Assessment of Alternatives in Vegetation Management at the Edge of Pavement

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"Pavement Edge Vegetation Management"

ASSESSMENT OF ALTERNATIVES IN VEGETATION MANAGEMENT AT THE EDGE OF PAVEMENT

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16. ABSTRACT

WSDOT has historically maintained a bare ground strip (formerly referred to as Zone 1) along most state highway pavement edges with the use of non-selective herbicides. However, many other state DOTs and county road maintenance organizations do not maintain a bare-ground strip on all road shoulders. WSDOT solicited the assistance of the University of Washington in conducting a preliminary study on what other state and county departments of transportation were doing and experiencing in managing vegetation at the edge of pavement. Initial study concluded that there were a variety of methods being applied in management of vegetation at the pavement edge, but very little documented data on costs and results.

This report is a follow-up to the 2005 UW study, documenting the costs, outcomes and recommendations resulting from 43 individual case studies on Washington State highways between the years of 2006 and 2009. Alternative approaches are grouped into five categories: Managed Vegetation up to the Edge of Pavement, Pavement Edge Design, Cultivation, Weed Barriers, and Non-Selective Herbicides. The first two categories are focused on a vegetated treatment at pavement edge, while the last three describe various methods of providing a non-vegetated pavement edge. Both of these conditions are now referred to as a Zone 1 treatment.

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EXECUTIVE SUMMARY

This report documents findings from case studies at 43 locations throughout the state which compare and contrast vegetation management alternatives at the pavement edge. This effort was conducted over a three year period by the Headquarters Maintenance Office with assistance from WSDOT maintenance crews throughout the state.

The traditional WSDOT practice of maintaining a bare-ground strip at pavement edge is being re-evaluated as a result of concerns about potential effects to the environment from these types of herbicide applications, and due to the observation that satisfactory results could be achieved without the use of herbicides at many locations. This study implemented strategies to either establish and maintain vegetation up to the pavement edge, or maintain a bare ground strip through non-chemical methods.

Due to the relatively short (three year) timeline of this effort, the successful establishment of desirable vegetation at many locations along with the requisite cycles of maintenance cannot be fully analyzed within the scope of this study. Nonetheless, certain conclusions can be drawn from the findings in this report which will serve as a useful basis by which to consider alternative methods, and to further refine WSDOT practices.

As referenced throughout the report, the varied site conditions specific to the 43 case studies also represent a challenge in terms of providing equitable comparison in evaluating results. It is clear that success at one location does not ensure success at another due to unique characteristics.

Another inherent limitation of the study is the variation in resource availability from area to area. It is evident that maintenance crews are a resourceful group and make the best use of the equipment and materials they have, but equipment and human resources vary throughout the state. This leads to some differences in cost and outcome at similar sites.

Findings

Evaluation of alternatives is based on a comparison of cost and results. Maintenance costs are averaged per mile, and per year since some activities might occur more or less than once per year. Results include impacts on maintenance objectives such as traffic safety, worker safety, environmental factors, and preservation of pavement and roadside hardware.

Results varied significantly between Eastern and Western Washington due in part to precipitation and vegetative growth. More vegetation generally resulted in an increase in maintenance requirements where there were impacts there impacts on traffic safety and stormwater drainage.

In Eastern Washington, particularly in the more arid areas, it was found that desirable grasses could be established up to the edge of pavement. This was accomplished either through soil preparation and planting with new construction, or through efforts by maintenance to manage the transition from bare ground shoulders to naturally occurring grasses over a series of years. In cases where desirable grasses were successfully established, there were no adverse impacts to maintenance objectives and the level of effort and cost to maintenance was shown to decrease over time.

In Western Washington where the climate promotes more vegetative growth, there was a corresponding increase in required maintenance resulting from impacts on traffic safety and stormwater management. Where tall grasses block sight distance at intersections and curves in the spring and early summer, increased mowing is required at a greater cost than if these areas had been maintained with a vegetation-free pavement edge. In locations where stormwater flows to the edge of pavement, it was found that the presence of grass at the pavement edge resulted in a buildup of soil and debris, and subsequent problems related to standing water on the roadway shoulder. Over the course of the study period a number of maintenance innovations were proven effective in removal of edge buildup, and in improving the efficiency of mowing operations. However, in the majority

of cases in Western Washington where vegetation was allowed to grow at the edge of pavement there was an increased cost and level of effort compared with the use of herbicides to maintain a vegetation-free pavement edge.

Conclusions

WSDOT will continue to focus attention and analysis of this subject in the coming years and build on information presented in this report. As a result of the findings presented in this report, together with the knowledge and experience of individual crews, each region and maintenance area will evaluate local practices and determine desired outcomes on a case by case basis. The Area Integrated Roadside Vegetation Management Plans and corresponding annual evaluation/planning/training process will serve as a mechanism for developing, tracking and implementing best practices by each crew for any given stretch of highway.

Information in this report supports the continued or renewed application of residual herbicides at the pavement edge in certain locations such as under guardrail and on Western Washington highways with narrow paved shoulders and abundant vegetative growth. In some areas where shoulders were allowed to grow vegetation over the course of this study, bare-ground treatments will be re-established with a narrow (2 to 3 foot) strip at the edge of pavement. In areas with unique environmental constraints, or where it has proven effective to manage pavement edge with mowing, grading, sweeping, or other routine maintenance practices, those practices will continue. In Eastern Washington, areas will continue to minimize and phase out bare-ground pavement edge strips as appropriate.

In the long-term the agency will develop new and refined details and specifications for construction of pavement edges and vegetated shoulder to reduce ongoing maintenance requirements, and to improve stormwater management and pollution control wherever possible. There are a number of promising pavement edge and vegetated shoulder design possibilities that will serve as a basis for these efforts.

BACKGROUND

Integrated Vegetation Management for Roadsides

The Washington State Department of Transportation (WSDOT) began an examination of herbicide use within the Roadside Vegetation Maintenance Program in the early 1990's as a result of documented public concern over their use on Washington roadsides. WSDOT contracted with a team of private consultants to complete a Programmatic Environmental Impact Statement in accordance with Washington State's Environmental Procedures Act in 1993[1]. This process included extensive statewide public comment and an analysis of seven alternative vegetation management approaches. The outcome of this study and response to public comment was agency commitment to the development and implementation of a roadside vegetation management system based on the proven and well established process referred to as Integrated Pest Management or IPM. The application of IPM in systems or structures requiring the control of insects or weeds has shown to reduce the need for maintenance input over time, thereby decreasing the need for chemical controls.

Today WSDOT has a well established program which implements the principles of IPM. Through a set of site-specific roadside vegetation management plans, maintenance crews are guided in the control of undesirable plant growth and encouragement of desirable vegetation. Roadside vegetation management plans are kept current and updated through an annual cycle which includes:

- monitoring and evaluation of actions
- review and refinement of area vegetation maintenance practices
- locations of key maintenance needs and sensitive areas
- IPM based training program conducted each spring for area maintenance crews.

WSDOT refers to this specialized application of the IPM process as Integrated Vegetation Management (IVM) for Roadsides. With the implementation and development of this process, WSDOT has gradually reduced herbicide use to approximately 30% of what was used on an annual basis in the early 1990's.

Managing Vegetation at the Edge of Pavement

Roadside vegetation management starts at the edge of pavement and extends to the edge of right of way, and sometimes beyond. The foremost goal for maintaining vegetation is the safety of the traveling public and of workers performing that maintenance. Providing efficient traffic flow and operations, controlling legally designated noxious weeds, protecting the environment, and preserving the natural scenic qualities of Washington State are other significant goals. The edge of pavement is where the greatest attention is required and where most herbicide has been used historically.

[1] Roadside Vegetation Management – Final Environmental Impact Statement, Washington State Department of Transportation – Compliance Services International, December 1993

Beginning in the 1950's and continuing through the early 1990's, WSDOT treated vegetation at the edge of pavement with the annual application of non-selective, soil residual herbicides. This application controlled vegetative growth in a solid 4 to 12 foot band throughout the state highway system. This practice was based primarily on the principle that preserving the structural integrity of the roadway surface was dependent on a free draining pavement surface and subsurface. It was believed that vegetation growing on the shoulder and at the edge of pavement not only obstructed surface drainage, but would prevent water from draining out of the roadway subsurface. The maintenance of vegetation-free shoulders with herbicides accounted for over 60% of the agency's overall annual herbicide use through the early 1990's.

In 1994 a multi-disciplinary team of WSDOT and Federal Highways experts conducted a study of the need for maintenance of a vegetation free zone at the edge of pavement. The team determined that in some cases a vegetation free zone was not needed at all, and where it was beneficial, it was only needed in a width of 2 to 4 feet. As a result of this study, WSDOT began reducing the width of vegetation free bands along the edge of pavement throughout much of the state highway system. With some exceptions, narrow bare-ground treatments continued throughout the state over the next ten years.

More recently, concerns have again been voiced about the use of herbicides for roadside vegetation management. Much of this concern stemmed from the debate over pesticides and their impact on the aquatic environment, with particular respect to threatened and endangered species such as salmon. Several political action groups also cited alleged detrimental impacts of WSDOT's herbicide use on human health and the environment. WSDOT has responded to these concerns by updating the scientific risk assessment on its use of herbicides[2] (a risk assessment was originally conducted as part of the 1993 EIS).

These concerns helped influence the initiation of this five year research project for further evaluation and study of the practices for vegetation management at the edge of pavement. Six Washington State Counties currently do not use herbicides in maintenance of their county roadsides. A preliminary survey of other state DOT's found that the majority did not use herbicides to maintain a vegetation-free strip on all pavement edges. In an initial WSDOT departmental study of this issue titled Comparison of Roadside Maintenance Practices – Impacts of Herbicides on Cost and Results[3], costs of maintaining shoulders with herbicides were compared to what it would cost the agency to replicate the programs being conducted in the "no-spray" Western Washington counties and found that costs of maintaining vegetation to the edge of pavement would be significantly more than maintenance of a vegetation free Zone 1.

In 2004 the University of Washington was enlisted to help assemble a multi-disciplinary advisory team and conduct research on the practice of managing vegetation at the edge of highway pavement. Following a literature search for relevant research on this topic and a

[2] 2003/2005 Supplement To: Appendix B, Environmental Impact Statement 1993 Roadside Vegetation Management, Washington State Dept of Transportation – Intertox, Inc. June 2005
[3] Comparison of Roadside Maintenance Practices – Impacts on Cost and Results, WSDOT, December 2003

survey of practices both nation-wide and at the local county level, it was determined that there was very little data on the benefits and costs of the various pavement edge maintenance practices[4]. At the conclusion of this initial research, WSDOT committed to conducting an internal, three-year follow-up study of field-tested alternatives for maintenance of vegetation at the edge of pavement, which is the primary subject of this report.

During the course of WSDOT's analysis of this topic, other state departments of transportation including Caltrans[5], Massachusetts DOT[6] have also published research on this topic and New York State DOT is currently conducting related research. Relevant findings from these other research projects are also considered in the conclusions reported in this document.

[4] Assessment of Alternatives in Roadside Vegetation Management – Hill and Horner, University of Washington, December 2005

[5] Caltrans Vegetation Control Products/Processes – Value Analysis Study Final Report, RH & Associates NCE, May 2008

[6] Herbicide Alternatives Research, Massachusetts Transportation Research Program/University of Massachusetts Amherst, June 2008

DESIGN OF THE STUDY

Determination of Maintenance Costs

Annual maintenance costs and infrastructure life cycle costs are important considerations in evaluating vegetation management alternatives. Many factors in management of vegetation at the pavement edge must be considered over a longer term than is permitted within the time constraints of this study. Impacts from design/construction, vegetation growth, traffic flow, and changing maintenance practices evolve and transpire over multi-year cycles. Therefore, personal judgment and estimates for certain long-term impacts and maintenance costs were used to account for these variables.

Maintenance costs were compiled based on the historical experience of area maintenance crews, and as documented in the WSDOT accounting system. These costs were reviewed and verified by the supervisors and crew leaders in each case study.

Accuracy of comparison of differing sites and methodologies is a challenge due to the variation in site conditions (weather, vegetation types, road design), crew make-up, and equipment resources. Therefore, costs have been averaged over the largest possible extent of time and geographical application and compared based on average cost per shoulder mile. To account for certain construction and maintenance activities that may be needed only once in the life-cycle, or in multi-year cycles, costs are also averaged by year. Overall costs for each viable alternative are presented in terms of average cost per mile, per year.

For some alternatives there are initial construction and/or installation costs. Where these costs apply they are presented and discussed, but are considered construction costs and not included as part of the maintenance life-cycle cost.

Consideration of Results

The resulting impacts or benefits from the various alternatives studied are in most cases from empirical evidence based on observation of the local maintenance crews and supervisors, and documented in monthly photograph points within each case study boundary.

The primary considerations in each case are impacts on highway maintenance and operational objectives. The most critical of these objectives are: traffic safety and operations, safety of the maintenance employees, and environmental factors such as pollution control and management of stormwater run-off.

Vegetation impacts on traffic safety include site distance (at driveways, intersections and corners/curves), visibility of highway delineators and other roadside hardware, and visibility of potential hazards at wildlife crossings. Another safety impact to be evaluated is build-up of a grass mat at the edge of pavement, which has the potential to hold water

on the roadway surface during storm events. If standing water extends into traffic lanes it creates the potential for vehicles to hydroplane or lose control.

Another effect on traffic safety is the presence and duration of maintenance equipment and/or activities on the shoulder. This can result in driver distraction which can impact the flow of traffic. Other traffic safety considerations from vegetation at the edge of pavement are fire starts and wildlife behavior in relation to animal/vehicle accidents. However, data for both of these considerations in relation to pavement edge alternatives studied vary widely from site to site and are largely inconclusive.

Safety of maintenance employees is largely affected by their exposure to traffic. Alternatives which place maintenance employees out on the roadside for longer periods of time and/or without vehicular protection increase the potential for accidents and injury.

Protection of the environment, when considering alternatives for managing vegetation at the pavement edge, is primarily a function of how the alternative practice affects stormwater management and the filtration of highway/traffic generated pollutants. The optimum condition for the pavement edge/roadside vegetation interface allows for an even sheet-flow of stormwater from the pavement surface, onto and through vegetated shoulder material (and in some cases additional filtration and retention facilities) before it enters surrounding water bodies or ground water. Herbicides applied for treatment of vegetation at the edge of pavement in some cases may also serve as potential sources of pollution. However WSDOT has taken precautionary steps above and beyond the requirements of state and federal law to reduce the potential for environmental impacts from herbicides.

Alternatives Considered

Alternatives considered were selected based on findings from the UW research with consideration for practical application on Washington State highways. Alternative practices for maintenance of vegetation at the edge of pavement are compared against the historical practice of maintaining a 2 to 6 foot band of vegetation-free ground adjacent to the edge of pavement using a mixture of non-selective post-emergent and soil residual herbicides.

Forty-three case studies were established and documented in locations throughout the state highway system. Alternatives studied were grouped into five categories:

- Managed Vegetation up to the Edge of Pavement
- Pavement Edge Design
- Cultivation
- Weed Barriers
- Non-Selective Herbicides

The set of alternatives studied in Managed Vegetation Up to the Edge of Pavement is the most extensive group of experiments. This alternative focuses on establishing desirable

vegetation (grasses) on the non-paved shoulder and maintenance with selective chemical and/or mechanical means (mowing and grading) in a variety of situations.

Pavement Edge Design included two locations where some form of paved break/edge drop was already present or constructed at the edge of the paved shoulder.

Cultivation included situations where a band 2 to 3 ft. wide was annually turned and repacked using a tractor mounted disking tool followed by a grader.

Weed Barriers tested a series of products/materials designed as soil cover/matting material for use under guardrail.

Non-Selective Herbicides evaluated annual treatment of solid 2 to 4 ft. band with various mixtures of non-selective, pre and post emergent herbicides each spring.

When the practice of maintaining the pavement edge with residual herbicides was prevalent within WSDOT, success relied heavily on the use of the herbicide Diuron. In 2003 a U.S. District Court decision restricted the use of Diuron near salmon-bearing waters due to concerns over aquatic toxicity. Given these concerns, WSDOT eliminated the use of Diuron in Western Washington, and restricted its use within 60' of water bodies on the east side of the state. As a result, the Western Washington case studies were evaluated with the use of non-Diuron residual herbicides which are typically more expensive than Diuron.

Definition of Zone 1

WSDOT has historically referred to Zone 1 as the maintained vegetation-free strip of ground adjacent to the edge of pavement. Prior to 2003, this type of vegetation free zone was maintained through the annual application of soil residual herbicides throughout most highways in the state system. However, with the transition of many of these formerly bare-ground shoulders to vegetation during the course of this study, this definition of Zone 1 no longer applies. For the purposes of this report in comparison of alternative methods, Zone 1 refers to the band of unpaved shoulder immediately adjacent to the edge of pavement where some form of routine, periodic vegetation maintenance is required.

Presence of Guardrail

An important distinction for all situations and alternatives studied is the presence or absence of guardrail installed adjacent to the paved highway shoulder. Maintenance objectives, actions, and associated costs and results vary significantly where guardrail is present. Findings and conclusions are classified by the presence or absence of guardrail.

Climatic Differences – East to West

Another important distinction is between sites in Eastern and Western Washington. The majority of cases studied were in Western Washington where more rainfall and corresponding vegetative growth create greater challenges in controlling vegetative growth and in managing stormwater. Findings and conclusions are discussed separately for situations in Eastern and Western regions of the state.

A table listing all alternatives and locations is included in this report as **Appendix A**.

FINDINGS AND CONCLUSIONS

Many conclusions drawn from the findings of this study are not universally applicable because there are significant variations between Eastern and Western Washington sites, as well as between traffic volumes, design configurations, roadside features, and surrounding environmental factors. Area specific labor and equipment resources also have an effect on the practicality and net cost of alternatives. The most appropriate treatment for any given location is dependent on the most advantageous combination of low life-cycle costs, positive short and long-term results, and consideration of local conditions and maintenance area resources.

It should also be noted that there are a number of potential innovations in both design/construction and maintenance practice which should be explored as WSDOT continues to refine the practice of maintaining vegetation at the edge of pavement.

Western Washington Findings

On the west side of the state the typical rate of vegetative growth, composition of plant material, and potential height and spread of vegetation require that some type of maintenance occur a minimum of once a year in most locations. In many cases, even where a vegetation-free strip is maintained, the shoulder is mowed at least once a year.

An example of a roadside in Western Washington that meets all required objectives at the lowest annual maintenance cost is US 12 between Elma and Centralia. The pavement edge (Zone 1) is treated once a year with residual herbicides and the remainder of the operational area (Zone 2) is only mowed occasionally and typically only receives selective cutting or spraying to control unwanted weeds, trees and brush.

Rapid build-up of a soil-grass mat was a significant result when a vegetation-free zone was eliminated and grass was allowed to grow at the edge of pavement in Western Washington. Edge build-up can result in a significant safety risk to traffic by trapping water on the road surface creating unsafe driving conditions during rain storm events. Periodic removal of this build-up can be expensive. However, maintenance innovations in some areas have proven to eliminate edge build up while conducting other routine operations such as sweeping or plowing shoulders in the winter.

In many cases the shoulder is mowed regardless of the presence of a vegetation-free zone. In these cases one of the main benefits of an added vegetation-free zone is prevention of edge build up. However, on the SR 2 corridor east of Gold Bar, the shoulder has been vegetated to the edge of pavement for the past 10 years and mowed two or more times each year. Edge build up in this area is routinely removed through winter plowing operations when operators run the edge of the plow blade along the edge of the pavement and the previous year's build up is broadcast away from the pavement toward the ditch.

The historic practice of maintaining a vegetation-free strip with herbicide was proven to be significantly less expensive than any of the alternatives tested. Due to the fact that mowing operations move at a much slower rate than spraying operations, it costs about half as much to spray rather than mow the edge. A vegetation-free strip also helps to alleviate edge build-up and surface drainage problems and reduces the life-cycle cost. However, there are many situations throughout Western Washington where shoulders are mowed regardless of the presence or absence of a vegetation-free edge. There are also cases where for various reasons edge build up is not a factor. In these cases, where annual mowing is done regardless and grass at the edge of pavement is not a factor or does not cause problems with surface drainage, maintenance of a vegetation free zone has no advantage and becomes an unnecessary extra cost.

Adjustments to maintenance practices such as sweeping and winter snow plowing help remove edge build up without adding cost. (isn't there a cost associated with sweeping?)

Pavement edge design also can help manage edge build up and allow for stormwater surface drainage where grass is allowed to grow up to the edge of pavement

For guardrail locations, the most effective and least expensive method of any of the alternatives tested was treatment with residual herbicides. This is due mainly to the fact that soil/debris deposition and edge build-up occur faster around guardrail posts when vegetation is present, and removal is more expensive. Also, in almost all locations in Western Washington where vegetation is allowed to grow around the base of guardrail, mowing or trimming is required and is

significantly more expensive and labor intensive than mowing on shoulders without guardrail.

Trimming vegetation around guardrails manually is time consuming and exposes maintenance workers to traffic and tripping hazards.

A variety of vegetation preventive covers were tested under guardrail with varying degrees of success. The initial cost of installing these products or of paving under guardrail, combined with the fact that some cleaning or manual debris removal is still required in any case, makes the life-cycle cost for any of these techniques more expensive than the use of herbicides to maintain a vegetation-free strip under guardrail installations.

Eastern Washington Findings

The arid climates typical of Eastern Washington present very different issues when compared to the west side of the state. Edge build-up, stormwater treatment, and excess growth of desirable vegetation are not as prevalent. It has been demonstrated at several sites that if desirable vegetation is established up to the edge of pavement, life-cycle costs are lower than with maintenance of a vegetation-free strip with residual bare-ground herbicides. Establishment of desirable grass does require a significant amount of time and in some cases a significant initial investment. This is due to several factors including the slow break-down of previously applied residual chemicals, lack of organic matter and nutrients in roadside soils and excessively drained roadside conditions. Due to these factors and the limited duration of this study, it will be necessary to continue to monitor some of the sites in Eastern Washington to better understand the relationship between initial investment and lifecycle costs.

The findings of this study support the establishment of desirable vegetation up to the pavement edge in most cases throughout the east side of the state. However, this requires an initial investment to plant and establish desirable vegetation on shoulders that typically consist of mostly crushed rock and lingering residual chemicals in the soil profile. A number of areas on the east side of the state are experimenting with methods to transition vegetation-free shoulders to desirable

grasses. In many cases new construction projects are installing amended base material that will support a grass stand, and seeding with appropriate species.

In guardrail locations, a narrow bare-ground treatment with residual herbicide continues to be the most common approach. Several trials were completed allowing desirable vegetation to regenerate under guardrail. In both cases the rail remained serviceable at a very low cost as long as wild fires did not destroy the posts. However the risk of losing guardrail posts to fire is well established and occurs on an annual basis with the potential to incur a substantial cost and poses a risk to the traveling public.

Three different types of weed matting were tested under guardrail with varying success. The two types of matting that performed best are options to be further considered as they provided excellent plant suppression with little or no maintenance over the span of this study. Matting, however, may have only limited applications due to the high installation and material cost; they would only be used in special site specific areas where herbicides cannot be used.

Conclusions

The best long-term management plan for any given location is dependent on local site conditions, highway configuration and design, and the operational structure of the local maintenance area. The data and findings included in this report provide a basis for informed decisions as to the most appropriate treatments for pavement edges throughout the state highway system. In the long term, best management solutions may be largely dependent on the assistance of design and construction projects. In any case, maintenance practices must be determined through evaluation of both short and long-term expenses for each location while considering impacts on critical management objectives such as safety and environment.

Area IVM Plans and the annual evaluation and planning cycle will allow the maintenance areas to plan, execute, and adapt the best long-term management strategies for all pavement edges. Appropriate treatments can be determined and documented in the IVM Plans by route and milepost to help insure accurate implementation by the crews.

In Eastern Washington, the study indicates that in non-guardrail areas, the best long term solution in most locations is to establish desirable grasses up to the edge of pavement. In these locations maintenance areas will need to determine the most cost effective means of establishing desirable grasses in gravelly soils that have been formerly maintained with residual herbicides. This can be accomplished through passive measures, such as treating broadleaf weeds with chemicals allowing desirable species to migrate into that zone. Or it can be accomplished through active measures by adding nutrients, reseeding and control of invasive species. Both require a long term commitment which should result in decreased vegetation lifecycle maintenance costs as compared with the standard residual bare-ground applications. In some cases the cost of establishing desirable vegetation may

need to be deferred until the work can be completed as part of a new construction project. New construction projects should provide for this type of shoulder maintenance wherever possible.

For Western Washington, the findings of this report may lead to the re-establishment of a vegetation-free strip along the pavement edge in some cases, including some locations where vegetation has been allowed to establish over the past 3 to 4 years. In these locations, it is critical that existing vegetation and soil build-up are removed, and shoulders reshaped, prior to initiation of annual residual herbicide treatments. Total re-establishment of a bare-ground zone could take several seasons to accomplish.

INDIVIDUAL CASE STUDY FINDINGS AND RECOMMENDATIONS

The findings and recommendations for each of the alternatives studied are grouped by the five categories and presented below. Each alternative is keyed to the table in **Appendix A** for further information on the location and extent of application, as well as reference to the individual WSDOT supervisors responsible for implementation and oversight. Cost estimation sheets breaking down the factors of labor, equipment and materials are included for reference in **Appendix B**.

1. Managed Vegetation Up to the Edge of Pavement

One of the major considerations in this study is the cost and impacts to maintenance and operations if vegetation (i.e. grass) is allowed to establish up to the edge of pavement. In most cases within this group of tests, the non-paved shoulder area is transitioning from a maintained vegetation-free strip to a grass stand. This series of case studies includes some experiments where this transition is accelerated using techniques for soil preparation and planting grasses. Other case studies illustrate the results of allowing vegetation to naturally move back into this zone without any maintenance intervention except for mowing.

One of the most significant impacts from allowing vegetation to establish up to the edge of pavement in Western Washington was the buildup of a soil and sod mat which inhibits stormwater drainage. In some cases the estimated cost to remove build up is added to the average cost/mile/year, in other cases it is assumed the areas will routinely remove buildup incidentally with sweeping and plowing operations. In Eastern Washington this proved to be a non-issue. Another significant impact is an increase in the necessity for mowing operations in Western Washington to manage tall grasses impacting sight distance at the edge of pavement. Mowing operations move slower than banded herbicide applications, increasing exposure of maintenance employees and equipment to traffic, driving up costs and taking up crew time needed for other work. Mowers are also more prone to break down, creating potential challenges in accomplishing the work.

1.1. Soil Amendment – Western Washington
Compost layer, seeded with desirable grasses
SR 525, MP 26.45 to 27.4

Description: Installed 2004 in conjunction with a project which included new pavement, some realignment, and widening of paved shoulders. A 2" layer of course compost was installed over compacted crushed-rock base course between the pavement edge and ditch bottom. The following fall, the local maintenance crew hydro-seeded over the compost with a mixture of low-growing native grasses.

Costs:

- Initial Cost – **$ 695/mile**
  - No added initial cost for compost, installed as a no-cost change order under contract.
  - Hydro seeding by the area crew – $555/mile (Appendix B, Page 31)
  - Custom mix native grass seed – 80 lb./acre, 1 acre seeded (2 miles of shoulder) @ $4/lb. = $320/acre or $120/mile
  - Hydro-seed mulch – 2 bales @ $20/bale = $40/acre or $20/mile
- Ongoing Maintenance Cost – **$60/mile/year**
  - Annual mowing with side mounted sickle bar – $60/mile (Appendix B, Page 24)
  - During the course of this study, edge buildup has not occurred in this area. Compost has gradually decomposed and settled easing the transition from pavement to grass. Also, the composted shoulder seems to act like a sponge and absorb water at the edge of pavement.

Results: Healthy, mostly weed-free grass stand after several initial years controlling broadleaf noxious weeds such as Tansy ragwort and Knapweed, emerged more frequently in compost as compared to untreated adjacent gravel shoulders. Minimal to no edge buildup in 5 years following construction, buildup has been offset from gradual compost settling, decomposition and compaction. Native grass seed mix was about twice the price per pound as the type typically specified in WSDOT roadside mixtures but performed well.

A compost layer is less expensive than top course crushed rock and aids in stormwater management. Course grade material compacts for a drivable surface.

5 years after construction this location has a well established grass stand and less edge buildup than other locations, shown here recently mowed with sickle bar.

Recommendation: This treatment method should be considered most preferable for new construction in locations where grass is to be established up to the edge of pavement. It is more straightforward and less expensive than placement of compost/rock mixtures and produced the same results or better results in vegetative growth and establishment of a desirable grass stand. It

would be advantageous to combine this with a safety-edge treatment on the pavement. (Ref. Case Study 2.1, Page 29-30)

1.2. Soil Amendment – Eastern Washington
Layer of Topsoil Type B amended with compost, seeded with native grasses
US 12 – MP 295.3 to 299.3

Description: The US 12 Phase II construction project was designed to allow for the installation of desirable vegetation to the edge of pavement. This project included new construction of the entire roadway prism and represented an opportunity to evaluate an alternative method of construction and maintenance. The roadsides within the project were constructed incorporating a 4-6" layer of native soil with a 2" layer of "Boise Cascade" compost incorporated into the native soil. Incorporation was accomplished with an agricultural "Swedish-tine" type cultivator to a depth of approximately 6". Roadsides were hydro-seeded in the fall of 2005 with a low growing perennial grass seed mix.

The two primary goals of this test plot are: 1) Evaluate the cost of maintaining the pavement edge zone (Zone 1) with desirable vegetation compared with traditional bare-ground condition; and 2) Evaluate the ability for desirable vegetation to establish at the edge of pavement.

US-12 Phase II, MP. 296 Spring 2006

US-12 Phase I, MP. 299, Summer 2008

Cost:

- Initial Costs
  - As noted in the Study Design section, installation costs incurred during construction of this roadway are not included in this evaluation.
- Ongoing Maintenance Costs – **$43/mile/year**
  - Estimated annual bare-ground cost for a 4' band at the edge of pavement zone – $93/mile/year (Appendix B, Page 11)

- Ongoing Maintenance Costs – $43/mile/year for application of 1-2 treatments of selective broadleaf herbicide for control of broadleaf noxious weeds, approximately 12' wide. (Appendix B, Page 10)
- Savings – Approximately $50/mile savings for labor, equipment and materials with current selective treatment methods compared to estimated bare-ground treatment methods.
- The cost savings realized in this test plot are due in part to the successful establishment of desirable vegetation. While weed control treatments are and will be necessary for the foreseeable future, the total number of acres treated has steadily declined over the duration of this study.

Results: Desirable vegetation quickly established throughout this site including the edge of pavement zone. This was due to both favorable spring growing conditions during the spring of 2005 and the improved roadside soils installed and incorporated during the construction phase. The establishment of desirable vegetation has deterred but not eliminated the growth of noxious weeds. Early infestations primarily included kochia, Russian thistle, a variety of knapweeds and cereal rye. The Herbicide treatments continue to be necessary at this time and will continue to be needed in the future. In general 1-2 selective herbicide applications between 8-12 feet wide should be adequate.

There were several vehicle related fire starts in the project area that were limited to the WSDOT right of way and did no significant damage to property or infrastructure. Data on fire starts is very difficult to obtain and compare from one location or road to another. There did not appear to be more fire starts or an increase in damage on the project area than other roadsides in the vicinity.

Pavement edge build-up has not been a problem in spite of a significant accumulation of corn silage, hey and wheat chaff that routinely blows off passing trucks. There are no locations where build-up has caused pooling on the roadway or required maintenance. The presence of stable desirable vegetation has clearly helped to reduce erosion at the edge of pavement and is likely serving as an effective bio-filter to roadway contaminants.

Recommendation: This plot clearly indicates that there is an opportunity to reduce life-cycle maintenance costs related to vegetation management at the edge of pavement with the establishment of desirable vegetation. This cost savings extends well beyond the edge of pavement as fewer herbicide applications were required and shoulders were better stabilized without impacting sight distance. While the cost of improving roadside soils during the construction phase was not considered in this study, it is recognized that there is a construction cost associated with this type of success. This cost/benefit relationship needs further research and clarification, however the success of this project clearly indicates that new constructions projects should consider this

option, and that Maintenance should influence that decision making process in the interest of providing long term, stable roadsides.

1.3. Soil Amendment – Western Washington
Compost/rock mixture, seeded with desirable grasses
SR 507 – MP 36.63 to 37

Description: Installed 2005 with construction project which included new pavement and widening of paved shoulders. A 2" layer of crushed rock base course was mixed with 40% by volume of course compost. Drop seeded and raked in the following fall by the local maintenance crew. Three variations of low-growing grass mixtures were used in sections across the site for evaluation.

Cost:

- Initial Cost – Seeding w/ desirable grasses, **$883/mile**
  - Compost/rock mixture installed with construction project at a cost comparable to traditional methods
  - Drop seeding and raking by the area crew – 4 hours, tech II, Lead tech, pickup = $785/mile (Appendix B, Page 32)
  - Seed mix – 100 lb./acre, .2 acre seeded at $1.95/lb. = $39 or $195/acre or $98/mile
- Ongoing Maintenance Cost – $10/mile/year
  - No maintenance of this site has been required since installation
  - The goal in this case would be to only use selective broadleaf weed control as necessary and no mowing. Selective broadleaf weed control once every three years - $10/mile year (Appendix B, Page 15)

Spreading seed by hand and raking in with an ATV and chain link proved effective and less expensive than hydro-seeding.

This location has fairly sparse grass growth but no weeds. To date this site has required no maintenance whatsoever.

Results: Stunted grass growth from all three seed mixes but still formed a competitive cover and no weeds emerged. Compared to other sites testing soil amendment mixes of rock and compost, this site was 60% rock by volume and was highly compacted during installation. This created a solid, drivable surface, and stunted grass has not required mowing.

Recommendation: The mixing of compost and rock adds some enhancement to the drivability of the shoulder when compared to a compost only layer, in cases where there is a narrow paved shoulder this may be more of a concern. Also the fact that the compacted mixture of compost and rock still supported a desirable, low-growing grass stand makes this a very successful case study. There was little difference between the three seed mixtures used.

1.4. Soil Amendment – Western Washington
Topsoil layer over base course, seeded with desirable grasses (Constructed 2007) SR 20 – MP 27.2 - 27.5, 28.1 - 28.3, 29.1 - 29.5, 30.1 – 30.3

Description: Topsoil salvaged from grading other areas of the construction project, was spread over base course crushed rock and seeded.

Cost:

- Initial Cost
    - Topsoil was salvaged from project area, construction and seeding costs were equivalent to traditional design and construction.
- Ongoing Maintenance Costs – **$60/mile/year**
    - Annual mowing with side mounted sickle bar – $60/mile/year (Appendix B, Page 24)
    - Edge buildup did not occur during the course of this study due to settling and compaction of the topsoil over time. If edge buildup does occur, the area plans to deal with it incidental to other activities such as plowing, sweeping, and removal in select locations by shovel as necessary.
    - In cases where dangerous edge conditions result from vehicles driving on the shoulder, additional rock must be added. This cost is not included in the above figure for ongoing maintenance costs.

Topsoil placed during construction was subject to erosion due to the fine particles in soil structure.

Tires tend to sink into shoulder when vehicles drive off pavement and even got stuck in wet conditions.

Results: Soil was installed too thick (0.7') and not compacted. Too soft, not safe when vehicles drive off edge of pavement, particularly when wet. Initial vegetative growth included a large percentage of nuisance weed species possibly from seeds in the salvaged topsoil.

Recommendation: This alternative should not be used due to the inability to compact the material. The resulting soft shoulder creates safety concerns if vehicles leave the pavement, and the potential for vehicles getting stuck. Where grass is intended to be established up to the edge of pavement through design/construction the recommended soil amendment should be a thin layer of course compost or a mixture of compost with sufficient crushed rock to provide support for errant vehicles.

1.5. Natural Succession – Western Washington
Discontinue maintenance of bare-ground w/ herbicides, annual mowing only (Since 1996)
US 2 – MP 28.75 to 56.75

Description: This was one of the first roads in Western Washington where traditional maintenance with residual herbicides was discontinued. Bare-ground herbicide treatments between the town of Gold Bar and the area boundary to the east were eliminated in 1997. Since that time the only maintenance of the shoulder has been selective control of broadleaf weeds in the first several years and annual routine mowing of the shoulder in a 6 to 8 foot swath adjacent to the edge of pavement two to three times each year. The section also requires frequent snow plowing in winter months and operators typically run the steel bit blades over the edge to remove any buildup throughout the winter.

Cost:

- Ongoing Maintenance Cost – **$68/mile/year**

- Mowing with truck mounted boom mower – $34/mile/cycle. Mowing for the past several years in this section has been accomplished with a mowing arm mounted on a truck chassis. This mower, as used in this area, is faster and more productive than traditional tractor mounted mowing equipment. The area has been renting this mower from a private vendor, but for the purposes of making this estimate equitable to other mowing costs studied, we have used the rental rate that the WSDOT equipment management division (TEF) would charge on an hourly basis. Mowing costs for this case include two mowing cycles per year. (Appendix B, Page 29)
- Removal of Edge Buildup – Since annual removal of edge buildup is incidental to winter plowing operations the only edge maintenance costs included for this case are mowing.

Results: This is perhaps the best example in Western Washington where maintenance has adapted and transitioned from a vegetation-free edge to a healthy grass stand. Shoulder buildup has not been an issue, being controlled incidental to winter plowing and sweeping operations. More frequent mowing also seems to contribute in minimizing edge buildup. Cost including two mowing cycles with the truck mounted boom mower is still only half the cost of other locations being mowed once annually using a tractor mounted drop-down side mower. Use of the truck mounted mower also allows the crew to do selective trimming as needed to control vegetation in Zone 2 beyond the pavement edge.

Not only the pavement edge, but the entire right of way along this corridor is a model of consistent IVM application over time. The result is a high level of service at the lowest life-cycle cost.

Use of a truck mounted boom mower allows the crew to mow the edge at an average speed of 7 miles/hour and drive to mowing sites at highway speed. The mower is also used to selectively trim vegetation on the back slopes.

Recommendation: This case study serves as an example for an approach allowing vegetation growth up to the edge of pavement that could be applied in other areas throughout Western Washington. The truck mounted mower has

proven to be an effective, efficient and uniquely versatile piece of equipment for this maintenance area.

1.6. Natural Succession – Western Washington
Discontinue maintenance of bare-ground w/ herbicides, annual mowing only
SR 525 – MP 9.18 to 30.52

Description: This study area was set aside largely in response to the concerns of residents on south Whidbey Island over herbicide use. As of the spring of 2004, herbicide use within this corridor has been limited to minimal use of selective control products for management of noxious weeds and seedling trees growing too close to the road. The only non-selective shoulder treatments have been use of an aquatically labeled formulation of Glyphosate for controlling vegetation under guardrail as needed annually in late May or June. All other vegetation at the pavement edge was allowed to grow naturally and mowed once or twice a year as needed. There were several other case studies evaluated within this overall area: 1.1, 1.10, 4.1, and 5.1.

Cost:

- Ongoing Maintenance Cost – **$60/mile/year**
    - Mowing with side mounted sickle bar – Mowing for the past several years in this section has been accomplished with a sickle-bar mounted on the side of a small tractor. This has some advantages over traditional side mounted flail mowers in that it is a lighter attachment mounted on a smaller tractor which can run almost entirely on the paved shoulder along highways on Whidbey Island with less impact on traffic flow. It also tends to move faster than the flail mowers (Appendix B, Page 24)
    - Since most of this section of highway was rebuilt shortly prior to the inception of this case study there has been limited buildup through the conclusion of this study. As buildup begins to occur, the area plans on dealing with it using innovative techniques similar to those being successfully used in other areas such as winter plowing and sweeping operations.

Results: Without any effort to manage the types of vegetation coming back in to what had been formerly maintained as bare-ground, weeds quickly became established in many areas. Depending on the surrounding area or traffic deposited seed source, tansy, knapweed, scotch broom and several other annual or perennial species of weeds have grown and spread along the shoulders. Scotch broom especially continues to persist and grow back even with repeated annual mowing.

In the first years after residual herbicide use was discontinued, a number of weed species established and spread along the pavement edge. Shown here is a heavy infestation of the annual weed Conyza canadensis or Horseweed.

Over 4 years most of the shoulders along SR525 have evolved into grasses and perennial nuisance weeds such as smooth catsear and occasional patches of scotch broom, tansy and knapweed.

With snow on the island in winter of 2009, double rubber bit plow was used and by running the edge just off the pavement, some buildup was removed. Sweeping 4 to 6 times per year and running sweeper along the edge also helps remove/prevent buildup. However, where buildup has occurred there are low spots where water channelizes down edge and creates potential point discharge into surface water flows. The area will continue to monitor and evaluate this phenomenon in the years to come.

One positive result of having grass shoulders where county roads intersect is gravel kick out at intersections and need for clean up has decreased.

Recommendation: Transition from bare-ground to mostly desirable grasses can be achieved much more effectively if selective products are used to control broadleaf weeds. Now that the study period is complete the area should consider use of these products to eliminate designated noxious weeds and undesirable trees and brush from the shoulder. The area will need to continue experimenting with innovative ways of periodically or routinely removing edge buildup.

1.7. Natural Succession – Western Washington
Discontinued maintenance of bare-ground w/ herbicides in the early 1990's
US 101, MP 94.4 to 100.33

Description: This site is in the City of Hoquiam's drinking water recharge area and the city has maintained an agreement with WSDOT over the past 15+ years to restrict herbicide use. It was included as a study site because of its long track record without herbicide use. The area has also done a fairly good job keeping records of cost and results in a heavily wooded setting with high annual rainfall.

Cost:

- Ongoing Maintenance Costs – **$1,128 mile/year**
  - Mowing w/ boom mounted rotary head – $175/mile (Appendix B, Page 25)
  - Removal of shoulder buildup – $1,777/mile, required once every seven years – $253/mile/year (Appendix B, Page 34)
  - Cleaning under guardrail – $ 3,496 mile, required once every five years - $700/mile/year (Appendix B, Page 33)

Results: This site serves as one of the best Western Washington examples demonstrating the cost and results of roadside vegetation management without the use of herbicides over an extended period of time (15+ years), not just at the pavement edge but throughout the right of way. For sites where herbicide use is not allowed for regulatory reasons or due to concerns over risks to human health and/or the environment, the only way to manage vegetation is by hand or with machinery. Cases like this one serve to demonstrate the long-term results, increased costs and time required when herbicide use is removed as a tool for IVM.

Recommendation: Continue to maintain mechanically as necessary to prevent guardrail and hardware overgrowth, and to preserve site distance. Remove shoulder build-up when necessary to aid highway drainage.

Field horsetail grows in wet areas and if not controlled will come up through several inches of asphalt causing the pavement to deteriorate. The only way to manage horsetail is with selective herbicides.

Vegetation and buildup under guardrail has been removed manually on a three year cycle since herbicide use was discontinued in the early 1990's.

1.8. Natural Succession without Guardrail – Western Washington
Discontinue maintenance of bare-ground w/ herbicides, area-wide mowing only
SW Region, Area 2, All Roads

Description: The area started phasing out residual herbicide shoulder treatments in 2003 and in 2005 only treated shoulders under guardrail.

Throughout the duration of the study period, the only vegetation management along the edge of pavement in situations without guardrail throughout the area was annual mowing and spraying for control of designated noxious weeds .

Cost:

- Ongoing Maintenance Costs – **$186/mile/year**
  - Annual mowing w/ side mounted flail (Appendix B, Page 26)
  - Removal of shoulder buildup – Over the course of the study period edge buildup became more apparent, and as of today, five full growing seasons since the area discontinued maintenance of a vegetation-free Zone 1 there are locations where water may pond out into traffic lanes during storm events. Maintenance has been addressing these locations by grading out sections of shoulder or cutting out small channels through the buildup with shovels. This work was done incidental to other tasks and no cost estimates were developed.

Sediment buildup tends to accumulate along the edge of pavement more rapidly at low spots and insides of curves.

Without multiple mowing passes in the spring and early summer, grass growth in places blocks sight distance and may impact traffic safety.

Results: In the first several years after discontinuing the use of residual herbicides there were a number of sections of highway where nuisance weeds and in some cases designated noxious weeds became established and started spreading along the shoulder. However, after three to four years of mowing and treating the noxious weeds selectively with herbicides most shoulder vegetation consists of grasses. Shoulder buildup started to cause problems in a number of areas around the third year, particularly in the insides of curves and the bottoms of dips or low points in the vertical alignment. Another problem arose where taller naturally occurring grasses established at curves, corners and intersections and mowing was not able to get done until late June or July. This created places with safety hazards due to lower traffic visibility, particularly on secondary roads where there is a narrow paved shoulder.

Recommendation: The area plans to map out locations throughout their roads where it would be beneficial to maintain a vegetation-free edge to reduce

buildup and help maintain traffic visibility at curves and intersections, and drainage at low spots. There are also a number of highways in the area with narrow paved shoulders where slow-moving mowing operations cause increased impacts to traffic and maintenance work exposure. The area will phase into this approach by initially treating selected sections with Glyphosate in the spring. Then year by year they will begin grading and reshaping shoulders in selected sections as time and resources allow, and subsequently establishing these areas as vegetation-free Zone 1 using soil residual herbicides.

1.9. Natural Succession Under Guardrail – Western Washington
Discontinue maintenance of bare ground w/ herbicides, mowing with a tractor on the back side
Interstate 5 – Vicinity MP 70

Description: Guardrail in this location is constructed with steel posts installed directly adjacent to the edge of pavement. Mowing was conducted annually, typically around the middle of June by a tractor driving on the slope behind the rail. This guardrail is constructed with steel posts placed just off the edge of pavement.

Cost:

- Ongoing Maintenance Costs – **$190/mile/year**
  - Mowing limited access freeway – $48/mile (Appendix B, Page 28)
  - Cleaning under guardrail – It is not known how frequently this section of guardrail will need to be cleaned, but it is likely that cleaning will be required at some point. The area estimates cleaning will be conducted on a 12 year interval at a life-cycle average cost of $142/mile/year. (Appendix B, Page 36)

Results: Compared to other locations where grass is allowed to grow under the guardrail, this site worked well. Because the pavement extends to the face of the steel posts and the mower can run right along the back side, grass growth did not obscure the rail. Edge buildup was not an issue at this location and although was beginning to show some signs at the end of the study period, the pavement was resurfaced in 2009 and buildup will not likely cause any problem for a number of years to come. There is a wide paved shoulder at this location and debris is either removed by shoulder sweeping operations or has been washed off the edge in storm events. It is estimated that the shoulder would be cleaned on a 12 year interval.

Even in late June prior to mowing this roadside is completely functional.

Buildup under the rail has not been cleaned since construction and is still not causing any problems as of the end of the study period.

Recommendation: This design configuration, running the pavement out to the face of the guardrail posts appears to offer a way to reduce the width if not eliminate the need to maintain a bare-ground strip. The area will continue to monitor this location for edge buildup. Mowing could be eliminated altogether in this location and selective herbicides used as need to further reduce cost/mile. Other locations throughout Western Washington with similar design configurations should be evaluated for treatment as conducted in this case.

1.10. Natural Succession (Control/Comparison to 1.11) – Western Washington
Discontinue maintenance of bare-ground w/ herbicides; allow natural vegetation re-establishment, mowing only
Interstate 5, MP 262.57 to 257.82, SB Outside Shoulder

Description: The intention for this site along with Case 1.11 was to look at a side by side comparison of letting the shoulder re-vegetate through natural succession only versus managed succession through soil preparation and seeding with desirable grasses. This case on the SB side of I-5 has been left to re-vegetate naturally without any maintenance except mowing. 2004 was the last year residual herbicides were applied along this stretch.

Costs:

- Ongoing Maintenance Costs – **$48/mile/year**
    - Mowing on limited access highway – $48/mile (Appendix B, Page 28)

Results: In the year after application of residual herbicide use was discontinued, the first plants to emerge along the edge of pavement were nuisance weed species, primarily annuals and yellow flowered perennial varieties, smooth cat's ear, dandelions, etc. However, by the end of the study period there was a roughly 50% mix of grass and perennial nuisance weeds.

These photos, taken in October of 2008, show the difference in vegetative composition between the between cases A10 and A11. Although A11, the planted SB shoulder (left) now contains a solid, desirable grass stand and relative few weeds, both sides exhibit similar results from a highway maintenance and operations standpoint.

Recommendation: See 1.11

1.11. Managed Succession (Comparison to 1.10) – Western Washington
Discontinue maintenance of bare-ground w/ herbicides, cultivate and seed w/ desirable grasses
Interstate 5, MP 257.82 to 262.57, NB Outside Shoulder

Description: On the northbound outside shoulder within the milepost limits as case 1.10 after residual herbicide applications were discontinued beginning in 2005, a band of non-selective post emergent herbicide (Glyphosate) was used to treat all emerging vegetation for the first two years, allowing any remaining residual herbicide in the soil to dissipate. In the third year (fall 2007) after discontinuing the use of pre-emergent herbicides, the shoulder rock/soil was tilled to a depth of 4", then hydro-seeded and re-compacted.

Costs:

- Initial Costs – **$693/mile**
    - Glyphosate only on limited access – $37/mile (Appendix B, Page 12)
    - Cultivation of existing shoulder material – The area used a rototiller to cultivate this area. The operation turned out to be slow and therefore relatively expensive. If this type of shoulder restoration were used in other areas a more efficient way of preparing the soil would be with the tractor mounted disc attachment used by NW Region, Area 3 in case study 3.1. Therefore, for the purposes of this estimated the cost sheet for cultivation from 3.1 is used here – $108/mile (Appendix B, Page 17)
    - Hydro-seeding by area crew – $ 556/mile (Appendix B, Page 31)

- Ongoing Maintenance Costs – **$48/mile/year**

- Mowing once/year on limited access – $ 48/mile/year (Appendix B, Page 28)
- Shoulder buildup may also be a cost in the long term, the area will continue to monitor and address as needed using innovative techniques.

Results: Compared to case 1.10 and other roads where the shoulder was left to re-vegetate without any attempt to manage the succession of vegetation, this process produced superior results in establishing a solid, low-growing grass stand. However, the cost to achieve this was relatively high and not something maintenance would typically invest in.

Recommendation: There was negligible difference in the overall performance of this site as compared to the SB shoulder. There were less nuisance type weed species in the seeded shoulder but not enough difference to create any problems from a highway maintenance and operations standpoint. From the experiences of these cases and those in other Western Washington areas where the shoulder was left to naturally re-vegetate, it was proven that in most cases natural succession combined with application of selective, broad-leaf herbicides as needed resulted in an acceptable grass stand within the three year transition period.

1.12. Managed Succession – Western Washington

Apply compost tea to naturally occurring grasses to test effects on health and vigor
SR 525, MP 25.65 to 26.45

Description: Compost tea is a liquid solution or suspension made by steeping compost in water. When properly produced and applied it has a number of beneficial qualities and is used in some forms of agriculture and gardening to improve the quality and structure of soil. This site was treated with a soil drench four times a year during the growing season, with tea produced and applied by a local company on Whidbey Island. Soil samples were taken each spring for three years during the treatment process. Samples were taken from the treated area along with samples from the untreated shoulder on the opposite side of the road. Samples were submitted for scientific analysis to determine if there were any changes in nutritional values or other beneficial content.

Cost:

- Initial Costs – Approximately **$11,845/mile**
  - Compost treatments – 4 treatments/year for 3 years = 12 treatments @ $683 = $8,196 for 0.8 miles = $10,245/mile
  - Soil analysis – 2 samples/year for 4 years = 8 tests @ $200 = $1,600
- Ongoing Maintenance Costs – **$ 60/mile/year**

- Mowing with sickle bar mounted on the side of a small tractor – $60/mile (Appendix B, Page 24)

Results: The application of compost tea did not produce any noticeable or detectable enhancement of soil structure or vegetative growth.

A total of 12 soil drench treatments were applied to the two mile stretch over the three year study period.

No detectable difference resulted from the treatments, either in the scientific soil analysis or visually in vegetative top growth.

Recommendation: Although compost tea is beneficial in some horticultural applications, it is not practical or beneficial for establishing or enhancing grass stands on the shoulder.

1.13. Managed Succession Under Guardrail – Eastern Washington
Managed Vegetation – Natural Succession, Guardrail
SR 821 MP 21.1 to MP 21.47

Description: Traditionally guardrail is treated with a 4-6' band of bare-ground chemical to control unwanted vegetation under the rail. The bare-ground zone under guardrail is maintained in order to control noxious weeds, provide sight distance, reduce hand work, improve conditions for rail maintenance, and to protect the rail from fire. In 2003 the use of bare-ground chemicals was eliminated as a test to evaluate this practice. The goal of this test plot was to treat designated noxious weeds and allow native desirable vegetation to move into this zone at without actively seeding the site.

Costs:

- Ongoing Maintenance Cost – **$38/mile/year** (Appendix B, Page 9)
  - Traditional Cost – $79/mile/year for a bare-ground chemical application 4' wide. (Appendix B, Page 2)
  - Savings – Approximately $41/mile/year savings per mile per year.

SR 821 MP 21.10, 2004 two years after bare-ground treatments ceased

SR 821 MP 21.10, fall of 2009, rabbit brush dominates the old bare-ground zone at the edge of pavement

Results: Native vegetation began migrating into the site earlier than anticipated considering the chemical history and arid climate. The first species to colonize the site was rabbit brush, cheat grass and several invasive weeds. Rabbit brush is a woody shrub native to this area, while it is not a species we would plant in this location it can be tolerated and in most cases is beneficial in terms of weed control. At some point it will be necessary to remove the rabbit brush and any other large woody vegetation either chemically or manually. Native perennial grasses have begun to slowly colonize the site as well as several forbs. The combination of shrubs, grass, forbs and cheat-grass appears to have reduced the growing potential of a number of invasive species on site. No maintenance was necessary on this section of guardrail during this test so no input was received as far as vegetation creating problems for maintenance activities.

No fire starts occurred on site, however, it is expected that had a fire started there would have likely been a loss of some of the posts. In general maintenance crews did not feel that the increase of vegetation would create a hardship when repairing guard rail.

Recommendation: South Central Region, Area 1 eliminated the use of bare-ground under guardrail area-wide in 2005. This decision was made at least in part due to the success that occurred on this test plot. While the size of this test plot makes it difficult to make far-ranging recommendations, the experience in the rest of the maintenance area supports this decision. Of approximately 96 miles of guard rail in the Area the only significant problem to date has been the loss of approximately 1/8 mile of guardrail posts to fire. In many locations vegetation has been slow to reestablish under the guardrail, for this reason ongoing evaluations should continue over the next several years. It is recommended that woody shrubs and trees be removed either by hand or chemically as needed in order to keep the guardrail zone free of these species. In arid climates this could be accomplished on a 5-6 year cycle, in higher precipitation zones the cycle may need to be shortened to a 2-3 year cycle.

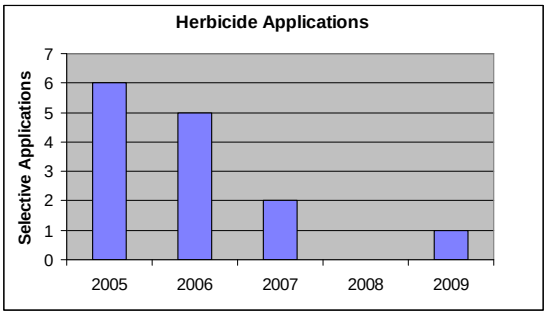
1.14. Managed Succession – Eastern Washington
Establish desirable grasses during construction project (2002)
US 97 – MP 153 to 168

Description: In 2002 US-97 Blewett Pass was repaved with a full overlay. After the edge treatments were made and grading was completed the site was hydro seeded with a perennial grass mix. Prior to this construction project the shoulders were traditionally maintained in a bare-ground condition approximately 4-6' wide. The site was seeded in the fall of 2002, with perennial grass emerging in the spring of 2003.

Costs:

- Initial Cost – $**1,875/mile**
  - Hydro seed 6' band at the edge of pavement. This cost was incurred as part of the construction project.
- Ongoing Maintenance Cost – **$18/mile/year**
  - Selective Herbicide Application- $22/mile, per year for 1 selective herbicide application. (Appendix B, Page 3)
  - Estimated Bare-ground Cost-$79/mile/year (Appendix B, Page 2)
  - Annual Maintenance Cost Savings – $57/mile/year
  - One 4' mowing pass was made in 2005 but was not deemed necessary therefore the cost of this treatment was not added. This treatment has not been repeated.

Results: Perennial grasses began to emerge in the spring of 2003. During the years of 2003-2004 some annual and perennial weeds did occur in this zone. These were treated as part of the regular selective weed control program. This was primarily accomplished with a 6-10' band-width application throughout the project area as needed. From 2004 on the focus was more directed at spot infestations. From this point forward selective spot applications continued in decreasing amounts to the present. The perennial grasses are well established throughout the project area and by all accounts have been instrumental in greatly reducing the spread and infestation of invasive species. We have received numerous comments from Kittitas County and Chelan County weed boards that weed control has steadily improved as perennial grasses have established.



Selective herbicide applications needed to control invasive species has substantially decreased as desirable vegetation has become established

Early in the project there were concerns regarding wildlife related sight distance, fire starts, drainage and buildup at the edge of pavement. These concerns have not materialized in any significant way. Deer kill data has not increased. We have had no significant fire starts in the project area. There have been several storm events that have caused significant erosion, but these events were well outside the scope of vegetation related problems. It is likely that the existing vegetation is at least partially responsible for limiting the damage. Edge buildup seemed to be the most likely issue. This however, did not materialize as a significant issue either. The transition away from an aggregate based snow and ice program to a chemical priority program reduced the amount of sand available to build up at the edge of pavement. It has also been observed that heavy plow activity that occurs throughout this project area mechanically maintains a very narrow 6-10" bare-ground at the edge of pavement and removes any buildup before it accumulates.

Recommendation: The establishment of vegetation at the edge of pavement on Blewett Pass has been an overwhelming success both from an economic and weed control standpoint. The increased precipitation on this site allowed for very low installation and maintenance costs. In more arid locations initial establishment of desirable vegetation would have likely been more difficult without improvements to roadside soils. Where conditions are similar to Blewett Pass in terms of precipitation, (15-20") and elevation it is highly recommended that this method be implemented. In addition to the operational success experienced on this project we have had positive feed back from a number of state and federal agencies as well as the general public who appreciate the overall visual quality and improved weed control.

1.15. Managed Succession – Eastern Washington
Eliminate bare-ground applications, allow vegetation to reestablish
US 2, MP 196 to 200

Description: Zone 1 bare-ground applications were eliminated on US 2 MP 196 to 200 eastbound and westbound in 2006. Noxious weeds were controlled by selective herbicide applications as needed. Desirable vegetation will be allowed to migrate into the site at its own pace, the site will not be reseeded. The goal of this test plot is to evaluate several aspects of the transition from bare-ground to desirable vegetation at the edge of pavement. The following aspects were evaluated:

1. The cost of transitioning from bare-ground application to a selective based maintenance program designed to promote desirable vegetation.
2. The length of time it takes to re-colonize the roadside with desirable vegetation.
3. The ability of desirable vegetation to establish on the roadside environment.
4. The effectiveness of these methods to meet roadside needs.

Cost:

- Ongoing Maintenance Cost – **$51/mile/year**
    - Historical Bare-ground Cost – $110/mile/year (Appendix B, Page 4)
    - Selective Herbicide Cost – $51/mile/year (Appendix B, Page 5)
    - Approximately $59/mile savings for labor, equipment and material with selective treatment method.
    - Currently there is no additional on-going maintenance costs, mowing may be needed in some locations to deal with basin wild rye, an extremely tall native grass species.
    - The cost savings realized in this test plot was due primarily to the fact that 1-2 selective herbicide applications are made on an annual basis. These applications generally occurred from the lower edge of the bare-ground out approximately 16’ into zone 2. When the bare-ground was eliminated the selective application was simply expanded by 6’ to include the old bare-ground. Had separate applications been needed there likely would not have been a cost savings.

Results: During the 2006 season very little vegetation of any type appeared in the former bare-ground zone. By 2007 kochia and Russian thistle began to emerge along with a variety of other nuisance species such as cheat grass, china lettuce, and marestail as well as some desirable grasses. The majority of weedy species was diminutive and in most cases did not produce seed. The desirable grass that began to emerge was predominantly Sand dropseed (*Sporobolus cryptandrus)* on the lower side of the roadway supers. This appears to be the result of increased drainage from both lanes and shoulders, which not only

increases the amount of precipitation available for vegetation but also likely increases the rate at which the residual chemical is diluted or washed lower in the soil profile. By 2008 Kochia, Russian thistle and cheat-grass can be observed throughout the test plots with desirable perennial grasses continuing to expand. Two selective applications have been successfully controlling the broadleaf weeds that occur on site. The site is not as clean as bare-ground sections but remains functional.

Overall regeneration of desirable species has been slower than anticipated. This is most likely due to a number of factors including low organic matter in the roadside soil, low rain fall and slow degradation of residual chemicals. While establishment of desirable vegetation has been very slow, it does appear to be making steady gains. The full transition from bare-ground to established desirable vegetation at the edge of pavement will likely continue for at least another 2-3 years. This test plot indicates that in this situation the transition while slow can meet roadside maintenance needs at a cost that is lower than the traditional bare-ground treatment. As establishment of desirable vegetation continues vegetation maintenance costs, should continue to improve.

US 2, MP 200 EB, 2006

US 2, MP 200 EB, 2009, three years after bare-ground applications ceased.

Recommendations: This method of maintaining the edge of pavement should be actively considered as an alternative to traditional bare-ground applications across the eastside of the state. This site demonstrates that a selective program can be as effective as a bare-ground program while realizing a significant per mile savings. This is particularly true if the near zone 2 is infested with designate weeds that require regular treatment. This allows the applicator to simply widen the band width application to include the former bare-ground zone.

Establishment of desirable vegetation has been predictably slow; at this stage it would likely be beneficial to seed the shoulders with desirable perennial grasses. Even without an active seeding program, if existing trends continue, desirable vegetation should continue to establish up to the edge of pavement which should reduce life cycle maintenance costs.

1.16. Managed Succession – Eastern Washington
Eliminate bare-ground applications, allow vegetation to reestablish
SR 17, MP 136 to 143

Description: Zone 1 was eliminated from the southbound shoulder on SR 17 between MP 136 and 143 in 2006. The northbound side will be maintained in the same way it has been historically, using a 4' band of residual chemical in conjunction with selective herbicides as needed to control noxious weeds. The southbound side will only be treated with selective chemicals, allowing desirable grasses and forbs to migrate into this zone at it's own pace. No seeding will take place.

The northbound shoulder was treated with a 4' band of bare-ground chemical annually. This treatment was followed up by a 14-16' band width of selective herbicides to control designate broadleaf weeds. The Southbound shoulders were treated with selective herbicides in a single pass at a width of approximately 16-20' to control designate broadleaf weeds. Follow-up spot treatments were made on both north and south bound shoulders as need to treat primarily Dalmatian toadflax and Knapweed species.

Cost:

- Ongoing Maintenance Cost – **$44/mile/year** (Appendix B, Page 6)
  - Historical Cost – $84/mile/year (Appendix B, Page 7)
  - Both shoulders were historically treated with a selective chemical application approximately 16' wide as measured from the bottom edge of the bare-ground out toward the right of way fence. For the northbound side the cost of treatment is simply the cost of a 4' bare-ground application ($66/mile/year). For the southbound side the cost of the 4' bare-ground treatment was eliminated. In its place the cost for the increase in selective herbicide needed to expand the yearly 16' selective treatment out to 20' include the old 4' bare-ground zone. Selective spot treatments are made on both road shoulders on an as needed bases, these costs were not included in the evaluation as they occurred similarly on both shoulders.
  - A cost savings of approximately $40/mile/year was realized on the south bound shoulder when compared to the traditional bare-ground application on the northbound side.

Results: The goal of this test plot was to evaluate the cost of two treatment types, bare-ground vs. selective and the rate and ability for native vegetation to establish without seeding. The unexpected cost savings was realized immediately and has continued throughout the duration of this study. The assumption was that there would need to be at least two selective band applications made to the old bare-ground zone on the southbound side. This

was never the case; the single band application that was historically used was simply widened to include the old bare-ground. There may have been some minor spot treatments done within this old bare-ground zone but this was very small and very difficult to capture in terms of cost.

SR 17 Northbound, annual maintenance with bare-ground chemicals.

SR 17 Southbound maintained with selective herbicides only. Native grasses have begun to establish along pavement edge.

Cheat grass was one of the first species to migrate into the old bare-ground zone, while this isn't a desirable species it is better than many of the noxious weeds we expected. We believe that the cheat grass was at least helpful in reducing kochia, Russian thistle and other noxious weeds. Sand dropseed (*Sporobolus cryptandrus)* began to appear in 2007 as well, particularly at the edge of pavement. This species has continued to move out and is slowly filling in. Several other species have appeared in smaller quantities including Sandberg bluegrass (Poa secunda) as well as several wheatgrass species. It should be noted that while both sides of the roadway provided adequate weed control the Southbound side did look a little more unkempt when compared to the traditional bare-ground option. This appears to only be an aesthetic issue and did not cause any operational issues during the duration of this test.

SR 17 Southbound, MP 143, summer 2009 maintained with selective herbicides only.

SR 17 Northbound, MP 143, summer 2009, annually maintained with bareground chemical

Recommendations: This method of maintaining the edge of pavement should be actively considered as an alternative to traditional bare-ground applications across the eastside of the state. This site demonstrates that a selective program can be as effective as a bare-ground program while realizing a significant per mile savings. This is particularly true if the near zone 2 is infested with designate weeds that require regular treatment. This allows the applicator to simply widen the band width application to include the former bare-ground zone.

Establishment of desirable vegetation has been predictably slow; at this stage it would likely be beneficial to seed the shoulders with desirable perennial grasses. Even without an active seeding program, if existing trends continue, desirable vegetation should continue to establish up to the edge of pavement which should reduce life cycle maintenance costs.

1.17. Hand Trim under Guardrail – Western Washington

Cut vegetation growing under guardrail manually using gas powered string trimmers

US 101, MP 219.11 – 231.46 (9.4 miles of guardrail)

Description: This section of US 101 runs adjacent to the shoreline of Lake Crescent in the Olympic National Park. Since the park restricts herbicide use within its boundaries, all work must be done manually or with machinery. In this case, as in case A18/W, the aspect being studied is a long-term program relying on manual trimming of vegetation around the base of the guardrail. Costs generated in this case study are from use of WSDOT maintenance technicians to trim vegetation once a year using gas-powered, hand-held string trimmers. This treatment results in significant buildup of debris and grass mat over time and restriction of surface drainage during rain events. In this case debris must be removed from under guardrail once every seven years.

Cost:

- Ongoing Maintenance Costs – **$673/mile/year**
  - Manual Trimming around Guardrail – $173/mile (Appendix B, Page 27)
  - Removal of buildup under guardrail – Required every seven years, $500/mile/year (Appendix B, Page 33)

Results: This method of trimming is effective in this location. The operation moves slow but cost per mile of mowing by hand is about the same as mowing with a tractor since there is less equipment and traffic control. The drawbacks as compared to traditional chemical control methods are the safety risks and exposure of the maintenance employees, and the fact that the vegetative debris in combination with dirt and debris generated by traffic cause edge build-up and

impeded roadway surface drainage. Although no injuries or accidents have been recorded at this site, the road is narrow and winding with sometimes heavy tourist traffic at the time mowing is required. Also there is uneven ground throughout on the back side of the rail and some areas that drop sharply into the lake.

Terrain behind the rail along this stretch of 101 and Lake Crescent is uneven and drops off steeply in places and is hazardous to operators.

Recommendation: If there is an opportunity in future construction or paving projects, WSDOT should consider installing pavement under guardrail, or one of the vegetation preventing mats tested in cases D1 – 6 in this study. This location could be effectively managed with herbicides, even if the use of aquatically labeled Glyphosate were allowed, cost and results would improve dramatically. WSDOT should work with the National Park to permit the use of limited herbicide application.

1.18. Hand Trim under Guardrail – Western Washington

Cut vegetation growing under guardrail manually using gas powered string trimmers

SR 20, MP 110.93 – 139.23 (25.62 miles of guardrail in the National Recreation Area)

Description: SR 20 runs through the North Cascades National Recreation Area at this location and herbicide use is restricted within the area boundaries. There are over 25 miles of guardrail through this section of winding road in high mountain terrain. In this case as compared to A17/W the work has been done with correction crews.

Cost:

- Ongoing Maintenance Cost – **$673/mile/year**
    - Manual Trimming around Guardrail has been done with Corrections Crews at times in the past but this resource has not been available in recent years. Costs for this study are assumed same as case study 1.17. $173/mile (Appendix B, Page 27)
    - Removal of buildup under guardrail – Required once every seven years, $500/mile/year (Appendix B, Page 33)

Results: Several factors make this method of trimming a challenge in this area. The elevation tends to force vegetative growth later into the summer months and the plant community in the area favors a number of species of larger forbs and typically periodic rain throughout the summer results in abundant growth. The terrain around guardrail installations often drops sharply from the edge of the road making access difficult and hazardous. Use of corrections crews to do this work is cost effective and relatively efficient. However, corrections crews are not always available when needed, in which case the work must be done by WSDOT maintenance technicians.

Without the use of herbicides, vegetation re-growth completely covers the guardrail every year.

Recommendation: This location would be much more effectively managed with herbicides, even if the use of aquatically labeled Glyphosate were allowed, cost and results would improve dramatically. WSDOT should keep trying to work with the National Recreation Area to permit the use of limited herbicide application. Another solution might be the opportunity in future construction or paving projects, to install pavement under guardrail, or one of the vegetation preventing mats tested in cases 4.1 – 4.6 in this study.

1.19. Selective Herbicides under Guardrail – Western Washington
Promote naturally occurring low-growing grasses to establish under guardrail, selective management of weeds and brush only
SR 20, MP 26 to 26.14

Description: The naturally occurring grasses in this area on Whidbey Island, particularly near the shoreline only reach 18 to 24 inches in height, and therefore do not interfere with guardrail visibility or function. However, there are some naturally occurring perennial, broadleaf plants in the area that would overgrow and obscure the rail if allowed. The intention at this site was to evaluate in cases where low growing grasses are present, mowing is not required and vegetation can be managed selectively only as needed.

Cost:

- Ongoing Maintenance Cost – **$13/mile/year**
    - Selective broadleaf weed control once every three years - $13/mile/year (Appendix B, Page 15)

Results: This is a rare case in Western Washington where no vegetation maintenance is required around the base of guardrail other than occasional selective weed control. The presence of native low growing grasses in this location is due to the dry micro-climate and proximity to the saltwater beach. If it were possible to establish a stable grass stand with low growing grasses in locations such as this there may possibilities of doing this in other locations such as was tested in case 1.21.

Native grasses in this area are sparse and low growing, requiring virtually no maintenance.

The only roadside maintenance at this site is some selective control of unwanted vegetation is needed.

Recommendation: 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. It would also be advantageous where low growing grasses can be established, to combine this type of treatment with an angled pavement edge design to help alleviate issues with edge buildup.

1.20. Selective Management Only, Including under Guardrail – Western Washington
(Construction 2006)
Establish low-growing grasses on all shoulders through soil amendment during new construction, selective management of weeds and brush only
SR 305, MP 0.22 – 6.83

Description: When the roadway surface of SR 305 was repaved in 2006, WSDOT took the opportunity to seed a low growing grass mix along the edge of pavement where the highway crosses Bainbridge Island. The plan for maintenance of these shoulders is to mow one pass once per year in the summer including the back sides of the guardrail, and to treat weeds and brush coming up around the rail with selective broadleaf herbicides as needed.

Cost:

- Initial Costs – Comparable to typical shoulder construction
    - Shoulder Soil Amendment and Seeding – Seed was mixed in with compost and rock at a cost comparable to the typical standard design using crushed rock.

- Ongoing Maintenance Costs – **$214/mile/year**
    - Selective Management of Brush and Broadleaf Weeds – $39/mile (Appendix B, Page 15)
    - Mowing w/ Tractor Mounted Side Arm Boom – $175/mile (Appendix B, Page 25)

Results: One of the greatest challenges on Bainbridge Island in this case was the fact that over the past 10 years a number of weed species have become established along the highway. This is mostly a result of insufficient resources to control the unwanted vegetation without the use of herbicides. When the new shoulders were constructed and seeded, weed seed from the adjacent roadside was deposited into the new shoulder soil with the grass seed and came up fairly thick in the years following construction. Treatment of these species required the used of broadleaf herbicides and after two years, some weeds are still persisting. Also, due to the high traffic volumes on this highway and large amounts of vegetative debris from surrounding trees, edge buildup began impeding surface drainage within two years after construction, particularly around the bases of guardrail.

Although this image does not show guardrail it does the amount of debris that accumulates on the shoulder and the amount of weed growth two years after shoulder reconstruction.

Two years after reconstruction low growing grass seeded on the shoulders and under guardrail is overgrown by weeds and blackberry vines throughout most of the highway corridor on the island.

Recommendation: This construction technique for seeding low growing grasses on the shoulder has worked well in other places. In this case there were a number of factors that detracted from success including the large quantity of tree litter and vegetation growth that resulted in rapid edge buildup, and the presence of noxious weed species on the adjacent roadside which were allowed

to seed into the new shoulder material. With adequate weed control and if an angled pavement edge were used along with this design it would likely be successful. Also the use of a truck mounted boom mower such as in case 1.5 would help reduce mowing costs.

2. Pavement Edge Design

This set of case studies indicated that possibly the best long-term solutions to managing vegetation at the edge of pavement involve creating a paved drop off at the outside edges of the pavement. This edge of sloping pavement essentially takes the place of a maintained vegetation-free zone. WSDOT is currently working within engineering design and construction to create a series of options for use in pavement resurfacing contracts and new construction projects.

2.1. Tapered Pavement Edge – Western Washington
Full depth (8") asphalt shoulder constructed with a 4:1 taper at edge
Interstate 5, MP 109.25 – 113.91

Description: The study area where this edge detail exists was constructed approximately 20 years ago. In this situation the lanes are paved with concrete and shoulders constructed with asphalt at the same thickness as the concrete (approximately 6 to 8 inches). The outside edge of the shoulder surface angles down at about a 30 degree angle to meet grade and the slope continues down to the bottom of a grass covered swale. This creates a 12 to 18 inch paved edge drop before the vegetated shoulder begins and allows for surface drainage of storm water. The use of this particular detail is only possible in larger volume freeway design, although it may be possible to create the same surface configuration with shallower depth asphalt with the entire cross-section of pavement angled down at the outside 12 inches or so.

Cost:

- Initial Cost – Comparable to typical shoulder construction
  - Construction for this type of edge is comparable to any other edge in this situation.
- Ongoing Maintenance Cost – **$48/mile/year**
  - Mowing Limited Access Highway – $48/mile (Appendix B, Page 28)
  - Although significant edge buildup does occur at this location, it does not impede surface drainage or cause any other problems and therefore is not considered a factor in ongoing maintenance.

Results: This is one of the most successful long standing examples of shoulder design where vegetation can be allowed to grow to the edge of pavement without impacting safety or pollution control objectives.

Recommendation: Work with design to develop a standard for this type of configuration for use wherever possible.

A sloping pavement edge takes the place of a gravel strip in this case and requires no maintenance.

A compost blanket was added to outside shoulders and median for enhanced stormwater management and pollution control along the section of freeway draining toward the Nisqually Delta.

2.2. Tapered Pavement Edge – Western Washington
Asphalt shoulder constructed with a rough 1 to 2 ft. wide tapering strip at the edge
Interstate 5, MP 98.42 to 100.93

Description: This section of Interstate 5 was repaved in 2004 with a shoulder design that includes a 2 ft. wide strip of slightly angled rough surface asphalt. This strip appears and functions the same as a gravel strip but with routine sweeping remains clean and vegetation-free with no other maintenance.

Cost:

- Initial Cost – Comparable to typical shoulder construction
  - Construction for this type of edge is comparable to any other edge in this situation.
- Ongoing Maintenance Cost – **$48/mile/year**
  - Mowing Limited Access Highway – $48/mile (Appendix B, Page 28)
  - Although significant edge buildup does occur at this location, it does not impede surface drainage or cause any other problems and therefore is not considered a factor in ongoing maintenance.

Results: This is another example of successful shoulder design where vegetation can be allowed to grow to the edge of pavement without impacting safety or pollution control objectives. Depending on constructability with this type of design there may be potential for use on secondary highways as well.

Recommendation: Work with design to develop a standard for this type of configuration for use wherever possible.

Roughened edge within the study site, shown here four years after installation in 2004.

Another example of a roughened, tapering edge, this one on I-90 near Lake Sammamish, constructed 1996, shown here in 2005.

2.3. Tapered Pavement Edge – Western Washington
Standard depth (2”-3”) asphalt shoulder constructed with a 30 degree angle taper
SR 410, MP 57.65 – 65.68

Description: The edge of asphalt pavement is finished with a 30 degree angle for the full depth of the paving layer. The term “safety edge” is used for this treatment because it allows vehicles to traverse off and back on the pavement at high speed without getting a wheel caught on a sharp edge drop. However, this treatment also allows for around 6 to 8 inches of sloping surface area for drainage before the non-paved and/or vegetated shoulder begins.

On SR 62 in Oregon (Crater Lake Highway) a safety edge is used in combination with an adjacent shoulder free of vegetation.

Cost:

- Initial Cost
    - Construction for this type of edge can be accomplished simultaneously with finish paving by attaching an angled plate to the side of the paving machine.

- Ongoing Maintenance Cost – **$186/mile**
    - Mowing Secondary Highway with Side Mounted Flail – $186/mile (Appendix B, Page 26) This cost could possibly be reduced by mowing with one of the other mowers in some cases, such as the truck mounted mower or the sickle bar.
    - Significant edge buildup is likely to occur at this location; at some point removal will be necessary unless winter plowing operation can be used to skim the buildup off on an annual basis.

In the study site on SR 410 in the Mt. Rainier National Park the safety edge is bordered by a grass shoulder. Shown here in the second year after construction.

During the three year study period, buildup occurred in some places, such as insides of curves, but much of the edge is still free draining five years after construction.

Results: This appears to be an effective treatment for pavement edge in new construction or in situations where a new layer of asphalt is being overlaid in resurfacing projects. This type of edge can be constructed with no additional cost by attaching a shoe to pack the edge at the desired angle in conjunction with the finished paving operation.

Recommendation: Some form of standard plan and/or general special provision should be developed for optional use in paving and new construction projects. It may be more appropriate to utilize in design configurations with wider paved shoulders, situations as shown in this case study where there is a narrow paved shoulder would require additional considerations if multiple overlays were constructed with the same detail. Where used, provisions should also include either a thin compost layer or compost/crushed rock mixture along with seeding and establishment of low-growing grasses on the adjacent non-paved shoulder.

2.4. Compacted Aggregate Edge – Western Washington
Pavement grindings placed in a strip along the edge of new pavement and heavily compacted to prevent vegetative growth
SR 516, MP 4

Description: Pavement grindings from resurfacing project were stockpiled then spread in a band along the edge of new paving. Grindings were heavily compacted but still function as a permeable surface.

Cost:

- Initial Cost – Potential cost savings
  - Construction for this type of edge could actually be considered cost saving when compared with traditional construction methods where new crushed rock is brought in, spread and compacted.
- Ongoing Maintenance Cost – **$58/mile/year**
  - Mowing Limited Access Highways – $48/mile (Appendix B, Page 28)
  - Occasional Banded Treatment with Glyphosate Only, assume once every three years – $12/mile/year (Appendix B, Page 12)

This shows the site in the fall after the paving project was completed in the summer of 2002.

By the end of the study period six years after construction, the strip of compacted grindings is over 50% grass cover. Grass establishment could be prevented with Glyphosate treatments on a 2 to 3 year or as needed basis.

Results: This edge held as mostly vegetation-free for three or four years before grasses began establishing. A periodic treatment with Glyphosate, administered just as the grasses start to emerge would likely keep the strip mostly vegetation-free. This detail and method of construction could be considered for any project with pavement grinding as part of the process.

Recommendation: Some form of standard plan and/or general special provision should be developed for optional use in paving and new construction projects. This type of treatment would require some type of occasional spot treatment to keep vegetation from becoming established.

3. Cultivation

In addition to managing vegetation, cultivation of a strip along the edge of pavement has the advantage of maintaining an even transition between pavement and the unpaved roadside. An even transition between the paved and unpaved shoulder is important for safety of errant vehicle recovery and for maintaining sheet flow of stormwater drainage, which enhances pollution control. The successful use of cultivation is dependent on several factors: 1.) The area being cultivated must be relatively free of vegetation, if there is an established mat of vegetation, cultivation will create clumps. 2.) The strip being cultivated must be relatively free of obstructions such as junction boxes and delineator posts (guide posts set outside the cultivated zone) and 3.) Operator training and experience has a significant effect on productivity and outcome.

The use of this method is still under development. There are questions as to the needed frequency of cultivation and as to the best combination of spraying and cultivating. There was also a wide range in documented costs of this approach. However, several maintenance areas are planning on continuing the testing and evaluation of this method in the years ahead.

Also, this method has limited applications to highways with long stretches of uninterrupted pavement edge, such as on limited access highways.

3.1. Annual Cultivation – Western Washington
Annual pre-treatment with Glyphosate followed by cultivation
Interstate 5, MP 183.3 – 207.77

Description: NW Region, Area 3, based out of Everett has been the main area to work at perfecting this method of shoulder maintenance. This alternative not only manages vegetation along the edge of pavement, but results in a very safe and even transition from paved to non-paved shoulder. This case study included both outside shoulder and median shoulder, as well as interchange ramps.

Costs:

- Ongoing Maintenance Costs – **$138/mile/year**
    - Zone 1 Chemical Application – $37/mile/year (Appendix B, Page 12)
    - Cultivation and Repacking of Shoulder Material (Everett) – $108/mile/year (Appendix B, Page 17)

Results: In this area cultivation works well and the area plans to continue using it on an annual or semi-annual basis. The method is still a relatively new technique and details of the process are still being evaluated and adjusted. There were several reasons cited for quality results and high rate of production in this case: 1.) Shoulders were relatively free of vegetation at the time the

alternative was first implemented. 2.) Operator practice and skill in running the cultivation arm was critical. 3.) All electrical junction boxes were located and marked the first year of implementation. 4.) All flexible guideposts/delineators were moved outside the band of cultivation prior to implementation. In the coming years the area will be evaluating the need to pre-treat with herbicide or possibly alternating between treatments with Glyphosate every two years and cultivation on the alternate years. It was also noted that some noxious weed species that had been present in Zone 1 in the area prior to implementing cultivation, were eradicated.

Timing on the cultivation is important. Best results were when the work was done sometime in June when most of the vegetative growth was done but soils were still somewhat damp.

By the fall a light grass stand begins to emerge in the cultivated area. As long as the area is cultivated annually this grass doesn't cause problems, but if it becomes well established will cause the cultivated soil to clump.

Recommendation: Compared with all other alternatives tested in this study, this approach has some advantages. However, the Everett maintenance area is still refining the method and other areas are just beginning to apply it on corridors where it may be practical. Ideally the use of cultivation and repacking could be used in place of complete regrading and removal of excess material if used in some combination with chemical treatment, to create a vegetation-free or sparsely vegetated pavement edge condition in Western Washington.

3.2. Annual Cultivation – Western Washington
Annual cultivation only
Interstate 5, MP 116.4 – 131.2

Description: Olympic Region, Area 2 (Tacoma) was not as successful as Everett in perfecting this method. As a result the area discontinued testing the alternative after two years. For the two years the alternative was implemented the area did used cultivation only and did not pre-treat the site with herbicide. This case included outside shoulders only.

Cost:

- Ongoing Maintenance Costs – **$657/mile/year**
    - Cultivation and Repacking of Shoulder Material -Tacoma (Appendix B, Page 18)

Results: Productivity with site was much lower than that in Everett resulting in a high cost per mile, however the results were comparable. Reasons cited for lower productivity were: 1. There were a number of electrical junction boxes buried on the shoulder and both years the test was being run a number of boxes were hit and repaired. 2. Guideposts/delineators were installed in the zone being cultivated and had to be worked around. 3. The crew and cultivation operator in this case was still learning and was not as efficient as the practiced hand in Everett.

This photo shows how the operation of cultivation works. A plow truck pushes the turned material back into place and the two buffer vehicles drive over the edge, packing it back into place.

At one point an errant vehicle left and returned to the road right at the location where the monthly documentation photos were taken, illustrating the importance of having a solid and even transition between paved and non-paved shoulder.

Recommendation: The contrasting cost of this case versus the one in Everett shows that this method may not work well in certain locations. It also brings out a point with relation to design and construction in relation to placement of junction boxes and delineation markers. If grass is allowed to grow to the edge of pavement, junction boxes will get buried under debris and subject to damage when any kind of shoulder reshaping is done. Delineators if not placed in a vegetation-free zone create obstacles to shoulder grading and/or mowing operations. Placement of these elements should be determined in conjunction with the overall design and planned maintenance approach for any given situation.

3.3. Annual Cultivation – Western Washington
Annual cultivation only
SR 8 MP 0.00 - 20.67, US 12 MP 10.05 - 46.57

Description: This case study was added late, when the Olympic Region, Area 4 (Aberdeen) started cultivating and repacking 156 miles of shoulders on the SR 8/US 12 corridor in 2008. Therefore, this situation considers only what happened as a result of implementing this alternative practice in 2008 and 2009. Shoulder configurations on this corridor tend to vary in relation to side slope and position of ditches and swales, making the practice somewhat more challenging than on the consistently even graded shoulders along I-5. Also, in 2009 there was significant re-growth of grasses so the decision was made to pre-treat the edge with Glyphosate and a mowing deck was added to the tractor pulling the cultivator so that mowing and cultivation occurred simultaneously. The area plans on continuing to experiment with this methodology in this corridor in the coming years. For this case study the following assumptions in relation to cost are made.

Cost:

- Ongoing Maintenance Cost – **$155/mile/year**
    - Zone 1 Chemical Application – $37/mile/year (Appendix B, Page 12)
    - Cultivation and Repacking of Shoulder Material - Aberdeen $125/mile/year (Appendix B, Page 19)

In some locations annual grasses such as crab grass shown here emerged over the summer months. However in a case like this the growth does not impact highway operations or weed management objectives.

In other locations the shoulder has remained vegetation free until the following fall when some re-growth typically occurs.

Results: This corridor did not look as clean as the sections on I-5, due to the differing slopes off the shoulder and clumps from grass growth in the cultivated zone. Also, productivity was less than that achieved in Everett. However, the results in terms of even transition between paved and non-paved shoulder and eliminating any problems associated with edge buildup and drainage make this a viable alternative. In coming years the area will continue to evaluate condition

and likely use a mix of treatment of the edge with Glyphosate and cultivation on a semi-annual basis depending on edge buildup. The use of a mowing deck in conjunction with the cultivator was successful and something that may be useful in other areas.

Recommendations: As with the other locations where cultivation is being utilized, there is a need to continue experimentation and evaluation. As stated in the other cases looking at this method, there are places where this approach is practical and advantageous, and other locations where use is not possible or unneeded. The preparation of shoulders prior to initial cultivation is crucial to the success of this method. It may be necessary to perform a shoulder material removal operation before cultivation is implemented so that sods and well established plants don't create an unsightly berm.

4. Weed Barriers under Guardrail

The use of a variety of solid mats (including pavement) under guardrail is another way of preventing vegetation from growing up around the rail. There are a number of products being marketed and sold for this purpose. The products evaluated in this study represent the state of the art for this application at the time the research was initiated in 2005. Some refinements in product design and installation procedures have been made in recent years. These products, if utilized would typically be installed through construction projects and to date only one contract in Washington State has specified under-guardrail matting.

For comparison purposes in this report, initial costs for all but one installation (4.4) are based on the assumption that crews doing the work are trained and experienced and using state of the art tools and procedures. Productivity of these operations is based on the manufactures observations and experience from installations across the country. Material costs are the most up to date pricing from the manufacturers. Case study 4.4 is included to demonstrate installation as a retrofit of existing rail using a typical maintenance crew.

For each of the cases studied in this section, there was a demonstrated need for annual cleaning, to remove accumulation of organic and inorganic debris. If this is not done, particularly in Western Washington or areas with overhanging trees, the mat quickly becomes covered with buildup and starts to grow grass and weeds. In pavement situations this buildup can be removed with equipment over a cycle of many years, although the costs of this type operation even when averaged over a cycle of seven years are significantly greater that annual cleaning. For installed matting products, it was shown to be necessary in some cases and much more cost effective in any case to clean matting under guardrail on an annual basis in any case. Ongoing maintenance costs for all non-pavement products are therefore estimated based on the assumption that they will need annual cleaning to avoid excess buildup and loss of function.

Use of pavement or matting under guardrails is the best solution for new construction projects where herbicide use is not allowed or subject to environmental concerns. However, savings in ongoing maintenance costs do not justify use of these techniques over the life cycle of any given highway.

Findings from these case studies show that where the use of some type of weed barrier under rail is justified, the most effective and least expensive methods for installing a solid surface under guardrail are asphalt pavement or the WeedEnder. The WeedEnder product has the additional advantage of being a porous surface and potentially offsetting construction project costs for mitigation treatment of stormwater runoff. Porous pavements may also have this advantage but were not tested as part of this study.

4.1. WeedEnder – Western Washington
Permeable fabric weed barrier installed by maintenance in 2002
SR 525 – MP 9.7 - 9.8

Description: This was the first installation of any type of weed barrier material in Washington State. This location on the south end of Whidbey Island receives an average amount of annual rainfall for Western Washington and is surrounded by forest.

WeedEnder is a permeable material made from recycled plastics woven into a ¼" inch thick, carpet-like fabric. It is installed in a 3 ft. wide strip with holes cut for each post and additional layers of collars to fit snuggly around the post. The fabric is secured with soil staples and caulking around the guardrail posts. In this case the material was installed by the area maintenance crew with assistance from the manufacturer. There was a slight problem with the installation in that the fabric was pre-cut for the post holes so that the front edge did not extend to the pavement edge and about a 4" gap was left between the fabric and pavement.

Costs:

- Initial Installation Cost – **$28,650/mile**
  - Material cost – $23,918/mile
  - Installed cost – $28,650/mile (Appendix B, Page 20)
- Ongoing Maintenance Costs – **$22/mile/year**
  - Clean once per year with a back pack blower – $22/mile/year (Appendix B, Page 35)
  - Repair of this product is also a consideration in ongoing maintenance cost, either when guardrail is hit or from normal wear and tear. However, this location has not been hit and the product has held up well since installation.

Results: In this location as in other Western Washington locations where there is ample moisture, heavy traffic, and overhanging trees, there are problems with

buildup of debris on top of the mat. In this location annual cleaning is required to keep the mat from getting buried and overgrown. Of course debris buildup will occur over time regardless of the presence of a weed barrier, but if installation costs are included along with annual cleaning costs in a case such as this, the life-cycle cost is significantly higher as compared to treatment with annual residual herbicide application and removal of buildup as needed typically on a 7 to 10 year cycle. There is also a question on the life expectancy of this product. The manufacturer currently guarantees the product for 15 years.

At about 5 years after installation in this case, moss growth became a significant factor. Moss in combination with debris from falling leaves and cut grass and brush serves as a seed bed unless annual cleaning is done.

Photo taken in June of 2009, seven years after installation and before annual cleaning is done.

In contrast with this location is an installation on the north end of Whidbey Island that was not monitored as part of the study. In that case WeedEnder was installed by a contractor along with a new section of guardrail. The micro-climate on the north end of the island is significantly drier and there are no overhanging or surrounding trees, also the slope away from the pavement is significant. After three years the North Whidbey site appears to be holding up well and not experiencing the same problem as on the site on the south end of the island.

On the north end of Whidbey Island the same product was installed by a contractor along with a new section of guardrail in 2006. At the time this photo was taken in June of 2009 it appears to be holding up well without maintenance attention.

Recommendation: The WeedEnder is the most extensively tested product of all the under guardrail mats and it has advantages over other similar products in

that it is permeable and therefore does not require mitigation for stormwater runoff, and it is fire retardant. This product as well as any of the under guardrail mats, is best utilized in conjunction with new construction projects where it is placed over clean and evenly packed crushed rock and there is adequate side slope to facilitate in removal of debris buildup. The surface must be routinely cleaned in some way or the product becomes covered and begins to grow vegetation. This product provides a viable option for use in new construction projects in areas where herbicide use is restricted for some reason.

4.2. WeedEnder – Western Washington
Permeable fabric weed barrier installed by maintenance in 2005
SR 112 – MP 31.99 – 32.02

Description: Weed Ender fabric was installed at this location by the area maintenance crew in 2005. It was installed under guardrail on both sides of the road where SR 112 crosses Jim Creek. The shoulder on the inside curve of the road in this location is constructed with a curb and contained drainage, so the mat begins behind the curb on this side and is somewhat protected from debris blowing and washing off the road surface. This is an area with high annual precipitation and is surrounded by forest. The area typically applies some sand to the road during winter snow and ice events. The ground surface was somewhat uneven at the time the mat was installed.

Costs:

- Initial Installation Cost – **$28,650/mile**
  - Material cost – $23,918/mile
  - Installed cost – $28,650/mile (Appendix B, Page 20)
- Ongoing Maintenance Costs – **$22/mile/year**
  - Clean once per year with a back pack blower – $22/mile/year (Appendix B, Page 35)
  - This installation was only cleaned once during the course of this study, photos below show what happens if the mat isn't cleaned on at least an annual basis in a location such as this.
  - Repair of this product is also a consideration in ongoing maintenance cost, either when guardrail is hit or from normal wear and tear. However, this location has not been hit and the product has held up well since installation.

Results: In this case minimal maintenance has been done to clean the surface of the mat. Due to the amount of sand applied for winter maintenance in this location there was significant buildup on the shoulder at the outside of the curve. However, on the inside shoulder where the mat is behind a curb there is very little debris buildup and the mat appears to be functioning adequately after four years. The installation, done by maintenance was not as precise as in other locations.

Recommendation: This location provided a good indication of the need to clean these types of installations on a regular basis. It is recommended that the area begin cleaning this location on a regular basis to avoid loosing the function of the product.

These pictures, taken at the same time three years after installation show the difference in accumulation of debris between inside corner with curb on the edge of pavement and the outside corner.

4.3. WeedEnder – Western Washington
Permeable fabric weed barrier installed by maintenance in 2005
SR 20, MP 112.1 – 112.3

Description: This location is in the North Cascades National Recreation Area, where herbicide has never been used on the shoulder and vegetation growth is abundant. Guardrails along this section of highway must be trimmed manually once a year to control rapidly growing grasses, noxious weeds, and native forbs. Pavement crack sealer was applied to seal the edge between fabric and pavement, in addition to the normal caulking specified for use around the post bases. In summer of 2007 a pavement overlay was installed at this location and the new pavement edge was extended 1 to 2 inches over the top of the fabric, further sealing the edge.

Costs:

- Initial Installation Cost – **$28,650/mile**
  - Material cost – $23,918/mile
  - Installed cost – $28,650/mile (Appendix B, Page 20)
- Ongoing Maintenance Costs – **$195/mile/year**
  - Clean once per year with a back pack blower – $22/mile (Appendix B, Page 35)
  - String trim around guardrail – $173/mile (Appendix B, Page 27)
  - Repair of this product is also a consideration in ongoing maintenance cost, either when guardrail is hit or from normal wear and tear. However, this location has not been hit and the product has held up well since installation.

Results: Although the surface of the soil was cut to the ground just prior to installation, the roots of the plants were well established and some of the more aggressive vegetation began coming up through cracks, around the base of posts, and along the edge between pavement and mat, despite all attempts to seal it off. As in the location on SR 112, this is a heavily forested area and the area applies sand at times during snow and ice events in the winter. These two factors resulted in the mat in this location becoming almost completely overgrown and buried within three years and requiring annual vegetation trimming with string trimmers.

Prior to installation of the fabric, vegetation completely covered the rail every year and had to be manually trimmed.

Three years after installation the mat is buried in sand and debris. Vegetation is beginning to establish over the top of the mat but growth is inhibited.

Recommendation: This installation failed due to the lack of adequate preparation and removal of existing live vegetative roots and viable seed. If installations are to be made in situations like this where products are placed around existing rail, all plant material should be treated with herbicide to ensure no re-growth occurs around the seams.

4.4. WeedEnder – Eastern Washington
Permeable fabric weed barrier installed by maintenance in 2005
SR 2 – MP 90.72 to 90.87/ 792 ft. of matting

Description: This material was installed by WSDOT maintenance crews as a retrofit of existing guard rail. It should be noted that the crew had no former experience or training on installation of this product and did not have the latest in pneumatic installation equipment. Undoubtedly these factors greatly influenced the installation cost of this product. WeedEnder weed control matting was installed under the guardrail on US-2 MP. 90.72 to 90.87 on the Southbound shoulder of US 97 in 2004. This site was selected for it's proximity to sensitive aquatic resources and the varied climate. This site experiences heavy snow fall in the winter and high summer temperatures. Of the eastern Washington weed matting test plots this site has been installed approximately 2 years longer and experiences the highest precipitation and the most snow fall

and resultant snow and ice removal activities. WeedEnder is a recycled role material that is fire resistant and pervious to water.

Costs:

- Initial Cost – **$98,958/mile**
  - The labor/equipment cost for 1/10 mile section was approximately $9,895 or approximately $98,958 per mile.
  - The site required substantial site preparation before the product could be installed including removal of woody vegetation, hand grading and scaling of large rocks. This cost was not included in this evaluation in order to better evaluate this product on par with other sites which did not need grading or vegetation removal.
- Ongoing Maintenance Cost – **$22/mile/year + repair costs**
  - Clean once per year with a back pack blower – $22/mile (Appendix B, Page 35)
  - An estimated $2,539 per mile for one time minor repair of matting seams at this location. This estimate is based on actual maintenance that is needed at this point and is estimated based on existing repair equipment currently on hand.

Results: WeedEnder Weed matting continues to function well on this test plot. This test plot location has subjected this product to a variety of weather conditions not encountered on other sites. These conditions include a substantial amount of snow and ice and related de-icing and snow removal. While no maintenance was required throughout the duration of this test plot, minor maintenance on several seams should occur within the next 12 months. Installation of the WeedEnder mats appeared to be more difficult to retrofit to existing guardrail than Traffix mats but have comparable overall performance in terms of weed control as well as some potential advantages including fire resistance the ability for water to filter through the material.

US-2, 2006 two years after installation

US-2, 2009 five years after installation

Recommendation: While the cost per mile is extremely high, this product may have applications on WSDOT right of way in specific locations, such as highly sensitive areas where chemicals are not an option. Installation costs should be

substantially lower than recorded in this study if installation occurs during new roadway construction instead of as a retrofit to existing guardrail. It is likely that retrofit costs could decline substantially with proper equipment and experience, however it is unlikely that this cost can be reduced enough to make this a viable option for retrofitting of WSDOT guardrail.

While no maintenance was needed during the life of this study it is reasonable to expect that the matting will need to be cleaned on a 1-2 year cycle to prevent vegetation from growing on top of the matting. When compared to an annual bareground chemical treatment of approximately $100 per mile for labor, equipment and materials it becomes clear that retrofitting weed matting is a far more expensive option regardless of the service life of the matting. It is recommended that this product be introduced to and considered by WSDOT design staff on new construction projects in sensitive areas.

4.5. Turboscape – Western Washington
Ground up tire mulch, spread over weed mat and coated with polyurethane installed by vendor in 2004
Interstate 5 – MP 20.08 (North end of bridge south of Woodland)

Description: This site was mostly free of vegetation when the product was installed. A typical type of weed barrier fabric was placed over the entire treated area. A two to three inch thick layer of chopped up recycled tire mulch was sprayed over the area using a blower truck. The top surface was then sprayed with a polyurethane coating material which bound the product together when dry.

Cost:

- Initial Installation Cost – **$5,474 to $7,820/mile**
  - This product is no longer being marketed for highway roadside use. At the time of installation the price quoted was $7 to $10 per square yard depending on the size of the project.
- Ongoing Maintenance Costs – **$37/mile/year**
  - Spot treatment with Glyphosate – $37/mile/year (Appendix B, Page 12)

Results: This material is permeable, but as dirt and debris generated by freeway traffic was deposited along the pavement edge and over the top, weeds and grass began to grow. As of today in the fall of 2009, five years after installation, the surface of the product is mostly covered with grass and weeds. Also, cars driving onto and over the surface of the material, tended to break the surface coating and dislodge the mulch. Concern was also expressed over the potential flammability of this product.

In the first year following installation, grasses are already beginning to establish.

By the fourth year after installation grasses and some weeds cover approximately half the surface of the treated area.

Recommendation: The Company promoting and selling this product is no longer installing Turboscape as a roadside treatment.

4.6. Traffix Weedmat – Eastern Washington
Thick rubber tiles installed by maintenance in 2006
SR 823, MP 4.1 – 4.2

Description: Approximately 500' of Traffix weed control matting was installed under the existing guardrail on SR 823 MP. 4.1 to 4.2, northbound, in November 2006. The matting was installed under existing guardrail by WSDOT maintenance crews. It should be noted that the crew had no former experience or training on installation of this product. Undoubtedly these factors greatly influenced the installation cost of this product. The matting consists of rubber pre-cut panels that interlock with one another. This matting appears to be resisting weeds better than the universal matting and is much easier to install and repair than the plastic panels.

Costs:

- Initial Installation Cost – **$39,200/mile**
  - Material cost – $35,429/mile
  - Installed cost – $39,200/mile (Appendix B, Page 22)
- Ongoing Maintenance Costs – **$22/mile/year**
  - Clean once per year with a back pack blower – $22/mile/year (Appendix B, Page 35)

Results: Traffix Weed matting continues to function well on this test plot. The few times the mats have been hit or moved it's been relatively easy to reposition them. Retrofitting the guardrail with Traffix matting was easier than WeedEnder and Universal weed matting and has consistently out-preformed Universal weed matting in terms of controlling weeds and durability.

Immediately following installation in 2006 *Photo taken in 2009*

Recommendation: While the cost per mile is extremely high, this product may have applications on WSDOT right of way in specific locations, such as highly sensitive areas where chemicals are not an option. Installation costs should be substantially lower than recorded in this study if installation occurs during new roadway construction instead of as a retrofit to existing guardrail. Of the three matting products that were evaluated Traffix weed matting was the easiest to retrofit of the three. However, it is likely even with experience and training that retrofit costs could decline enough to make this a viable option for retrofitting of WSDOT guardrail.

A concern that was not addressed in this study is the susceptibility of this material to fire. Every year we have guardrail posts that burn as a result of grass fires. The matting should be evaluated for the potential to ignite in grass fire situations.

While no maintenance was needed during the life of this study it is reasonable to expect that the matting will need to be cleaned on a 1-2 year cycle to prevent vegetation from growing on top of the matting. When compared to an annual bare-ground chemical treatment of approximately $100 per mile for labor, equipment and materials it becomes clear that retrofitting weed matting is a far more expensive option regardless of the service life of the matting. It is recommended that this product be introduced to and considered by WSDOT design staff on new construction projects in sensitive areas.

4.7. Traffix Weedmat – Western Washington
Thick rubber tiles installed by maintenance in 2006
SR 20 – MP 115.02-115.11

Description: This product is made of ground up, recycled tires and comes in 3/8” thick, 4 ft. square tiles. The tiles are placed under the rail, overlapping 3 to 4 inches at each seam and stuck together with a heavy duty adhesive strip. Openings for guardrail posts align with the seams and are cut with a utility

knife. At this location 475 feet of the Traffix mats were installed side by side with the plastic Universal Weed Cover.

Costs:

- Initial Installation Cost – **$39,200/mile**
  - Material cost – $35,429/mile
  - Installed cost – $39,200/mile (Appendix B, Page 22)
- Ongoing Maintenance Costs – **$22/mile/year**
  - Clean once per year with a back pack blower – $22/mile (Appendix B, Page 35)

Results: This product is relatively heavy and at the time of installation was the most expensive of all under-guardrail weed barriers considered. However, possibly because of its weight and composition was the product that held up best over the three year duration of the study. The product is semi-permeable but due to its thickness tends to catch and channel water along the pavement edge. The expense of the material itself and extra cost in shipping is somewhat offset by the ease of installation. One thing learned after installation is that the overlapping edge of the mats at the seam should be with the direction of traffic. In this installation the overlapping edge faces toward traffic and tends to catch winter sand and debris at the seams.

The Traffix Weed Mat were the easiest of the under guardrail products to install. This is the product being installed in 2006.

This is the mat after three years. Some sand build-up, but it seems to blow or wash off over the course of each summer, no maintenance has been done at this location.

Recommendation: One potential drawback for this product is the lack of permeability and the possibility that use in projects could trigger the regulatory requirement for additional stormwater management facilities, impacting project design and overall cost. However for the duration tested, the Traffix Weedmat proved to be durable and functional in preventing vegetative growth.

4.8. Universal Weed Cover – Eastern Washington
Plastic tiles installed by maintenance in 2006
SR 823, MP 4.1

Description: Universal weed control matting was installed under the guardrail on SR 823 MP. 4.1. Southbound in October 2006. The matting was installed under guardrail for approximately 475 feet. The matting consists of interlocking plastic panels. These panels were cut on site and placed together individually, staked or nailed into place. The panels were somewhat brittle and several panels became damaged in the course of installations.

Costs:

- Initial Installation Cost – **$25,000/mile**
  - Material cost – $21,225/mile
  - Installed cost – $25,000/mile (Appendix B, Page 23)
- Ongoing Maintenance Costs – $**22/mile** +**Complete replacement**
  - Assumed need for annual cleaning with a back pack blower – $22/mile (Appendix B, Page 35)
  - Repair is currently needed; nearly all of the mats are damaged or broken. Repair would constitute almost total replacement. Panels become damaged both at the edge of pavement, due to a snow removal as well as on the outer edge apparently due to temperature or some other factor.

Results: In general this product was difficult to install and generally did not perform particularly well. It did however provide some weed control through the life of the project, this level of suppression appears to be diminishing annually as the condition of the mats deteriorates. The material didn't hold up well to any type of impact from traffic or an inadvertent plow blade. Further it was more difficult to move or patch these mats when they did become damaged.

SR 823, Installed in 2006

SR 826, fall 2009- Cracked and damaged matting with vegetation growing up through the mats.

Recommendations: The cost of installation and maintenance required to keep this material in operation preclude this from serious consideration as an alternative treatment for WSDOT guardrail. WeedEnder and Traffix matting both significantly outperformed this product.

4.9. Universal Weed Cover – Western Washington
Plastic tiles installed by maintenance in 2006
SR 20 – MP 114.8 – 115.05

Description: This product is a molded plastic, interlocking tile that is pinned to the ground with soil staples or stakes. Tiles are roughly 4 ft. square and are cut with a router on a template to fit around the guardrail posts at the seams. In this location the product was installed side by side with the rubber Traffix mats for direct comparison.

Costs:

- Initial Installation Cost – **$25,000/mile**
  - Material cost – $21,225/mile
  - Installed cost – $25,000/mile (Appendix B, Page 23)
- Ongoing Maintenance Costs – **$22/mile/year + repair costs**
  - Assumed need for annual cleaning with a back pack blower – $22/mile (Appendix B, Page 35)
  - Repair is currently needed; approximately 10% of the mats are damaged.

Results: Since the installation of this product in 2006, the manufacturer has made several modifications in design and fabrication to try and alleviate the problems experienced at this and the Eastern Washington test site. However, with the product as designed and manufactured in 2006 there were a number of problems.

Tiles were damaged by snow and ice thrown by passing plow trucks.

Grass came through where the panels joined together and where the material cracked.

The biggest problem was that the plastic used in fabrication of these tiles was relatively brittle and tended to crack and break if stepped on, particularly in cold weather. Any of the under guardrail mats, if the front edge extends beyond the face of the rail, are susceptible to damage from snow plow blades. In this case even though the edge of the mat was protected from plow damage behind the face of the rail, the edge broke apart in places just from snow and ice thrown by the passing plow trucks. Also, within the first year grasses began growing through small openings along the seams of the tiles and consequently collecting debris. Flammability was another question raised in relation to this product.

Of all the under guardrail products tested, this was the least expensive to purchase and easiest to ship because it is light weight and panels stack together. However, installation was relatively slow due to the need to cut each post hole with a router.

Recommendation: The same questions apply to this product in relation to creating additional impermeable surface and stormwater mitigation requirements. Also if this product is to be considered for future use, additional testing and evaluation will be required since the product design and specifications have changed significantly.

4.10. Pavement under Guardrail – Western Washington
Paved shoulder extends under guardrail constructed 2003
SR 105 – MP 42.38 – 42.49, 42.93 – 43.02, 43.42 – 43.50, 43.94 – 44.02, 45.12 – 45.22, 46.00 – 45.91 = 2061 linear ft. of pavement.

Description: There are quite a few locations around the state where the shoulder has been designed and constructed with pavement extending beyond the guardrail. In these cases, holes are cut in the asphalt and posts either augured or driven through the holes. At the locations evaluated in this case study, construction was relatively recent making it possible to determine how fast debris builds over the top of the asphalt and how often removal is necessary.

Cost:

- Initial Installation Cost – **$18,480/mile**
    - Installation costs estimated based on current average bid prices for asphaltic pavement on WSDOT projects, assuming guardrail can be installed through the pavement at the same cost as it would off the edge of pavement.
- Ongoing Maintenance Costs – **$895/mile/year**
    - Cleaning Paved Shoulder under Guardrail once every seven years – $6,265/mile (Appendix B, Page 21)

Results: This treatment works well in preventing vegetation growth, however cleaning buildup from under guardrail in any case is time consuming and a

significant maintenance expense. The rate of buildup and need for removal varies with location depending on traffic and maintenance operations, but in this case cleaning appears to be necessary on a 5 to 7 year cycle. The pavement surface under the rail in this case is flat which tends to build up debris faster than if the surface slopes away from the lanes.

New pavement and guardrail was installed in 2003. Photo on the left shows condition in 2005 after two years, photo on the right is from 2007 showing debris accumulation after four years. Rails along this section of SR 105 were cleaned in 2008.

Recommendations: The cost of cleaning under the rail as done in this case shows that it would be less expensive to sweep or somehow remove debris on a more regular basis. The durability of pavement and ability to use heavy equipment in removing buildup allows for more flexibility in cleaning over other products tested and together with comparative cost of installation makes this the most advantageous under guardrail treatment of those evaluated. The creation of added impervious surface in construction projects may be a concern, however there are porous pavement products available and if construction costs for these treatments can be adsorbed then this would be the best under guardrail solution.

4.11. Pavement – Western Washington
Paved shoulder extends under guardrail constructed 1994
Interstate 90 – MP 16.7

Description: This location is adjacent to some of the heaviest traffic volume in the state and has been in place for over ten years, giving a good indication of maintenance cycles. The pavement under the rail has more slope to it as compared to the SR 105 sites, and the outer 2 feet or so drops off at about a 30 degree angle. (There is approximately 740 linear ft. at this location)

Cost:

- Initial Installation Cost – **$18,480/mile**
    - Installation costs estimated based on current average bid prices for asphaltic pavement on WSDOT projects, assuming guardrail can

- Ongoing Maintenance Costs – **$895/mile/year**
    - Cleaning Paved Shoulder under Guardrail once every seven years – $6,265/mile (Appendix B, Page 21)

Six years since the site was last cleaned, enough dirt and debris has deposited to support a grass stand over the pavement.

Photo taken after the pavement was cleaned off in the spring of 2008.

Results: Due to the heavy traffic volume at this location, dirt and debris accumulate more rapidly in this location as compared to the SR 105 site. Surface of the pavement is angled down at the outside edge which helps direct debris out from under the rail, but significant accumulation still results in the entire paved area under and behind the rail being completely covered and growing vegetation within 5 years after cleaning.

Recommendation: Same as case 4.10.

5. Maintenance using Non-Selective Herbicides

This set of alternative methods looks at different types and mixtures of chemical controls to limit or prevent vegetative growth in a band along the edge of pavement. Methods range from use of post-emergent herbicides only to periodically remove top growth to mixtures of post and pre-emergent (soil residual) herbicides intended to prevent seed germination as well as remove any top growth.

This method, as compared to all others studied has the advantage of greater speed in operation. In cases where a bare-ground strip is maintained year round, particularly in Western Washington, there is the advantage of preventing edge buildup and associated problems with storm water management.

5.1. Non-Selective Post Emergent Herbicide under Guardrail – Western Washington

Annual treatment with non-selective, post emergent herbicides in June
SR 525 – MP 12.9 to 30.52

Description: For this section of highway on Whidbey Island, a non-selective post emergent herbicide was applied in a 2 to 3 foot band under guardrail sections. The herbicide used, Glyphosate, must come in contact with green, growing plant tissue in order to be effective, so applications were made in mid to late spring.

Cost:

- Ongoing Maintenance Costs – **$526/mile/year**
  - Annual treatment under guardrail with Glyphosate only – $37/mile (Appendix B, Page 12)
  - Remove and dispose of buildup under rail once every 7 years – $ 6,265/mile – $895/mile/year (Appendix B, Page 21)

Although non-selective, post emergent herbicides stop vegetation growth when applied in the spring, dead vegetation still remains in place and catches debris at the edge of pavement causing edge build over time and trapping water.

Results: The use of a post emergent herbicide only controls vegetation that is green and growing. It does not control seed germination and sometimes does not kill the roots of existing vegetation. Therefore, this type of herbicide treatment essentially acts as a chemical mowing, with vegetation re-growth as soon as adequate precipitation occurs. However, this method worked well in keeping the rails from becoming overgrown. In some locations a follow-up treatment was required using selective herbicides to control horsetail and occasional patches of conifer seedlings. Because dead vegetation remains in place after treatment there is still accelerated edge buildup as compared to a vegetation free shoulder. Even dead material creates a barrier and catches debris, adds to buildup. For two to three weeks following treatment it is apparent that herbicide treatments were made, due to the color contrast of the dead vegetation.

There are also certain weeds such as horsetail that are not effectively controlled with Glyphosate only. If left untreated, horsetail can grow up the shoulder,

under the pavement and up through the surface. Follow up, separate treatments may be required to control these types of plants and/or designated noxious weed species if present.

Recommendation: This treatment produces roughly the same results as mowing around guardrail posts either by hand or with some type of equipment. Edge build-up over time still impacts drainage. In places where surface drainage is not required or the impacts of buildup on drainage do not effect operations or stormwater management, this type of treatment would be a much more cost effective option than mowing by hand. However, maintenance of a completely vegetation free condition by adding soil residual herbicides to the mix in this type of application is a more practical approach.

5.2. Mixture of Non-Selective Post Emergent and Light Pre-Emergent Herbicides – Western Washington

Apply a mixture of Glyphosate, Sulfometuron-methyl, and Chlorsulfuron annually in May

Multiple areas throughout Western Washington

Description: This is the most common mixture of herbicides that has been used for chemical treatment of Zone 1 on the west side over the past 5 years. Particularly in areas with average or greater annual rainfall there is typically some grass re-growth prior to treatment in the spring although often stunted and sparser.

Cost:

- Ongoing Maintenance Cost – **$50/mile/year**
    - Zone 1 treatment with Glyphosate, Sulfometuron, and Chlorsulfuron (Appendix B, Page 13)

Results: This mixture does a better job than a Glyphosate only treatment, but depending on seasonal rainfall and corresponding plant growth there can be significant grow-back in some cases and there are some weed species that are not suppressed by the per-emergent activity in Sulfometuron-methyl. The Chlorsulfuron in the mix does control horsetail where it is present, keeping it from grow up under and through the pavement edge.

Sparse and stunted re-growth occurs in areas annually treated with this mixture of herbicide. This cuts back on the amount of growth and subsequent edge buildup at the edge of pavement, however treated vegetation is visually apparent for several weeks following treatment, until surrounding vegetation begins to go dormant.

Recommendation: This type of treatment seems to work well in some areas and conditions. It is possible that additional pre-emergent herbicides could be added to the mix in some years when more vegetative growth is observed.

5.3. Mixture of Non-Selective Post Emergent and Most Effective Pre-Emergent Herbicides – Western Washington
Apply a mixture of Glyphosate, Norflurazon, Sulfometuron-methyl, and Chlorsulfuron annually in May
SR 9 – MP 66.88 – 98.17

Description: The goal in this case was to maintain a two foot wide vegetation-free condition along the edge of pavement. Since WSDOT discontinued the use of the long lasting pre-emergent herbicide Diuron on the west side in 2003, a number of alternative products has been evaluated for ease of use, cost and effectiveness. The herbicide Norflurazon (trade name Predict) was found to be the most effective. This product in combination with the other products included in this trial is the combination typically used by Oregon DOT for their shoulders in Western Oregon.

Cost:

- Ongoing Maintenance Cost – **$74/mile/year**
    - Maintenance of Zone 1 with Glyphosate, Norflurazon, Sulfometuron, and Chlorsulfuron annually (Appendix B, Page 14)

Results: This application was tested over a broad area and results varied throughout. In locations where there was an existing vegetation-free shoulder and consistent, annual applications were made throughout the study period, the result was a year-round vegetation free condition. However, there were a number of problems with making successful applications. The product, Predict, is a powder that is mixed with water and applied. During the first year of application there were problems with the herbicide settling out in the tank and plumbing of the spray truck, causing the equipment to malfunction. Also, changes in operators and challenges with budget resulted in some areas getting missed at times. The end result of pavement edge conditions in this area range

from vegetation free shoulders to vegetated, and in some cases weed infested shoulders.

Locations where accurately applied annual applications were made, Zone 1 remained vegetation-free.

Where annual applications were skipped in certain years and locations, grasses became established. The presence of vegetation, even if dead tended to make subsequent applications less effective, because herbicide was tied up in organic matter on the surface. Also, even dead vegetation at the pavement edge contributes to edge buildup.

Recommendation: If this type of treatment is to be used, it is critical that the starting condition is a clean gravel shoulder. If this type of treatment is decided to be applied in a condition where a vegetated shoulder exists, the grass mat should be removed with grading prior to initiation of a soil residual herbicide treatment program. It is recommended that each area evaluate their shoulders and pavement edge objectives throughout the area and set goals for reclaiming and treating vegetation-free Zone 1 sections where appropriate. This approach can be planned and applied through the area IVM plans and the annual planning cycle to annually adjust how this process unfolds.

5.4. Pre-Emergent Bare-ground Application – Eastern Washington SR 271 MP 0-8

Description: Non-selective bare-ground chemicals were used in this location to maintain a 4-5’ bare-ground zone. Two pre-emergent chemicals are used on this roadway; Portfolio (Sulfentrazone) at 4.6 oz and Landmark (Chlorsulfuron + Sulfometuron-methyl) at 12 oz. This mixture is applied in late March to early April with 50-60 gallons of carrier. This site receives approximately 20” of precipitation annually; the roadway ditches remain moist for the majority of the year.

Cost:

- Ongoing Maintenance Cost – **$92/mile/year**

- Zone 1 Bare-ground Application – $92/mile/year (Appendix B, Page 1)

Results: This application was very effective throughout the 16 shoulder miles. It held up very well with no measureable failures. In this case the bare-ground application eliminated 2 to 3 mowing passes per year.

Bareground treatment on SR271, 2008.

Recommendation: The bare-ground application has performed well in this situation. The combination of Landmark and Portfolio controlled all weeds and unwanted grasses throughout the growing season. The alternative, allowing vegetation to grow at pavement edge would require 2-3 mowing operations to control the 6' tall reed canarygrass (*Phalaris arundinacea*) as well as one selective spot application. Given the climate, shoulder width and site conditions this is an appropriate treatment and should be continued.

5.5. Pre-Emergent Bare-ground Application under Guardrail – Eastern Washington
SR 225 MP 6 to 7

Description: Treat guardrail sections to maintain a 4-6' bare-ground condition under the rail. The bare-ground zone under guardrail is maintained in order to control noxious weeds, provide sight distance, reduce hand work, improve conditions for guardrail maintenance and to protect the posts from fire damage. Krovar (bromacil) was applied at a rate of 8 lbs per acre with 35 gallons of water during the spring, generally between mid March and early April. The site is located in one of the states most arid regions receiving approximately 6 inches of precipitation per year.

Cost:

- Ongoing Maintenance Cost – **$167/mile/year**
  - Zone 1 Bare-ground Application under Guardrail Only – $167/mile/ (Appendix B, Page 8)

Bareground treatment on SR225, 2008.

Results: This application was very effective at controlling vegetation throughout this area. It held up very well with no significant breakthrough. Costs are substantially higher than standard bare-ground applications due to the amount of travel time between rail sections. For guardrail treatments in eastern Washington the average miles treated for a 4-6' band with was 14 miles. This low production quickly pushes up the cost per mile for this treatment.

Recommendation: The bare-ground application has worked well in this situation and continues to be the standard treatment for eastern Washington guardrail. It is recommended however that due to the high costs per mile, managers should evaluate the option of reducing or eliminating the use of bare-ground chemicals under guardrail. This should not be done unilaterally but with careful consideration of fire potential, vegetation type, height, shoulder width and sight distance.

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Appendix A

Case Study Summary

Managed Vegetation Up to the Edge of Pavement

REFERENCE CODE	ALTERNATIVE TYPE	LOCATION TYPE	DESCRIPTION	APPLICATION LIMITS	MAINTENANCE CONTACTS	ON GOING MAINTENANCE COST	FINDINGS/RECOMMENDATIONS
1.1	Soil Amendment/ Western Washington	No guardrail	2" compost layer over crushed rock, seeded with native grasses	SR-525 Whidbey, MP 26.45 to 27.4	Clint Terwilliger/ Kathryn Rogers	$60/mile/year	Best solution for new construction in W. Wash. where grass is intended to be established over rock ballast on shoulders
1.2	Soil Amendment/ Eastern Washington	No guardrail	Type B top soil added over CSBC @ 4-6" with 2" compost added and incorporated over the type B topsoil	US-12, Snake River Bridge to Casey Pond. MP 295.3-299.3	Scott Smith	$43/mile/year	Good solution if this procedure can be included at the time of new construction. The combination 2" of compost incorporated into 6-8" of native soil performed very well.
1.3	Soil Amendment/ Western Washington	No guardrail	2" later of 40% compost mixed w/ 60% crushed rock, placed over rock base, seeded in three sections w/ low-grow grass mixes	SR 507 Roy, MP 36.63 to 37	John Davis	$10/mile/year	Good solution for new construction in W. Wash. although more complicated and potentially more expensive to install than method used in Alt. 1.1, low grass mix did not require mowing and no weeds
1.4	Soil Amendment/ Western Washington	No guardrail	2" topsoil layer over crushed rock, seeded with native grasses	Whidbey Island SR 20 MP 27.20 - 27.50, 28.10 - 28.30, 29.10 - 29.50, 30.01 - 30.30	Clint Terwilliger/ Kathryn Rogers	$60/mile/year	Not recommended in any case, uncompactable material results in soft shoulder and vehicles causing ruts and getting stuck when driven on
1.5	Natural Succession/ Western Washington	No guardrail	Discontinue maintenance of Zone 1 w/ herbicides (1997)	US-2 Monroe to Region Boundary, MP 28.75 to 56.75	Cecil Rench	$68/mile/year	Best long-term example of natural succession grass on shoulders, success and low cost due to frequency of mowing with high-speed mower and annual blading of shoulder in conjunction with winter plowing
1.6	Natural Succession/ Western Washington	No guardrail	Discontinue maintenance of Zone 1 w/ herbicides (2004)	SR -525 Whidbey, MP 9.18 to 30.52	Clint Terwilliger/ Kathryn Rogers	$60/mile/year	Initial revegetation of former bare-ground included numerous nuisance and noxious weeds
1.7	Natural Succession/ Western Washington	With and without guardrail	Discontinue maintenance of Zone 1 w/ herbicides (199?)	US-101 Hoquiam Watershed, MP 94.4 to 100.33	Theodore Twigg	$1,128/mile/year	Demonstrated high cost of purely mechanical maintenance over a long period of time in high-rainfall, forested area.
1.8	Natural Succession/ Western Washington	No guardrail	Discontinue maintenance of Zone 1 w/ herbicides (2005)	Chehalis Maintenance Area	Larry Stritmatter	$186/mile/year	Edge buildup and drainage problems began to result at the end of the study period. The area plans to re-establish veg.-free Zone 1 in selected areas as needed.
1.9	Natural Succession/ Western Washington	With guardrail	Discontinue maintenance of Zone 1 w/ herbicides (2005)	I-5 MP, Vicinity MP 70	Larry Stritmatter	$190/mile/year	Wide paved shoulder to face of steel guardrail posts, minimal buildup in this location. Possibly could eliminate mowing to reduce cost in this case.
1.10	Managed Succession/ Western Washington	No guardrail	Discontinue maintenance of Zone 1 w/ herbicides and allow existing grasses to establish in former Zone 1	I-5 Bellingham to Ferndale SB, MP 262.57 to MP 257.82	Ric Willand	$48/mile/year	Negligible difference when compared with results of 1.11. Initial emergence of nuisance weeds could be effectively managed with the use of selective broadleaf herbicides.
1.11	Managed Succession/ Western Washington	No guardrail	Discontinue maintenance of Zone 1 w/ herbicides and establish grass in former Zone 1	I-5 Bellingham to Ferndale NB, MP 257.82 to MP 262.57	Ric Willand	$48/mile/year	Significant cost to establish grass, but significantly less nuisance weeds than in case 1.10.

Managed Vegetation Up to the Edge of Pavement, continued

REFERENCE CODE	ALTERNATIVE TYPE	LOCATION TYPE	DESCRIPTION	APPLICATION LIMITS	MAINTENANCE CONTACTS	ON GOING MAINTENANCE COST	FINDINGS/RECOMMENDATIONS
1.12	Managed Succession/ Western Washington	No guardrail	Apply compost tea to naturally occurring vegetation in former Zone 1	SR-525 Whidbey, MP 25.65 to 26.45	Clint Terwilliger/ Kathryn Rogers	$60/mile/year	No measurable change in soil structure or vegetation growth from the application of compost tea.
1.13	Managed Succession/ Eastern Washington	Under guardrail	Discontinue use of zone 1 bare-ground applications under guardrail	SR 821 MP 21.1 - 21.47	Galen Roger	$38/mile/year	This alternative is a viable option with certain considerations. While fire did not damage any rail in this test the loss of guard rail to fire is of concern. Selective herbicides should be used to control woody vegetation within 2-4'of rail.
1.14	Managed Succession/ Eastern Washington	No guardrail	Revegetated shoulders during a pavement overlay project.	US-97 Blewett Pass, from Liberty Rd. to Blewett Shed	Rick wood	$18/mile/year	Very good solution, acceptable initial cost followed by good establishment of desirable species. Weed control costs and weed presence on site steadily decreased as site matured
1.15	Managed Succession/ Eastern Washington	No guardrail	Discontinue use of zone 1 bare-ground applications in favor of encouraging desirable vegetation to colonize the site.	US-2 MP 200	Tom Hennigh	$51/mile/year	This method should be actively considered despite the fact that desirable vegetation was slow to establish. Costs were below traditional bare-ground control costs.
1.16	Managed Succession/ Eastern Washington	No guardrail	Evaluate and compare bare-ground treatment method to selective weed control method.	SR 17 MP 136 to 143	Wayne Rice	Selective $44/mile/year Bare-ground $66/mile/year	Selective option was less expensive, while not as clean as bare ground it was very functional. The cost per mile is expected to continue to decline as desirable vegetation continues to establish.
1.17	Hand Trim/ Western Washington	Under guardrail	Use gas powered string trimmers to cut vegetation under and around guardrail, clean under rail once every seven years	US 101 Lake Crescent, all guardrail runs within the NP	Tim Roening	$673/mile/year	No herbicide use allowed in the National Park, abundant growth and rapid edge buildup make this the only option at this location. High cost, greater risk to operators.
1.18	Hand Trim/ Western Washington	Under guardrail	Use gas powered string trimmers to cut vegetation under and around guardrail, clean under rail once every seven years	SR 20 North Cascades, all guardrail runs within the National Rec. Area	Clint Terwillliger	$673/mile/year	Same comments as above.
1.19	Selective Herbicides/ Western Washington	Under guardrail	Allow grass to grow under guardrail w/out mowing, control brush and broadleaf weeds with selective herbicides	SR-20 Whidbey Island, Penn Cove	Clint Terwilliger/ Kathryn Rogers	$13/mile/year	Very little buildup in the location over the study period In this location and others where low growing grasses can be established.
1.20	Selective Herbicides/ Western Washington	Under guardrail	Establish low-growing grass under guardrail	SR-305 Bainbridge Island MP 0.22 - 6.83	Frank Allen	$214/mile/year	Rapid shoulder buildup in this case due to heavy traffic, overhanging tree canopy and weed pressure from seed source pre-existing on the right of way.

Appendix A

Case Study Summary

REFERENCE CODE	ALTERNATIVE TYPE	LOCATION TYPE	DESCRIPTION	APPLICATION LIMITS	MAINTENANCE CONTACTS	ON GOING MAINTENANCE COST	FINDINGS/RECOMMENDATIONS
Pavement Edge Design							
2.1	Tapered pavement edge	No guardrail	Shoulder pavement angles down at outside edge creating a paved Zone 1	I-5 Lacey MP 109.25 - 113.91	John Davis	$48/mile/year	Long standing demonstration that a paved edge drop can achieve desired goals without maintenance of vegetation-free gravel strip.
2.2	Tapered pavement edge	No guardrail	Add site with rough asphalt edge	I-5 south of Tumwater MP 98.42 - 100.93	John Davis	$48/mile/year	Another successful example of a paved break functioning in place of a maintained veg. free strip. This detail could be used in resurfacing projects using "mill and fill".
2.3	Tapered pavement edge	No guardrail	Add site with safety edge	SR 410 Mather Memorial	Mike Golden	$186/mile/year	This is the only case testing the "Safety Edge" being promoted by FHWA. It appears to work well in decreasing the rate of edge buildup. May be better utilized in new pavement projects with wide paved shoulders.
2.4	Compacted aggregate edge	No guardrail	Pavement grinding material placed along the edge of pavement and compacted to create Zone 1	SR 516 at MP 4	Mike Golden	$58/mile/year	Similar to case 2.2 although in this case the recycled grindings were heavily compacted but not heated. This design requires occasional selective glyphosate use to control grasses if they emerge in compacted material.
Zone 1 Maintenance with Cultivation							
3.1	Glyphosate/Cultivation	No guardrail	Treat w/ glyphosate in April prior to cultivation in June	Everett Maintenance Area, all limited access highways	Steven Russel/Ken Higdon	$138/mile/year	Longest standing test of this method, demonstrating the importance of learned operator skill.
3.2	Cultivation once/year	No guardrail	Cultivate annually in Aug/Sept, selective treatment with glyphosate if/where heavy vegetation develops	I-5 Tacoma and SR 101	John Davis	$657/mile/year	Slow operation in this case resulted in higher costs as a result of site conditions and inexperience operators.
3.3	Cultivation twice/year	No guardrail	Pre-treat with Glyphosate attach mower to front of cultivator for better results.	Around section of GR and Rock outcropping between MP 101.7 to 102.95 on SR 2	Gregg Schmidtz	$155/mile/year	This case began in the second year of the study period and the area has improved technique and speed of operation each year.
Weed Barriers							
4.1	Weedender/Western Washington	Under guardrail	Woven fiber permeable mat	SR-525 Whidbey MP 9.7 - 9.8	Clint Terwilliger	$22/mile/year	This is the oldest installation of Weedender and in this location at the south end of Whidbey grows moss and requires annual cleaning.
4.2	Weedender/Western Washington	Under guardrail	Woven fiber permeable mat	SR-112 Jim Creek, both sides of road	Tim Roening	$22/mile/year	Similar results to case 4.1 although where this installation was behind an asphalt curb and with limited overhanging tree canopy it performed much better.
4.3	Weedender/Western Washington	Under guardrail	Woven fiber permeable mat	SR-20 North Cascades	Clint Terwilliger	$195/mile/year	This installation was put down in an area where there was extensive existing weed and brush growth, resulting in growth thru the material at the edges and joints.
4.4	Weedender/Eastern Washington	Under guardrail	Woven fiber permeable mat	SR 2 MP. 90.72 to 90.87	Charlie Styles	$22/mile/year	Installed in an area with significant snow fall and snow and ice operations. The product preformed very well with minimal maintenance costs. Extremely expensive installation cost preclude this from most sites.
4.5	Turboscape/Western Washington	Under guardrail	Ground up tire mulch, placed over weed fabric, sealed with polyurethane coating	I-5 Woodland, North end of bridge South of Woodland	Sam Arola	$37/mile/year	This product is no longer being marketed for use on road shoulders. Within two years after installation weeds and grass began to seed in over the top.

REFERENCE CODE	ALTERNATIVE TYPE	LOCATION TYPE	DESCRIPTION	APPLICATION LIMITS	MAINTENANCE CONTACTS	ON GOING MAINTENANCE COST	FINDINGS/RECOMMENDATIONS
Weed Barriers, continued							
4.6	Traffix Weedmat/ Eastern Washington	Under guardrail	Interlocking rubber tiles made of recycled materials	SCR A-2 SR 823 MP 4.11 to 4.20 NB	Scott Clark	$22/mile/year	Relatively easy to retrofit to existing guardrail, this product performed very well with little maintenance costs. Extremely expensive installation cost precludes this from most sites
4.7	Traffix Weedmat/ Western Washington	Under guardrail	Interlocking rubber tiles made of recycled materials	SR-20 North Cascades MP 115.02 - 115.11	Clint Terwilliger	$22/mile/year	The most expensive material of the weed barriers but easiest to install. This also preformed best of the products tested although it forms an impermeable surface.
4.8	Univ. Weed Cover/ Eastern Washington	Under guardrail	Interlocking molded plastic tiles	SCR A-2 SR 823 MP 4.20 to 4.11 SB	Scott Clark	$22/mile/year	This product was relatively difficult to install and suffered significant damage throughout test. Not recommended.
4.9	Univ. Weed Cover/ Western Washington	Under guardrail	Interlocking molded plastic tiles	SR-20 North Cascades MP 114.8 to 115.05	Clint Terwilliger	$22/mile/year	This was a prototype product and the manufacturer has since improved the design and durability. The product as installed was brittle and subject to cracking.
4.10	Pavement/Western Washington	Under guardrail	Pavement under guardrail	SR-105 Grays Harbor	Theodore Twigg	$895/mile/year	Of all the under guardrail barriers this is the least expensive to install and most durable. Maintenance costs would be comparable to those above ($22/mile) if cleaning was done annually.
4.11	Pavement/Western Washington	Under guardrail	Pavement under guardrail	I-90 Issaquah MP 16.7	John Stecher	$895/mile/year	Of all the under guardrail barriers this is the least expensive to install and most durable. Maintenance costs would be comparable to those above ($22/mile) if cleaning was done annually.
Zone 1 Maintenance with Herbicides							
5.1	Non-Selective, Post Emergent Herbicide	Under guardrail	Maintain Zone 1 through the summer months with non-selective post emergent herbicides as necessary	SR-525 Whidbey, all guardrail runs except in designated sensitive areas.	Clint Terwilliger/ Kathryn Rogers	$526/mile/year	Annual regrowth prior to treatment each spring still created enough edge growth to catch debris and accelerate the rate of edge buildup, therefore periodic removal of edge build up is included in the estimate.
5.2	Mixture of Non-Selective, Post Emergent and Light Pre Emergent Herbicides	All shoulders	This is the most common Zone 1 maintenance prescription in W. Wash.	Multiple locations throughout Western Washington	Multiple	$50/mile/year	After multiple years of this mixture it was common to see localized growth and spread of annual grasses and broadleaf weeds throughout the summer months.
5.3	Mixture of Non-Selective, Post Emergent and Heavy Pre Emergent Herbicides	All shoulders	Maintain a 2 ft. wide vegetation free condition along edge of pavement. The herbicide Norflurazon was found most effective.	SR 9 MP 66.88 - 98.17	Rod Morgan	$74/mile/year	Where this was applied successfully and at the right time it worked well. However there were a number of technical problems with the spray equipment and resulting skips in control.
5.4	E. Washington Pre-emergent sites	All shoulders	Bare-ground zone-1 application	SR 271 MP 0-8	Bob Taylor	$92/mile/year	This site is an example of the type of site that should be treated with bare-ground applications. The cost was acceptable given the alternative of extensive mowing to control reed canary grass.
5.5	E. Washington Pre-emergent sites	Under guardrail	Bare-ground zone-1 application under guardrail	SR 225 MP 6-7	Scott Smith	$167/mile/year	Bare-ground options performed well, another site where bare-ground is a viable option. Cost is higher than typical because bare-ground applications are many miles apart.

Appendix B

Pavement Edge Maintenance Activity

REGION/MAINTENANCE AREA:

Eastern Region, area 2

CASE STUDY REFERENCE:

5.4

OPERATION:

Pre-Emergent Bare Ground Application

AREA SUPERVISOR:

Bob Taylor

APPLICATION:

None-selective bare ground chemicals were used to maintain a 4-5' bare ground zone next to pavement edge.

PURPOSE:

Maintain a vegetation free zone next to pavement edge for a clear errant vehicle recovery zone, reduce water ponding, and maintain site distance around curves.

DESCRIPTION OF WORK PERFORMED:

4 foot spray pattern at 10-12 mph. Accomplish about 55 miles a day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

This application is very affective througout the 16 shoulder miles in the area. This particular activity reduce the amount of time the area mowed per year.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II (spray pay)	Applicator	10.0	$35.68	$356.80
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5	Maint. Tech II	Early warning driver	10.0	$33.41	$334.10
6					
7					
8					
9			LABOR SUBTOTAL		$1,381.80
10					
11			LABOR TOTAL		$1,381.80
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	Herbicide Sprayer Truck		10.0	$9.08	$90.80
14	Truck Attenuator		10.0	$6.63	$66.30
15	Truck, flatbed, extended cab		10.0	$4.49	$44.90
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$202.00
21					
22			EQUIPMENT TOTAL		$202.00
23	**MATERIALS:**				
24	Portfolio	4.6 ozl/acre	35	$19.87	$695.45
25	Landmark	12 ozd/acre	35	$80.76	$2,826.60
26					
27					
28			MATERIALS SUBTOTAL		$3,522.05
29					
30					
31				**Typical Daily Accomplishment**	**$5,105.85**
32				**Average Cost per Mile**	**$92.83**

REGION/MAINTENANCE AREA:
Eastern Washington

CASE STUDY REFERENCE:
1.13

OPERATION:
Zone 1chemical application

AREA SUPERVISOR:
Galen Rogers

APPLICATION:
Typical zone 1 application for guardrail

PURPOSE:
Provide bareground under guard rail 4' wide

DESCRIPTION OF WORK PERFORMED:
4 foot spray pattern at 15 mph. Accomplish about 55 miles a day.

RESULTS, COMMENTS AND CROSS-REFERENCES:
For means of cost comparision with alternative methods a general bareground application including Labor, equipment and materials with appropriate traffic control as per the M54-44 specification.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II (spray pay)	Applicator	10.0	$35.68	$356.80
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5	Maint. Tech II	Early warning driver	10.0	$33.41	$334.10
6					
7					
8					
9			LABOR SUBTOTAL		$1,381.80
10					
11			LABOR TOTAL		$1,381.80
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	Herbicide Sprayer Truck		10.0	$9.08	$90.80
14	Truck Attenuator		10.0	$6.63	$66.30
15	Truck, flatbed, extended cab		10.0	$4.49	$44.90
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$202.00
21					
22			EQUIPMENT TOTAL		$202.00
23	**MATERIALS:**				
24	Payload	10 ozd/acre	35	$66.40	$2,324.00
25	Oust	3 ozd/acre	35	$13.35	$467.25
26					
27					
28			MATERIALS SUBTOTAL		$2,791.25
29					
30					
31				**Typical Daily Accomplishment**	**$4,375.05**
32				**Average Cost per Mile**	**$79.55**

REGION/MAINTENANCE AREA:
North Central Region, Area 1

CASE STUDY REFERENCE:
1.14

OPERATION:
Selective Treatment in Zone 1

AREA SUPERVISOR:
Rick Wood

APPLICATION:
Selective

PURPOSE:
Treat designate weeds. Estimate below covers cost for .5 of the annual treatment as not all of the treatment falls within zone 1.

DESCRIPTION OF WORK PERFORMED:
Treat designate weeds in zone 1. Bareground herbicide applications eliminated in 2003 and zone 1 regraded and replanted as part of an overlay construction project.

RESULTS, COMMENTS AND CROSS-REFERENCES:
Excellent growth of desirable vegetation, reduction of designate weeds present, good roadshoulder stabilization all with fewer applications per year. Overall cost savings, reduction of routine maintenance necessary to maintain the roadway. Routine maintenance now only requires 1 selective spot herbicide application per year of approximately 4' wide for entire ROW.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10.0	$35.68	$356.80
3	Maint. Tech. II	Spray Driver	10.0	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10.0	$33.41	$334.10
5	Maint. Tech. II	Traffic Control	10.0	$33.41	$334.10
6					
7					
8					
9					
10					
11			LABOR SUBTOTAL		$1,381.80
12					
13			LABOR TOTAL		$1,381.80
14	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
15	Truck Attenuator		10	$6.63	$66.30
16	Herbicide Spray Truck		10	$9.51	$95.10
17	Truck w/ Arrowboard		10	$4.53	$45.30
18					
19					
20					
21			EQUIPMENT SUBTOTAL		$206.70
22					
23			EQUIPMENT TOTAL		$206.70
24	**MATERIALS:**				
25	Escalade 2	48 ozl/arce	35	22.08	$772.80
26	LI 700	22 ozl/acre	35	4.40	$154.00
27			MATERIALS SUBTOTAL		$ 926.80
28					
29			MATERIALS TOTAL		$926.80
30					
31				**Total Opertional Cost**	**$2,515.30**
32				**Average Cost per Mile**	**$22.87**

Apppendix B

Pavement Edge Maintenance Activity

REGION/MAINTENANCE AREA:
North Central Region, Area 3 (Bareground)

CASE STUDY REFERENCE:
1.15

OPERATION:
Comparison of Z-1 Bareground Maintenance to Z-1 Selective-Only Treatment

AREA SUPERVISOR:
Tom Hennigh/Wayne Rice

APPLICATION:
Historic Bareground Application

PURPOSE:
Evaluate the cost, and viability of eliminating Zone 1 Bareground in favor of selective applications.

DESCRIPTION OF WORK PERFORMED:

RESULTS, COMMENTS AND CROSS-REFERENCES:
Bareground application performed well, no significant break-through.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10	$35.68	$356.80
3	Maint. Tech. II	Spray Driver	10	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
5	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
6					
7					
8					
9					
10					
11					
12			LABOR SUBTOTAL		$1,381.80
13					
14			LABOR TOTAL		$1,381.80
15	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
16	Truck Attenuator		10	$6.63	$66.30
17	Herbicide Sprayer Truck		10	$9.51	$95.10
18	Truck w/ Arrowboard		10	$4.53	$45.30
19					
20					
21					
22			EQUIPMENT SUBTOTAL		$206.70
23					
24			EQUIPMENT TOTAL		$206.70
25	**MATERIALS:**				
26	Krovar	8 lbs/acre	51	86.08	$4,390.08
27	In-Place	16 ozl/acre	51	2.40	$122.40
28			MATERIALS SUBTOTAL		
29					
30			MATERIALS TOTAL		$ 4,512.48
31					
32				**Total Opertional Cost**	**$6,100.98**
33				**Average Cost per Mile**	**$110.93**

REGION/MAINTENANCE AREA:
North Central, Area 3 (No-Bareground)

CASE STUDY REFERENCE:
1.15

OPERATION:
Comparison of Z-1 Bareground Maintenance to Z-1 Selective-Only Treatment

AREA SUPERVISOR:
Tom Hennigh/Wayne Rice

APPLICATION:
Eastbound shoulder treated with selective only, Westbound shoulder treated with typical 4' BG treatment

PURPOSE:
Evaluate the cost, and viability of eliminating Zone 1 Bareground in favor of selective applications.

DESCRIPTION OF WORK PERFORMED:
6' Selective Application

RESULTS, COMMENTS AND CROSS-REFERENCES:
Note: The actual cost for the selective treatment in this case would be less than $51.43/mile indicated on the chart above. This is because two selective applications approximately 16' wide are made annually to control invasives in zone 2. The real cost is calculated by subtracting the cost per mile from a 22' wide application from the traditional cost per mile of a 16' application. $118-$110=$16x2 applications =$32 per mile for treating the additional 6' with selective.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10	$35.68	$356.80
3	Maint. Tech. II	Spray Driver	10	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
5	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
6					
7					
8					
9					
10					
11			LABOR SUBTOTAL		$1,381.80
12					
13			LABOR TOTAL		$1,381.80
14	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
15	Truck Attenuator		10	$6.63	$66.30
16	Herbicide Sprayer Truck		10	$9.51	$95.10
17	Truck w/ Arrowboard		10	$4.53	$45.30
18					
19					
20					
21			EQUIPMENT SUBTOTAL		$206.70
22					
23			EQUIPMENT TOTAL		$206.70
24	**MATERIALS:**				
25	Escalade 2	48 ozl/acre	51	22.08	$1,126.08
26	MSO	32 ozl/acre	51	2.24	$114.24
27					
28					
29					
30			MATERIALS SUBTOTAL		
31					
32			MATERIALS TOTAL		$ 1,240.32
33					
34				**Total Operational Cost**	**$2,828.82**
35				**Average Cost per Mile**	**$51.43**

REGION/MAINTENANCE AREA:

North Central Region, Area 3 (4' Selective)

CASE STUDY REFERENCE:

1.16

OPERATION:

Compare Z-1 Bareground Maintenance to Z-1 Selective-Only Treatment

AREA SUPERVISOR:

Wayne Rice

APPLICATION:

Eastbound shoulder treated with selective only, Westbound shoulder treated with typical 4' BG treatment

PURPOSE:

Evaluate the cost difference and rate at which desirable vegetation establishes on it's own (no seeding) for the two methods.

DESCRIPTION OF WORK PERFORMED:

Eastbound shoulder treated with selective only, Westbound shoulder treated with typical 4' BG treatment. No seeding is to be accomplished throughout the trial to allow us to evaluate the ability for desirable vegetation to migrate into old BG

RESULTS, COMMENTS AND CROSS-REFERENCES:

Pros: Despite slow migration of desirable species the cost to maintain vegetation on eastbound (no bg) was equal to or less than the cost of maintaining the west bound shoulder with a 4' bg. This cost should decrease as desirable vegetation continues to fill in which in theory will require less and less selective work to maintain.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10.0	$35.68	$356.80
3	Maint. Tech. II	Spray Driver	10.0	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10.0	$33.41	$334.10
5	Maint. Tech. II	Traffic Control	10.0	$33.41	$334.10
6					
7					
8					
9					
10					
11					
12			LABOR SUBTOTAL		$1,381.80
13					
14			LABOR TOTAL		$1,381.80
15	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
16	Truck Attenuator		10	$6.63	$66.30
17	Herbicide Spray Truck		10	$9.51	$95.10
18	Truck w/ Arrowboard		10	$4.53	$45.30
19					
20					
21					
22			EQUIPMENT SUBTOTAL		$206.70
23					
24			EQUIPMENT TOTAL		$206.70
25	**MATERIALS:**				
26	Escalade 2	48 ozl/acre	35.0	22.08	$772.80
27	MSO	32 ozl/acre	35.0	2.24	$78.40
28			MATERIALS SUBTOTAL		
29					
30			MATERIALS TOTAL		$ 851.20
31					
32				**Total Opertional Cost**	**$2,439.70**
33				**Average Cost per Mile**	**$44.36**

REGION/MAINTENANCE AREA:

North Central Region, Area 3 (4' Bareground)

CASE STUDY REFERENCE:

1.16

OPERATION:

Compare Z-1 Bareground Maintenance to Z-1 Selective-Only Treatment

AREA SUPERVISOR:

Wayne Rice

APPLICATION:

Eastbound shoulder treated with selective only, Westbound shoulder treated with typical 4' BG treatment

PURPOSE:

Evaluate the cost difference and rate at which desirable vegetation establishes on it's own (no seeding) for the two methods.

DESCRIPTION OF WORK PERFORMED:

Eastbound shoulder treated with selective only, Westbound shoulder treated with typical 4' BG treatment. No seeding is to be accomplished throughout the trial to allow us to evaluate the ability for desirable vegetation to migrate into old BG

RESULTS, COMMENTS AND CROSS-REFERENCES:

Pros: Despite slow migration of desirable species the cost to maintain vegetation on eastbound (no bg) was equal to or less than the cost of maintaining the west bound shoulder with a 4' bg. This cost should decrease as desirable vegetation continues to fill in which in theory will require less and less selective work to maintain.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10.0	$35.68	$356.80
3	Maint. Tech. II	Spray Driver	10.0	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10.0	$33.41	$334.10
5	Maint. Tech. II	Traffic Control	10.0	$33.41	$334.10
6					
7					
8					
9					
10			LABOR SUBTOTAL		$1,381.80
11					
12			LABOR TOTAL		$1,381.80
13	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
14	Truck Attenuator		10	$6.63	$66.30
15	Herbicide Spray Truck		10	$5.24	$52.40
16	Truck w/ Arrowboard		10	$5.09	$50.90
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$169.60
21					
22			EQUIPMENT TOTAL		$169.60
23	**MATERIALS:**				
24	Krovar	8 lbs/acre	35	86.08	$3,012.80
25	In-Place	16 ozl/acre	35	2.40	$84.00
26			MATERIALS SUBTOTAL		$ 3,096.80
27					
28			MATERIALS TOTAL		$ 3,096.80
29					
30				**Total Operational Cost**	**$4,648.20**
31				**Average Cost per Mile**	**$84.51**

REGION/MAINTENANCE AREA:

South Central Region Area 3

CASE STUDY REFERENCE:

5.5

OPERATION:

Zone 1 Bareground Application On Guardrail Section

AREA SUPERVISOR:

Scott Smith/Larry Wilhelm

APPLICATION:

Zone 1 Bareground Application

PURPOSE:

Maintain Guardrail for control of noxious weeds, provide sight distance, reduce hand work, improve conditions for guardrail maintenance and to protect the guardrail from fire.

DESCRIPTION OF WORK PERFORMED:

Treat guardrail with bare-ground application to control all vegetation.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Clean bareground, controlled all species, no significant break-through. Typical production in a 10 hour day is approximately 14 miles or approximately 8.5 acres.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II (spray pay)	Applicator	10.0	$35.68	$356.80
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5	Maint. Tech II	Early warning driver	10.0	$33.41	$334.10
6					
7					
8					$1,381.80
9					
10			LABOR TOTAL		$1,381.80
11	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
12	Herbicide Sprayer Truck		10.0	$9.08	$90.80
13	Truck Attenuator		10.0	$6.63	$66.30
14	Truck, flatbed, extended cab		10.0	$4.49	$44.90
15					
16					
17			EQUIPMENT SUBTOTAL		$202.00
18					
19			EQUIPMENT TOTAL		$202.00
20	**MATERIALS:**				
21	Krovar DF	8 lbs/acre	8.5	$86.08	$731.68
22	In-Place	16 ozl/acre	8.5	$2.40	$20.40
23	Fighter F	4 ozl/acre	8.5	0.56	$4.76
24					
25			MATERIALS SUBTOTAL		$752.08
26					
27					
28				**Typical Daily Accomplishment**	**$2,335.88**
29				**Average Cost per Mile**	**$166.85**

REGION/MAINTENANCE AREA:
South Central Region, Area 1

CASE STUDY REFERENCE:
1.13

OPERATION:
Selective Treatment in Zone 1 Guardrail

AREA SUPERVISOR:
Galen Rogers/ Win Charlton

APPLICATION:
Selective

PURPOSE:
Control designate weeds as needed when they appear under guardrail.

DESCRIPTION OF WORK PERFORMED:
For estimate assume 1, 4' band application yearly of a selective herbicide. In reality it has been more typically 1-2 spot treatments annually, this treatment covers both zone 1 and zone 2. However for the purposes of estimation we will assume 1, 4' band application.

RESULTS, COMMENTS AND CROSS-REFERENCES:
Excellent results in terms of cost for selective compared to bareground. A variety of vegetation has migrated into the guardrail zone over the past 4 years. Several woody shrubs including rabbit brush and sagebrush have grown up next to the guard rail. This would create some issues if repair was needed to the rail or posts. No fires occured within the project area.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II (spray pay)	Operator	10.0	$35.68	$356.80
3	Maint. Tech. II (spray pay)	Spray Driver	10.0	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10.0	$33.41	$334.10
5					
6					
7					
8					
9					
10			LABOR SUBTOTAL		$1,047.70
11					
12			LABOR TOTAL		$1,047.70
13	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
14	Herbicide Spray Truck		10	$9.51	$95.10
15	Truck w/ Arrowboard		10	$4.53	$45.30
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$140.40
21					
22			EQUIPMENT TOTAL		$140.40
23	**MATERIALS:**				
24	Escalade 2		35.0	22.08	$772.80
25	LI 700		35.0	4.40	$154.00
26			MATERIALS SUBTOTAL		
27					
28			MATERIALS TOTAL		$ 926.80
29					
30				**Total Opertional Cost**	**$2,114.90**
31				**Average Cost per Mile**	**$38.45**

REGION/MAINTENANCE AREA:

South Central Region, Area 3 (Selective @ 4')

CASE STUDY REFERENCE:

1.2

OPERATION:

Maintain vegetation to the edge of pavement up to the edge of pavement.

AREA SUPERVISOR:

Scott Smith/Larry Wilhelm

APPLICATION:

A variety of selective applications

PURPOSE:

Evaluate the cost of maintaining weeds at the edge of pavmement in established native grasses.

DESCRIPTION OF WORK PERFORMED:

US-12 Phase II was designed and constructed with soil amendments that would support native grasses to the edge of pavement. It was seeded as part of the contract and maintained for the first year by the contractor. The native grasses are well established in the majority of the roadshoulders, however there has been some maintenance required to keep this desirable vegetation in good condition.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Desirable vegetation is well established, broadleaf weed control is still required on an annual basis. Typically this treatment is a combination of band-width and spot treatment within zone 1.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II (spray pay)	Operator	10	$35.68	$356.80
3	Maint. Tech. II (spray pay)	Spray Driver	10	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
5	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
6					
7					
8					
9					
10					
11			LABOR SUBTOTAL		$1,381.80
12					
13			LABOR TOTAL		$1,381.80
14	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
15	Truck Attenuator		10	$6.63	$66.30
16	Herbicide Truck Sprayer		10	$9.51	$95.10
17	Truck w/ arrow board		10	$4.53	$45.30
18					
19					
20			EQUIPMENT SUBTOTAL		$206.70
21					
22			EQUIPMENT TOTAL		$206.70
23	**MATERIALS:**				
24	Escalade 2		35	22.08	$772.80
25	Super Spreader 90		35	0.96	$33.60
26	highlight		0	0.50	$0.00
27			MATERIALS SUBTOTAL		
28					
29			MATERIALS TOTAL		$ 806.40
30					
31				**Total Opertional Cost**	**$2,394.90**
32				**Average Cost per Mile**	**$43.54**

REGION/MAINTENANCE AREA:
South Central Region, Area 3 (Bareground Alternaitve)

CASE STUDY REFERENCE:
1.2

OPERATION:
Comparison of Z-1 Bareground vs Selective treatment

AREA SUPERVISOR:
Scott Smith/Larry Wilhelm

APPLICATION:
No application made- Compare cost to selective applications made

PURPOSE:
Comparision of cost without vegetation to edge of pavement

DESCRIPTION OF WORK PERFORMED:
N/A

RESULTS, COMMENTS AND CROSS-REFERENCES:

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10	$35.68	$356.80
3	Maint. Tech. II	Spray Driver	10	$35.68	$356.80
4	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
5	Maint. Tech. II	Traffic Control	10	$33.41	$334.10
6					
7					
8					
9			LABOR SUBTOTAL		$1,381.80
10					
11			LABOR TOTAL		$1,381.80
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	Truck Attenuator		10	$6.63	$66.30
14	Herbicide Truck Sprayer		10	$9.51	$95.10
15	Truck w/ arrow board		10	$4.53	$45.30
16					
17					
18			EQUIPMENT SUBTOTAL		$206.70
19					
20			EQUIPMENT TOTAL		$206.70
21	**MATERIALS:**				
22	Krovar DF @ 8 lbs		35	86.08	$3,012.80
23	Oust		35	13.35	$467.25
24	In-Place @ 16 ozl		35	2.40	$84.00
25					
26			MATERIALS SUBTOTAL		
27					
28			MATERIALS TOTAL		$ 3,564.05
29					
30				**Total Operational Cost**	**$5,152.55**
31				**Average Cost per Mile**	**$93.68**

REGION/MAINTENANCE AREA:

Northwest Region, Area 2

CASE STUDY REFERENCE:

1.11 - 2.4 - 3.1 - 3.3 - 4.5 - 5.1

OPERATION:

Zone 1chemical application (mixture 1) None-Selective Post Emergent Only

AREA SUPERVISOR:

Clint Terwilliger

APPLICATION:

Typical zone 1 application may be used on both limited access and secondary routes.

PURPOSE:

To kill all vegetation within a 2 foot swath of vegetation next to pavement edge to prevent encroaching vegetation, preserve site distance around corners and at intersections, maintain visibility of hardware.

DESCRIPTION OF WORK PERFORMED:

2 foot spray pattern at 10-12 mph. Accomplish about 55 miles a day. One day's work includes mixing and loading, mobilization to the work sites as well as clean up and record keeping at the end of the day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

The use of Glyphosate only does not prevent regrowth and in some cases, if this is the only treatment used shoulder vegetation in Western Washington can form a thick layer of regrowth by the time treatments are made in the spring. Use of Glyphosate only essentially acts as a "chemical mowing" operation.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II (spray pay)	Applicator	10.0	$35.68	$356.80
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5	Maint. Tech II	Early warner driver	10.0	$33.41	$334.10
6					
7					
8					
9			LABOR SUBTOTAL		$1,381.80
10					
11			LABOR TOTAL		$1,381.80
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	829 Herb. Sprayer Truck		10.0	$9.51	$95.10
14	8C23 - Truck, flatbed 38,000 GVW		10.0	$5.66	$56.60
15	4C14 - Truck, flatbed, extended cab		10.0	$4.49	$44.90
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$196.60
21					
22			EQUIPMENT TOTAL		$196.60
23	**MATERIALS:**				
24	Roundup-Pro Conc.	64ozl/acre	16.8 acres	$26.88/acre	$451.58
25	Sta-Put	45ozl/ acre	16.8 acres	$2.25/acre	$37.80
26					
27					
28			MATERIALS SUBTOTAL		$489.38
29					
30					
31				**Typical Daily Accomplishment**	**$2,067.78**
32				**Average Cost per Mile**	**$37.60**

REGION/MAINTENANCE AREA:

Southwest Region, Area 2

CASE STUDY REFERENCE:

5.2

OPERATION:

Zone 1 Chemical Application (Mixture 2) Non-Selective Post Emergent plus Light Pre-Emergent

AREA SUPERVISOR:

Larry Stritmatter

APPLICATION:

Typical zone 1 application may be used on both limited access and secondary routes.

PURPOSE:

To mostly clear a 2 foot swath of vegetation next to pavement edge to prevent edge build up and water ponding, prevent encroaching vegetation, preserve site distance around corners and at intersections, and to maintain visibility of hardware.

DESCRIPTION OF WORK PERFORMED:

2 foot spray pattern at 10-12 mph. Accomplish about 55 miles a day. One day's work includes mixing and loading, mobilization to the work sites as well as clean up and record keeping at the end of the day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

With this mixture in most cases on the west side of the state, it can be expected that some regrowth will occur by the time annual treatments are made in the spring.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II (spray pay)	Applicator	10.0	$35.68	$356.80
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5	Maint. Tech II	Early warner driver	10.0	$33.41	$334.10
6					
7					
8					
9			LABOR SUBTOTAL		$1,381.80
10					
11			LABOR TOTAL		$1,381.80
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	829 Herb. Sprayer Truck		10.0	$9.51	$95.10
14	8C23 - Truck, flatbed 38,000 GVW		10.0	$5.66	$56.60
15	4C14 - Truck, flatbed, extended cab		10.0	$4.49	$44.90
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$196.60
21					
22			EQUIPMENT TOTAL		$196.60
23	**MATERIALS:**				
24	Roundup-Pro Conc.	64ozl/acre	16.8 acres	$26.88	$451.58
25	Landmark XP	6ozd/acre	16.8 acres	$40.38	$678.38
26	Stay Put	45ozl/acre	16.8 acres	$2.25	$37.80
27	Spreader 90	12ozl/area	16.8 acres	$0.84	$14.11
28					
29			MATERIALS SUBTOTAL		$1,181.87
30					
31					
32				**Typical Daily Accomplishment**	**$2,760.27**
33				**Average Cost per Mile**	**$50.19**

REGION/MAINTENANCE AREA:

Northwest Region, Area 1

CASE STUDY REFERENCE:

5.3

OPERATION:

Zone 1 Chemical Application (mixture 3) Year Round Pre-Emergent Control

AREA SUPERVISOR:

Rod Morgan

APPLICATION:

Typical Zone 1 application may be used on both limited access and secondary routes.

PURPOSE:

To maintain a 2 foot swath of bare ground next to pavement edge to prevent edge build up and water ponding, prevent encroaching vegetation, preserve site distance around corners and at intersections, and to maintain visibility of hardware.

DESCRIPTION OF WORK PERFORMED:

2 foot spray pattern at 10-12 mph. Accomplish about 55 miles a day. One day's work includes mixing and loading, mobilization to the work sites as well as clean up and record keeping at the end of the day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

This type of application is most effective when there is minimal regrowth in the treated area. If vegetative growth is too thick, the soil residual, pre-emergent herbicides will tie up in the organic matter on the surface and not be as likely to move down into the top of the soil column where they can effect plant growth.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II (spray pay)	Applicator	10.0	$35.68	$356.80
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5	Maint. Tech II	Early warner driver	10.0	$33.41	$334.10
6					
7					
8					
9			LABOR SUBTOTAL		$1,381.80
10					
11			LABOR TOTAL		$1,381.80
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	829 Herb. Sprayer Truck		10.0	$9.51	$95.10
14	8C23 - Truck, flatbed 38,000 GVW		10.0	$5.66	$56.60
15	4C14 - Truck, flatbed, extended cab		10.0	$4.49	$44.90
16					
17					
18					
19			EQUIPMENT SUBTOTAL		$196.60
20					
21			EQUIPMENT TOTAL		$196.60
22	**MATERIALS:**				
23	Roundup-Pro Conc.	64ozl/acre	16.8 acres	$26.88	$587.06
24	Oust	4ozd/acre	16.8 acres	$17.80	$388.75
25	Payload	10ozd/acre	16.8 acres	$66.40	$1,450.18
26	Stay Put	45ozl/acre	16.8 acres	$2.25	$49.14
27	Spreader 90	12ozl/acre	16.8 acres	$0.84	$18.35
28					
29			MATERIALS SUBTOTAL		$2,493.47
30					
31					
32				**Typical Daily Accomplishment**	**$4,071.87**
33				**Average Cost per Mile**	**$74.03**

REGION/MAINTENANCE AREA:

Southwest Region, Area 2

CASE STUDY REFERENCE:

1.19 - 1.20

OPERATION:

Zone 1 selective chemical application

AREA SUPERVISOR:

Larry Stritmatter

APPLICATION:

Typical application, used where needed in establishing grasses on the shoulder.

PURPOSE:

Selectively control broadleaf weeds and emerging seedling trees and brush, so that grasses can establish up to the edge of pavement.

DESCRIPTION OF WORK PERFORMED:

Spray banded broadcast application of selective broadleaf controlling herbicides. 2 foot spray pattern at 10-12 mph. Accomplish about 55 miles a day. One day's work includes mixing and loading, mobilization to the work sites as well as clean up and record keeping at the end of the day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II (spray pay)	Applicator	10.0	$35.68	$356.80
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5	Maint. Tech II	Early warner driver	10.0	$33.41	$334.10
6					
7					
8					
9			LABOR SUBTOTAL		$1,381.80
10					
11			LABOR TOTAL		$1,381.80
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	829 Herb. Sprayer Truck		10.0	$9.51	$95.10
14	8C23 - Truck, flatbed 38,000 GVW		10.0	$4.91	$49.10
15	4C14 - Truck, flatbed, extended cab		10.0	$4.81	$48.10
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$192.30
21					
22			EQUIPMENT TOTAL		$192.30
23	**MATERIALS:**				
24	Garlon 3A	64 ozl/acre	16.8 acres	$32.64	$548.35
25	Stay Put	45 ozl/acre	16.8 acres	$2.25	$37.80
26	Spreader 90	12 ozl/acre	16.8 acres	$0.84	$14.11
27					
28					
29			MATERIALS SUBTOTAL		$600.26
30					
31					
32				**Typical Daily Accomplishment**	**$2,174.36**
33				**Average Cost per Mile**	**$39.53**

REGION/MAINTENANCE AREA:

Northwest Region, Area 2

CASE STUDY REFERENCE:

5.1

OPERATION:

Zone 1 Bare Ground Treatment Underguardrail only

AREA SUPERVISOR:

Clint Terwilliger

APPLICATION:

Typical Zone 1 bare ground application may be used on guardrail runs for both limited access and secondary routes.

PURPOSE:

Maintain a 3 foot swath of bare ground next to pavement edge under guardrail to prevent edge build up and water ponding, visiblity and maintainability of roadway hardware.

DESCRIPTION OF WORK PERFORMED:

2 foot spray pattern at 10-12 mph, skipping over areas without guardrail. Production only includes treatment of guardrail runs so daily miles accomplished increase with the percentage of shoulder containing guardrail. Whidbey Island has approximately 130 shoulder miles with 10.98 miles of guardrial on SR 20 and SR 525. One day's work includes mixing and loading, mobilization to the work sites as well as clean up and record keeping at the end of the day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Lead Tech (spray pay)	Applicator	10.0	$43.25	$432.50
3	Maint. Tech II (spray pay)	Spray Truck Driver	10.0	$35.68	$356.80
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5					
6					
7					
8					
9			LABOR SUBTOTAL		$1,123.40
10					
11			LABOR TOTAL		$1,123.40
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	832 Herb. Sprayer Truck		10.0	$9.51	$95.10
14	8C23 - Truck, flatbed 38,000 GVW		10.0	$5.66	$56.60
15	4C14 - Truck, flatbed, extended cab		10.0	$4.49	$44.90
16					
17					
18			EQUIPMENT SUBTOTAL		$196.60
19					
20			EQUIPMENT TOTAL		$196.60
21	**MATERIALS:**				
22	Razor Pro	64 oz/.acre	160	$0.26	$41.60
23	Oust XP	4 oz./acre	2.8	$4.45	$12.46
24	Milestone VM	6 oz./acre	4.2	$2.50	$10.50
25	Spreader 90	16 oz./area	11.2	$0.07	$0.78
26	Suspender	0.5 ozl/acre	0.35	$0.23	$0.08
27	Fighter F	0.5 ozl/acre	0.35	$0.14	$0.05
28	Blazon Blue	5 ozl/acre	0.35	$0.25	$0.09
29					
30			MATERIALS SUBTOTAL		$65.56
31					
32					
33				**Typical Daily Accomplishment**	**$1,385.56**
34				**Average Cost per Mile**	**$126.19**

REGION/MAINTENANCE AREA:

Northwest Region, Area 3

CASE STUDY REFERENCE:

1.11 - 3.1

OPERATION:

Cultivation and repacking of shoulder at the edge of pavement

AREA SUPERVISOR:

Steve Russell (Assistant Superintendent), Ken Higdon (Current Section Supervisor)

APPLICATION:

Northwest Region, Area 3 has used this method on all limited access highway shoulders in the area for the past 4 years.

PURPOSE:

Prevent/limit vegetative growth at the edge of pavement to preserve traffic sight distance, maintain even transition between paved and non-paved shoulder, delineate highway edge, prevent vegetation from encroaching on traffic and encourage a healthy grass stand.

DESCRIPTION OF WORK PERFORMED:

Cultivation and repacking of shoulder at the edge of pavement. NW area 3 cultivates 73.8 miles of pavement edge per year on secondary and limited access routes. This work is accomplished in 5 days.

RESULTS, COMMENTS AND CROSS-REFERENCES:

This estimate represents experienced personnel working an area where the shoulder is cultivated on an annual basis and the area has been prepared for this activity by moving guideposts and j-boxes out of the cultivation zone.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. III	Operator	50.0	$36.22	$1,811.00
3	Maint. Tech. II	Spotter	50.0	$33.41	$1,670.50
4	Maint. Tech. II	Spotter	50.0	$33.41	$1,670.50
5	Maint. Tech. II	Operator	50.0	$33.41	$1,670.50
6					
7					
8					
9			LABOR SUBTOTAL		$6,822.50
10					
11			LABOR TOTAL		$6,822.50
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	Truck w/ Arrowboard		50.0	$4.53	$226.50
14	Truck w/ Arrowboard		50.0	$4.53	$226.50
15	Truck Attenuator		50.0	$6.63	$331.50
16	Tractor Full size		50.0	$5.26	$263.00
17	Tractor Small size		50.0	$2.11	$105.50
18					
19					
20			EQUIPMENT SUBTOTAL		$1,153.00
21					
22			EQUIPMENT TOTAL		$1,153.00
23	**MATERIALS:**				
24					
25					
26			MATERIALS SUBTOTAL		
27					
28			MATERIALS TOTAL		
29					
30					
31				**Total Operational Rate**	**$7,975.50**
32				**Average Cost per Mile**	**$108.07**

REGION/MAINTENANCE AREA:

Olympic Region, Area 1

CASE STUDY REFERENCE:

3.2

OPERATION:

Cultivation and repacking of shoulder at the edge of pavement

AREA SUPERVISOR:

John Davis (Area Roadside Supervisor)

APPLICATION:

This is only applicable to a limited area of I-5, based on the experience of the Oly Region, Area 1 crew.

PURPOSE:

Prevent/eliminate vegetative growth at the edge of pavement to preserve traffic sight distance, even out the transition between the paved and non-paved, delineate highway edge, prevent vegetation from encroaching on traffic and encourage a healthy grass stand.

DESCRIPTION OF WORK PERFORMED:

Cultivation and repacking of shoulder at the edge of pavement. OL area 1 cultivates 14.64 miles of zone 1 per year on I-5 from MP 116.4 to 131.20

RESULTS, COMMENTS AND CROSS-REFERENCES:

There is a dramatic difference between production of this crew and that of NW Region, Area 3 and Olympic Region, Area 5. This estimate includes time required to work around exisint guideposts and to stop and repair and mark locations for junction boxes.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Main. Tech. II	Tractor Operator	80.0	$33.41	$2,672.80
3	Main. Tech. II	Grader Operator	80.0	$33.41	$2,672.80
4	Main. Tech. II	Traffic Control Operator	80.0	$33.41	$2,672.80
5					
6					
7					
8					
9					
10			LABOR SUBTOTAL		$8,018.40
11					
12			LABOR TOTAL		$8,018.40
13	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
14	8-20 - Trk, Flatb, Rd. Warrior		80.0	$6.63	$530.40
15	Grader 35K Articulated		80.0	$8.10	$648.00
16	Tractor Full size		80.0	$5.26	$420.80
17					
18					
19			EQUIPMENT SUBTOTAL		$1,599.20
20					
21			EQUIPMENT TOTAL		$1,599.20
22	**MATERIALS:**				
23					
24					
25			MATERIALS SUBTOTAL		
26					
27			MATERIALS TOTAL		
28					
29					
30				**Total Operational Rate**	**$9,617.60**
31				**Operational Cost Per Mile**	**$656.94**

REGION/MAINTENANCE AREA:

Olympic Region, Area 3

CASE STUDY REFERENCE:

3.3

OPERATION:

Cultivation and repacking of shoulder at the edge of pavement on SR 8 and US 12

AREA SUPERVISOR:

Gregg Schmidtz

APPLICATION:

This application on the SR 8/US 12 corridor is different from the I-5 case studies in that the shoulder was somewhat vegetated during the first year of application and in that there is more irregularity in the side slope. Therefore this estimate is only applied to case study C3.

PURPOSE:

Reduce vegetation height at the edge of pavement to preserve traffic sight distance, delineate highway edge, prevent vegetation from encroaching on traffic and encourage a healthy grass stand.

DESCRIPTION OF WORK PERFORMED:

Cultivation and repacking of shoulder at the edge of pavement. Crew are able to cultivate appoximately 16 miles per day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Results below reflex work accomplished by trained personel at optimal level of performance in the second year of implementation.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. III	Operator	10.0	$36.22	$362.20
3	Maint. Tech. II	Spotter	10.0	$33.41	$334.10
4	Maint. Tech. II	Spotter	10.0	$33.41	$334.10
5	Maint. Tech. II	Operator	10.0	$33.41	$334.10
6	Maint. Tech. II	Operator	10.0	$33.41	$334.10
7					
8					
9					
10			LABOR SUBTOTAL		$1,698.60
11					
12			LABOR TOTAL		$1,698.60
13	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
14	Truck Attenuator		10.0	$6.63	$66.30
15	Truck w/ arrow board		10.0	$4.53	$45.30
16	Sweeper		10.0	$4.67	$46.70
17	Tractor		10.0	$5.26	$52.60
18	Mower, sidemount attachment		10.0	$1.42	$14.20
19	Grader 35K		10.0	$8.10	$81.00
20					
21					
22			EQUIPMENT SUBTOTAL		$306.10
23					
24			EQUIPMENT TOTAL		$306.10
25	**MATERIALS:**				
26					
27					
28			MATERIALS SUBTOTAL		
29					
30			MATERIALS TOTAL		
31					
32					
33				**Total Operational Rate**	**$2,004.70**
34				**Average Cost per Mile**	**$125.29**

REGION/MAINTENANCE AREA:
North Central Region, Area 1

CASE STUDY REFERENCE:
4.3-4.4

OPERATION:
Installation of WeedEnder matting

AREA SUPERVISOR:
Rick Wood

APPLICATION:
Assumed as a typical installation estimate for a clean, well prepared site using an experience crew and state of the art tools.

PURPOSE:
Matting is intended to serve as a solid cover and prevent all vegetative growth in a 4' stip under guardrail runs.

DESCRIPTION OF WORK PERFORMED:
Installation of matting only, assuming the site has a smooth, well compacted surface and is free of all vegetation. Productivity (800 ft./day) is based on the manufacturer's estimate.

RESULTS, COMMENTS AND CROSS-REFERENCES:
Weedender matting installed was extremely expensive due in great part to site characteristics and the learning curve as the crew's gained experience. For the purposes of this comparision we did not include site preperation costs in the below estimate. In theory, once crews are familiar with the product, with the correct tools (pnumatic instead of manual staplers) this installation would drop significantly (30-50%). The product has held up very well with no maintenance required.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II	Site prep/Installation	10.0	$33.41	$334.10
3	Maint. Tech II	Site prep/Installation	10.0	$33.41	$334.10
4					
5					
6					
7					
8					
9			LABOR SUBTOTAL		$668.20
10					
11			LABOR TOTAL		$668.20
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13					
14	5E37-3 - L/T	Site prep/Installation	10.0	$4.80	$48.00
15					
16					
17					
18					
19			EQUIPMENT SUBTOTAL		$48.00
20					
21			EQUIPMENT TOTAL		$48.00
22	**MATERIALS:**				
23					
24	$4.53 per linear ft. of Weedneder				$3,624.00
25					
26					
27					
28			MATERIALS SUBTOTAL		$3,624.00
29					
30					
31				**Installation Cost**	**$4,340.20**
32				**Average Installation Cost per Mile**	**$28,645.32**

REGION/MAINTENANCE AREA:

Northwest Region, Area 5

CASE STUDY REFERENCE:

4.10 - 4.11 - 4.11 - 5.1

OPERATION:

Pavement Underguardrail cleaning

AREA SUPERVISOR:

John Stecher (Section Supervisor)

APPLICATION:

This estimate is assumed comparable for work done in any situation where debris and vegetative build up is removed from pavement under and behind guardrail

PURPOSE:

Pavement serves to prevent vegetative growth under guardrail and eliminates the need to manage vegetation in this type of situation.

DESCRIPTION OF WORK PERFORMED:

Periodically remove soil and vegetation from buildup from around guardrail post to improve surface water drainage and to preserve hardware. This test site contains 739.2 feet (0.14 miles) of pavement under guardrail and has only been cleaned twice in the last ten years. Total operational cost for this activity is $877.20. Removed material is hauled to a pit site. To clean a full mile of pavement under guardrail would cost $6,265.71.

RESULTS, COMMENTS AND CROSS-REFERENCES:

The cost of this method of cleaning averaged on a per year basis should be compared with the cost of annual cleaning with the use of blowers or flushers.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech III	Machine Operator	10.0	$36.22	$362.20
3	Maint. Tech II	Labor	10.0	$33.41	$334.10
4					
5					
6					
7					
8			LABOR SUBTOTAL		$696.30
9					
10			LABOR TOTAL		$696.30
11	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
12	6A6 - Truck 38,000 GVW		10.0	$9.45	$94.50
13	10A5		10.0	$1.61	$16.10
14	12A6 - Backhoe; Excavator; Comp.		10.0	$2.92	$29.20
15	5A32 - 3/4 Ton Extended Cab		10.0	$4.11	$41.10
16					
17					
18			EQUIPMENT SUBTOTAL		$180.90
19					
20			EQUIPMENT TOTAL		$180.90
21	**MATERIALS:**				
22					
23					
24			MATERIALS SUBTOTAL		
25					
26			MATERIALS TOTAL		
27					
28					
29				**Total Operational Rate**	**$877.20**
30				**Operation Cost Per Mile**	**$6,265.71**

REGION/MAINTENANCE AREA:

South Central Region, Area 2

CASE STUDY REFERENCE:

4.6 - 4.7

OPERATION:

Installation of Traffix matting under guard rail

AREA SUPERVISOR:

Scott Clark/Gary Wolf

APPLICATION:

Assumed as a typical installation estimate for a clean, well prepared site using an experienced crew

PURPOSE:

Mats are intended to form a solid cover and prevent all vegetative growth in a 4' strip along guardrail runs.

DESCRIPTION OF WORK PERFORMED:

Installation of matting only, assuming the site has an existing even, compacted surface and is free of any vegetation. Productivity of 1,000 ft./day is based on the manufactures estimate.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Traffix matting installed relatively easily and proformed very well, some of the matts were impacted by snow removal equipment and required some minor maintenance. This involved moving the existing impacted mats back into place. This occurred only once and took one tech less than an hour. The total Installation costs should only used as a general indication of cost as production would improve as experencie increases.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II	Installation	10.0	$33.41	$334.10
3	Maint. Tech II	Installation	10.0	$33.41	$334.10
4					
5					
6					
7					
8					
9			LABOR SUBTOTAL		$668.20
10					
11			LABOR TOTAL		$668.20
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13					
14	5E37-3 - L/T	Installation	10.0	$4.34	$43.40
15					
16					
17					
18					
19			EQUIPMENT SUBTOTAL		$43.40
20					
21			EQUIPMENT TOTAL		$43.40
22	**MATERIALS:**				
23	$6.71 per linear ft.				$6,710.00
24					
25					
26					
27					
28			MATERIALS SUBTOTAL		$6,710.00
29					
30					
31				**Installation Cost**	**$7,421.60**
32				**Average Installation Cost per Mile**	**$39,186.05**

REGION/MAINTENANCE AREA:

South Central Region, Area 2

CASE STUDY REFERENCE:

4.8 - 4.9

OPERATION:

Installation of Universal Weed Cover

AREA SUPERVISOR:

Scott Clark/Gary Wolf

APPLICATION:

Assumed as a typical installation estimate for a clean, well prepared site using an experienced crew

PURPOSE:

Mats are intended to form a solid cover and prevent all vegetative growth in a 4' strip along guardrail runs.

DESCRIPTION OF WORK PERFORMED:

Installation of matting only, assuming the site has a clean and even grade and is free of any vegetation. Productivity (1,000 ft./day) is based on the manufacturer's estimate.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Universal Weed Cover matting was a little problematic to install. It required the use of a jig and and router to custom cut around each post. Some pannels were broken or damaged during instalation. More damage occured during the first 2 winters during snow removal. Most of the pannels are now damaged and should be replaced. The matting did control much of the weeds but cracking has slowly allowed weeds and grass to grow through and on top of the matting. The total instalation costs should only used as a general indication of cost as production would improve as experencie increases.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II	Installation	10.0	$33.41	$334.10
3	Maint. Tech II	Installation	10.0	$33.41	$334.10
4					
5					
6					
7			LABOR SUBTOTAL		$668.20
8					
9			LABOR TOTAL		$668.20
10	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
11	5E37-3 - L/T	Installation	10.0	$4.34	$43.40
12					
13					
14					
15					
16					
17					
18			EQUIPMENT SUBTOTAL		$43.40
19					
20			EQUIPMENT TOTAL		$43.40
21	**MATERIALS:**				
22	$4.02 per linear ft.				$4,020.00
23					
24					
25					
26					
27			MATERIALS SUBTOTAL		$4,020.00
28					
29					
30				**Installation Cost**	**$4,731.60**
31				**Average Installation Cost per Mile**	**$24,982.85**

REGION/MAINTENANCE AREA:

Northwest Region, Area 2

CASE STUDY REFERENCE:

1.1 - 1.4 - 1.6 - 1.12

OPERATION:

Shoulder secondary highway w/ side mounted sickle bar

AREA SUPEVISOR:

Clint Terwilliger (Section Supervisor), Kate Rogers (Section Lead Tech)

APPLICATION:

Mow single pass with sickle bar mounted on small tractor. Whidbey is the only crew currently using this type of equipment.

PURPOSE:

Reduce vegetation height at the edge of pavement to preserve traffic sight distance, delineate highway edge, prevent vegetation from encroaching on traffic and encourage a healthy grass stand.

DESCRIPTION OF WORK PERFORMED:

Summer of 2006, the Whidbey Island crew mowed both SR 525 and SR 20 which totaled 87.85 shoulder miles. In Fall of the same year, the crew mowed an additional 8.67 shoulder miles of SR 525 from mile post 25.4-30.4. Total shoulder miles mowed for calendar year 2006 = 96.52 miles in 80 hours including mobilization.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Pros: Can be mounted on a smaller tractor which works well on Whidbey Island's narrow shoulders. This type of mowing leaves a nice, clean cut appearance and puts less stress on desirable vegetation. Cons: Equipment break down has been more prevalent than other types of mower and expensive to fix.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	80.0	$33.41	$2,672.80
3	Maint. Tech. II	Early Warner	80.0	$33.41	$2,672.80
4					
5					
6					
7					
8					
9			LABOR SUBTOTAL		$5,345.60
10					
11			LABOR TOTAL		$5,345.60
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	Tractor - 17A6-551		80.0	$2.12	$169.60
14	Truck w/ Arrowboard		80.0	$4.53	$362.40
15					
16					
17					
18					
19			EQUIPMENT SUBTOTAL		$532.00
20					
21			EQUIPMENT TOTAL		$532.00
22	**MATERIALS:**				
23					
24					
25			MATERIALS SUBTOTAL		
26					
27			MATERIALS TOTAL		
28					
29					
30				**Total Operational Rate**	**$5,877.60**
31				**Average Cost per Mile**	**$60.90**

REGION/MAINTENANCE AREA:

Olympic Region, Area 4

OPERATION:

Mowing shoulder w/ boom mounted rotary head

CASE STUDY REFERENCES:

1.7 - 1.20

AREA SUPERVISOR:

Ted Twigg (Oly Region, Area 4 Westside Supervisor)

APPLICATION:

This is a common method of mowing shoulders. This case has good records of cost and productivity and is therefore used as reference for other situations and areas where tractor mounted boom mowers are used.

PURPOSE:

Control vegetation growth along the edge of pavement. Since the mower is mounted on an arm these operations often work to control tree and brush growth back from the pavement edge.

DESCRIPTION OF WORK PERFORMED:

Mowing shoulder w/ boom mounted rotary head, assumes mowing the first pass only along all shoulder including behind guardrail which is appoximately 12 miles.

RESULTS, COMMENTS AND CROSS-REFERENCES:

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	16.6	$33.41	$554.61
3	Maint. Tech. II	Operator	16.6	$33.41	$554.61
4	Maint. Tech. II	Spotter	16.6	$33.41	$554.61
5					
6					
7					
8					
9			LABOR SUBTOTAL		$1,663.82
10					
11			LABOR TOTAL		$1,663.82
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	Tractor Full size		16.6	$5.26	$87.32
14	Boom mower attachment		16.6	2.05	$34.03
15	Pickup/VMS		16.6	$6.69	$111.05
16	Dump Truck		16.6	$11.95	$198.37
17	Tandem axle truck		1.0	$13.09	$13.09
18	3 axle trailer		1.0	$1.61	$1.61
19					
20					
21			EQUIPMENT SUBTOTAL		$445.47
22					
23			EQUIPMENT TOTAL		$445.47
24	**MATERIALS:**				
25					
26					
27			MATERIALS SUBTOTAL		
28					
29			MATERIALS TOTAL		
30					
31					
32				**Total Operational Daily Rate**	**$2,109.29**
33				**Average Cost per Mile**	**$175.77**

REGION/MAINTENANCE AREA:

Olympic Region, Area 3

OPERATION:

Mowing secondary highways w/ side wing flail head

CASE STUDY REFERENCE:

1.8 - 2.3

APPLICATION:

Used as a basis for estimate on all cases involving mowing w/ a side wing flail head

SUPERVISOR:

Tim Roening (Westside Supervisor), Larry Adams (Eastside Supervisor)

PURPOSE:

Reduce vegetation height at the edge of pavement to preserve traffic sight distance, delineate highway edge, prevent vegetation from encroaching on traffic and encourage a healthy grass stand.

DESCRIPTION OF WORK PERFORMED:

Activity is conducted area-wide, once a year beginning the first of July. Some areas/locations require additional mowing before or after July due to safety concerns from vegetation blocking sight distance. Daily average shoulder miles accomplished - 7.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Accomplishment is an average of total shoulder miles in the area, divided by the hours spent mowing for vegetation obstructions within the three year study period. Maintaining a grass stand at the edge of pavement contributes to soil build up over years and impeading surface drainage. Periodic removal of buildup is required in select areas to prevent stormwater ponding on the paved shoulder or point discharge and erosion.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II	Operator	10.0	$33.41	$334.10
3	Maint. Tech II	Spotter	10.0	$33.41	$334.10
4	Maint. Tech II	Spotter	10.0	$33.41	$334.10
5					
6					
7					
8			LABOR SUBTOTAL		$1,002.30
9					
10			LABOR TOTAL		$1,002.30
11	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
12	Flail attachment		10.0	$2.32	$23.20
13	Attentuator		10.0	$3.08	$30.80
14	3/4 Ton Pick Up		10.0	$4.18	$41.80
15	Message board		10.0	$1.53	$15.30
16	Tandom Axil Truck		10.0	$11.81	$118.10
17	Trailor		2.0	$0.96	$1.92
18	Small Tractor		10.0	$7.11	$71.10
19			EQUIPMENT SUBTOTAL		$302.22
20					
21			EQUIPMENT TOTAL		$302.22
22	**MATERIALS:**				
23					
24					
25			MATERIALS SUBTOTAL		
26					
27				**Typical Daily Accomplishment**	**$1,304.52**
28				**Average Cost per Mile**	**$186.36**

REGION/MAINTENANCE AREA:
Olympic Region, Area 3

CASE STUDY REFERENCE:
1.17 - 4.3

OPERATION:
Manual Trimming around Guardrail

AREA SUPERVISOR:
Larry Adams (Section Supervisor)

APPLICATION:
This estimate can be used as typical average cost for this operation throughout Western Washington

PURPOSE:
Preserve hardware and guardrail post, maintain visibiliy of hardware, allow for repair, prevent vegetation from encroaching on traffic.

DESCRIPTION OF WORK PERFORMED:
Trim vegetation around guardrail post with a hand held String Trimmer

RESULTS, COMMENTS AND CROSS-REFERENCES:
2 employees can trim 4 linear miles in an 10 hour work day, including mobilization to and from the site and moving between guardrail sections.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II	Applicator	10.0	$33.41	$334.10
3	Maint. Tech II	Applicator	10.0	$33.41	$334.10
4					
5					
6					
7					
8					
9			LABOR SUBTOTAL		$668.20
10					
11			LABOR TOTAL		$668.20
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	1/4 Ton Extended Cab 2x4		10.0	$2.30	$23.00
14					
15					
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$23.00
21					
22			EQUIPMENT TOTAL		$23.00
23	**MATERIALS:**				
24					
25					
26					
27					
28					
29			MATERIALS SUBTOTAL		
30					
31					
32				**Typical Daily Accomplishment**	**$691.20**
33				**Average Cost per Mile**	**$172.80**

Appendix B

Pavement Edge Maintenance Activity

REGION/MAINTENANCE AREA:

Southwest Region, Area 2/Olympic Region Area 1

CASE STUDY REFERENCE:

1.9 - 1.10 - 1.11 - 2.1 - 2.2 - 2.4

OPERATION:

Mowing limited access freeway

AREA SUPERVISOR:

John Davis (Oly, Area 1 Roadside Supervisor), Larry Stritmatter (SW, Area 2 Supervisor)

APPLICATION:

In a 10 hour day, 7 hours are spent actually mowing. Both areas average 2 1/2 mph, so 17.5 miles in a day is average accomplishment. SW area 2 always has an attenuator present while OL area 1 uses an attentuator about 40% to 50% of the time, but here we assume an attenuator is part of the operation. Transporting equipment to site is a relatively small part of this operation so only one hour per day is applied.

PURPOSE:

Reduce vegetation height at the edge of pavement to preserve traffic sight distance, delineated highway edge, prevent vegetation from encroaching on traffic and encourage a healthy grass stand.

DESCRIPTION OF WORK PERFORMED:

Mow one pass along the edge of pavement with either a double or triple deck flail mower, including mowing around/through interchanges.

RESULTS, COMMENTS AND CROSS-REFERENCES:

This is an average operation with variation in production depending on the location and crew.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10.0	$33.41	$334.10
3	Maint. Tech. II	Spottter	10.0	$33.41	$334.10
4					
5					
6					
7			LABOR SUBTOTAL		$668.20
8					
9			LABOR TOTAL		$668.20
10	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
11	Triple gang attachment		10.0	$3.19	$31.90
12	Large Tractor		10.0	$5.26	$52.60
13	Truck Attenuator		10.0	$6.63	$66.30
14	Tandem axle truck		1.0	$13.09	$13.09
15	3 axle trailer		1.0	$1.61	$1.61
16					
17					
18					
19			EQUIPMENT SUBTOTAL		$165.50
20					
21			EQUIPMENT TOTAL		$165.50
22	**MATERIALS:**				
23					
24					
25			MATERIALS SUBTOTAL		
26					
27			MATERIALS TOTAL		
28					
29				**Total Operational Daily Rate**	**$833.70**
30				**Average Cost per Mile**	**$47.64**

REGION/MAINTENANCE AREA:

Northwest Region, Area 3 (Everet Office)

CASE STUDY REFERENCE:

1.5

OPERATION

Mowing secondary highway w/ truck cat mower

AREA SUPERVISOR:

Cecil Rench

APPLICATION:

The area has been renting this mower from a private vendor but for the purposes of making this estimate equitable to other mowing costs studied, we have used the rental rate WSDOT's equipment management division would charge on an hourly basis.

PURPOSE:

Reduce vegetation height at the edge of pavement to preserve traffic sight distance, delineate highway edge, prevent vegetation from encroaching on traffic and encourage a healthy grass stand.

DESCRIPTION OF WORK PERFORMED:

Northwest Region area 3 mows from Monroe City limits out to the regional boundary at mile post 56.76. Approximately 100 shoulder miles are mowed twice a year with a truck cat mower, excluding areas where the cities maintain the roadsides.

RESULTS, COMMENTS AND CROSS-REFERENCES:

The area is able to mow more per hour with a truck mounted cat mower than your normal tractor mounted mower resulting in lower opertion cost.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Labor/Spotter	10.0	$33.41	$334.10
3	Maint. Tech. III	Operator	10.0	$36.22	$362.20
4					
5					
6					
7					
8					
9					
10			LABOR SUBTOTAL		$696.30
11					
12			LABOR TOTAL		$696.30
13	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
14					
15	Truck Cat Mower		10.0	$11.00	$110.00
16	Truck w/ arrow board		10.0	$4.53	$45.30
17					
18					
19					
20					
21					
22					
23			EQUIPMENT SUBTOTAL		$155.30
24					
25			EQUIPMENT TOTAL		$155.30
26	**MATERIALS:**				
27					
28					
29			MATERIALS SUBTOTAL		
30					
31				**Total Operational Rate**	**$851.60**
32				**Average Cost per Mile**	**$34.06**

REGION/MAINTENANCE AREA:

Northwest Region, Area 2

CASE STUDY REFERENCE:

1.12

OPERATION:

Managed Vegetation to the Edge of Pavement - Application of Compost Tea to Enhance Existing Vegetation

AREA SUPERVISOR:

Clint Terwilliger (Section Supervisor), Katherine Rogers (Section Lead Tech.)

PURPOSE:

Compare side by side w/ soil and plant vigor in untreated conditions. Looking for any potential benefits from application of compost tea to build soil structure. Tea applied to north bound shoulder, but not south bound.

DESCRIPTION OF WORK PERFORMED:

Compost tea (produced and applied by Creative Gardens, Inc. out of Coupeville) to naturally occuring vegetation in a 4' band along the edge of pavement on SR 525 at MP 25.65 to 26.45 (1.8 miles), four times per year thoughout the growing season. Mow shoulders once per year in June/July w/ sicle bar.

RESULTS, COMMENTS AND CROSS-REFERENCES:

Soil samples taken and analyzed in May of 2006 (prior to first tea application) and in May of 2007, 2008, and 2009. There were no significant measurable changes in soil quality either in comparison with the non-treated side by side site or in the treated site over time. Soil analysis reports are included in this appendix on the sheets following. Average cost per mile for mowing with sicle bar from cost sheet ____.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14			LABOR TOTAL		
15	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
16					
17					
18					
19					
20					
21					
22			EQUIPMENT SUBTOTAL		
23					
24			EQUIPMENT TOTAL		
25	**MATERIALS:**				
26	Compost Tea	Apply 4 times per year by	4.0	682.29	$2,729.16
27	(Materials and application)	contractor			
28			MATERIALS SUBTOTAL		
29					
30			MATERIALS TOTAL		$2,729.16
31					
32					
33					
34			**Annual Operational Rate for Tea Application**		**$2,729.16**
35			**Average Cost/Mile/Year for Tea Application**		**$1,516.20**

REGION/MAINTENANCE AREA DATA SOURCE:

Northwest Region, Area 2, varified for accuracy with other areas where this estimate is used.

CASE STUDY REFERENCE:

1.1 - 1.11

OPERATION:

Hydroseeding with slide-in unit

AREA SUPERVISOR:

Clint Teriwiggler (Section Supervisor), Kate Rogers (Section Lead Tech)

APPLICATION:

Region specific grass seed mix, combined with mulch and water and sprayed over shoulder area

PURPOSE:

Establish low growing grass to out compete undesirable vegetation.

DESCRIPTION OF WORK PERFORMED:

Hydroseeders used by WSDOT in these case studies are 100 gallon tanks which require refilling during operation through a separate water truck. The tank truck was able to return to the yard and refill as necessary during the operation.

RESULTS, COMMENTS AND CROSS-REFERENCES:

There are a number of ways to plant grass seed on the shoulder. Hydroseeding is compared with other methods of seeding in this report. It was found to be particularly effective in case study A1/W where applied over a layer of course compost.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	10.0	$33.41	$334.10
3	Maint. Tech. II	Operator	10.0	$33.41	$334.10
4	Maint. Tech. II	Spotter	10.0	$33.41	$334.10
5					
6					
7					
8					
9			LABOR SUBTOTAL		$1,002.30
10					
11			LABOR TOTAL		$1,002.30
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	Hydroseeder Skid Mounted		10.0	$0.68	$6.80
14	Water Tank 500 gal. Trailor Mounted		10.0	$1.09	$10.90
15	1/2 Ton Extended Cab 4X2		10.0	$2.48	$24.80
16	Truck Attentuator		10.0	$6.63	$66.30
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$108.80
21					
22			EQUIPMENT TOTAL		$108.80
23	**MATERIALS:**				
24	Custom Seed Mix	See individual cases in report			
25	Hydro-seed Mulch	See individual cases in report			
26					
27					
28			MATERIALS SUBTOTAL		$0.00
29					
30			MATERIALS TOTAL		$0.00
31					
32					
33				**Total Operational Daily Rate**	**$1,111.10**
34				**Average Cost per Mile**	**$555.55**

REGION/MAINTENANCE AREA:

Olympic Region, Area 1

CASE STUDY REFERENCE:

1.3

OPERATION:

Seeding shoulder with low growing grasses

AREA SUPERVISOR:

Jim Andersen (Area Roadside Supervisor), John Davis (Roadside Lead Tech)

PURPOSE:

Establish desirable (relatively low-growing) native grass mixture in a 2" thick layer of compacted shoulder rock/course compost blend.

DESCRIPTION OF WORK PERFORMED:

Grass seed was spread over a 4ft. wide band of course compost using a belly grinder spreader, and raked into the ground with a piece of chain link fence pulled behind an ATV. Seed was planted in fall of 2005.

RESULTS, COMMENTS AND CROSS-REFERENCES:

This technique is comparable to planting with hydroseeder and may be more appropriate in situations Raking over the seed is an essential step in successful planting in order to maximize potential germination. Cost per mile is higher in this case due to the short length of the site, and would be comparable to hydroseeding in situations where a longer strech of shoulder was seeded.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Lead Tech		4.0	$40.98	$163.92
3	Maint. Tech II		4.0	$33.41	$133.64
4					
5					
6					
7					
8					
9			LABOR SUBTOTAL		$297.56
10					
11			LABOR TOTAL		$297.56
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	All Terrain Vehicle		4.0	$1.58	$6.32
14	1/2 Ton Extended Cab		4.0	$2.48	$9.92
15					
16					
17					
18					
19			EQUIPMENT SUBTOTAL		$16.24
20					
21			EQUIPMENT TOTAL		$16.24
22	**MATERIALS:**				
23	Seed Mix 100 Lb./acre	0.2 acres accomplished	$1.95/lb		
24		See case study for reference			
25			MATERIALS SUBTOTAL		$0.00
26					
27			MATERIALS TOTAL		$0.00
28					
29					
30					
31				**Total Operation Cost for This Site**	**$313.80**
32				**Cost Per Acre**	**$1,569.00**
33				**Cost Per Mile**	**$784.50**

REGION/MAINTENANCE AREA:

Olympic Region, Area 4

CASE STUDY REFERENCE:

1.7 - 1.17 - 5.1

OPERATION:

Pavement Underguardrail cleaning

AREA SUPERVISOR:

Theodore Twigg

APPLICATION:

This estimate is assumed comparable for work done in any situation where debris and vegetative build up is removed from pavement under and behind guardrail

PURPOSE:

Pavement serves to prevent vegetative growth under guardrail and eliminates the need to manage vegetation in this type of situation.

DESCRIPTION OF WORK PERFORMED:

Periodically remove soil and vegetation from buildup from around guardrail post to improve surface water drainage and to preserve hardware. The Hoquiam Watershed has about 2.67 miles of guardrail and on average can clean 4000 feet per day.

RESULTS, COMMENTS AND CROSS-REFERENCES:

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech III	Machine Operator	10.0	$36.22	$362.20
3	Maint. Tech II	Dump truck	10.0	$33.41	$334.10
4	Maint. Tech II	Dump truck	10.0	$33.41	$334.10
5	Maint. Tech II	Flagger	10.0	$33.41	$334.10
6	Maint. Tech II	Flagger	10.0	$33.41	$334.10
7	Maint. Tech II	Labor	10.0	$33.41	$334.10
8	Maint. Tech II	Labor	10.0	$33.41	$334.10
9					
12			LABOR SUBTOTAL		$2,366.80
13					
14			LABOR TOTAL		$2,366.80
15	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
16	Loader, 1 cubic yard bucket		10.0	$0.55	$5.50
17	Dum Truck		10.0	$9.78	$97.80
18	Dum Trick		10.0	$9.78	$97.80
19	5A32 - 3/4 Ton Extended Cab		10.0	$6.63	$66.30
20	Tandem axle truck		1.0	$13.09	$13.09
21	3 axle trailer		1.0	$1.61	$1.61
22					
23			EQUIPMENT SUBTOTAL		$282.10
24					
25			EQUIPMENT TOTAL		$282.10
26	**MATERIALS:**				
27					
29			MATERIALS SUBTOTAL		
30					
31			MATERIALS TOTAL		
32					
33					
34				**Total Daily Operational Rate**	**$2,648.90**
34				**Total Operation Rate**	**$9,335.78**
35				**Operation Cost Per Mile**	**$3,496.55**

REGION/MAINTENANCE AREA:
Olympic Region, Area 4

CASE STUDY REFERENCE:
1.7

OPERATION:
Removal of Shoulder Build up

AREA SUPERVISOR:
Theodore Twigg

APPLICATION:
The operation in this location required trucking of removed material to a fairly remote pit site.

PURPOSE:
Rapid build up of edge material in this location requires removal to prevent water ponding on the roadway during rain events.

DESCRIPTION OF WORK PERFORMED:
Remove build up along the Hoquiam Water Shed on SR 101 between MP 94.4 - 100.3. Total number of miles without guardrail is 9.33

RESULTS, COMMENTS AND CROSS-REFERENCES:

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech. II	Operator	50.0	$33.41	$1,670.50
3	Maint. Tech. II	Operator	50.0	$33.41	$1,670.50
4	Maint. Tech. II	Spotter	50.0	$33.41	$1,670.50
5	Maint. Tech. II	Spotter	50.0	$33.41	$1,670.50
6	Maint. Tech. II	Spotter	50.0	$33.41	$1,670.50
7	Maint. Tech. II	Operator	50.0	$33.41	$1,670.50
8	Maint. Tech. II	Operator	50.0	$33.41	$1,670.50
9	Maint. Lead Tech.	Operator	50.0	$40.98	$2,049.00
10					
11			LABOR SUBTOTAL		$13,742.50
12					
13			LABOR TOTAL		$13,742.50
14	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
15	1/4 ton extended cab		50.0	$2.30	$115.00
16	Truck Attenuator		50.0	$6.63	$331.50
17	Truck w/ arrow board		50.0	$6.63	$331.50
18	Dump Truck		50.0	$9.78	$489.00
19	Dump Truck		50.0	$9.78	$489.00
20	Athey Loader		50.0	$4.45	$222.50
21	Grader 35K Articulated		50.0	$8.10	$405.00
22	Sweeper non pickup		50.0	$4.67	$233.50
23	Truck w/ arrow board		50.0	$4.53	$226.50
24					
25			EQUIPMENT SUBTOTAL		$2,843.50
26					
27			EQUIPMENT TOTAL		$2,843.50
28	**MATERIALS:**				
29					
30			MATERIALS SUBTOTAL		
31					
32			MATERIALS TOTAL		
33					
34					
35			**Total Operational Daily Rate**		**$16,586.00**
36			**Average Cost per Mile**		**$1,777.71**

REGION/MAINTENANCE AREA:

Generic estimate based on discussions with several maintenance supervisors

CASE STUDY REFERENCE:

4.1 - 4.2 - 4.3 - 4.4 - 4.6 - 4.7 - 4.8 - 4.9

OPERATION:

Annual cleaning of under guardrail mats

APPLICATION:

Assumed as a typical average cost for this type of work.

PURPOSE:

Remove annual build up of organic and inorganic debris from mats to keep them from getting buried and loosing function.

DESCRIPTION OF WORK PERFORMED:

Using a gas powered backpack blower, the maintenance technichian walks along the face of the rail and blows all accumulated debris off towards the back side of the rail. Estimate includes mobilization to, from and between sites, and contingencies. Assumes 1/2 mph average speed of operation.

RESULTS, COMMENTS AND CROSS-REFERENCES:

There may be other ways of accomplishing this work such as with brooms or with a flusher truck.

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Tech II	Machine Operator	10.0	$33.41	$334.10
3					
4					
5					
6					
7					
8					
9					
10			LABOR SUBTOTAL		$334.10
11					
12			LABOR TOTAL		$334.10
13	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
14	1/4 Extended Cab 2x4		10.0	$2.30	$23.00
15					
16					
17					
18					
19					
20			EQUIPMENT SUBTOTAL		$23.00
21					
22			EQUIPMENT TOTAL		$23.00
23	**MATERIALS:**				
24					
25					
26			MATERIALS SUBTOTAL		
27					
28			MATERIALS TOTAL		
29					
30					
31				**Total Operational Rate**	**$357.10**
32				**Operation Cost Per Mile**	**$22.32**

REGION/MAINTENANCE AREA:
Southwest Region, Area 2

CASE STUDY REFERENCE:
1.9

OPERATION:
Debris removal from under guardrail

AREA SUPERVISOR:
Larry Stritmatter

APPLICATION:
Typical zone 1 application for both limited access and secondary routes.

PURPOSE:
Removal of build up from under guardrail to prevent ponding.

DESCRIPTION OF WORK PERFORMED:
About 4000 ft. of guardrail were cleaned per day. In this case material was not removed from the site, but shifted to the back slope beyond the rail.

RESULTS, COMMENTS AND CROSS-REFERENCES:

LABOR, EQUIPMENT AND MATERIAL COSTS:

	WORKMAN AND/OR EQUIPMENT WORKING	OCCUPATION OF WORKMAN OR EQUIPMENT SIZE	Total Hours REG.	RATE	AMOUNT
1	**LABOR:**				
2	Maint. Lead Tech	Operator	10.0	$40.98	$409.80
3	Maint. Tech II	Operator	10.0	$33.41	$334.10
4	Maint. Tech II	TMA driver	10.0	$33.41	$334.10
5					
6					
7					
8					
9			LABOR SUBTOTAL		$1,078.00
10					
11			LABOR TOTAL		$1,078.00
12	**EQUIPMENT:**	**Operational Rate (If Applicable)**			
13	3/4 Ton Extended Cab 4x2		10.0	$3.63	$36.30
14	Single Axel Dump		10.0	$5.99	$59.90
15	Trailer		10.0	$0.63	$6.30
16	Small Cat Excavator		10.0	$4.47	$44.70
17	Truck Attenuator		10.0	$6.63	$66.30
18					
19					
20			EQUIPMENT SUBTOTAL		$213.50
21					
22			EQUIPMENT TOTAL		$213.50
23	**MATERIALS:**				
24					
25					
26					
27					
28					
29			MATERIALS SUBTOTAL		
30					
31					
32				**Typical Daily Accomplishment**	**$1,291.50**
33				**Average Cost per Mile**	**$1,704.78**