highway right-of-way and adjacent croplands, and
4. Lack of mowing leads to the deterioration of the roadside.

The analysis and development of warrants for each activity would be based on a comprehensive investigation.

CONCLUSIONS

Deferred maintenance is now widely practiced, sometimes without an in-depth consideration of possible consequences. Since all indicators point toward a simultaneous shrinking of the maintenance dollar and an increase in maintenance requirements that results from the aging and the wearing out of road systems, especially Interstate highways, deferred maintenance will increase in the future. This is a just cause for concern among highway engineers. If the wrong decisions are made, disastrous results could occur and bring harm to the entire highway system. It is hoped that the deferred maintenance logic suggested in this report will aid highway administrators in making as many correct decisions on deferments as possible.

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Roadside Management

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The functional requirements of a transportation facility, and its neighbors' needs, dictate roadside management activities as part of the total highway maintenance program. Aesthetic improvement is a no-cost fringe benefit. The roadside is defined as the area between the outside edge of a shoulder and the right-of-way boundary. The median strip on multilane highways and interchange areas are included. The Washington Department of Transportation manages the roadside, either constructed or natural, as a public resource. Four methods of vegetation control are discussed; special emphasis is given to chemical control. Three work zones and separate treatments for each are identified. Planning and timely accomplishments are the keys to effective long-range vegetation management. Roadside maintenance managers must be trained to recognize the roadside as a resource and learn to manage it in the most efficient and effective way. Field-level employees must be well trained before the planned program can be implemented.

The opening paragraph on roadsides in the 1976 American Association of State Highway and Transportation Officials (AASHTO) Maintenance Manual (1) describes the philosophy of the Washington Department of Transportation (WDOT) on roadside management.

> Recent changes in public attitudes have given roadside maintenance new dimensions. As much as any other part of the roadway, the roadside, when properly maintained, presents a new look that recognizes the value of a pleasing and ecologically balanced environment. Roadsides with natural growth present a challenge to the maintenance manager to combine objectives of low cost and effectiveness with elements to improve the roadside environment.

The roadside includes the area between the outside edge of the shoulder and the right-of-way boundary. The median strip and interchange areas within a multilane highway are also part of the roadside. Roadsides can be constructed or be in a natural condition that includes the land remnants adjacent to the construction zone. Constructed roadsides should be maintained to a level that provides a satisfactory contribution to the safety, convenience, appearance, and pleasure of the public and the preservation of the roadway itself. The composite areas, either constructed or natural, need to be managed as a public resource.

Each state or region obviously has its own unique ecosystems within its boundaries, and they must be appropriately controlled and stabilized if the roadside is to function as intended. Special knowledge and treatment are necessary to control the dense brush and tree growth indigenous to the coastal regions of the Pacific Northwest; the juniper, desert grass, and cactus of the Southwest; the mixed hardwoods and brambles of the Northeast; the pine forest, kudzu vines, and aquatic weeds of the Southeast; and the grasslands of the Central States. Washington State's several climatic regions foster many different ecosystems that may be similar to

those found in other parts of the nation.

In roadside maintenance, we recognize that our first obligation is to the road user. The traveling public is entitled to use a highway reasonably free from vegetation that reduces visibility, obscures signs, and otherwise introduces safety hazards. We also recognize that a roadside is a resource that can be exploited without detriment to the traveler. For example, it can become a game habitat, a songbird sanctuary, or a source of native fruit. It can also accommodate public utilities, provide trail systems, and produce commercially valuable agricultural crops and still be aesthetically pleasing.

METHODS OF VEGETATION CONTROL

In order to originate a good vegetation management program, we must have a thorough understanding of the effects of human manipulation of natural vegetation patterns. There are four basic methods for controlling vegetation patterns: biological, mechanical, cultural, and chemical.

Biological Control

Biological control consists of the introduction of insects, animals, or specific diseases into an ecosystem. These act as predators on the specific plant species to be controlled. In the Northwest, for example, the cinnabar moth has been introduced. Its larvae are successfully attacking tansy ragwort, a noxious weed. Seed fly and flea beetle species have also been used for biological control of tansy ragwort. The spread of gorse, a plant native to Scotland and imported into the coastal regions of Oregon, has been successfully reduced by the introduction of the gorse seed weevil. The gall midge and gall mite are being studied as possible agents for the control of skeleton weed. Puncturevine is controlled by the puncturevine seed weevil in some areas of the Pacific Northwest. Grazing by farm animals can also be considered as a biological control of dense grass stands. The white amur (a giant carp) and sea cow (or manatee) will control certain types of aquatic vegetation in the tropical climates.

We are not suggesting that biological control is the best method for controlling vegetation on highway roadsides; however, knowledge of existing biological control programs should be a factor during the development of a more practical integrated program for vegetation control. We do not want to introduce other controls that will jeopardize an established program.

Mechanical Control

Mechanical control involves the use of tools and equipment to eliminate a portion of a plant, an entire plant, or all of a plant community. Mowing, cutting, and cultivation are examples of mechanical control. Washington's program of mechanical control requires the use of various types of mowers, including reels, rotaries, flails, and sickle bars. We also use the Bomford and Roanoke machines for mowing heavy vegetation. Other tools used are chainsaws, airsaws, and chippers.

Cultural Control

The third method, cultural control, encourages desirable vegetation to grow, thus enabling it to crowd out the undesirable species. For example, we fertilize and lime grass stands to stimulate strong growth of desirable grasses. This action discourages tree seedlings and weed plants, which are poor competitors at best, from reestablishing themselves.

Chemical Control

A popular method for vegetation control is the use of chemicals. This fourth method is now widely practiced by most states because it is so cost effective. Chemicals, called herbicides, are developed for a variety of uses. Herbicide selection depends on the desired results, since herbicides can be very selective or totally nonselective.

ROADSIDE ZONES

Vegetation management techniques employed in the state of Washington vary. The state's roadsides are divided into three zones.

1. The first, the bare-earth zone, extends from the edge of the pavement or paved shoulder to the centerline of the roadside ditch. The bare-earth zone, on embankment sections, extends beyond the guardrail to the toe of the pavement ballast. All vegetation within this zone is eliminated by the use of nonselective herbicides. The bare earth adjacent to the traveled way ensures proper drainage from the pavement structure, discourages fire starts, and prevents concealment of roadside appurtenances.
2. The second is called the selective vegetation zone. Generally, this zone begins at the outside edge of the bare-earth zone and extends to a point at which the vegetation does not greatly affect the functional requirements of the roadway. Chemical, mechanical, and cultural methods of vegetation control are used to govern the encroachment of plants that will shade pavements and obscure sight lines on curves and to distant views.
3. The third and final zone is known as the transition zone. It extends from the selective vegetation zone to the edge of the right-of-way. As its name implies, this zone functions as a transition between the operating roadway and the lands that abut the transportation corridor. Public relations and aesthetic aspects come into play during the management of this third zone. Sculpturing tree lines, opening views, establishing buffers, and addressing local needs are principal factors to be considered in management of this zone. In areas where a highway changes from an urban to rural environment, special treatment may be necessary to blend a formal landscaped roadside with the natural. Properly controlled native vegetation can be developed as a substitute for ornamental plants wherever a formal landscaped area is desired.

EFFECTIVE ROADSIDE VEGETATION MANAGEMENT

The effectiveness of the four methods of control in any of the three zones will vary. As a general rule, one must consider each vegetation complex and treat it in a prescriptionlike fashion. This prescription may require the use of one or more of the four methods of control.

Planning and timely accomplishments are the keys to effective long-range vegetation management. An example occurred in Washington State recently. Maintenance forces cleared trees and brush from less than an acre of roadside on which vegetation control had been deferred for several years. The cost of removal was in excess of $6500. These same funds, and about one-thirtieth as many employee hours, could have paid for the treatment of more than 150 acres of roadside vegetation if the work had been planned and completed when the trees and brush were seedlings. We are now planning to plant grass as a

competitive ground cover to reduce the possibility that the trees and brush seedlings will again dominate the area.

Vegetation control is a continuing program, not just a one-shot clearing and spraying activity. A planned program is less costly in the long run than an intermittent remedial response to a crisis condition. This is why the whole process is appropriately called "vegetation management".

A person involved in planning for roadside maintenance must have a broad general knowledge of the roadside to be managed. This person should have an appreciation of botany in order to know the dynamics of plant replacement in specific vegetation groups or patterns. He or she must have the knowledge of plants' optimum growth conditions, levels of fertility, and moisture, light, and soil pH requirements. Above all, this person must know how the four methods of plant control interact with each other. An understanding of the consequences of any one or a combination of methods and knowing how to compensate for creating adverse conditions is necessary. Since chemical control is the most complicated and sensitive of all methods of vegetation control, a person must have specific knowledge of how each herbicide will work. Finally, he or she must be skilled in public relations and in ways of selling a program to the public and fellow employees.

In our opinion, chemical herbicide control is the most cost-effective and efficient method used in a vegetation management program. There are, however, a variety of cautions to consider if this type of control is planned. Chemicals must be properly used under very controlled conditions. For this reason, employees who apply the herbicide must be thoroughly trained and certified by the U.S. Environmental Protection Agency (EPA) or a state agency that conducts an EPA-recognized certification program.

WDOT has approximately 200 trained and certified herbicide applicators. Only about 75 of these people are involved in herbicide application at any one time. In Washington State, the Department of Agriculture is the EPA-recognized certifying agency and, with its assistance, we train our own employees. Training for employees to use herbicides begins with a 3- to 4-h program, followed by a written examination. Once our employees are licensed, they are given additional training every two years. This training involves 16 classroom hours. The course includes 4 h of instruction on the whys and wherefores of vegetation management, 8 h on specific spray programs, 2 h on the personal safety and legal aspects of herbicide programs, and 2 h for a final discussion by the participants, staff, and representatives from the herbicide industry.

IMPORTANCE OF GOOD PLANNING AND MAINTENANCE

We believe the benefits of a properly executed roadside management plan are many. It is particularly important to maintain clear shoulders and drainage facilities so that water does not collect and damage the shoulder or pavement edge. Any buildup or encroachment of grass or weeds on the shoulder produces a dike that will trap water on or within the roadway structure. We all know that water is the road's worst enemy.

Signs that are obscured by brush cannot perform as intended. Stop signs at intersections that are unseen by a motorist could place the driver in jeopardy. If a driver does not see a sign and runs the intersection, a severe accident may occur.

Fence lines should be kept clear of brush and vegetative growth. Fencing materials deteriorate more rapidly in a microclimate created by dense stands of vegetation. The vegetative cover may also mask a hole or break in the fence.

A properly maintained roadside can improve winter driving conditions. Snow and ice persist on pavements shaded by tall trees or encroaching brush. How often is a driver surprised on a cold, bright, sunny winter day by driving into a shady spot where the pavement is still covered with glare ice? A proper management program will minimize this possibility. In certain localities, a hedge of brush or fencelike row of trees can act as an effective snow fence. In the wrong location, however, these same growths can hamper snowplowing operations by causing snow drifts to form on the roadway and by reducing snow storage areas. Selective thinning of trees and dense brush within the zones adjacent to the bare-earth zone can provide windows, allowing sunlight to fall on the roadway. Selective thinning also creates transition zones between intensely shaded pavements and those in full sunlight.

This type of control is not only necessary from the standpoint of snow and ice control, but it also reduces driver eye stress. This unnatural stress is caused by the rapid adjustment of the eyes to different levels of light. The constant adjustment causes fatigue and short periods of impaired vision--obviously, an undesirable condition.

Roadside management program planning must take into account the effects of the program on the road's neighbors. The results of a vegetation control program must be compatible with the majority of the properties adjoining a highway right-of-way and defensible when challenged by the minority.

Washington state law and local ordinances require citizens to control noxious weeds and, as a state agency, WDOT must provide a model of compliance. Therefore, noxious-weed-control activities are an integral part of the WDOT roadside maintenance management program.

In some areas within Washington State, a grass surface is part of the roadway structure. To perform as expected, these sod surfaces must remain green and active during the summer months when fire dangers are the greatest. One way WDOT has found to maintain this type of shoulder, without irrigation or extensive mowing, is by the use of growth-regulating chemicals. These chemicals reduce grass growth and inhibit seed formation. The stunted grass plants will often survive on natural soil moisture, remaining green several weeks longer than mowed grass. Inhibition of development of the seed head also stops grass plants from maturing and from browning out. Until recently, the use of growth regulants for control in mixed grasses gave erratic results. The modern growth regulants can now be used effectively with many grass species, assuring a reasonably good control in mixed stands. Herbicides used to control broadleafed weeds can be applied in combination with these regulants, thereby eliminating the need for a second application.

CONCLUSION

The need for roadside management is not new. In July 1930, the American Association of State Highway Officials' Committee on Roadside Beautification held its first meeting. They adopted resolutions that described the need for roadside beautification and its various activities to reduce highway maintenance costs caused by erosion, slides, and snow.

Roadside maintenance is an integral part of a state's overall maintenance program, and its importance should not be overlooked. A good roadside maintenance program is cost effective, and it should not be eliminated on the grounds that impacts are for aesthetic purposes only and should not be

financed. Improved roadside appearances are actually a measure of a well-maintained roadway and represent the department's concern for the environment through which the roadway passes.

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Abridgment

Minimizing Roadway Salt Problems in Maine

KENNETH M. JACOBS AND RICHARD SCOFIELD

In an effort to reduce the salt problems in Maine that have resulted from winter maintenance operations, a three-phase program was implemented: (a) early detection of salt toxicity to vegetation, (b) reduction in the amount of salt used, and (c) dispersal of sodium ions in the soil. Aerial-photograph interpretation by using color infrared photography was developed for early detection of vegetation damage. Reduction in the amount of salt used was achieved through calibration of salt-spreading equipment and through intensive yearly instructional meetings to inform the operators of the importance of reducing salt use. These two methods allowed the Maine Department of Transportation to reduce the use of salt from 99 000 t (110 000 tons) in the winter of 1967-1968 to 57 600 t (64 000 tons) in the winter of 1978-1979. Sodium-induced stresses on vegetation were further reduced by dispersing sodium ions in the soil through the application of gypsum.

To minimize the effects of salt (NaCl) on the environment and reduce costs, the Maine Department of Transportation (MDOT) developed a method of detecting early damage to vegetation by using color infrared photographs, a program to control the amount of salt applied, and a method for alleviating the sodium toxicity of soil.

Through the use of aerial-photograph interpretations of color infrared photography, it was possible to obtain information on damage that possibly resulted from saline runoff. This method made it possible to determine whether any vegetation damage was visible for the areas adjacent to the roadway and/or salt-storage areas.

Once sodium toxicity to vegetation became evident, it was difficult to correct. However, for some situations it was found desirable to lower sodium levels of the soil in order to reduce the toxicity to vegetation. Thus, research was undertaken to determine whether some means of alleviating this problem was possible. Through this effort, gypsum ($CaSO_4$) was found beneficial in lowering sodium levels in soil.

METHODOLOGY

The first phase was to determine whether vegetation damage existed and whether the damage resulted from saline runoff. This was accomplished by the use of color infrared photography. The second phase, on which the main emphasis was placed, was to reduce the amount of salt used, thus preventing as many salt-related problems as possible. The third phase was the use of gypsum to disperse the sodium ions in the soil.

Detecting Vegetation Damage

It was determined to be feasible to use aerial-photograph interpretation techniques in order to detect possible early vegetation damage that might be salt related. The objectives were to locate and map damaged areas, analyze possible causes, and recommend corrective action.

Color and color infrared 35-mm photographs were used for the study areas; the photographs were taken at various stages of foliage development, from the budding through the coloration period. The aerial photographs were taken from oblique through near vertical angles by means of a hand-held 35-mm camera. It was possible by use of color infrared photography to distinguish healthy vegetation from the damaged vegetation within an area, especially if the area contained the same tree species. Color infrared photography provided the highest image contrast between the healthy and damaged species late in the growing season.

There are other causes for stress, such as blight, insects, plant diseases, herbicides, winter kill, and modification of groundwater level by cuts, embankments, and culverts. However, salt in combination with poor drainage conditions does cause considerable damage. Assistance from forestry personnel may be required to determine the cause of early stress.

Reducing the Salt Application

Various procedures were instituted to keep the use of salt to an absolute minimum and still maintain the desired results. The equipment was calibrated and personnel were trained so that only the desired amount of salt was used. MDOT generally tried to use 113 kg per two-lane kilometer (400 lb per two-lane mile) per application. Although a reapplication was sometimes needed, which required additional work and truck hours, there was still an overall dollar saving.

MDOT reduced the use of salt by attacking the problem in three ways:

1. Old equipment was modified so that it could be calibrated; newer equipment was purchased with calibration in mind.
2. Yearly instructional meetings were held with the operators of all equipment to reinforce MDOT's position on the importance of reducing salt use. These meetings were followed by shorter meetings at the division office level.
3. Supervisors inventoried the salt used in each of the divisions. This information was provided to the division engineers so that they could take corrective action if it appeared that salt use was