DF Herbicide (Diuron), BASF Plateau (Imazapic ammonium salt), Dow AgroSciences Accord®XRT (glyphosate), BASF Pendulum (Pendimethalin)) is used in most places and an alternative formulation (of BASF Plateau (Imazapic ammonium salt), Dow AgroSciences Accord®XRT (glyphosate), BASF Pendulum (Pendimethalin)) is used in sensitive areas. Both provided adequate vegetation control when applied once per year. A third formulation (Dow AgroSciences Accord®XRT (glyphosate)) did not adequately control vegetation. Herbicide treatments result in bare ground for most of the year. Erosion can be a problem when bare ground is maintained. After treatment, a brown zone of vegetation exists below the guardrail; which can be unsightly, especially when spray drift or misapplication results in an uneven treatment edge. We know that herbicides will prevent roadside vegetation from interfering with the guardrail and herbicides provide an inexpensive control option at a cost of about $45 per 100 linear feet of guardrail per year. The goal of this project was to find a more environmentally satisfactory alternative to herbicide use, so alternative control measures must compare favorably to herbicide use in terms of effectiveness, cost, environmental impact and aesthetics.

Weed control barriers are manufactured products that fit under the guardrail, exclude light and prevent any type of vegetation from growing around the guardrail. Weed control barriers are expensive to install, with an average cost of $2,282.81 per 100 linear feet. If one assumes a 10 year life of a weed barrier on the roadside (not yet tested in Delaware), the cost over the lifespan of the product is $228.28 per 100 linear feet. Hand trimming was required on weed barrier plots that had a strip of exposed vegetation between the barrier and the road surface. This resulted in an additional yearly maintenance cost of approximately $50 per 100 linear feet of guardrail for hand trimming. U-Teck™ WeedEnder custom cut installation was more expensive than the U-Teck™ WeedEnder standard cut installation. However, if installed properly so the maintenance cost of hand trimming were avoided, the additional cost (over 10 years) of $40.80 would be balanced by the lack of yearly hand trimming ($50). The TrafFix weed barrier was the third most expensive product with a depreciated cost of $260.70 per 100 linear feet per year. This product is the sturdiest of the products tested and has the greatest potential to last 10 years on the roadside. The Universal Weed Cover barrier was the most expensive barrier tested. It was an awkward product to handle and install, and was inferior to the other barriers tested. It is no longer on the market as a weed control barrier for use on roadsides.

Weed control barriers are difficult to retrofit in existing sites where the weed barrier cannot be laid true to the side of the road and on a perfectly flat surface. They are more appropriate in new road situations where grading and consistent distance between guardrail and road surface can be controlled. Vegetation growing over the surface of the barrier is not a problem since the plants that grow over the surface are low. Deposition of organic material on the barrier surface that supports weed growth may result in taller weed growth and is more likely to happen the longer the barrier stays in place on the roadside. Caulk is the weakest portion of the barrier and may degrade faster than the barrier fabric resulting in break through vegetation. Installation error is

also a cause of barrier break-through. Expertise (possibly by vendors themselves) is required for installation.

Low fescue turf is used under guardrail to provide a solid low growing ground cover that competes with other weedy plants that will grow taller and disturb the integrity of the guardrail. Low fescue turf did not establish adequately from a spring seeding and without appropriate site preparation (preparation of a seed bed with one inch of growing medium (compost)). Low fescue established more successfully with a fall seeding and proper site preparation (at a cost of $444.33 per 100 linear feet under guardrail). But, even with appropriate seeding methodology, low fescue did not establish a thick enough cover in one growing season to provide competitive weed control. In 2009 and 2011, selective herbicides were used to reduce the broadleaved weed and annual grass competition. The average cost per 100 linear feet for selective weed control per year during establishment was $41.64. An additional $17.09 was spent per 100 linear feet to hand trim tall dead weeds after selective herbicide application. Since DelDOT would like to reduce herbicide use on roadsides under guardrails, low fescue as an alternative vegetation strategy will be most effective if it provides a dense cover within 2-3 years after planting. Assuming the selective herbicide and hand trimming would be required for 3 years after planting, a cost per year for 100 linear feet of low fescue turf depreciated over 10 years was $58.63 per year. Low fescue, once established, is the most attractive guardrail treatment with low growing, relatively uniform green vegetation providing a solid mat under guardrail. Erosion is greatly reduced when a solid mat of low fescue is achieved.

Zoysiagrass did not establish from seed in 2012, but zoysiagrass sod established within one month and provided a competitive cover under the guardrail. In two plots, zoysiagrass was planted adjacent to the road surface. It provided a neat, clean vegetative cover under the guardrail. In the third plot, there was a significant strip of existing median vegetation between the guardrail and the road. This area was mowed during routine mowing but grew significantly taller than the zoysiagrass under the guardrail and detracted from the neat, clean look of zoysiagrass sod. Zoysiagrass sod was competitive enough to prevent significant weed incursion during the first year after planting. It did not require mowing during the first year. Zoysiagrass sod plots turned brown by the November 11 data collection. Zoysiagrass sod cost $1582.28 to establish per 100 linear feet of guard rail. Amortized over a 10-year period, this cost ($158.23) is less than any of the weed control barriers and only twice the cost of establishing low fescue seed.

FlightTurf was planted in October, so it was observed at only one data collection date in 2012. At that time, it was starting to germinate and there were sporadic clumps of new grass in the plot.

Hand trimming is a mechanical control strategy for keeping existing vegetation under guardrail to an appropriate height for guardrail function. Hand trimmed plots required trimming twice a year for the first two years of the study, when they were trimmed in May and September. By waiting until mid-June for the first trimming, most plots were maintained at an appropriate height for guardrail function with one hand trimming per year. The cost to maintain plots by hand trimming could be as low as $17.09 per 100 linear feet of guardrail if trimmed once a year by DelDOT crews. On average over the 4 years of data collection and all the hand trimming plots, these plots were trimmed 1.5 times/year. Hand trimming results in relatively solid

vegetation under the guardrail, which reduces erosion potential and is more attractive than bare ground treatment.

Table 4. Cost comparison of guardrail treatments in Delaware (per 100 linear feet of guardrail).

Treatment	Installation cost	Yearly maintenance cost	Installation cost (amortized over 10 years)	Total yearly cost (incl. amortized installation cost)
Standard herbicide formulation (1)	0	$44.92	0	$44.92
Sensitive site herbicide formulation (2)	0	$44.20	0	$44.20
Accord (glyphosate) only formulation (3)	0	$38.58	0	$38.58
U-Teck™ WeedEnder standard cut	$1789.52	$24.00[1]	$178.95	$202.95
U-Teck™ WeedEnder custom cut	$2197.54	$8.00[2]	$219.75	$227.75
Universal Weed Cover	$2607.00	0	$260.70	$260.70
TrafFix	$2537.17	$24.00[1]	$253.72	$277.72
Low fescue	$444.33	$47.02[3]	$44.43	$75.34
Hand trimming	0	$24.00[1]	0	$24.00
Zoysia sod	$1,582.28	0	$158.23	$158.23
Zoysia seed	$345.28	$16.00[4]	$34.53	$50.53
FlightTurf	$541.93	TBD	$54.19	$54.19
Control	0	0	0	0

[1]Includes 1.5 hand trims /100 linear feet, no herbicide treatment
[2]Includes .5 hand trims /100 linear feet, no herbicide treatment
[3]Includes 1.5 hand trims/100 linear feet, and 1.25 herbicide treatments/100 linear feet (The herbicide treatment for low fescue is assumed to be required for 3 years until the low fescue stand becomes thick enough to out-compete other vegetation.)
[4]Includes 1 hand trim/100 linear feet (this is based on only one year of data and assumed to be at least 1.5x in future years)

When you consider amortization over a 10 year life span, weed control barriers are still the most expensive vegetation control option under guardrail. They may be warranted in highly sensitive areas where herbicide use in unacceptable or other conditions warrant the complete lack of vegetation under guardrail.

Low fescue, if it established within three years, provided a competitive enough mat of vegetation such that selective herbicides were no longer needed and competes favorably in cost per 100 linear feet with herbicide treatments. Herbicide use has not been eliminated for the first three years, but the herbicide use is selective rather than a non-selective burn back of all existing vegetation. So, erosion is not a problem and the guardrail treatment is more aesthetically pleasing than bare ground, especially compared to an uneven treatment edge that often exists between the guardrail zone and the median vegetation with bare-ground herbicide treatment.

Hand trimming is the least expensive control method employed in this study (other than the control). This was true when DelDOT crews performed the hand trimming. If outside contractors were hired to hand trim, the cost per year would be approximately double the herbicide and low fescue treatments.

Since zoysiagrass did not establish from seed during the first year, this does not appear to be a viable establishment protocol on the roadside. Seed will be planted a second time in late spring 2013 to see if it established under different seasonal conditions. Zoysiagrass sod appears to be an effective vegetative cover. North Carolina has reported that centipedegrass and zoysiagrass can provide a stable competitive vegetation under guardrail (Yelverton and Gannon, 2004). In Delaware, zoysiagrass appears to be competitive enough to prevent weed incursion, at least in the first year after establishment. It will be interesting to continue observation of zoysiagrass sod plots to see how frequently hand trimming is required and if it remains competitive under the guard rail. Based on the performance of zoysiagrass in lawns in Delaware, it is expected to start to grow into the adjacent median. The rate of that spread will be interesting to note.

The low fescue treatment has not been shown to be competitive enough yet to prevent weeds from developing under guardrails. This study is ongoing to further test the potential of low fescue to develop a competitive ground cover as well as to continue to test the life span of the weed control barriers. Zoysiagrass will continue to be tested as a vegetative alternative under guard rails. Additionally, FlightTurf (http://www.flightturf.com/), a patented seed mix intended to provide cover and reduced mowing for utility turf areas will observed after its establishment in Fall 2012.

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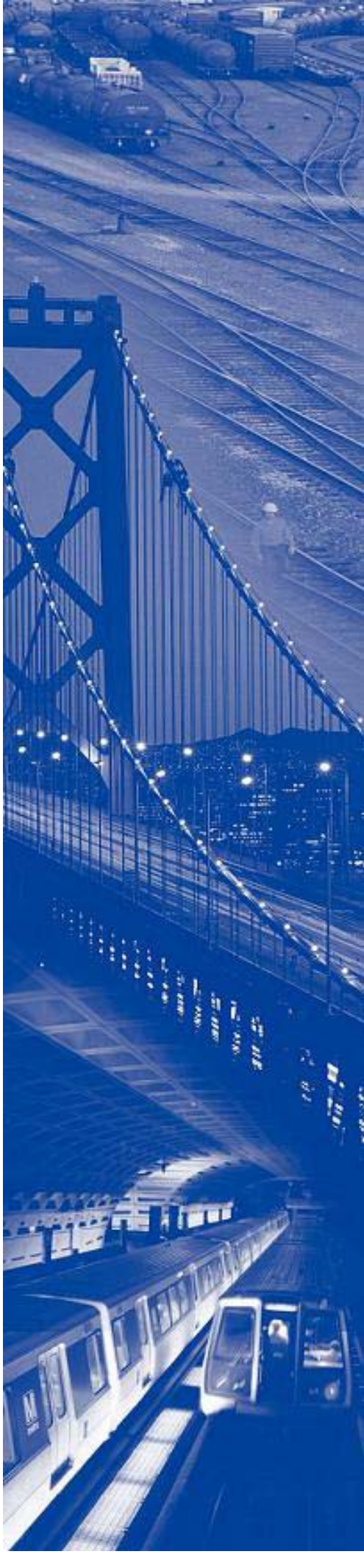

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