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# Row-Crop Response to Topsoil Restored on Borrow Areas

STANLEY J. HENNING AND HAROLD D. DOLLING

Borrow areas are created where soil is needed to provide fill for construction projects. The changes in row-crop productivity resulting from removal of soil for highway construction in Iowa and restoration methods, which included addition to topsoil, subsoil tillage, manure application, and 2 yr of legume growth before row cropping, were evaluated. The research was carried out from 1977 to 1981 at four locations. Corn and soybean yields from borrow areas have been below, equal to, and greater than yields from undisturbed neighboring farmland. Little or no yield increase was noted from restored topsoil at coarse-textured sites. At finer-textured sites, a marked yield increase of both crops occurred after the addition of 6 in. of topsoil but little added yield increase resulted from restoring 12 in. of topsoil. Subsoil tillage has shown little or no beneficial effect on crop yields. The manure treatment has resulted in a corn yield increase but only in the first year after application.

Borrow areas are created where soil is removed from one place to provide fill material needed at another place. The material removed from the borrow areas where this research was conducted was used for highway embankment construction. In all instances, the borrow needed for construction had to be obtained from beyond the right-of-way, and the land was to be returned to private ownership. All the borrow areas in this study were used for agriculture after the borrowing was completed.

When a site is selected to provide borrow material, there are generally two criteria to be determined: the suitability of the soil for construction and the proximity of the borrow to the area in which there is need for the soil.

For this research project, four borrow-area sites were selected. At each site, highway construction was under way. The sites were selected so that they represented a wide range of soil conditions that might be encountered in Iowa. The locations (Figure 1) of the sites are Audubon County, representing the deep loess soils of western Iowa; Buchanan County, representing coarse-textured or sandy soil; Lee County, where soil had developed on several feet of loess deposited over pre-Illinoian glacial till; and Hamilton County, where soil had developed on late Wisconsin glacial till.

Research was begun at the sites in Audubon and Buchanan Counties in 1978. The sites in Lee and Hamilton Counties were used for research starting in 1979. The experimental plan called for plots to receive 6 or 12 in. of salvaged topsoil, and these plots were to be compared with others that received no topsoil. In order to replace the desired depth of topsoil, trenches were cut in the subsoil to either 6 or 12 in. At the Hamilton County site, each

trench was 40 ft wide and 400 ft long. After the trench was filled with topsoil, the research area was finished to a 2 percent grade to provide surface drainage. In addition to topsoil replacement, the research plan called for comparisons of manure applications versus none, subsoil tillage versus none, and corn and soybean production following 2 yr of alfalfa growth versus none. Of these additional treatments, only the response to alfalfa will be included in the results presented here.

A row-crop rotation consisting of corn alternated with soybeans was followed at each borrow-area research site. The replications were divided so that corn and soybeans were grown each year. A similar division of plots was employed in which alfalfa was grown for 2 yr, and both corn and soybeans were allowed to appear in the same year on those plots.

Both corn and soybeans were grown by using conservation tillage practices. Fertilizer was applied according to soil test recommendations and herbicides were also applied according to label recommendations. Weeds germinated abundantly in the topsoil-treated plots and herbicides were required.

## RESULTS

Research data for 3 yr have been collected at each of the four borrow sites selected to be representative of major soil materials in Iowa.

### Audubon County

At the Audubon County borrow site (Figures 2 and 3), corn and soybean yields equaled or exceeded county average yields during the last 2 yr of the 3-yr study. This was done without topsoil replacement. Topsoil treatment was deleted from this site because it was too small to include such treatment. Second, topsoil was not salvaged at this site. Previous research work done by Iowa State University has shown that excellent crop yields can be achieved on loess subsoil in western Iowa if it is properly fertilized and managed. The other treatment variables were included in the research at this site, but their effects were insignificant or short-lived, as in the case of the manure application. The alfalfa treatment resulted in greatly depressed yields of row

Figure 1. Borrow-area research sites.

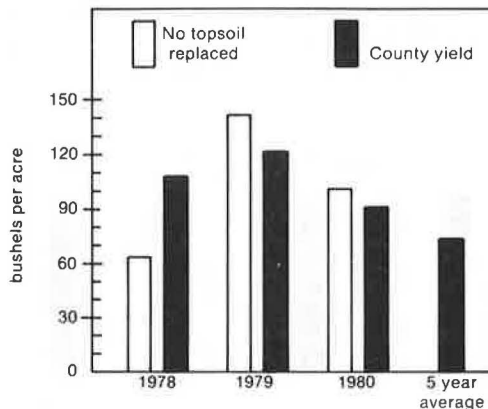
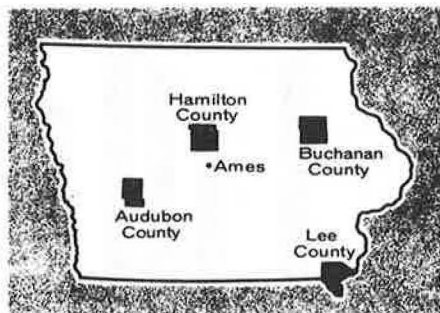


Figure 2. Corn yield response at loess borrow area in Audubon County.

crops because it removed nearly all the plant-available water the year before row crops were planted and there was not enough precipitation to grow corn and soybeans without the subsoil moisture reserve.

#### Buchanan County

Corn and soybean yields exceeded county average yields [Figures 4 and 5 (0, 6, 12 refer to depth of topsoil in inches)] in only 1 of 3 yr at the Buchan-

Figure 3. Soybean yield response at loess borrow area in Audubon County.

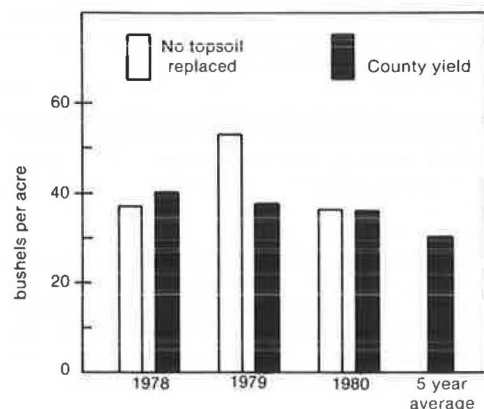


Figure 4. Corn yield response to restored topsoil at coarse-textured borrow area in Buchanan County.

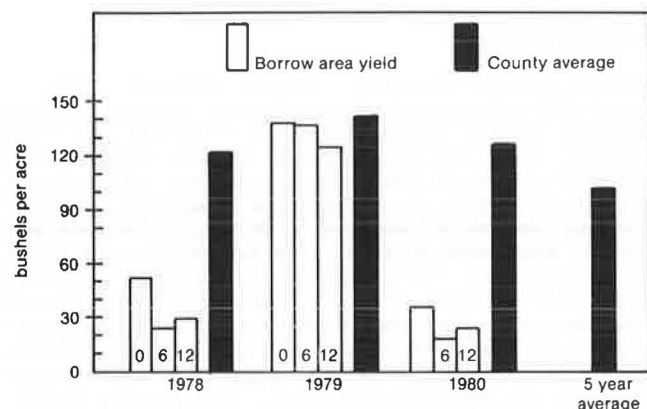
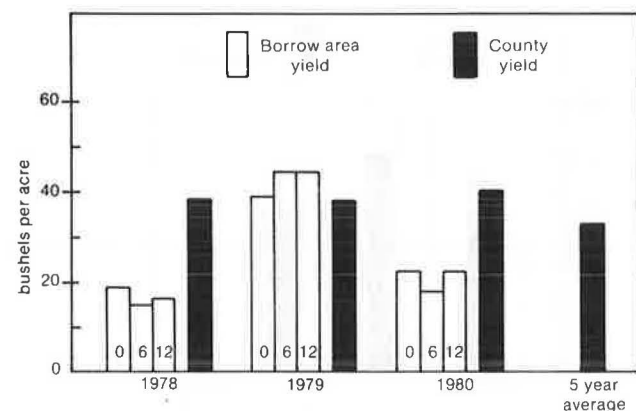


Figure 5. Soybean yield response to restored topsoil at coarse-textured borrow area in Buchanan County.



an County borrow site. The first year's yields were greatly reduced as a result of the poor seedbed, which was prepared only a few days after the site was restored by heavy earth-moving machinery. All other sites used in this research were restored in the fall before the first year of crop production. In the second year of research, 1979, excellent corn and soybean yields were measured at the borrow area and they exceeded the county averages. The results of the third and final year were disappointing because heavy rains, wind, and hail damaged the corn and soybean plots so much that the yields suffered greatly. The most important result from this research site was the lack of response by corn and soybeans to topsoil replacement.

#### Hamilton County

Corn yields (Figure 6) have equaled county average yields at the Hamilton County borrow site in 2 out of 3 yr where topsoil was restored. Only the second year's results showed no response to topsoil, and corn yields were greatly reduced compared with the county yield. Drought severely affected all plots in 1979 and there was a differential in pollination date between plots with and without topsoil. Corn grown without topsoil pollinated 2 weeks later than corn grown on topsoil. The stress from the drought was much more severe during the earlier pollination period and a greater percentage of barren plants resulted. Alfalfa treatment tended to increase corn yields slightly, but the effect was not significant.

Soybean yield (Figure 7) at the Hamilton County site was of some interest. In the first year, yields from plots receiving topsoil were twice as great as yields from plots without topsoil. The county's average soybean yield was equaled by soybeans grown on topsoil, but there was no significant difference in yield between plots receiving 6 or 12 in. of topsoil. In the second year of the study, drought greatly reduced soybean yields at the borrow site compared with the county, but unlike corn, the yields from plots receiving topsoil were twice as great as the yields from plots receiving no topsoil. In 1981 the effect of alfalfa growth on soybean yields could be evaluated and it was significant. Soybean yields where no topsoil was restored were three times as great following 2 yr of alfalfa growth. The yield increase on plots receiving topsoil was nearly 20 bushels/acre. The explanation for the yield increase from previous alfalfa growth was a less frequent occurrence of *Phytophthora* root rot infection. This disease organism probably became established when the first crop of soybeans was

Figure 6. Corn yield response to restored topsoil and alfalfa treatment at late Wisconsin glacial till borrow area in Hamilton County.

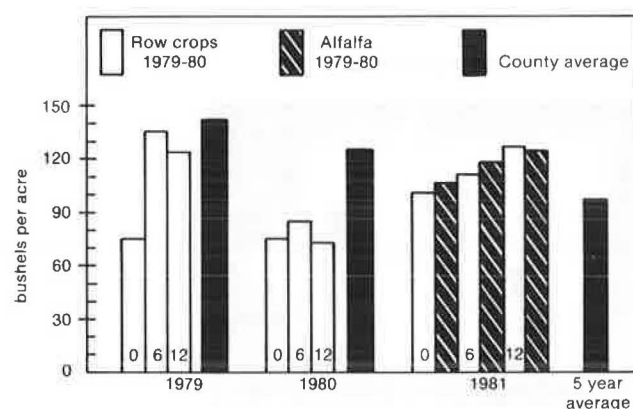


Figure 7. Soybean yield response to restored topsoil and alfalfa treatment at late Wisconsin glacial till borrow area in Hamilton County.

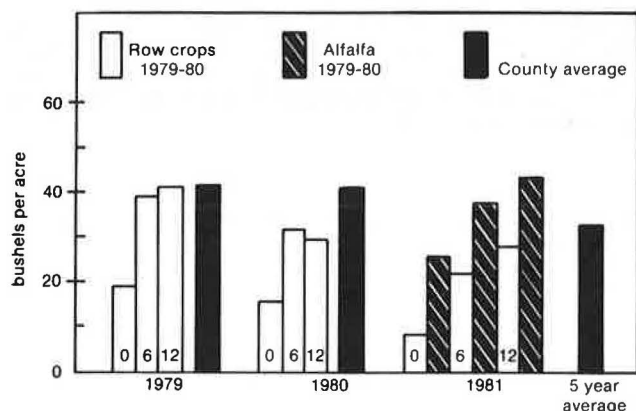
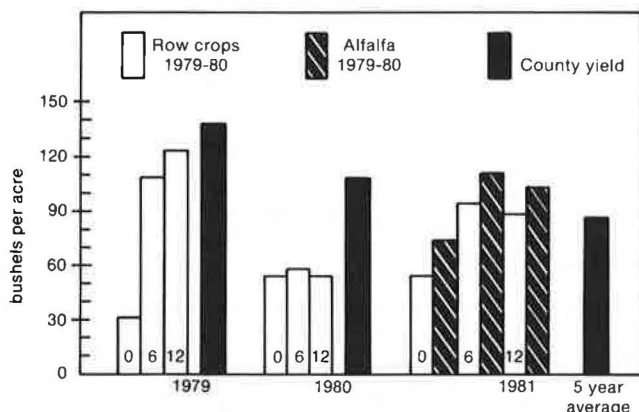


Figure 8. Corn yield response to restored topsoil and alfalfa treatment at Kansan glacial till borrow area in Lee County.



grown in 1979 and became severe in the second crop, grown in 1981. Restoration of topsoil lessened the severity of the disease somewhat but not enough to prevent a yield reduction of approximately 20 bushels/acre.

#### Lee County

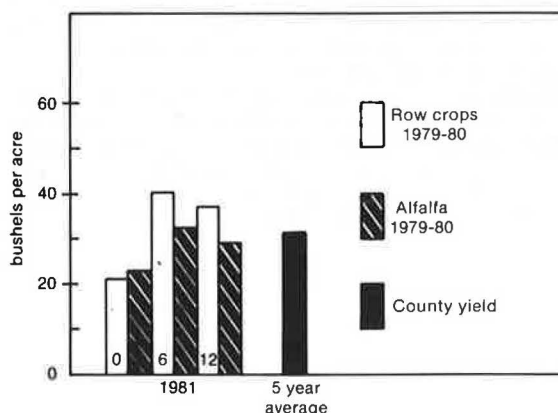
Corn yields (Figure 8) have been disappointing at the Lee County borrow site. There has been a significant response to topsoil replacement, but little difference has been found between the 6- and 12-in. depths. Corn yield appeared to increase after 2 yr of alfalfa growth, but the response was not significant.

Soybean yields (Figure 9) are reported for only the last year of the study. Topsoil replacement accounted for a large yield increase, but the difference between 6 and 12 in. of topsoil was not significant.

Two years of alfalfa growth did not improve soybean yields as it did in Hamilton County. However, there was no infection of soybeans by *Phytophthora* root rot at the Lee County site.

Injury of the crop or other management problems caused by weather probably accounted for much of the variability in yields at this site. In 1980 heavy rains in excess of 7 in. during 24 hr washed away plants, fertilizers, and herbicides. In 1981 the planting date was greatly delayed by wet weather and only the plots that had received topsoil were in a

Figure 9. Soybean yield response to restored topsoil and alfalfa treatment at Kansan glacial till borrow area in Lee County.



good condition when seed was planted. Consequently, plant density at harvest was greatly reduced on the subsoil plots because of poor seed germination and emergence of seedlings. Nevertheless, this did serve to point out that topsoil was a superior material when seedbeds were prepared.

#### CONCLUSIONS

This research showed that topsoil replacement is not always necessary at borrow areas. At coarse-textured sites that include deep loess and sandy materials, excellent yields may be obtained without topsoil replacement. Where finer-textured soil materials occur over glacial till, 1 ft of topsoil should be salvaged before borrowing and replaced when the borrow area is reclaimed. Salvaging the top foot of soil will ensure that at least 6 in. of topsoil will be restored to the borrow area because losses of up to 50 percent of the topsoil may occur through handling and shrinkage.

Alfalfa or other suitable legumes should be grown in the years immediately after a borrow area has been reclaimed. Where topsoil is not restored, this practice should be mandatory to prevent erosion. When these areas are row cropped, conservation tillage practices should be applied to continue to minimize erosion. Another benefit of conservation tillage will be a reduction in soil crusting where organic matter is low, especially when topsoil was not applied. Alfalfa treatment appears to lessen the severity of *Phytophthora* root rot infection in soybeans. This benefit from alfalfa is still being studied at the Hamilton County borrow site.

Subsoil tillage generally was not beneficial for row crops. The tillage equipment used for this research could not penetrate beyond 20 in. into the soil. This same zone is also greatly affected by freezing and thawing and wetting and drying. The advantage of subsoil tillage, in the first year after reclamation, is to loosen the soil when construction equipment compacts it, particularly when borrow is removed during wet conditions.

Manure application was beneficial to corn grown the first year after application. This is generally expected. However, excellent corn yields can be achieved without manure. Farmers with available manure will generally apply it to lands that they wish to improve, and borrow areas are no exception. Many of the benefits of manuring may be duplicated with good conservation tillage programs where crop residues are left at the surface. Manures can also provide a mulching effect, but other materials can serve equally well where mulch is needed.

Finally, some conclusions regarding productivity can be drawn from this research. Row-crop yields may be greatly reduced in the first year after a borrow area has been restored. Yields were greatly reduced if row-crop production was initiated immediately after reclamation without the benefit of a winter freezing and thawing. After a period of one to several years, yields from these areas can equal or exceed county average yields. Certain sites, such as those developed on glacial till, will require the replacement of at least 6 in. of salvaged topsoil and may equal countywide yield in a period of 2 yr.

#### ACKNOWLEDGMENT

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## Establishment and Growth of Shelterbelt Species and Grass Barriers on Windswept Wyoming Rangeland

DAVID L. STURGES

Survival and growth of six shelterbelt species and three rangeland shrubs were evaluated for 6 yr at a single windswept site adjacent to Interstate 80 in south-central Wyoming. Placing plants behind a snow fence to reduce wind speed did not influence their establishment success or their growth rate. Rodent depredation limited establishment and growth of some species more severely than the harsh climate. After 6 yr, survival of three deciduous species planted as bare-root stock ranged from 16 to 65 percent; survival of three conifers planted as container-grown stock ranged from 73 to 91 percent. A number of years would be required for a shelterbelt to become tall enough to effectively deposit drifting snow in locations where environmental conditions are similar to those of the study site. Such plantings would require extensive land areas to retain quantities of snow similar to those retained by snow-fence systems protecting I-80. Russian olive and white rabbitbrush were about 85 cm tall after six growing seasons, and Colorado blue spruce and ponderosa pine were about 65 cm tall. The ability of a stripping treatment imposed on sagebrush rangeland to increase on-site snow storage and reduce snow relocation was also evaluated. Sagebrush was fertilized with nitrogen at rates of 0, 22.4, and 44.8 kg/ha. The stripping treatment was only effective where livestock grazing was excluded and crested wheatgrass was planted on grass strips. The grass stand caused on-site snow retention to double. Winter snow accumulation behind a snow fence decreased about 20 percent because of reduced snow relocation.

Shelterbelts have been widely planted on the Great Plains to reduce wind speed and drifting snow around farms and ranches. Technical information is available about adapted species and techniques to establish a planting (1-4). Plantings have not been made on the high plains of south-central Wyoming where Interstate 80 is located. Environmental conditions are much more severe along I-80 than on the Great Plains, and snow relocation is common in winter months. At this time, about 52 km of snow fence protect 49 km of the highway between Laramie and Walcott Junction that has the most severe winter weather. The height of approximately 70 percent of these fences is 3.8 m (5). Possibly the severity of snow relocation might be reduced by shelterbelt plantings or through management of native rangeland vegetation.

The current study was conducted in cooperation with the Wyoming State Highway Department and was designed to evaluate survival and growth characteristics of six tree and shrub shelterbelt species and three rangeland shrubs planted in a location with and without snow-fence protection. In addition, the ability of grass strips to increase on-site snow

retention and reduce snow drifting on sagebrush rangeland was investigated.

#### STUDY SITES AND EXPERIMENTAL METHODS

##### Shelterbelt Study

The single shelterbelt planting site was located on the south side of I-80 about 8 km east of the town of Elk Mountain near mile 264. The site is 2300 m in elevation, and native vegetation is dominated by Wyoming big sagebrush (*Artemisia tridentata* sub. *wyomingensis*) about 10 cm tall. Soil has a sandy loam texture in the A and B horizons; the combined depth of these horizons is 30 cm. The study site was 35 by 155 m and it was enclosed by a snow fence 3.8 m tall across the downwind side and by a fence of woven wire on the remaining three sides so that livestock grazing was excluded. At study initiation, the site was plowed to kill native vegetation; 1 yr later the site was sprayed with herbicide to control weeds.

Three conifer species--Colorado blue spruce (*Picea pungens*), ponderosa pine (*Pinus ponderosa*), and white fir (*Abies concolor*)--were evaluated along with three deciduous species--Russian olive (*Elaeagnus angustifolia*), Siberian elm (*Ulmus pumila*), and Siberian peashrub (*Caragana arborescens*). Rocky mountain juniper (*Juniperus scopulorum*) is one of the most commonly planted shelterbelt species in the central Great Plains. However, at study initiation, planting stock of juniper was unavailable and this species was not evaluated.

Conifer species were grown in containers and were 10 to 15 cm tall when planted. Deciduous species were planted from bare-root stock that had been held in cold storage for about 6 weeks. Two slow-release fertilizer tablets (20 percent nitrogen, 10 percent phosphorus, 5 percent potassium) were placed in the soil adjacent to each plant as they were planted on June 27 and 28, 1975. The plants were placed in holes 61 cm in diameter in which soil was loosened to a 61-cm depth. To eliminate water stress as a survival factor, rainfall during the 1975 and 1976 growing season was supplemented by irregular waterings. Most plants that died in the first year of



study were replaced in June 1976. Study measurements for these individuals ended 1 yr later than those for individuals planted in 1975 to permit the expression of data on the basis of number of years since planting.

A planting of two common western shrubs and a sagebrush species native to Europe was also evaluated. Two sources of basin big sagebrush (*A. t.* sub. *tridentata*) collected in Colorado and Nevada, white rabbitbrush (*Chrysothamnus nauseosus* sub. *albicaulis*), and the exotic, oldman wormwood (*A. abrotanum*), were tested. The shrubs were selected because of rapid growth characteristics at a shrub garden maintained by the Intermountain Forest and Range Experiment Station in Ephraim, Utah. Big sagebrush and white rabbitbrush seedlings were dug from the garden May 11, 1976, and planted 2 to 3 days later at the shelterbelt site. Rooted and unrooted cuttings of oldman wormwood were also obtained from the shrub garden.

Each coniferous and deciduous species was planted in a single row 125 m long oriented perpendicular to prevailing winds, except for Siberian peashrub, which was planted in two rows (Figure 1). About 60 percent of each row was located downwind of a snow fence 3.2 m tall, whereas the remainder of the row was fully exposed to prevailing winds. Plant rows were between 38 and 65 m from the upwind snow fence. The location of snow fences 3.2 and 3.8 m tall with respect to the rows of plants, spacing between plants within a row, and spacing between rows are shown in Figure 1.

Rangeland shrubs were placed 0.5 m on either side of Colorado blue spruce and ponderosa pine. The

three shrub species were planted sequentially at 0.8-m intervals until 28 individuals of a species were placed on either side of the two conifers. Rooted oldman wormwood cuttings were adjacent to Colorado blue spruce, and unrooted cuttings were adjacent to ponderosa pine. Half the plants of the Colorado and Nevada selections of big sagebrush were placed in rows associated with spruce and pine. The shrub planting did not extend the full length of the conifer rows. Thus, the influence of fence protection on rangeland shrub establishment and growth could not be evaluated.

Plant survival was determined as growth commenced in the spring (June) and at the close of the growing season (early October). Differences in survival of each species between locations protected and unprotected by the upwind snow fence were tested for statistical significance by chi-square. An analysis was made for data collected 1 and 2 yr after planting, when most mortality occurred. Plant height was measured each fall beginning the third season after planting. Height differences between plants growing in locations protected and unprotected by the upwind snow fence were tested for statistical significance with a t-test based on data collected three to six growing seasons after planting. Statistical significance in this paper is based on a 0.05 level of probability.

#### Sagebrush-Grass Strips

The study involving sagebrush and grass strips was conducted on rangeland dominated by Wyoming big sagebrush and black sagebrush (*A. nova*) that was about 10 cm in height. Study sites were on the south side of I-80 at Dana Ridge (mile 246) and west of the town of Elk Mountain (mile 255). The Dana Ridge site was 2210 m in elevation, and Elk Mountain was 2220 m. Most snow is relocated by strong westerly winds following precipitation events. Treatment was based on the premise that sagebrush height could be increased by removing half of the sagebrush stand in alternate strips to provide additional soil water to residual sagebrush plants. To further stimulate height growth, the effects of fertilizing sagebrush vegetation with nitrogen at rates of 0, 22.4, and 44.8 kg/ha were also investigated. The study began in 1975 and ended after snow measurements in 1980.

Study sites were 120 m square. Strips 1-12 and 4-15 were used for the study at Elk Mountain and at Dana Ridge, respectively (Figure 2). A snow fence

Figure 1. Location of snow fences with respect to shelterbelt planting (top) and location of each row of species, spacing between plants, and spacing between rows (bottom).

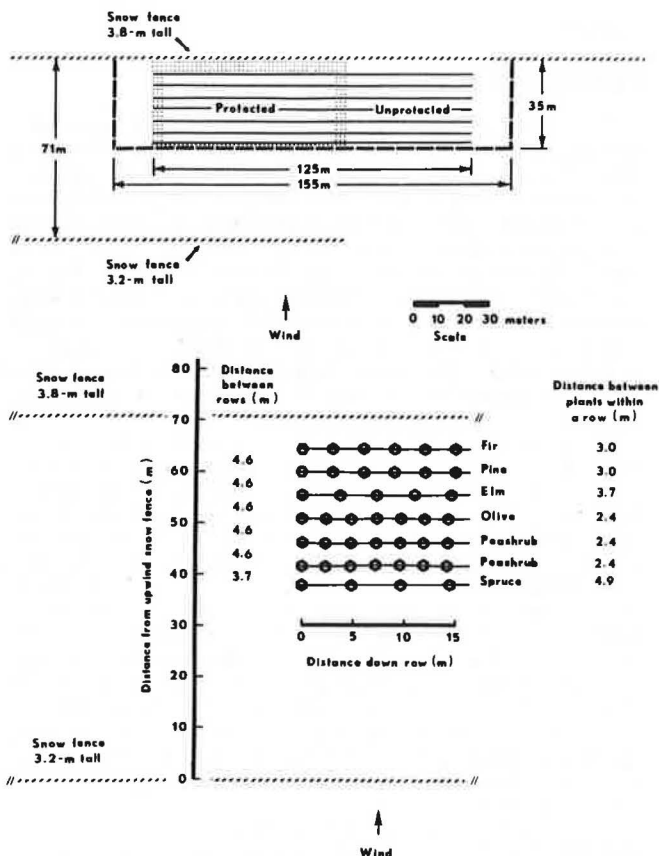
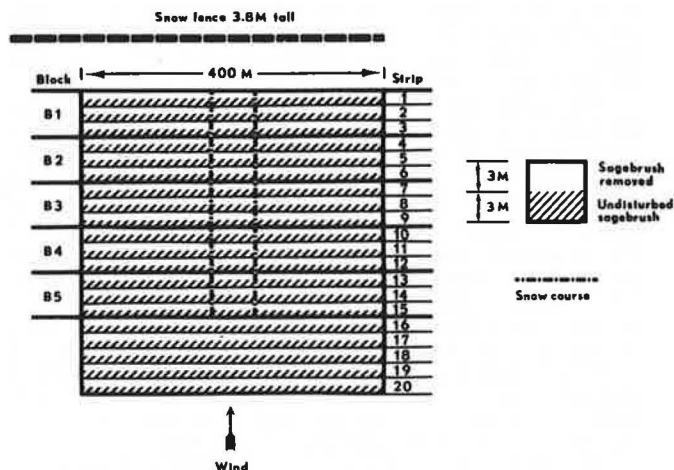


Figure 2. Sagebrush and grass stripping study sites.



3.8 m tall was located 70 m downwind from the Elk Mountain strips and 12 m downwind from the Dana Ridge strips. Sagebrush was controlled in strips 3 m wide that alternated with untreated strips of vegetation also 3 m wide. The long axis of strips was perpendicular to prevailing wind direction. The stripped-untreated sequence was repeated 20 times. Nitrogen was applied as ammonium nitrate or urea in late fall or spring; the first application was in June 1975. The Elk Mountain site was heavily grazed, but the Dana Ridge site was fenced to exclude grazing.

Sagebrush on treated strips was controlled by using a thermal procedure that heats plant tissue enough to cause death but not enough to cause ignition (6). Hot air, generated by burning propane, was used to control vegetation. Dana Ridge was treated June 9, 1975, and treatment at Elk Mountain followed 8 days later. The thermal technique was not effective against the diminutive sagebrush stand. Vegetation at Elk Mountain was retreated November 10, 1975, by mowing slightly above the soil surface. In May 1976, thermally treated strips at Dana Ridge were disked and planted with crested wheatgrass (*Agropyron cristatum*) at a seeding rate of 11.1 kg/ha.

Study measurements were confined to the 12 pairs of sagebrush and grass strips nearest the snow fence at Elk Mountain; at Dana Ridge strips 4-15 were used to avoid the upwind drift cast by the fence. The effects of stripping on sagebrush height growth and on snow accumulation were evaluated within a randomized block design; blocks were replicated four times at each study location. Each block consisted of three pairs of sagebrush and grass strips; the sagebrush strips were fertilized with nitrogen at 0, 22.4, or 44.8 kg/ha. Fertilization rates were randomly assigned within a block. An analysis of variance was performed for data collected on each snow-measurement date and for sagebrush height data collected in 1975 and 1979. Separate analyses were performed for data collected at Dana Ridge and Elk Mountain.

The height of six randomly selected sagebrush plants on the 12 measurement strips was determined at the beginning of study in 1975 and in 1979 after fertilization for five growing seasons. Sagebrush density was determined at the beginning of study by counting the number of plants rooted within six belt transects on measurement strips. Comparable sagebrush measurements were made in 1976 and in 1979 in front of snow fences at Dana Ridge and Elk Mountain on transects used to measure snow retention in undisturbed rangeland vegetation. Sagebrush in front of the Dana Ridge snow fence was twice as tall as that on the stripping study area. A second set of transects in vegetation comparable to that on the stripped area was placed 30 m south of the stripping site. Vegetation on transects outside of the stripped area was grazed at both study locations.

The influence of stripping on snow retention was evaluated by measuring the depth of snow remaining on sagebrush and grass strips on two transects located 8 m from the center of the stripping area after major drifting events (Figure 2). Snow was probed at distances of 0.3, 0.9, 1.8, and 2.7 m from the windward edge of a strip. The depth of snow retained by undisturbed sagebrush rangeland in front of the snow fence was measured at intervals of 3 m on two transects 120 m long. Average snow density on measurement dates was determined by weighing the water contained in individual cores collected with a Federal snow sampler. Five cores were usually collected on sagebrush strips, and five were collected on strips where sagebrush was controlled.

The effect of stripping on overwinter snow relo-

cation was evaluated in late March by measuring the volume of snow stored behind the snow fence. In addition, measurements of drift volume were usually taken when snow retention was measured on the stripped area. The drift behind the snow fence was cross-sectioned at three locations downwind of stripped and undisturbed rangeland vegetation. Snow density was measured on the center transect with a Federal snow sampler. The other two transects were probed at 3-m intervals with an aluminum rod to determine the depth of snow (7).

#### CLIMATIC CHARACTERISTICS

Temperature and precipitation records are available for the town of Elk Mountain at a National Oceanic and Atmospheric Administration Cooperator Station. Wind-speed data were collected by the Wyoming State Highway Department at the sagebrush stripping study site at Elk Mountain (8). Climatological data from these stations are believed indicative of general conditions at the three study locations.

Long-term annual precipitation in the town of Elk Mountain is 32.7 cm; 10.6 cm of the yearly total falls from November through March during the snow-drifting season and 11.4 cm is received between June and September in the growing season. Deciduous shelterbelt species leaf out in late May, and leaf fall is in September. Native plants begin growth earlier in the spring than shelterbelt species. July is the warmest month, with an average monthly maximum of about 27°C. Night-time temperatures are consistently above freezing only during July and August. Average annual temperature is 6°C. Wind speeds are greatest in winter, and average monthly speeds range from 6 to 9 m/sec between November and March. Thus, plants are subjected to severe desiccation stresses in winter because of the long period of subzero temperatures, frozen soils, and strong, persistent winds.

#### RESULTS

##### Shelterbelt Planting

Differences in survival between locations protected and unprotected by the upwind snow fence were not statistically significant for coniferous or deciduous species (Table 1). The heights of Siberian elm and Colorado blue spruce protected by the upwind snow fences were significantly greater than those for individuals in the unprotected location during the fifth and sixth growing season, respectively. However, browsing by white-tailed jackrabbits (*Lepus townsendii*) on the trunk and branches of elms in winter months, not fence protection, was the primary factor influencing elm height in later years of the study.

Data on the number of individuals of each species planted in 1975 and 1976 and average species survival are given in Table 2 for the 6 yr of study. Data from the two fence locations were combined because the upwind fence did not affect survival and had no consistent effect on growth rates. Colorado blue spruce had the highest survival rate of coniferous species at the end of 6 yr (91 percent), whereas Siberian elm, with a 65 percent survival rate, was the highest of the deciduous species. Only 16 percent of Russian olive plants lived as long as 2 yr, but there was no additional mortality. Russian olive died mainly during the winter, which suggests that planting stock was not sufficiently hardy for the severe winter conditions at the study site.

Rangeland shrub survival was poor (Table 2). Neither the Colorado nor the Nevada selections of

basin big sagebrush were adapted to severe winter conditions and died throughout the study. Initial survival of rooted oldman wormwood cuttings was much higher than that of unrooted cuttings because of browsing by Richardson's ground squirrels (*Spermophilus richardsonii*). Wire cages were placed around oldman wormwood plants about a month after planting, when it was discovered how palatable the herbage was to the squirrels. Survival of white rabbitbrush was also very low. At the end of the first growing season, 23 percent of the plants were alive and 20 percent were alive after 1 yr, but

there was no additional mortality. The method of handling the rabbitbrush seedlings before planting probably contributed to the high mortality rate.

Average height of species three to six growing seasons after planting is shown in Figure 3. The rate of growth for coniferous species was quite uniform. Colorado blue spruce and ponderosa pine were about 65 cm tall after six growing seasons, whereas white fir was 12 cm shorter. Russian olive was 84 cm tall at the end of the study. It had a densely branched growth form with a crown spread approximately equal to plant height. This species was damaged by herbicide drifting across the study site when roadside weeds were sprayed. Average height dropped sharply in the fifth growing season, but plants grew vigorously the following year. Siberian peashrub exhibited a very spindly growth form and would have to be closely planted to form an effective windbreak. Basin big sagebrush was taller than other species after six growing seasons but was not winter hardy. After establishment, white rabbitbrush was very hardy, and it was 81 cm tall at the close of the study.

Depredation by indigenous rodent species limited establishment and growth of some species. White-tailed jackrabbits girdled the trunks of Siberian elms in winter months and ate the twigs and smaller branches. The height of elms generally decreased after the third growing season because of rabbit damage. None of the plants regained a treelike form

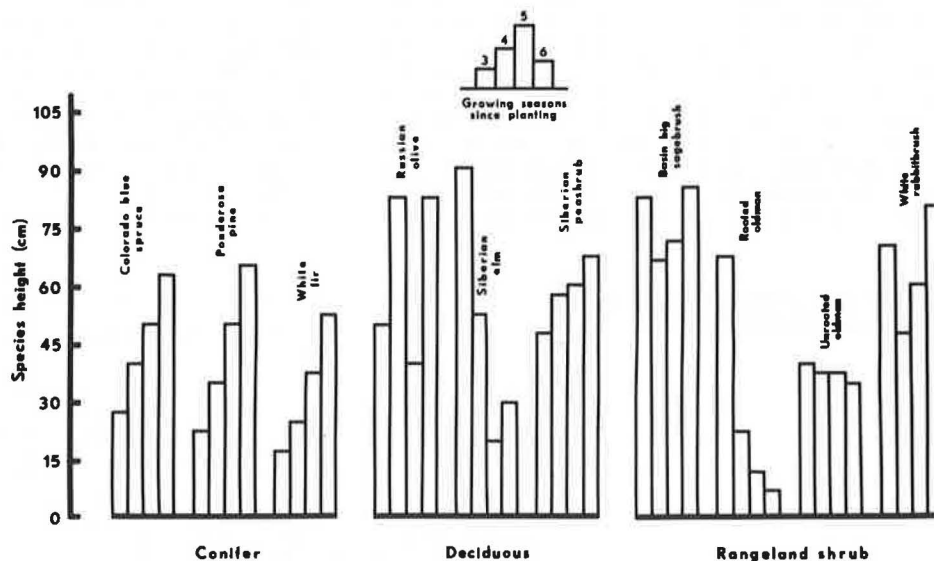
Table 1. Survival percentage for coniferous and deciduous species 1 and 2 yr after planting in locations protected and unprotected by upwind snow fence.

| Group and Species | Survival Percentage by Year After Planting |           |             |           |
|-------------------|--|-----------|-------------|-----------|
|                   | One  |           | Two         |           |
|                   | Unprotected                                | Protected | Unprotected | Protected |
| Coniferous        |  |           |             |           |
| Blue spruce       | 100  | 100       | 94          | 94        |
| Ponderosa pine    | 75   | 80        | 65          | 80        |
| White fir         | 79   | 97        | 79          | 88        |
| Deciduous         |  |           |             |           |
| Russian olive     | 54   | 30        | 29          | 8         |
| Siberian elm      | 77   | 76        | 77          | 67        |
| Siberian peashrub | 82   | 73        | 61          | 53        |

Table 2. Number of individuals planted and survival in first 6 yr after planting.

| Group and Species   | No. Planted |      |       | Survival Percentage by Year After Planting |     |       |      |      |     |
|---------------------|-------------|------|-------|--|-----|-------|------|------|-----|
|                     | 1975        | 1976 | Total | One  | Two | Three | Four | Five | Six |
| Coniferous          |             |      |       |  |     |       |      |      |     |
| Blue spruce         | 25          | 10   | 35    | 100  | 94  | 94    | 94   | 94   | 91  |
| Ponderosa pine      | 40          | 15   | 55    | 78   | 75  | 75    | 73   | 73   | 73  |
| White fir           | 41          | 10   | 51    | 90   | 84  | 84    | 84   | 84   | 82  |
| Deciduous           |             |      |       |  |     |       |      |      |     |
| Russian olive       | 51          | 10   | 61    | 39   | 16  | 16    | 16   | 16   | 16  |
| Siberian elm        | 34          | 0    | 34    | 76   | 71  | 71    | 71   | 65   | 65  |
| Siberian peashrub   | 101         | 11   | 112   | 76   | 55  | 54    | 54   | 54   | 54  |
| Rangeland shrub     |             |      |       |  |     |       |      |      |     |
| Basin big sagebrush |             |      |       |  |     |       |      |      |     |
| Colorado source     | 0           | 56   | 56    | 38   | 32  | 27    | 11   | 11   | 11  |
| Nevada source       | 0           | 56   | 56    | 38   | 38  | 30    | 25   | 25   | 25  |
| Oldman wormwood     |             |      |       |  |     |       |      |      |     |
| Rooted cutting      | 0           | 56   | 56    | 84   | 84  | 84    | 79   | 32   | 9   |
| Unrooted cutting    | 0           | 56   | 56    | 32   | 32  | 32    | 32   | 32   | 30  |
| White rabbitbrush   | 0           | 112  | 112   | 20   | 20  | 20    | 20   | 20   | 20  |

Figure 3. Average height of species.



once the trunk had been girdled. Rabbits also browsed twigs of white rabbitbrush and basin big sagebrush in winter, but plants were not irreparably harmed.

Richardson's ground squirrels devastated oldman wormwood. The squirrels were active from April until August and ate any foliage within reach. For protection, circular wire cages 46 cm long and 10 cm in diameter were placed around rooted and unrooted oldman cuttings the year of planting. The cages remained around plants that started as unrooted cuttings through the study, and the height of these plants was similar from year to year (Figure 3). The entire row containing oldman wormwood originating from rooted cuttings was fenced at the beginning of the second growing season to permit oldman to express its growth potential. Fencing was moderately successful the summer of installation. Plant height increased from 53 cm the previous summer to 69 cm. However, ground squirrels browsed oldman wormwood so severely in subsequent years that survival decreased from 84 percent in the third year after planting to 9 percent in the sixth year (Table 2). Richardson's ground squirrels also browsed white rabbitbrush during the summer but much less severely than oldman wormwood.

The configuration of snow fences at the planting site had a complicating effect on the shelterbelt study but should not have materially changed study results. The planting was not far enough downwind from the 3.2-m snow fence to be free of the drift cast by the fence in winters with high snow transport. Of course, plants were completely protected from wind when covered by snow and were in a uniform temperature regime at slightly below freezing until snowmelt started. The drift failed to reach the planting site in three winters of below-normal precipitation and completely covered the site at the end of two winters with above-average precipitation. About 2.5 m of snow covered the Colorado blue spruce row in these winters. Snow decreased in depth across the planting site and white fir was covered by 1 m of snow. Some breakage of blue spruce and Siberian peashrub did result from snow settlement.

Turbulence generated at the end of a snow fence acts to reduce snow accumulation near the end of the fence. The rows of plants extended across the boundary between the fenced and unfenced areas, so that plants near the boundary received somewhat less than full wind protection.

Wind speed is also reduced on the windward side of a snow fence, which causes an upwind drift to form. The upwind drift of a Wyoming Highway Department snow fence 3.8 m tall extends 47 m from the fence and has a maximum depth of 1.8 m when the fence is filled with snow (9). Thus, the drift in front of the snow fence could have extended across the entire planting site. However, actual snow storage by this fence was small in relation to its capacity. The upwind drift was shallow and barely reached the row of white fir that was closest to the

fence. It is assumed that the presence of the fence on the downwind side of the planting site had a negligible effect on wind speeds where shelterbelt species were located.

#### Sagebrush Height Growth

Sagebrush was 10.1 and 9.5 cm tall at the Elk Mountain and Dana Ridge study sites, respectively, at the beginning of the study (Table 3). Sagebrush density at Dana Ridge was 67,200 plants/ha and at Elk Mountain density was 41,500 plants/ha.

Sagebrush plants on Elk Mountain strips increased 2 cm in average height during study, a statistically significant increase but of no practical importance (Table 3). Fertilization had no influence on sagebrush height. The height of plants outside the stripped area did not change between 1976 and 1979. Data thus suggest that sagebrush responded to stripping but not to fertilization. Vegetation was heavily grazed by antelope, sheep, cows, and horses. Individual sagebrush plants were closely hedged and produced few or no seed heads, which indicates a low state of vigor.

The study site at Dana Ridge was not grazed by livestock, and sagebrush responded to stripping and fertilization with a significant increase in height (Table 3). Plants that received 44.8 kg/ha of nitrogen increased from 9.9 cm in 1975 to 15.2 cm in 1979, a 50 percent increase in height. Unfertilized plants increased 1 cm. Sagebrush located in front of the snow fence and 30 m south of the stripping site in undisturbed rangeland had similar heights in 1976 and 1979.

#### Snow Retention and Relocation

The stripping treatment at Elk Mountain had little effect on snow retention. Snow depths on sagebrush and mowed strips and on undisturbed rangeland were similar through the study. Snow storage behind the Elk Mountain snow fence downwind of stripped and undisturbed vegetation was similar in all of the years of the study.

The depth of snow retained on the Dana Ridge stripping site increased during the study but not in response to sagebrush growth (Table 4). Rather, crested wheatgrass became the dominant roughness agent, or factor, controlling snow retention. The grass stand was still quite open the winter after planting (1976-1977) (Figure 4), and grass strips retained significantly less snow than sagebrush strips on all measurement dates (Table 4). Crested wheatgrass grew vigorously the year after planting, and seed stalks were 40 to 50 cm in height. Snow accumulation on grass and sagebrush strips was similar beginning in the 1977-1978 winter, since each grass strip performed as a living snow fence and cast a drift across the adjacent downwind sagebrush strip. After crested wheatgrass had developed fully, snow was usually about twice as deep on the stripping study site as on undisturbed rangeland

Table 3. Sagebrush height at stripping sites and in undisturbed rangeland at beginning and end of study.

| Site         | Year | Height (cm) by Nitrogen Level (kg/ha) |                  |                  |                   | Year | Height (cm) by Location in Nonstripped Rangeland |                         |
|--------------|------|---------------------------------------|------------------|------------------|-------------------|------|--|-------------------------|
|              |      | 0                                     | 22.4             | 44.8             | Avg               |      | At Snow Fence                                    | South of Stripping Site |
| Elk Mountain | 1975 | 9.2                                   | 10.5             | 10.7             | 10.1 <sup>a</sup> | 1976 | 10.0   |                         |
|              | 1979 | 12.1                                  | 11.9             | 13.1             | 12.3              | 1979 | 9.1  |                         |
| Dana Ridge   | 1975 | 9.4                                   | 9.3 <sup>a</sup> | 9.9 <sup>a</sup> | 9.5 <sup>a</sup>  | 1976 | 19.4   | 10.3                    |
|              | 1979 | 10.6                                  | 14.1             | 15.2             | 13.3              | 1979 | 18.7   | 8.7                     |

<sup>a</sup>Significant difference between years at the 0.05 probability level. Duncan's multiple-range test was used to identify significant means for nitrogen fertilization levels.



**Table 4. Snow density and depth at Dana Ridge study site.**

| Winter    | Date               | Snow Density (cm) | Snow Depth (cm)           |      |      |                                     |                         |
|-----------|--------------------|-------------------|---------------------------|------|------|-------------------------------------|-------------------------|
|           |                    |                   | By Nitrogen Level (kg/ha) |      |      | By Location in Rangeland Vegetation |                         |
|           |                    |                   | 0                         | 22.4 | 44.8 | At Snow Fence                       | South of Stripping Site |
| 1975-1976 | 03/06              | 0.24              | 7.7                       | 6.7  | 6.4  | 20.1                                | -                       |
| 1976-1977 | 12/07 <sup>a</sup> | 0.13              | 6.2                       | 6.7  | 6.5  | 11.7                                | 6.9                     |
|           | 01/05 <sup>a</sup> | 0.12              | 9.4                       | 10.7 | 10.3 | -                                   | 10.7                    |
|           | 03/29 <sup>a</sup> | 0.15              | 5.5                       | 5.6  | 5.6  | 9.9                                 | 7.6                     |
| 1977-1978 | 11/22              | 0.19              | 15.5                      | 16.8 | 15.1 | -                                   | 6.6                     |
|           | 12/02              | 0.23              | 6.7                       | 8.5  | 7.1  | 13.2                                | 3.6                     |
|           | 01/09              | 0.17              | 7.0                       | 7.9  | 7.7  | 11.2                                | 3.6                     |
|           | 01/17              | 0.14              | 23.5                      | 25.1 | 24.5 | 26.9                                | 14.2                    |
|           | 01/28              | 0.22              | 27.4                      | 27.7 | 27.2 | 31.5                                | 16.0                    |
|           | 02/21              | 0.25              | 38.2                      | 39.5 | 39.9 | 43.7                                | 26.4                    |
| 1978-1979 | 11/13              | 0.19              | 6.0                       | 7.2  | 5.8  | 4.6                                 | 4.1                     |
|           | 11/29              | 0.17              | 13.3                      | 15.8 | 15.4 | 13.7                                | 7.1                     |
|           | 12/12              | 0.24              | 18.2                      | 20.6 | 20.4 | 18.5                                | 7.9                     |
|           | 12/18              | 0.31              | 17.3                      | 18.7 | 19.9 | 19.1                                | 4.6                     |
|           | 01/09              | 0.27              | 28.1                      | 28.8 | 29.3 | 30.0                                | 15.5                    |
|           | 02/15              | 0.31              | 29.7                      | 29.3 | 31.4 | 31.0                                | 9.9                     |

<sup>a</sup>Snow depth significantly greater on one or more fertilized sagebrush strips than on adjacent crested wheatgrass strips at a 0.05 probability level.

**Figure 4. Snow accumulation on sagebrush and crested wheatgrass strips at Dana Ridge, winter 1976-1977.**

vegetation to the south (Table 4). Accumulation of snow by undisturbed sagebrush vegetation in front of the snow fence was initially much deeper than by vegetation on the stripping study site; however, accumulation on the two areas was similar beginning in the 1977-1978 winter.

Before establishment of crested wheatgrass, the volume of snow stored by the Dana Ridge snow fence downwind of the stripped area was about 43 percent greater than that stored by the fence downwind of untreated vegetation at the end of winter (Table 5). This disparity arose because of differences in vegetation height and because of differences in fetch upwind from the two segments of the fence. A ridge delineating the upwind fetch boundary was appreciably closer to that portion of the snow fence downwind of untreated vegetation than to the fence downwind of stripped vegetation. Consequently, the ratio comparing snow accumulation behind the fence downwind of stripped and untreated vegetation was the most meaningful parameter for assessing the effects of grass strips on snow transport.

The sagebrush stripping treatment at Dana Ridge increased on-site snow retention, thus reducing snow

**Table 5. Snow storage by Dana Ridge snow fence.**

| Winter    | Date  | Snow Storage (m <sup>3</sup> /m) |                      |                            |
|-----------|-------|----------------------------------|----------------------|----------------------------|
|           |       | Stripped Location                | Undisturbed Location | Ratio Stripped/Undisturbed |
| 1974-1975 | 04/22 | 94.7                             | 65.5                 | 1.45                       |
| 1975-1976 | 10/30 | 6.3                              | 3.0                  | 2.10                       |
|           | 12/02 | 9.7                              | 4.8                  | 2.02                       |
|           | 01/22 | 60.8                             | 42.5                 | 1.43                       |
| 1976-1977 | 03/06 | 81.2                             | 55.9                 | 1.45                       |
|           | 03/24 | 78.6                             | 55.4                 | 1.42                       |
|           | 12/07 | 4.6                              | 2.6                  | 1.77                       |
| 1977-1978 | 03/24 | 28.1                             | 15.5                 | 1.81                       |
|           | 11/22 | 12.9                             | 15.0                 | 0.86                       |
|           | 01/09 | 12.4                             | 12.8                 | 0.97                       |
|           | 01/17 | 23.4                             | 25.1                 | 0.93                       |
|           | 01/28 | 53.6                             | 45.5                 | 1.18                       |
|           | 02/21 | 79.5                             | 69.8                 | 1.14                       |
| 1978-1979 | 03/20 | 94.7                             | 78.6                 | 1.20                       |
|           | 11/29 | 4.5                              | 5.6                  | 0.80                       |
|           | 12/12 | 34.5                             | 29.0                 | 1.19                       |
|           | 01/09 | 52.5                             | 44.1                 | 1.19                       |
|           | 02/15 | 123.7                            | 101.4                | 1.22                       |
| 1979-1980 | 03/16 | 126.5                            | 101.7                | 1.24                       |
|           | 03/21 | 146.6                            | 122.2                | 1.20                       |

relocation and snow storage behind the snow fence. In 1975 and 1976, the snow-accumulation ratios (stripped/untreated) were 1.45 and 1.42 (Table 5). The ratio increased to 1.81 in 1977, when snow was scoured from strips of newly planted crested wheatgrass. The ratio decreased after the grass stand thickened and was 1.19 in 1978, 1.24 in 1979, and 1.20 in 1980. Thus, the 20 strips of crested wheatgrass extending 120 m in a windward direction reduced winter snow transport approximately 20 percent.

Vegetation was most effective in reducing snow transport early in the winter before its storage capacity filled. The snow-accumulation ratio in the 1975-1976 winter (before planting crested wheatgrass) was about 2.0 during the time that snow storage downwind of untreated sagebrush vegetation was less than 15 m<sup>3</sup>/m of fence length (Table 5). The ratio was less than 1.0 at a similar stage of drift formation in later years, which suggests that the grass stand reduced snow transport about 50 percent. The snow-accumulation ratio increased to 1.2 when snow storage downwind of untreated sagebrush vegetation reached about 30 m<sup>3</sup>/m of fence length and remained at this value the rest of the winter.

## DISCUSSION AND CONCLUSIONS

Three coniferous, three deciduous, and three rangeland shrubs were tested at a single shelterbelt planting site adjacent to I-80 to determine survival and growth characteristics under harsh environmental conditions. Placement of the planting behind a snow fence to provide protection from the wind did not improve survival or height growth in the 6-yr period after planting.

Growth of all species was slow; the tallest species--Russian olive, basin big sagebrush, and white rabbitbrush--were about 85 cm in height after six growing seasons. Colorado blue spruce and ponderosa pine increased in height from 10 to 65 cm in the 6 yr of study. Siberian peashrub was about 70 cm tall but had a very spindly growth form. The canopy of Russian olive was as wide as the plant was tall. This species would form an excellent wind-break. Russian olive survival was only 16 percent after 2 yr but probably could be enhanced by obtaining planting stock from plants adapted to the harsh environment. The selections of basin big sagebrush from Colorado and Nevada were not winter hardy, and mortality continued through the study period.

Wildlife depredation can limit survival and growth of plant species as much as the severe climate when shelterbelts are situated on rangeland. White-tailed jackrabbits girdled the trunks and browsed twigs and branches of Siberian elms in winter months and also ate stems and branches of white rabbitbrush and big sagebrush. The foliage of oldman wormwood was extremely palatable to Richardson's ground squirrels, and it is not a suitable shelterbelt species where these squirrels are present. A wildlife inventory should precede establishment of shelterbelts in rangeland situations so that species attractive to wildlife will not be planted.

Because of plant breakage caused by snow settlement, shelterbelts should not be placed behind a single row of snow fence. Rather, tandem snow fences are required. The first snow fence stores incoming snow, whereas the second fence provides wind protection. The planting should not extend more than 30 times fence height downwind from the protection fence to maximize wind protection (9). The height of snow fences required to store drifting snow at a specific site can be calculated by knowing precipitation during the drifting season and snow-retention characteristics of vegetation and terrain in the zone contributing snow to the fence (10).

The drift behind snow fences represents a potential source of irrigation water for shelterbelts. Snowmelt is slow enough that surface runoff seldom extends more than a few meters from a drift unless the site is underlain by relatively impermeable soil. A planting lying at a lower elevation than the drift might be subirrigated. Melt water could also be stored to supply a trickle irrigation system.

The shelterbelt study was not designed to determine snow-accumulation characteristics of planted species. However, it is possible to estimate the size of a planting required to store the same volume of snow as stored by snow fences currently protecting I-80. For example, snow fences 3.8 m tall retain up to 316 m<sup>3</sup> of snow for each meter of length and the drift is 158 m long. A shelterbelt would have to be 632, 316, 211, and 158 m in width for each meter of length to store the same volume of snow as the 3.8-m fence, assuming plants retain snow in a uniform blanket 0.5, 1.0, 1.5, and 2.0 m deep, respectively. Clearly, in regions of high snow transport, the use of shelterbelts to control drifting snow will require substantial reservations of land. Plants are biological organisms with a finite

life span, as well as susceptible to damage from weather, disease, and insects. A strong maintenance program to keep the shelterbelt in a vigorous state of health would be essential to maximize retention of blowing snow.

The grass stripping treatment imposed on sagebrush rangeland shows that snow relocation can be reduced by increasing vegetation height to retain more of the winter's snowfall on site. Crested wheatgrass was much taller than native sagebrush and the drift cast by grass strips covered the adjacent strip of sagebrush vegetation. Thus, snow storage can be increased by only partly treating an area. The benefits of vegetation management are further enhanced in locations where appreciable melt occurs between storms because of a renewal of vegetation's storage capacity. Management of rangeland for snow retention does require that livestock grazing be closely regulated. Snow management will also benefit vegetation productivity by increasing water available for plant use.

The effects of vegetation management on snow transport can be determined for any location if winter precipitation, snow-retention characteristics of terrain, and snow-retention characteristics of treated and untreated vegetation are known (10). Retaining snow that falls on site would obviate the need for structural snow-control measures. In locations where precipitation exceeds the storage capacity of vegetation, vegetative treatments can reduce snow transport at a downwind location.

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## Vegetation of Roadside Slopes in Massachusetts

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The achievements and conclusions of some of the research carried out on the establishment of roadside vegetation and sand-dune control from 1962-1977 are reviewed. Fall and early spring seedings of basic grasses—creeping red fescue (*Festuca rubra*), Kentucky-31 tall fescue (*Festuca elatior* var. *arundinacea*), ryegrass (*Lolium* spp.), redbud (*Agrostis alba*), and Kentucky bluegrass (*Poa pratensis*)—and a legume, white clover (*Trifolium repens*), are successful for erosion control and vegetative cover on roadsides properly limed and fertilized. Hay, excelsior mat, wood cellulose, and wood-chip mulches provided excellent erosion control and assistance in seedling establishment. For more permanent cover, low-maintenance leguminous species that can be substituted for grasses are crownvetch (*Coronilla varia*), flat pea (*Lathyrus sylvestris*), and lespedeza (*Lespedeza cuneata*), but they require more precise soil preparations of liming and fertilization for establishment. Methods were found of establishing woody species quickly and inexpensively through the use of root cuttings of sweet fern (*Comptonia peregrina*), bristly locust (*Robinia fertilis*), and sumac species (*Rhus* spp.); spot seeding of other woody species and even legumes is successful and inexpensive. Proper wood-chip depth is important. Moving sand dunes on Cape Cod initiated experiments that showed that American beachgrass (*Ammophila breviligulata*) can be successfully grown by machine planting with the use of a complete fertilizer; during the second season, the area was completely covered with beachgrass. Coastal panicgrass (*Panicum amarulum*), weeping lovegrass (*Eragrostis curvula*), and tall fescue provided good cover after having been seeded with a grain drill modified to plant the seeds 2 in. deep. Woody species such as pines (*Pinus* spp.) and bayberry (*Myrica pensylvanica*) can be planted on stabilized dunes as climax vegetation.

With the rapid expansion of the U.S. Interstate system of highways, the Highway Research Board in 1932 created a joint committee to help guide the practical application of roadside development. Some years later, another committee of the same organization was formed to consider the technical and research aspects. Roadside development, then, is concerned with the many facets of a progressive highway construction program, including the historical background of an area, aesthetics, conservation of natural resources, rest areas, scenic overlooks, erosion control, landscaping, safety considerations, right-of-way ramifications, and future development (1).

From 1962 to 1977, the University of Massachusetts was involved in a roadside development research program, the purpose of which was to test new methods and materials for practical and economic stabilization on roadsides in the state.

Field studies showed the value of fescue grass species for stabilizing sandy slopes. The seeds of some of these species were incorporated into the grass slope seed mixture and the per-acre rate of seeding was cut to 100 lb from the previously used 180-lb/acre rate. The value of lime and fertilizer for permanent slope cover, especially for legumes like crownvetch, was investigated and recommendations were accepted by the Department of Public Works. As wood-chip use increased for erosion control on slopes, investigations were directed to the seeding of legumes, shrubs, forbs, and trees into mulched areas. Root cuttings for shrub establishment in mulched areas were also studied. The re-

sults of these studies with the seeding methods mentioned above showed that both methods of vegetating slopes produced rapid cover at a minimum cost.

### BACKGROUND INFORMATION

The soils in Massachusetts are classified as Brown Podzolic forest soils, which are formed under deciduous, mixed deciduous, and coniferous forests in a cool humid climate. So the challenge in Massachusetts initially was to grow grasses and legumes, which are the best species for rapid erosion control, in an ecological environment of climate and soil that is conducive to shrub and tree vegetation. Fortunately, the climate is favorable to grass growth.

Some of the problems one encounters when trying to establish grasses, legumes, and forbs along newly constructed highways in Massachusetts are listed below:

1. Shallow topsoil: More than 60 percent of Massachusetts land area is in forest cover, and in areas where tree removal is necessary during construction, a large portion of the topsoil is inevitably removed from the site along with the tree stumps.
2. Acid soils: The topsoil and subsoil are acid due to leaching losses of calcium and magnesium.
3. Sandy soils: The texture of many of the soils is sandy. Such soils have a very low organic-matter content, low percentage of water-holding capacity, and a low basic exchange capacity.
4. Low natural fertility: Most of the soil fertility is in the organic fraction of the soil. Soluble plant-food elements have been lost by leaching, and the original granitic parent material from which the soil was formed contains only low amounts of plant-food elements.
5. Rocks and boulders: Most areas in Massachusetts are glaciated and contain rocks and boulders that interfere with seed-bed preparation.

A typical analysis of an undisturbed sandy loam soil (Merrimac) showed a pH of 4.6; 0.85 percent organic carbon; a total exchange capacity of 6.1 meq of calcium, magnesium, potassium, sodium, and hydrogen; a 30 percent base saturation; and low phosphorus content. The above soil analysis illustrates the low availability of nutrients in the state, and if such soils are to be seeded to grasses and legumes, there is need for the addition of lime, nitrogen, phosphorus, and potassium.

## GRASS ESTABLISHMENT

Because many existing slopes in Massachusetts that had been seeded originally to grass were deteriorating and seriously eroded, it was necessary to investigate the adaptability of specific grass species to this environment and also to determine optimum seeding dates and rates of seeding of these grass species. It was found that better soil stabilization was obtained on slopes by using a seed mixture that included a high percentage of basic grasses--creeping red fescue (*Festuca rubra*), hard fescue (*F. ovina* var. *duriuscula*), Kentucky-31 tall fescue (*F. elatior* var. *arundinacea*), and Kentucky bluegrass (*Poa pratensis*)--and a small percentage of temporary grasses. As time went on, Kentucky bluegrass was eliminated from the seed mixture used on sandy slopes but was retained for seeding flat areas. Our final modified seed mixture contained creeping red fescue, tall fescue, domestic ryegrass (*Lolium* spp.), redtop (*Agrostis alba*), and white or ladino clover (*Trifolium repens*). This mixture was used at reduced rates (one-half the standard rate of 175 lb/acre used by the Department of Public Works), and it produced a good stand of grass and performed adequately in checking soil erosion (2).

The recommended grass mixture for median and loamed areas was 50 percent creeping red fescue, 20 percent domestic ryegrass, 5 percent redtop, and 25 percent Kentucky bluegrass.

The time-of-seeding experiment indicated that quality turf can best be established in this area in the fall and spring of the year. Weeds and drought are responsible for poor-quality sod when seedings are made at other times of the year (2).

## Mulches

In comparison studies of various mulches for grass seed germination and establishment and for erosion control on steep banks, it was found that hay, excelsior mat, and wood chips were most helpful. The hydroseeding method of establishing grass with wood cellulose as a mulch produced good results when the wood cellulose was used at a rate of 1,500 lb/acre (2). This hydroseeding method was incorporated into the standard specifications of the Massachusetts Department of Public Works.

Various chemical mulches were also compared for their effectiveness in controlling wind and water erosion during seedling establishment. It was found that DCA-70 (product of Union Carbide) mixed with water at a 1:20 rate and applied at 2 gal/yd<sup>2</sup> showed excellent sand-binding power and very good erosion control with no adverse effects on germination and seedling establishment of grasses (3).

## Lime and Fertilization

Ground limestone is readily available in Massachusetts and performs satisfactorily in correcting soil acidity because its coarse particles are effective over a period of years. Lime corrects soil acidity best when mixed into the soil, but satisfactory stands of grass were established with surface applications. Limestone rates were based on the lime-requirement test for each soil (2).

During the roadside development research studies, it was found that satisfactory turf was grown when a complete fertilizer (10-10-10) was applied to the study area at the rate of 800-1,000 lb/acre. Higher rates can be used on soils that have not been loamed. However, established grasses deteriorate if they are not limed and fertilized regularly. This deterioration is especially visible and striking on slopes consisting mostly of subsoil. On median

strips, good-quality turf that had not received lime or fertilizer for more than 5 yr continued to produce satisfactory cover, but it was showing signs of thinning and weed encroachment (2). A comprehensive program for liming and fertilizing turf was set up during the early part of the research period, but lack of maintenance funds prevented full implementation of the program by the Department of Public Works. Therefore, in the late 1960s, the focus of the research changed and emphasis was placed on establishment of trees, shrubs, and legumes rather than on grasses and legumes.

## LEGUME ESTABLISHMENT

Another major focus of the roadside development research program was the establishment of legumes. Crownvetch (*Coronilla varia*) had been grown successfully in the Northeast for several years for control of erosion and reduction of maintenance costs. Early efforts to grow this legume in Massachusetts failed, so a study was initiated to find a method of growing it here. Through research conducted in a greenhouse in which different soils were used, it was found that good establishment and growth could be obtained provided the limestone deficiencies of the soils were remedied and applications of 0-20-20 fertilizer were made at the rate of 800 lb/acre. Also helpful was the addition of 20 lb/acre of nitrogen on infertile soils to help crownvetch establish itself until the nodules have formed. Crownvetch generally has poor seedling vigor. Attempts to establish this species in combination with grass species were generally not successful, because the crownvetch was choked out by the rapid growth of the faster-growing grass (3).

Nurse crops seeded with crownvetch were very beneficial in controlling erosion on newly constructed cut-and-fill slopes. It is important that the nurse crop be seeded at a rate of no more than 20 lb/acre to prevent competition with the crownvetch. A few of the more compatible nurse crops that can be recommended as a result of our research are creeping red fescue, perennial ryegrass (*Lolium perenne*), and Kentucky-31 tall fescue (3). An extension bulletin was published that gave recommendations for seeding and planting crownvetch in Massachusetts.

Research showed that boron deficiency occurs in crownvetch when it is seeded on subsoil slopes. This deficiency appears on new growth as yellowing and slight browning of the leaf edges; the inflorescence is underdeveloped (a few clusters of florets), and later stages show few and small seed pods in contrast to those found on healthy plants. The application of 10 to 15 lb/acre of borax before seeding crownvetch, it was found, prevents boron deficiency (4).

Another perennial legume that is excellent for erosion control, requires no maintenance once established, and allows encroachment by no other types of vegetation is flat pea (*Lathyrus sylvestris*) (5). It does not have the showy pinkish-purple flowers of crownvetch but is established in the same way and does the job as well. Other leguminous species recommended for seeding in Massachusetts as a result of our research are goat's rue (*Galega officinalis*), false blue indigo (*Baptisia australis*), birdvetch (*Vicia cracca*), Cicer milkvetch (*Astragalus cicer*), bristly locust (*Robinia fertilis*), and dyer's greenweed (*Genista tinctoria*). The legumes listed above plus sericea lespedeza (*Lespedeza cuneata*) and shrub lespedeza (*Lespedeza bicolor*) were all successfully spot seeded on 4- to 5-ft centers onto slopes and flat areas covered with wood chips as mulch (3,6).



The lime requirement seed dormancy treatment, seeding rate, and time of seeding were tested on the seeds of 25 legume, shrub, and forb species for use on roadside sites. Recommendations for their establishment were provided to the Department of Public Works for incorporation into their standard specifications.

The success of the research project in finding methods of making crownvetch grow in Massachusetts is shown by full implementation of the results in all districts of the state by the maintenance division of the Department of Public Works. Both crownvetch and flat pea seed are included in the prime contract and the department itself estimated that it saved some \$300,000 yearly in erosion repair costs and an even greater amount in roadside and interchange mowing costs.

#### TREE AND SHRUB ESTABLISHMENT

At the time that the emphasis of the research was redirected from grass to shrub establishment, a no-burning law was instituted in Massachusetts. This meant that instead of trees being burned on construction sites, they could be converted to wood chips, which were beginning to be recognized as excellent mulch material for erosion control. The Department of Public Works now had the use of 100,000 yd<sup>3</sup> of chips annually and the new environmental approach of covering slopes immediately under the prime contract was a natural and practical solution to the erosion problem. Wood chips can be spread with a slope cat, a grade-all, or a crane with a large clam bucket. One company has developed a machine that blows and spreads wood chips up to 100 ft away at the rate of 1 ton/min (6).

Research has shown that wood chips do not have to be composted before they are used. They decay slowly because they are large and seldom cause the problem of nitrogen deficiency in plants, as is the case with sawdust mulch. If nitrogen deficiency does occur, a small amount of nitrogen fertilizer broadcast around each plant will correct the problem (7).

Some slopes were being covered with 4 to 5 in. of wood chips at this time by the Department of Public Works to keep erosion under control until natural invasion by shrubs and trees occurred. To speed the process of vegetating such areas, studies were initiated with spring and fall seedings of woody species under a 2-in. cover of chips. After one growing season, all species showed good seedling emergence. Two growing seasons later, the following species were well established and on their way toward stabilizing the roadbank: black locust (*Robinia pseudoacacia*), autumn olive (*Elaeagnus umbellata*), bayberry (*Myrica pensylvanica*), red cedar (*Juniperus virginiana*), fragrant sumac (*Rhus aromatica*), Arnot bristly locust, and mountain indigo bush (*Amorpha glabra*).

A critical factor in growing woody plants from seed is, of course, seed dormancy. Various treatments for overcoming dormancy were tested in the laboratory before the seeds were planted on roadsides. Some success was realized with some species, but the proper treatment for other species was not determined (6).

Another critical factor requiring attention when woody species are seeded under wood chips is the correct depth of chips to use in relation to the size of the seed being planted. Greenhouse investigation revealed that Arnot bristly locust, a relatively large-seeded species (25,000 seeds/lb), emerged easily through a 2-in. mulch. However, tatarian honeysuckle (*Lonicera tatarica*), a somewhat small-seeded species (118,000 seeds/lb), had diffi-

culty pushing through the 2-in. depth but did very well at a 1-in. depth of chips, which is too shallow a depth to prevent erosion on steep roadbanks. Small-seeded species, it was found, can be spot seeded with a Panama seeder into areas mulched with wood chips and covered with hay or other type of mulch. Spot seeding onto sites mulched with wood chips was successful for most species (6).

Establishment of vegetation by root cuttings was rapid and successful on sites mulched with wood chips for species of sweet fern (*Comptonia peregrina*), bristly locust, and several sumacs (8).

By 1977 some 500 miles of slopes had been covered with vegetation under wood chips and mowing costs were reduced by more than 25 percent.

#### CAPE COD SAND DUNES

A totally different phase of the roadside development research was a study involving control of drifting sand dunes on Cape Cod. These moving dunes were depositing some 10,000 ft<sup>3</sup> of sand annually on Route 6, a major state highway on the Cape. During stormy periods, cars traveling this route experienced severe sandblasting and pitting of windshields. Winds of 100 mph have been recorded at the Race Point Coast Guard Station in Provincetown. As a consequence, roadside areas and median strips are in constant need of repair.

What was needed was a rapid and effective means of controlling the moving dunes. It was found that American beachgrass (*Ammophila breviligulata*) planted by machine on a wide spacing with fertilizer produced a solid stand of grass cover the second year and was effective in stabilizing movement of the sand. Over a summer, 3 to 5 beachgrass culms developed 18 to 30 clumps with rhizomes more than a yard long. Our method of machine planting reduced the number of transplants required per acre from 19,360 to 9,680 (9).

Dune building and repair in blow-out areas were successful with the use of snow fences; several dunes were rebuilt in this way. Once a dune has been rebuilt, it should be planted immediately with beachgrass, or, in all likelihood, it will be blown away the following year.

Direct seeding of grasses on sand dunes was accomplished on a large scale with a grain drill. The planting units of the drill were modified to allow the seed to be planted 2 in. deep; shallow seeding is unsuccessful. Direct seedings in the spring of coastal panicgrass (*Panicum amarulum*), weeping lovegrass (*Eragrostis curvula*), Kentucky-31 tall fescue, and cereal grasses did well in stabilizing moving sand in somewhat protected areas and on the leeward side of dunes.

After a dune has been stabilized with grass, climax vegetation should be established. Excellent woody species to serve as climax vegetation are bayberry, Japanese black pine (*Pinus thunbergii*), Austrian pine (*P. nigra*), Scotch pine (*P. sylvestris*), and the native pitch pine (*P. rigida*). Plants should be mulched with hay after being set. No fertilizer is recommended, but 500 to 600 lb/acre of castor pomace (5 percent nitrogen) should be applied the second year (9).

Dune stabilization is difficult but critical if the sand dunes in Provincetown and other Cape Cod locations are to be saved. This sand dune research made a valuable contribution to the state, the Department of Public Works, and the country as a whole. In the late 1960s, the decision was made by the federal government to take over care of seashore areas and this work ceased.

## ACKNOWLEDGMENT

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## Right-of-Way Forestry

HAROLD E. YOUNG AND DAVID B. HATTON

Since World War II, the landscape-architecture approach to the maintenance of the right-of-way (ROW) of our major highway systems has been most commendable. The grade of the nonpaved portion of the ROW has been aesthetically maintained by planting grass and a combination of woody shrubs and trees. This was accomplished at relatively low cost compared with the annual new-highway construction budget. Since 1973, widespread inflation has caused a marked reduction in annual transportation department budgets, which has made a review of maintenance costs necessary. An alternative approach to ROW maintenance is forestry. This should reduce costs considerably and under normal economic conditions should actually yield a net profit. In addition, ROW forestry will produce many thousands of tons of biomass annually for energy, food and fodder, and feedstock for the chemical industries.

When the U.S. highway system was primarily gravel roads, the width of the right-of-way (ROW)--owned, easement, or both--was usually one chain or four rods, which is 66 ft. The advent of the Interstate highway system in the 1950s encouraged an expanded ROW at least 300 ft wide with a median strip of variable width. This permitted better use of existing grades to meet the standards of the new highway system. The most practical way to keep the nonpaved portion of the total ROW in place at the desired grade was by planting grass. Then interest and concern with the overall aesthetic appearance of the highway system led to the planting of perennial woody shrubs and trees to supplement natural vegetation.

It was logical to turn to the landscape architects for support in ROW maintenance, because their training and philosophy fitted into the perceived needs of ROW management as delineated above. During the 1950s and 1960s, when all of the states were participating in the construction of the Interstate

highway system, the ROW maintenance budget was small compared with the new-road construction budget. With the funds available to them, a comparatively small corps of landscape architects and supporting technicians did a magnificent job of maintaining and beautifying the Interstate highway system, for which they deserve much credit. As construction of the Interstate highway system slowed in the 1970s, the annual maintenance budget, which had not increased substantially, appeared to be a larger portion of the total annual budget. Now in the 1980s each state transportation department is being forced to reduce every component of its annual budget, including maintenance. Under these circumstances it is appropriate to raise such questions as: Why mow grass? Why plant perennial woody shrubs and trees? Are there alternative uses of the nonpaved portion of the ROW that might produce essential usable material and income? The purpose of this paper is to explore answers to these questions from the point of view of forestry.

## FORESTRY

From a strategic point of view, forestry has been defined by the Society of American Foresters as the science, the art, and the practice of managing and using for human benefit the natural resources that occur on and in association with forest land. The tactics of forestry have followed the wave theory (1) proposed for the development of human society. The first wave, the use of solid wood, began thousands of years ago similar to the evolution and development of agriculture and encompasses building, boats, furniture, and so forth. The second wave,

reconstituted products from wood, began about 1870, 200 yr after the beginning of the industrial revolution, with the manufacture of paper and continued more recently with the manufacture of particleboard and waferboard. The third wave, the molecular use of wood, is just now getting under way and parallels the computer age and the return of cottage industries. It is the use of wood by the chemical industries as an alternative for oil, coal, and gas. The molecular use of wood will alter the molecular structure of the wood and virtually eliminate the significance of species or tree size, which have been important factors. The first two waves have been able to coexist because there has been an abundance of forests and a relatively small world population. The third wave undoubtedly will compete with the first two waves because there is already keen competition for the available raw material from the world's forests due to annual shrinkage in the area of forests and a world population, now about 4 billion, that is doubling every 30 yr.

In 1959 Young and Chase of the University of Maine began a series of biomass, nutrient, and pulp-ing studies of merchantable-size trees, later extended it to smaller trees, and finally included woody shrubs. This effort led initially to the complete-tree concept and eventually to the complete-forest concept, which is now defined as follows: biological and technological investigation of all of the woody-shrub and tree species in the forest from the root tips to the leaf or needle tips inclusive with a view to intensive management of a portion of the forest for (a) solid products, (b) reconstituted products, (c) solid or liquid fuel, (d) food and fodder, and (e) feedstock for the chemical industries. Studies within the complete-forest concept have required the collaboration of many scientists and the assistance of many students. This effort has been documented (2) in more than 120 papers and bulletins. The perspective of this research during the past 23 yr has been biomass in the sense of all of the woody vegetation in the forests; it must always be borne in mind that clean air, clean water, and recreation are priority considerations in sound forest management.

The complete-forest concept is imbedded in the basic strategy of sound forest management and is compatible with all three waves. It is flexible in the tactics of forest management and represents not only the present but also the future, when the full potential of the forest is reached as chemists and engineers extend their research and industrial talents into the biologically complex environment known as the forest.

#### FOREST ENGINEERING

Axes, crosscut saws, and oxen and horses for transportation characterized forest harvesting until World War II. Since then, forest engineering encompassing all aspects of mechanization in forest management, harvesting, and transportation has truly come into its own because the new equipment has been and is being designed for forestry purposes and with regional and climatic factors in mind. There is now a tremendous range in size and variety of forest-engineering equipment and more is becoming available each year because of the market potential. The limiting factors now may be the ingenuity and imagination of the design engineers because the price of some self-propelled machines exceeds \$250,000. The tactics of forest management should be modified to utilize mechanized procedures within economically sound planning in conjunction with markets and demand trends. There is little evidence that foresters have fully taken machines in stride. At the

same time, existing and potential forest industries are not fully aware of the millions of tons of forest material that can be harvested and transported to industrial sites at relatively low cost.

A few examples will be helpful. Since World War II hundreds of mechanized tree planters have been used to plant more than 20,000,000 acres in the southeastern United States. Since 1970 more than 800 mobile chip harvesters, a type of forest biomass harvester, have been used to produce chips from the entire above-ground portion of trees. This has doubled production in hardwood stands due to the utilization of tops and small trees that otherwise would be left as waste. There are about 150 stump-root harvesters in use in the Scandinavian countries and the United States. These are more efficient than bulldozers in removing the stump-root system from the earth, and the process makes more material, about 20 percent of mature stands or as much as 40 fresh tons/acre, available for use. Currently several prototypes of multistem harvesters, designed especially for dense stands of small trees and woody shrubs, are being tested. One of the machines being tested can pick up material lying on the forest floor and can harvest the above-ground portion of stumps.

#### RIGHT-OF-WAY FORESTRY

In 1972, as a pioneering venture, Young (3) proposed woody-fiber farming on ROWs as a means of producing usable material for reconstituted products (paper, particleboard, and so forth). The following year (4) this was extended into forest management of ROWs for the entire gamut of forest products as a means of reducing ROW maintenance costs. In 1973 dramatic increases in oil prices, an awareness of the finite amount of oil in the world and of the need for alternative sources of energy, and the beginning of a long period of inflation occurred. As a result of these developments, the potential for forest management on ROWs was brought up to date in presentations before the Landscape and Environmental Design Committee of the Transportation Research Board at a meeting in Orono, Maine, in 1981 and during the Symposium on Environmental Concerns in Right-of-Way Management held in San Diego, California, in 1982.

To explore the forestry possibilities along ROWs in some detail, Hatton (5) completed a study of a 23-mile section of Interstate 95 just south of Bangor, Maine. A field inventory conducted on a sampling basis indicated that about 22 acres/mile is currently mowed and another 22 acres/mile is covered with vegetation that ranges from a combination of grass and wood shrubs to deciduous and coniferous stands in the 40- to 50-ft height class. Inasmuch as the Interstate system in Maine is approximately 300 miles, the total available for forestry purposes is about 14,000 acres.

Analysis of the inventory data led Hatton to recommend that most of the nonpaved ROW should be encouraged to produce puckerbrush (currently noncommercial species), commercial tree species, or both with a limited acreage allocated to hybrid aspen and conifer plantations. Within 20 yr it should be possible to harvest Christmas trees, fuel wood, bolt wood, and saw timber annually. Plantation ventures have a higher initial cost but should bring a greater return in less time than if existing natural vegetation was merely allowed to grow until market conditions permitted harvesting.

It is not possible or desirable to switch abruptly from the landscape-architecture to the forestry approach. It is anticipated that current mowing and spraying practices will be diminished and plantations and other forest management practices

will increase. It is anticipated that foresters and landscape architects will blend their professional backgrounds to develop ROW maintenance practices that will be aesthetically appealing, safe, and productive of many thousands of tons of woody material that can be used. Just as landscaping Interstate highways is not identical with landscaping estates, forestry on ROWs will not be identical with forest management of farm woodlots or large tracts.

We are convinced that there is little to be gained from more studies similar to those cited earlier. The next logical step is for one or more state transportation departments to try a combination of forestry and landscape architecture. For those so engaged this will be a new venture in which everyone will learn by trial and error. Results cannot be assessed after only 1 or 2 yr, for markets must be developed, contractors encouraged to participate in this new venture, and both field and safety methods determined. The potential decrease in maintenance costs as well as the potential contribution of an enormous amount of biomass to the nation's economy encourage a positive dynamic approach to developing ROW maintenance from a widely expanded point of view.

## New Program of Chemical Mowing Along Indiana Roadsides

D. JAMES MORRÉ

The objective of this research project—full-season vegetation control along Indiana roadsides through a single spray application with no need for additional herbicide application and the complete elimination of mechanical mowing—has been realized. A combination of materials is used that consists of a grass growth retardant, a primary agent to control broadleaf weeds, and various additives that potentiate the mixture. The application is made during a 1-month period in early spring by using standard commercial spray equipment. Formation of grass seedheads is prevented and by frost, in the fall, total grass height is still less than 12 in., well within the normal mowing limits specified by the state. Thus, the feasibility of chemical mowing has been demonstrated. In addition, by means of low-cost potentiating additives, the economics are such that the cost of the treatment is substantially less than current costs of three-cycle mechanical mowing with a herbicide treatment. Additional cost-reduction approaches are under investigation. The program has immediate application for difficult-to-mow areas or narrow medians, guard rails, bridge approaches, and so forth, where both cost and safety considerations favor complete elimination of conventional mechanical mowing.

Chemical mowing is the outcome of a program of research in roadside vegetation management initiated for the state of Indiana in 1966 under the auspices of the Joint Highway Research Project of the Department of Civil Engineering of Purdue University. The research was structured to include four phases (Table 1).

The first research phase, from 1966 to 1970, was largely one of problem identification in which surveys were conducted to evaluate existing vegetation management practices and to identify specific needs that, if met, would result in significant cost savings to the state.

The second phase, development of a herbicide program, was the first to be implemented. The program began in 1971 and was fully implemented in 1972–

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1973. A fall application of an environmentally safe amine formulation of 2,4-D was followed by a second application in early spring on a 3-yr rotation. This program was presented in 1975 (1) and has been very successful.

Research on phase 3, reduced mechanical mowing, was initiated in 1971 and first implemented in 1974. A report on this phase was made in 1978 (2) and remains the basis for current mechanical mowing practices in Indiana.

The project has now entered the implementation of phase 4, or chemical mowing. The objective was to develop and test materials that would eliminate or reduce the need for mechanical mowing and provide

Table 1. Indiana program of roadside vegetation management.

| Phase | Designation               | Begin | End  | Total Study Cost (\$) | First-Year Cost Savings (\$) |
|-------|---------------------------|-------|------|-----------------------|------------------------------|
| 1     | Problem identification    | 1966  | 1970 | 25,000                | None                         |
| 2     | Herbicide program         | 1971  | 1973 | 30,000                | 300,000                      |
| 3     | Reduced mechanical mowing | 1974  | 1976 | 45,000                | 1,100,000                    |
| 4     | Chemical mowing           | 1977  | 1983 | 125,000               | 2,000,000 <sup>a</sup>       |

<sup>a</sup>Projected.



efficient total vegetation management at reduced costs to the state.

#### CONCEPT OF CHEMICAL MOWING

As the name implies, chemical mowing is the use of chemicals to prevent or reduce the growth of vegetation so that the need for mechanical mowing is either eliminated or reduced. Some of the characteristics of the desired treatment are summarized below:

1. Single spray application;
2. Control of broadleaf weeds, brush, and annual grasses;
3. No seedheads formed in turf species;
4. Maximum grass height below acceptable mowing limits;
5. No mechanical mowing necessary;
6. No weakening of root system, no adverse effects to desirable species, repeated annual use possible;
7. Healthy, lawn-type appearance;
8. Low cost; and
9. Environmental safety.

Ideally, a single spray application would prevent seedhead formation and maintain maximum grass height below acceptable mowing limits. For use in Indiana, it must be effective against both fescue and bluegrass, the dominant turf species in the state, as well as give control of broadleaf weeds and brush. Annual grasses, such as giant foxtail, also must be controlled; a preemergence action that prevents the germination of annual grass seeds in the spring is one approach that offers considerable promise. The most important performance criterion, however, is to suppress seedhead formation. Most roadsides require mowing to control seedheads, especially with tall fescue. If even a few seedheads form, the roadside will appear unsightly. For whatever treatment is used, the elimination of seedheads is essential.

In addition to the above criteria, it is important that the treatment be environmentally safe. There should be no weakening of the grass root system, no injury to desirable species, and no carryover that would limit repeated annual use. A healthy, lawn-type appearance to the turf would be ideal.

Finally, the treatment must be economical. The total cost of a single spray application must not exceed the current maintenance costs. For Indiana this consists of a fall-spring spraying rotation and limited three-cycle mowing. If possible, the treatment should not only be cost-effective but also provide substantial cost savings.

#### EXPERIMENTAL APPROACH

Independently and through the assistance of the industry, a large number of commercially available and experimental materials were screened for plant-growth-regulator (PGR) activity in a series of laboratory, greenhouse, and field studies. More than 500 materials were screened. From these, about 20 materials were selected for detailed study.

Finally a series of test plots was established under roadside conditions to begin the evaluation of the materials selected from the preliminary laboratory, greenhouse, and field trials. More than 2,000 test plots were evaluated. Included in the grass evaluations were degree of growth regulation; effects on seedhead suppression, color, vigor, and root growth; and mode of action. Measurements of individual plant parts were taken at weekly or bi-weekly intervals to help understand how grass growth

was being affected. Emphasis was on evaluating how growth was regulated, for how long, and to what extent. Any material showing promise on one species was tested on other species as well. Five materials, effective on both bluegrass and fescue, were selected for detailed evaluation in combination with a primary agent to control broadleaf weeds.

The five materials were tested in large plots, primarily along the Interstate highway system, for optimum rate of application at a fixed date and for optimum date of application at a fixed rate. Date studies were initiated about once every 2 weeks from early March to mid-September in the first years and from early March to early June in the 3 succeeding years. Rate studies were conducted in early, mid-, and late spring; midsummer; and early fall in the first year and in early, mid-, and late spring in the 3 succeeding years. Several potentiating additives were also evaluated.

#### RESEARCH FINDINGS

##### Effective Three-Way Mixture of PGR plus Herbicide plus Additive

One of the mixtures tested over the past 4 yr consistently gave the desired results. This mixture consisted of three different materials: mefluidide (1 lb/acre) plus an experimental additive (1 lb/acre) plus the lithium salt of 2,4-D lithate (2.5 lb/acre). A single spray application of this combination in early spring (March 20 to May 1) gave complete suppression of both tall fescue and bluegrass seedheads, and the roadsides maintained a healthy lawn-type appearance, well within current mowing standards, for the entire growing season without the need for mechanical mowing. The inclusion of 2,4-D in the mixture gave control of broadleaf weeds and, through preemergence action, most annual grasses. There was no weakening of the root system of the turf grasses, and no visible carryover effects were observed the next season. Repeated applications of this material have been made to the same site for 5 yr with no evidence of adverse effects. All materials have been judged to be environmentally safe.

Mefluidide, the active ingredient in Embark 2S PGR, is the primary grass regulator in the mixture. Its advantages are effectiveness, safety, and no appreciable inhibition of root growth. A disadvantage is that a high rate of application is required to control seedheads in fescue. These high rates may injure native bluegrass. The material is also relatively costly.

The additive was included in the mixture as a means of decreasing cost by reducing the rate of Embark required for seedhead suppression in fescue. This material also had the additional potential of reducing phytotoxicity and improving grass color and appearance. As a single agent, the additive was ineffective.

Neither Embark nor additive alone or in combination gave significant control of broadleaf weeds, so a third component was necessary for this purpose. Amine formulations of 2,4-D or related phenoxy-type herbicides, especially at lower rates of application, sometimes showed an antagonism with low application rates of Embark. For this reason, a lithium formulation of 2,4-D was chosen initially. The lithium 2,4-D was safe, effective, nonvolatile, and sold commercially as a water-soluble powder (lithate). The main disadvantage of lithium 2,4-D over 2,4-D amine was its greater cost. Other materials, dicamba or picloram, could be substituted for 2,4-D, but cost remained the primary consideration in selecting 2,4-D.

**Table 2. Seedhead suppression and growth inhibition from Embark alone and Embark plus additive applied to tall fescue and Kentucky bluegrass.**

| Embark <sup>a</sup><br>(lb/acre) | Additive  | Seedheads per<br>Square Foot |           | Height (in.) |           |
|----------------------------------|-----------|------------------------------|-----------|--------------|-----------|
|                                  |           | Fescue                       | Bluegrass | Fescue       | Bluegrass |
| None                             | None      | 17 ± 3                       | 8 ± 4     | 31 ± 4       | 18 ± 1    |
| 0.125                            |           | 3 ± 1                        | 5 ± 2     | 22 ± 1       | 11 ± 3    |
| 0.375                            |           | 4 ± 1                        | 3 ± 0     | 23 ± 2       | 13 ± 3    |
| 0.50                             |           | 2 ± 1                        | 1 ± 1     | 17 ± 2       | 11 ± 1    |
| 0.125                            | XM-12S    | 1 ± 1                        | 4 ± 1     | 17 ± 3       | 9 ± 2     |
|                                  | 1 percent |                              |           |              |           |
| 0.375                            |           | 1 ± 0                        | 5 ± 4     | 13 ± 4       | 9 ± 2     |
| 0.50                             |           | 0 ± 0                        | 1 ± 1     | 10 ± 1       | 8 ± 3     |

Note: applied April 27; evaluated May 27; initial height of fescue = 10 in.; initial height of bluegrass = 7 in.

<sup>a</sup>As mefluidide.

The results obtained with the Embark-additive-lithium 2,4-D combination established the feasibility of chemical mowing. One chemical treatment, applied in the spring, suppressed seedhead formation in all grass species. The treated grass maintained a uniform height and a healthy lawn-type appearance. The appearance was judged to be superior to that of a mowed roadside. Results were consistent in three consecutive years at several locations within Indiana.

The major disadvantage of the Embark-additive-lithium 2,4-D mixture was its cost. Based on results obtained during the 1980 season, a modified combination was developed for application in the spring of 1981. This combination consisted of 0.50 lb/acre of mefluidide plus 0.06 lb/acre of the additive and 2.2 lb/acre of lithium 2,4-D. The estimated cost of materials was \$65/acre, the approximate break-even point compared with the cost of three-cycle mowing. This cost estimate unfortunately could not be realized in practice due to the unavailability of the additive, and the next 2 yr were spent in developing a practical alternative to the original three-part mixture.

#### New Additives to Enhance Growth-Retardant Action and Reduce Material Costs

In 1982 two new additives to replace the original one in the mixture were field tested. They were designated XM-12S and IN-IIA. Both materials were inactive when used alone but when combined with Embark reduced the effective rate required by approximately half (Table 2). The additives are inexpensive, costing no more than \$3.00 to \$6.00/acre.

Additive XM-12S was especially effective and enhanced not only the action of the Embark but also that of the 2,4-D. This effect is summarized below (species present included wild carrot, dandelion, red clover, black medic, goldenrod, aster, common plantain, buckhorn plantain, milkweed, and thistle; XM-12S is given as percent by volume of the total spray mixture; the active ingredient in Embark is mefluidide):

| Treatment                  | Amount<br>(lb/acre) | Weeds per<br>10 ft <sup>2</sup> | Control<br>(%) |
|----------------------------|---------------------|---------------------------------|----------------|
| Unsprayed<br>check         | --                  | 19                              | 0              |
| Embark + 2,4-D             | 0.5 + 2             | 15                              | 21             |
| Embark + 2,4-D<br>+ XM-12S | 0.5 + 2 + 1         | 1                               | 95             |

As a result, the XM-12S overcame any 2,4-D antagonism in the mixture with Embark. Although some reduction in the rate of 2,4-D was indicated from the

results, it may still be wise to retain the high rate of at least 2 lb/acre in order to achieve good control of resistant broadleaf weeds such as wild carrot and red clover, which, if not fully controlled, quickly become unsightly.

Additional cost savings may be possible by using a combination of the two new additives, SM-12S plus IN-IIA. Preliminary results obtained during the 1982 growing season were encouraging but additional tests will be required to complete evaluation.

Due to the effectiveness of XM-12S, it will be possible to use the amine formulation of 2,4-D in the mixture rather than the more expensive lithium formulation. This in itself will result in considerable cost savings compared with that of the original mixture.

#### RECOMMENDATIONS

The treatment schedule for implementation in Indiana in the spring of 1983 is summarized below. The cost will be competitive with three-cycle mowing plus the usual 2,4-D herbicide treatment.

1. Materials: Embark PGR containing 2 lb/gal active ingredient (mefluidide) plus 2,4-D amine from concentrate containing at least 4 lb acid equivalent/gal plus additive XM-12S.

2. Rate: Material is mixed at the rate of 0.66 gal of Embark (2 lb/gal active ingredient) plus 1.25 gal of 2,4-D amine (4 lb/gal active ingredient) plus 1 gal of XM-12S in 100 gal of water. The mixture is applied at the rate of 40 gal/acre.

3. Application schedule: Recommended for spring application only. Apply as soon as the grass begins to green up until well before emergence of seedheads from the boot (end of March to the end of April in Indiana).

It is clear from our experience that Embark alone at the rate of 0.375 lb/acre of mefluidide or less is insufficient to control seedhead formation in tall fescue in the tough spots along roadsides (medians, adjacent to pavement, adjacent to fence). The 0.375-lb/acre rate may be sufficient for interchanges but not for the bulk of the roadside. At best, only 50 to 60 percent control of seedheads in fescue has been achieved. However, by employing additives, the effectiveness of the Embark has been increased and any 2,4-D antagonism overcome.

The recommended treatment, Embark at 0.5 lb/acre of mefluidide plus 1 percent XM-12S plus 2 lb/acre of 2,4-D amine, should be applied before seedheads form between the end of March and the end of April. It can be applied to already-mowed roadsides, but this partly reduces the cost-effectiveness and defeats the purpose. Commercial spray equipment can be used in making the application. Although an error factor of 2 can be tolerated (either underdosing by half or overdosing by twice) without complete loss of effectiveness or adverse effects, uniformity of application is considered critical and spray coverage is essential.

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# Evaluation of 2.4-m Fences and One-Way Gates for Reducing Deer-Vehicle Collisions in Minnesota

JOHN LUDWIG AND TIMOTHY BREMICKER

Two segments of 2.4-m fence with one-way gates along new Interstate highways in Minnesota were evaluated for 18 months for their effectiveness in reducing deer-vehicle collisions. The fences were 4 and 5.1 km long with 9 and 10 pairs of gates, respectively. Passage by deer through the one-way gates was monitored by the use of baler counters and track beds. Sixty-nine percent of 51 passages through the gates were in a positive direction (from inside the fenced highway corridor to the outside). The reported number of deer hit was reduced 60 and 93 percent from the expected number in the two segments. A benefit-cost ratio of 3.61 appeared most appropriate for use in determining whether to erect such fences. Recommendations are made for design considerations in any future such fence construction.

Deer-vehicle collisions occur frequently when a new highway is opened through an area of high deer density or bisects an area used by deer in moving to and from feeding and resting areas. This increased mortality can result in the elimination of small populations of deer (1). Property damage, inconvenience, and personal injuries can cause severe problems for the motorists involved.

In some situations, fencing has proved effective in reducing the numbers of deer gaining access to highways (2). Whereas the standard 1.2-m highway fence is easily jumped by deer, 2.4-m fences have proved successful in reducing the numbers of deer gaining access to particularly troublesome stretches of highway (3,4). Where such deerproof fences are in short segments, however, some deer venture around the ends and get funneled into and entrapped on the highway corridor by the fence, eventually to become highway casualties. In such situations exits are needed to allow deer to leave the highway corridor. One-way gates (4) offer the greatest promise in this regard.

In 1978 the then Minnesota Department of Highways constructed two pilot segments of 2.4-m fence with one-way gates along new sections of Interstate highways. Cooperative evaluation of these projects by the Minnesota Department of Natural Resources (DNR) and Department of Transportation (MnDOT) was undertaken to determine whether such fences and gates could effectively reduce deer-vehicle collisions along future new highway segments.

## OBJECTIVES

The purposes of this project were to determine the effectiveness of a 2.4-m fence in preventing deer access to the highways and to determine the effectiveness of one-way gates in facilitating the safe exits of any deer that gained access to the fenced highway corridors.

## METHODS

The two projects were

1. A 4-km segment along I-94 near St. John's College in Stearns County, which had 9 pairs of one-way gates, and
2. A 5.1-km segment along I-90 through the Walnut Lake Wildlife Management Area in Faribault County, which had 10 pairs of one-way gates.

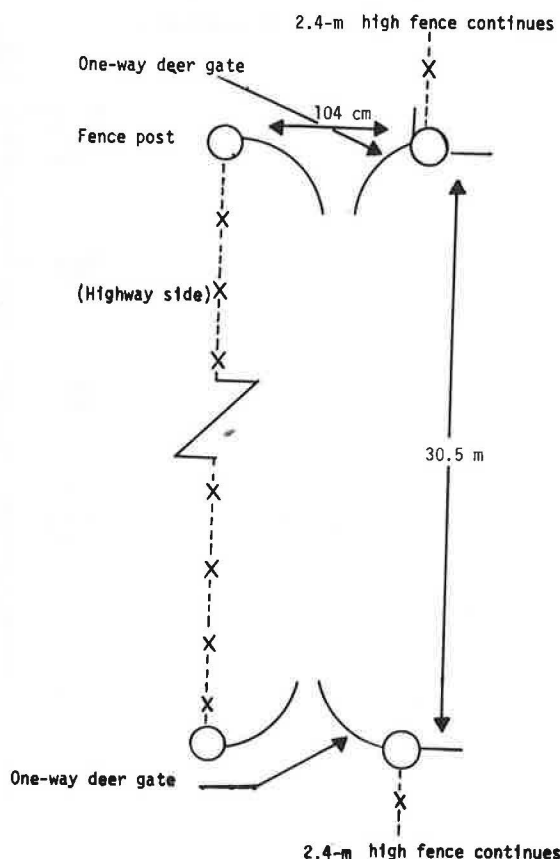
Details of one-way gate design were as outlined by Reed, Pojar, and Woodard (4) and as shown in Fig-

ures 1-3. Gates were set in pairs facing in opposite directions with 30.5-m spacing between gates of a pair. Pairs of gates were located near each end of the fence segments and along the fences near locations where deer might gain access to, or possibly try to leave, the highway corridor.

All deer known to be killed in these highway corridors and near each end were recorded. An attempt was made to gather data on the behavior of the deer hit, but drivers did not stay at the site of the collision until they could be interviewed. The number of deer killed after fence construction was compared with the number killed along corresponding segments of the adjacent older highways during the previous year.

Effectiveness of the fence and gates was monitored by the use of counters and track beds. Small baler counters (International Harvester) were installed at each gate to register positive passages through the gates. Counters were checked and reset biweekly when conditions allowed. At the same time, deer tracks indicating travel in each direction were recorded from track beds created inside and outside each gate and at each end of the fence where it connected to the standard 1.2-m fence.

Figure 1. General design of pair of one-way deer gates.



Few data were available on deer behavior and movements before fence construction. In an attempt to evaluate deer density in areas of the fence projects, winter aerial counts were made when conditions allowed. To obtain some before-fence data on deer movements for comparison, several track counts were made on the unfinished highway segments 2 days after heavy rain or snow.

## RESULTS AND DISCUSSION

Fence installation was completed, with gates and counters in place, by July 15, 1978. In the prior year, 15 deer were reported killed by cars along each old highway segment adjacent to the fenced areas. This does not take into account deer hit but not reported, either because they were not killed or

Figure 2. Top view of one-way gate and position of deer passage counter.

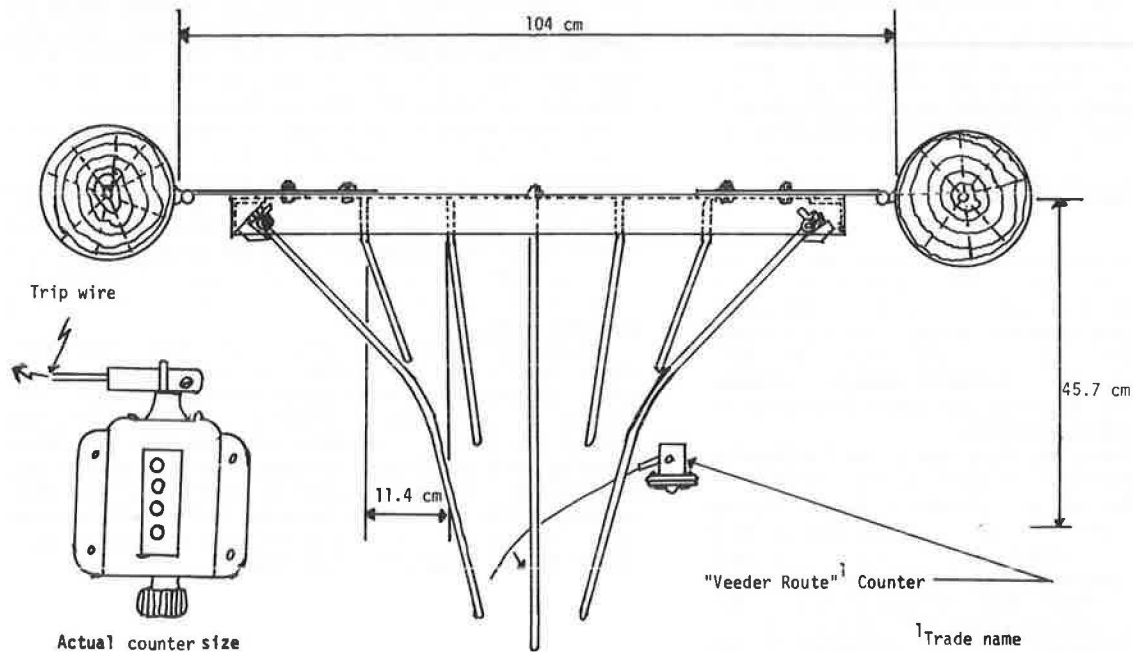
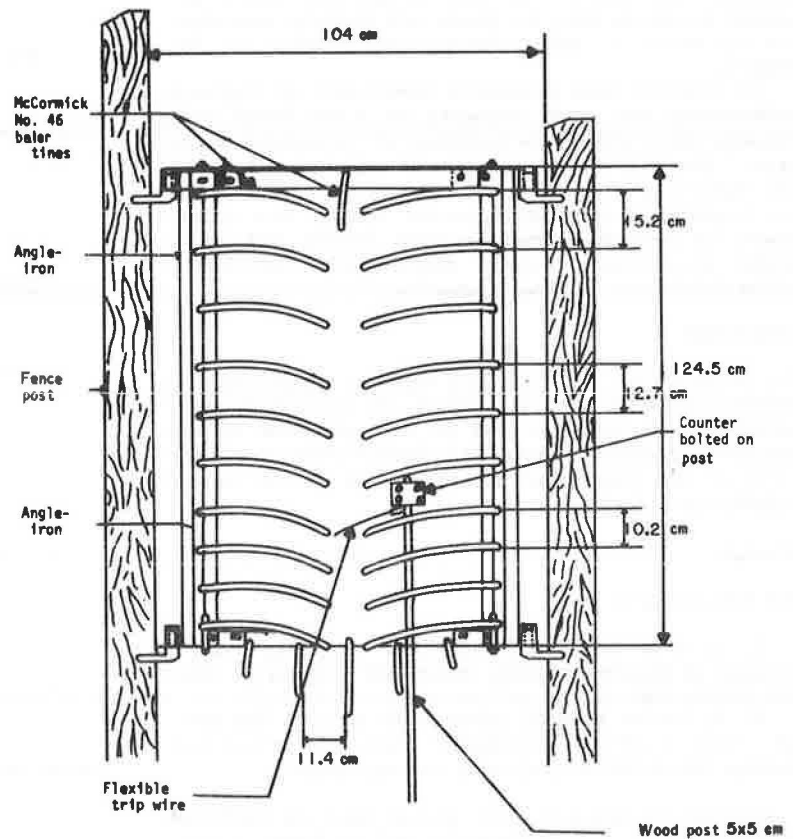


Figure 3. Front view of one-way gate with deer passage counter in position.





because they were picked up illegally. Local conservation officers estimated that unreported deer may have accounted for an additional one to two hit in the Walnut Lake area and four to five hit in the St. John's area. Track counts made before the fence construction--three at Walnut Lake and four at St. John's--revealed an average of 12.1 and 21.2 crossings per night of the to-be-fenced highway segments, respectively.

Counters and track beds at gates were monitored for 18 months. By this time several counters were nonfunctional in each area, and vandalism had become a problem at the St. John's project. Also, because of standing water, counters and track beds were never installed at six gates at Walnut Lake.

During the 18-month monitoring period, 25 positive passages (inside corridor to outside) and 8 negative passages (outside corridor to inside) by deer through the one-way gates were recorded at Walnut Lake, and 10 positive and 8 negative passages at St. John's. Reed, Pojar, and Woodard (4) reported that only 4 percent of passages through gates in Colorado was negative. The difference in this study (31 versus 4 percent) appears to be due to public interference with gates and to some damage by cattle and falling trees.

At Walnut Lake, 13 deer were reported killed by cars--12 inside the fenced corridor and 1 just outside the west end. At St. John's, 5 deer were reported killed--2 inside the fenced corridor and 3 near the ends of the fenced segment.

Aerial deer counts in areas adjacent to the St. John's fenced corridor provided estimates of 90 deer each in the winters of 1977-1978 and 1978-1979, and 130 deer in 1979-1980. For Walnut Lake, the estimates were 130 deer in 1977-1978 and 110 deer in 1978-1979. No count was made at Walnut Lake in 1979-1980 due to insufficient snow for adequate counting; nevertheless the local conservation officer believed that there were more deer in the area than in the preceding winter.

Population modeling has also indicated changing deer populations in the antlerless quota areas containing the two fences; the number of deer increased about 40 percent from 1977 to 1979 in the Faribault County area and 15 percent in the Stearns County area. From 1977 to 1979, the number of deer killed by cars increased 56 percent in Faribault County (up 34 percent in the surrounding DNR region IV) but decreased 13 percent in Stearns County (up 17 percent in the surrounding DNR region III). Most of the 13 percent decrease in total number of deer killed by cars in Stearns County can probably be attributed to deer not hit at St. John's.

It was assumed that at least 20 deer per year, or 30 deer in the 18-month monitoring period, would have been killed in each of the Interstate segments if only the standard 1.2-m fences had been present. The 12 deer reported killed inside the Walnut Lake fence corridor and the 2 in St. John's thus represent a theoretical 60 and 93 percent reduction in deer-vehicle collisions, respectively (mean = 76.5 percent). This compares with an average 78.5 percent reduction for six such fences tested in Colorado (5).

Reasons for the difference in effectiveness of the two fences can be related to design differences. Two problems were apparent at Walnut Lake: (a) the segment of 2.4-m fence was too short and allowed the deer to enter the fenced corridor easily around the ends without having to deviate far from their normal travel routes, and (b) the fence was located in the lowest part of the road ditch and much of it stood in up to a meter of water most of the time. Thus, six (30 percent) of the gates at Walnut Lake never were usable by the deer, and be-

cause of the water in the ditch, deer tended to walk on the road shoulder when they crossed the fenced corridor.

We conclude that the fence at St. John's was effective in keeping deer off the highway. At Walnut Lake the inadequate length of the fence did not deny deer access to the highway, although it would have been difficult to lengthen the fence because there was an interchange at the west end where five of the deer were hit (four just inside the fenced corridor and one just outside). The location of the fence in the ditch precluded access to, or use of, a number of the gates once deer were in the highway corridor.

Cost-effectiveness of the fences and gates was evaluated by calculating benefit/cost ratios. The difficulty in such an exercise is in identifying and quantifying all benefits and costs (6). The major benefits include savings in vehicle repair costs and the value of deer not killed. We assumed that each collision prevented saved \$503 in vehicle repair costs in 1978 (7). This value was multiplied by the estimated 18 fewer collisions annually at St. John's and 8 at Walnut Lake. The values were then adjusted for inflation by compounding annually (8) to estimate the average damage prevented in each of the next 20 yr. (The assumed rate of inflation was 9.028 percent, which is the average annual change in the price of motor vehicle parts from 1967 to 1981, inclusive, according to the producer prices and price indexes of the Bureau of Labor Statistics, U.S. Department of Labor.

Again following Lundgren (8), the inflated future benefits were individually discounted from year 1 to 1978. Discounting is used to reflect society's preference to have future monies (benefits) available earlier or to reflect what would be earned by an alternative investment. The assumed interest rate was 13.5 percent, which is the real rate of growth in the gross national product plus the general rate of inflation for all products at the wholesale level, on the average, during 1967-1981, inclusive (9). The rate of 13.5 percent was chosen as being a logical measure of the long-term growth of capital.

The value of a deer has been estimated at \$709 by Norman (10) and \$844 by Hartman (11), based solely on hunter expenditures. Leitch (12) estimated hunter expenditures at \$270 per deer in 1974 with a meat value of \$60. Hunter expenditures vary considerably due to hunting season length, harvest success rate, the proportion of nonlocal hunters, the perceived need for hunting equipment, and so forth. Hunter expenditures by themselves would not be so valid an estimator as the much larger capitalized value needed to produce the annual returns. We chose \$500 as the value of a deer in 1978 and treated this estimate as we did the repair costs. (The annual inflation rate used for deer values was 7.284 percent, based on the change in the producer price index for toys, sporting goods, firearms, and ammunition, 1967-1981.)

The sum of inflated and discounted annual benefits was then divided by the incremental fence construction costs in 1978 of \$66,000 at St. John's and \$85,000 at Walnut Lake. The incremental cost, the cost of a 2.4-m fence plus gates beyond that of a standard 1.2-m fence, was used because the standard fence would have been installed anyway and it would not keep deer off the highway.

The resulting benefit/cost (B/C) ratios were 3.61 for St. John's alone, 1.24 for Walnut Lake alone, and 2.28 combined. We conclude that the fences are a cost-effective means of reducing deer-vehicle collisions in this situation. Because of design problems at Walnut Lake, we believe that the ratio for St. John's alone is the best estimator.

Extension of the economic analysis must be approached with caution because the input data would be different in other locations. Also, we do not know how reliable (variable) our estimate may be because we do not have any replication. Further, not all considerations were, or can be, reflected in the economic analysis. Factors not considered that would have lowered the B/C ratio include fence maintenance costs and allowance for self-repair of some vehicles after collisions with deer. Fence maintenance costs are not expected to be high, however, especially for the early years of the fence. Self-repair of vehicles appears most likely in cases where the deer are not severely damaged and may wander off or be taken by motorists before investigation; in neither case would a car kill likely be recorded under this system. Factors that would have increased the B/C ratio include probable traffic increases (both over the years and due to the attraction of highway traffic to the Interstates), future growth in the local deer herd, and the time and inconvenience on the part of public and private entities in handling collisions and the dead deer. On balance, the economic analysis is believed to be a fair but conservative evaluation of the effectiveness of the fences.

The only observed adverse effect of the fence was that two deer trapped against the outside of the fence at Walnut Lake were killed by dogs. This is a problem best solved by proper dog control. No adverse comments from the public were heard, and it was concluded that public acceptance of the fences was high. Hikers, skiers, hunters, woodcutters, and other pedestrians made considerable use of the gates, and there was some damage by cows and falling trees. Adequate attention must be paid to keeping the gates in proper working order to prevent deer from entering the highway corridor through the gates.

In conclusion, fence and gate design used at St. John's with an estimated 93 percent reduction in deer kills and B/C ratio of 3.61 was a successful and cost-effective method of reducing deer kills. If any such fences are built in the future, the design of the St. John's project should be followed; i.e., the fence should be located at the top of the backslope and be long enough to extend well beyond the area of normal deer movements. If this cannot be done, the fence will probably be ineffective. However, more thought should be given to routing new highways to avoid areas of high deer concentrations. Fences such as those tested must be considered a site-specific potential solution to reducing deer-vehicle collisions.

#### ACKNOWLEDGMENT

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# Roadside Vegetation: Implementation of Fine Fescue Grasses

ROBERT F. BAKER

The implementation phase of the roadside vegetation study began in July 1975 with Rutgers University acting as consultant. Effective July 1977, this effort was undertaken and continued by the New Jersey Department of Transportation (NJDOT). The objectives were to evaluate and compare the new standard Type A-2 grass mixture with the old standard Type A grass mixture in large roadside plots. The new Type A-2 grass mixture was evaluated for reduced mowing, better appearance, and better adaptability to New Jersey roadsides. Five locations were selected for approximately half-acre plots of Type A and Type A-2 grass mixture. The plots were evaluated and compared periodically by the Division of Research of NJDOT. The data-collection program was hampered by the 1979 gasoline crisis, the 1980 drought, and the department's policy of curtailed mowing. However, height data indicated that the Type A-2 grass mixture grows less vigorously and approximately half the height of the old Type A grass mixture. It was concluded that the new grass mixture will require less mowing than the old Type A grass mixture and will have a better appearance. The Type A-2 grass mixture is somewhat slower to establish than Type A. It is recommended that Manhattan ryegrass be added to the Type A-2 grass mixture to improve initial establishment and germination. It is also recommended that the sowing rate be 100 lb/acre instead of the initially suggested 60-lb/acre rate. This should eliminate the need to overseed after initial establishment.

New Jersey roadsides are an integral part of the utility and beauty of the complete highway system. Roadsides provide a pleasant diversion and break in monotony for motorists. Poorly established and maintained roadsides eventually contribute to highway deterioration. Dying vegetation may hinder highway drainage, which creates costly soil erosion and washouts, and may be a fire hazard. Tall grasses create snow accumulation and drifting. Unmowed roadside grasses allow encroachment of deciduous trees, which eventually create traffic hazards (1).

The public awareness of environmental quality and the economical need for roadside maintenance necessitate aesthetically acceptable roadsides and high-energy-related mowing. However, roadside maintenance budgets are strained by cost increases in labor and equipment. One solution to this problem is to replace the highly productive coarse grasses that require high-energy mowing with finer turf-type grasses that require less mowing energy and grow less vigorously.

In February 1970 the New Jersey Department of Transportation (NJDOT) contracted with the Department of Soils and Crops of Rutgers University's Cook College to develop a grass mixture specifically for New Jersey roadsides. The initial research objectives were to crossbreed and to develop a low-growing, less vigorous, more attractive roadside grass. The department desired a grass that required less mowing and that was better adapted to New Jersey roadsides. The grass mixture was intended primarily for new roadsides of typically loamy soils that are widespread throughout central New Jersey and secondarily for reseeding programs of older roadsides.

The initial research developed a grass mixture designated New Jersey Type A-2, which includes Fortress spreading fescue, Banner Chewings fescue, and Kenblue Kentucky bluegrass in equal proportions. The final report for the initial research project (2) claims that the new grasses will improve roadside appearance, reduce mowing, and have better establishment characteristics.

It was estimated that the lower-growing fine fescue grasses will require two to three less mowings per year, depending on environment and soil fertility. The new fine grasses eliminate tall seedheads, which require excessive mowing and contaminate lawns and field crops. The new lower, slower-growing fine fescue grasses are also reported to be capable of spreading into damaged areas, thus eliminating the need for labor-intensive reseeding. The denser cover of the new grasses provides better support for vehicles that stray from the paved roadway and better lodging characteristics (laid over grass foliage) and will protect steep slopes from costly wind and water erosion. In addition, the new fine fescues should be more tolerant of poor roadside soils and provide better resistance to drought and common grass diseases.

The implementation phase of the roadside vegetation study began in July 1975 with Cook College acting as consultant to NJDOT. The study proposed to evaluate plots 0.25 to 0.50 acre in size of the newly developed Type A-2 grass and to compare the new mixture with the old Type A grass mixture. The new grass mixture would be evaluated for claims made in the final report (3). Both grass mixtures are described below:

| Proportion (%) | Variety                    |
|----------------|----------------------------|
| Type A-2       |                            |
| 33.3           | Fortress spreading fescue  |
| 33.3           | Banner Chewings fescue     |
| 33.3           | Kenblue Kentucky bluegrass |
| Type A         |                            |
| 20             | Kentucky bluegrass         |
| 35             | Red fescue                 |
| 20             | Kentucky 31, tall fescue   |
| 10             | Redtop                     |
| 10             | Perennial ryegrass         |
| 5              | White clover               |

Effective July 1, 1977, the implementation phase of the project was taken over and continued by NJDOT and the contract with Rutgers was terminated. In essence, it was established that the need for an additional basic research phase that involved an extension of the previous basic research activities had diminished and that the implementation phase could better be performed by department staff. The Bureau of Transportation Structures Research, the Bureau of Landscape Architecture, and the Bureau of Maintenance acted together to coordinate the experimental plot seeding and monitoring efforts on new highway construction and maintenance renovations in accordance with an amendment to the implementation research proposal of February 20, 1975.

## STUDY PROCEDURES

The Division of Construction and Maintenance and the Bureau of Landscape Architecture assisted with the establishment of the large roadside plots. Landscape construction projects were usually hydroseeded after the contractor had prepared the area by standard procedures of grading, topsoiling, liming, and fertilizing. Landscape projects are usually mulched with straw. Large roadside maintenance renovation

projects were tilled, fertilized, and limed as required by the Bureau of Maintenance. Renovation plots were hand seeded by maintenance and research personnel. The Bureau of Maintenance coordinated mowing schedules.

Soil tests were taken on all roadside plots to determine pH, nitrogen, phosphorus, and potash contents. A Sudbury soil test kit was used to analyze two soil samples from each plot. The tests were averaged and are shown in Table 1. The soil tests evaluated the similarity of soil qualities for plot comparisons.

Roadside plots were monitored by the Bureau of Transportation Structures Research on a 4- to 6-week schedule during late spring, summer, and early fall. Monitoring included site evaluations, grass height measurements, subjective analysis, and photographs to evaluate the establishment characteristics and mowing requirements.

## RESULTS

The results of the implementation phase are discussed for each roadside plot location. Four roadside plot locations were established by the Bureau of Transportation Structures Research specifically for the implementation study. One additional plot location (I-195, Allaire State Park) was established by the Bureau of Landscape Architecture and will be discussed in this section.

### I-195, Jackson Mills

Two median plots were installed by the contractor on September 29, 1977. The two plots, each 40 by 500 ft, were hydroseeded at 60 lb/acre of Type A and Type A-2 grass mixture after the contractor had

applied 50 lb/acre of lime and 300 lb/acre of 10-20-10 fertilizer. Soil tests are shown in Table 1. The soil at this location is sandy.

The plots were initially mowed in spring and summer 1978 by the construction contractor to control volunteer ryegrass and contaminants from the mulch and topsoil. The Type A and Type A-2 grasses established a good turf until a summer washout forced the contractor to reseed and mulch the center 2 to 3 ft of the median. Essentially, this did not affect the test plots but did add volunteer white clover (probably from the mulch). The white clover, which is a vigorous grower, predominated in the center of the median until the 1980 summer drought.

Figure 1 shows the Type A-2 grass in the spring of 1978. The area of Figure 1 is adjacent to the area of Figure 2, which shows the Type A grass at the same time. The Type A-2 grass is 2 to 4 in. tall. In Figure 2 the tall seed stalks of the Type A grass show a significant difference from the Type A-2 grass. Height measurements indicate that the Type A grass is 4 to 6 in. tall and the seed stalks are 12 to 16 in. tall. The Type A grass requires mowing but the Type A-2 grass does not. The grasses shown in Figure 2 in the I-195, Jackson Mills, plot were typical for all plots.

The plots were not mowed during the 1979 spring and early summer gasoline crisis. Measurements in early June indicated that the Type A-2 grass was 2 to 4 in. tall and the Type A grass was 4 to 6 in. tall. The plots were mowed in the late summer and fall of 1979. Measurements made approximately 1 week before fall mowing indicated that the Type A-2 grass was 3 to 4 in. tall and the Type A grass was 6 to 8 in. tall. Essentially, the Type A-2 grass did not require mowing during 1979. However, mowing was required to control weeds and volunteer grasses.

Table 1. Soil tests.

| Identification   | pH  | Content (lb/acre) of |            |        | Remarks                            |
|--|-----|----------------------|------------|--------|------------------------------------|
|  |     | Nitrogen             | Phosphorus | Potash |                                    |
| NJ-55, milepost 22.5, Type A-2 mixture (before fertilizer and lime)                        | 4.5 | 190                  | 2          | 160    | No organic, sandy soil             |
| NJ-55, milepost 22.5, Type A mixture (before fertilizer and lime)                          | 5.2 | 100                  | 2          | 160    | Some organic, sandy soil           |
| US-22, north branch (Type A) (after fertilizer and lime), milepost 29.2                    | 7.5 | 20                   | 20         | 40     | Some organic, fine sandy-clay soil |
| US-22, north branch (Type A-2) (after fertilizer and lime), milepost 28.4                  | 7.5 | 20                   | 40         | 40     | Some organic, fine sandy-clay soil |
| I-195, milepost 5.9, Robbinsville, renovation area (Type A-2) (before fertilizer and lime) | 5.2 | 10                   | 40         | 80     | Loamy clay, some organic           |
| I-195, Robbinsville, renovation area (Type A), milepost 5.8 (before fertilizer and lime)   | 5.2 | 190                  | 4          | 10     | Loamy clay, some organic           |
| I-195, Type A-2, Jackson Mills (after fertilizer and lime), milepost 24.5                  | 7.5 | 40                   | 40         | 40     | Sandy soil                         |
| I-195, Type A, Jackson Mills (after fertilizer and lime), milepost 24.5                    | 7.5 | 40                   | 40         | 80     | Loamy clay                         |
| I-80, Type A-2, Allamuchy-Hope (after fertilizer and lime), milepost 19.5                  | 6.7 | 50                   | 20         | 20     | Loamy clay                         |
| I-80, Type A, Allamuchy-Hope (after fertilizer and lime), milepost 11                      | 6.7 | 50                   | 20         | 20     | Sandy soil                         |
| I-195, Type A-2, Howell Twp. (after fertilizer and lime), milepost 33.7                    | 6.7 | 100                  | 81         | 5      | Sandy soil                         |
| I-195, Type A, Howell Twp. (after fertilizer and lime), milepost 33.7                      | 6.7 | 100                  | 41         | 10     | Sandy soil                         |



In 1980 grass mowing frequency was reduced by the drought, which slowed grass growth. Figure 3 shows the Type A-2 grass in June 1980, approximately 2 weeks after mowing. The Type A-2 grass has a dense, dark green turf about 4 in. tall. Figure 4 shows the Type A grass at the same time. The Type A grass has a sparse turf 4 to 5 in. tall. As the summer drought progressed, both the Type A-2 and the Type A

Figure 1. I-195, Jackson Mills, Type A-2 grass, spring 1978.



Figure 2. I-195, Jackson Mills, Type A grass, spring 1978.



Figure 3. I-195, Jackson Mills, Type A-2 grass, June 1980.



grasses did not persist well. The apparent drought susceptibility of both grasses is attributed to the inadequate root system of the newly established grasses. It is possible that the grasses would have better sustained the drought if the grass plants had been more mature.

In May 1981 white clover dominated much of both plots. However, the Type A-2 and the Type A grasses persisted in providing adequate vegetative cover. Height measurements indicate that both grasses were less than 4 in. tall.

The 1980 drought and poor soil on the full length of I-195 are probably the reasons for the poor establishment of the Type A-2 and the Type A grasses. The soil and environment of this route may severely inhibit the establishment of vegetation not entirely suited to the prevailing conditions.

#### US-22, North Branch

Two median plots in the renovated crossovers of US-22 were installed by the Bureau of Maintenance on May 10, 1978. The two plots were each 60 by 80 ft and were hand seeded with 20 lb (180 lb/acre) of Type A and 20 lb of Type A-2 grass mixtures after maintenance had rototilled the soil and applied 20 lb of lime and 20 lb of 5-10-5 fertilizer. Each plot was mulched with seed-free oat straw.

The soil in these plots was fertile, which was shown by the soil tests shown in Table 1. Soil tests were taken after liming and fertilizing.

The turf surrounding the plots is dominated by tall fescue, redtop, clover, and weeds.

The Type A and Type A-2 grass mixtures produced an initially acceptable turf in a reasonable time. The plots were mowed in the late summer and fall of 1978 to control weeds. Type A and Type A-2 grasses were not sufficiently mature to require mowing. Automobiles traversed the plots, and the wheel tracks had to be reseeded.

The gasoline shortage in the spring of 1979 reduced the availability of mowing when the grasses matured. Weeds that grew to 4 ft volunteered from the surrounding areas into both plots. The Type A-2 grass was not sufficiently vigorous to compete with the weeds and tall fescue from the surrounding area. Approximately 25 percent of the area of the Type A-2 plot was contaminated by the volunteer vegetation.

However, the volunteer vegetation did not prevent measurement of the grass height in both plots in the fall of 1979. Before mowing, the Type A-2 foliage was 4 to 8 in. tall and the Type A foliage was 8 to 16 in. tall. Both plots were mowed at a 4-in.

Figure 4. I-195, Jackson Mills, Type A grass, June 1980.



height. The Type A-2 grass measured 4 to 5 in. approximately 3 weeks after a late fall mowing. The Type A grass measured 7 to 10 in. at the same time.

In the spring, summer, and fall of 1980, the Type A and Type A-2 grasses showed less growth due to the severe drought. However, spring measurements of grasses before mowing indicated that the Type A-2 grass was 4 to 6 in. and the Type A was 10 to 12 in. tall. The Type A grass, which is more vigorous, crowded out weeds and maintained a good stand of grass. The Type A-2 grass, which is reported to be drought tolerant, was not sufficiently persistent to crowd out weeds. Surrounding tall fescue and redtop volunteered into the Type A-2 grass, which was weakened by weeds during the previous year.

#### NJ-55, Millville

Two roadside renovation plots were installed on the southwest side of NJ-55, Millville, by the Bureau of Transportation Structures Research on May 12, 1978. The two plots are each 60 by 200 ft and were hand seeded with 25 lb (90 lb/acre) of Type A and Type A-2 grass mixtures. The Bureau of Maintenance rototilled the plots and applied 150 lb of 10-6-4 fertilizer and 500 lb/acre of lime. It was found that hand seeding by inexperienced research personnel required more seed than mechanical hydroseeding. Essentially, it was not possible to maintain the recommended 60 lb/acre of seed. The plots were mulched with weed-free straw.

The objective of the study of plots on NJ-55 was to evaluate the new grass on the sandy, arid soil of southern New Jersey. The research consultant had used this specific area in the previous study for small roadside plots. With the exception of a few fine fescue grasses, all other grass had died. Some native grasses had established in the southern portion of the Type A plot when experimental grasses died out. The remainder of the plot was devoid of vegetation.

The initial establishment of turf of both the Type A and Type A-2 grass plots was sparse. However, the Type A-2 grass mixture produced slightly more grass plants than the Type A mixture did.

Soil tests are shown in Table 1. The tests indicate that the NJ-55 plots were the most fertile of all roadside plots. However, the area appeared infertile because it supported little natural vegetation.

The plots were initially mowed in September 1978 and July 1979 to control volunteer weed and seed stalks. Grasses in sandy soil grow less vigorously than in a loamy soil and do not require as many mowings. No other mowings were made on these plots, primarily because the sandy soil would not support mowers.

On October 31, 1979, Camden composted sludge was top-dressed on the center sections of both plots. The objective was to evaluate the effect of the composted sludge on vegetation in sandy soil and to improve the sparse turf on the plots. The wood-chip composted sludge was applied at 25 tons/acre. The sludge improved the vegetation in both plots. However, the Type A-2 showed the greatest improvement by producing rhizomes and new grass plants.

The 1980 drought adversely affected the noncomposted grasses. However, the Type A and Type A-2 composted grasses persisted during the drought. Measurements of the composted Type A grass in the summer and fall of 1980 indicated a height of 4 to 6 in. Measurements of the composted Type A-2 grass in the same period indicated a height of less than 4 in.

In the spring of 1981, measurements indicated that the Type A grass foliage was 8 to 12 in. tall and the Type A-2 grass foliage was less than 6 in.

The study of NJ-55 grass plots did not provide mowing data. However, it was demonstrated that the Type A-2 grass mixture provides an adequate, dense turf in a sandy soil. The Type A-2 grass survived the drought in the composted and noncomposted areas. The composted area of the Type A-2 provided a denser turf than the noncomposted Type A-2. The Type A grass mixture provides a sparse, clumpy turf of vigorous, tall fescue grass plants.

#### I-80, Allamuchy-Hope

The construction contractor seeded a plot of Type A grass and a plot of Type A-2 grass on November 16, 1978, in the median of I-80 at mileposts 11 and 19.5. Each plot measured an acre. Both plots were seeded at 60 lb/acre and were fertilized and limed by the contractor.

Mowing problems were encountered when the Bureau of Maintenance mowed the Type A plot and a mowing contractor mowed the Type A-2 plot. Essentially, plots were mowed at different times and it was impossible to regulate mowing at the required times.

Another problem was encountered with grass establishment in the Type A-2 plot. The initial turf in the spring of 1979 was sparse and dominated by weeds. The poor initial establishment was attributed to the late fall seeding and the possibility of inferior-quality seed. Unfortunately, no Type A-2 grass seed was available for verification of the seed mixture composition.

In April and May of 1980, an adequate turf of the Type A-2 grass had developed for evaluation. New grass plants were beginning to produce a dense, fine fescue turf. Portions of the A-2 plot were mowed in May 1980. Before the mowing, measurements of grass foliage showed that the Type A-2 grasses were less than 4 in.; weeds necessitated the mowing.

By May 1980 the Type A grass had produced a sparse turf of clumpy grass plants with thick foliage. Measurements, which were taken at the same time as those of the Type A-2 grass, revealed that the Type A grass was more than 8 in. tall. Although the Type A grass was affected by the drought, its vigorous nature enabled it to develop a denser foliage.

Measurements in fall 1980 (after the drought) indicated that the Type A and Type A-2 grasses did not grow at normal rates. The height of the Type A-2 grass averaged less than 4 in.; the height of the Type A grass was 4 to 6 in.

In the spring of 1981 fine fescue grasses (probably Pennlawn) persisted on the north-facing slope of the Type A plot. This was attributed to some tall fescue failure during the 1980 summer. The fine fescue grass of the Type A-2 grass mixture persisted in the spring of 1981. The Type A-2 grass measurements revealed a 4-in. height.

Type A tall fescue grasses were measured at the same time as the Type A-2 grass. The tall fescue grass measurements revealed an 18-in. height. Neither test plot was mowed before the measurements. The dense, tall foliage of the Type A grass requires excessive mowing energy. The Type A tall fescue grasses are vigorous producers of thick, clumpy foliage that requires extensive mowing for uniformity of appearance. The Type A-2 fine fescue grasses provide dense, uniform turf.

#### I-195, Allaire State Park

The I-195, Allaire State Park, plots were installed by the Bureau of Landscape Architecture and were not under the roadside vegetation study. Nevertheless, these plots will be discussed in this section.

Two plots were installed on a north-facing slope

by the construction contractor on April 20, 1980. Both plots were fertilized and limed. The Type A-2 grass plot was hydroseeded at 60 lb/acre. The Type A grass plot was hydroseeded at 100 lb/acre.

The objective of the study of these plots was to evaluate the rate of establishment of the Type A-2 grasses. It appeared that in the plots discussed earlier, the Type A-2 grass established at a somewhat slower rate than the Type A. The slower establishment is probably attributed to the absence of ryegrass in the Type A-2 grass mixture. Ryegrass appeared in the Type A plot about 8 to 10 days after seeding. Unidentified grasses appeared in the Type A-2 plot at the same time and fine fescue grasses appeared about 2 weeks after seeding. It was not conclusive that the Type A-2 grasses were significantly slower in establishing than the Type A grasses.

The summer drought adversely affected the maturity of both grasses. However, by May 1981 the Type A-2 grass mixture had established an adequate turf. The Type A-2 grass was a dense, low-growing turf. The Type A grass was a sparse and weedy-appearing turf.

No mowing data were obtained from the study of these plots. Nevertheless, the plots showed that the Type A-2 grass provides an adequately dense initial turf in a reasonable time.

## DISCUSSION

### Smothering of Fine Fescue Grasses

The smothering of fine fescue grasses in several small areas on slopes has been noted on recently seeded roadsides of the Type A-2 grass mixture. Smothering has not occurred, however, in the experimental plots and on old roadsides where fine fescues have dominated from the Type A grass mixture. Smothering is the laying of foliage over the grass (lodging), which kills the grass plants. Not all lodging causes smothering and death to the grass plants. Lodging of grass plants provides soil and erosion protection, assists in reducing evaporation of moisture from the soil, and provides an acceptable unmowed appearance.

The evaluation of smothering must consider numerous variables such as soil fertility, moisture, soil pH, quantity and variety of seed, and slope contours. When the nature of the variables is not known, it is difficult to determine the cause of smothering.

The isolated smothering on Type A-2 grass slopes is most likely due to excessive seed and highly productive sites. The smothering would appear to be not directly attributed to the Type A-2 grass mixture. When the Type A-2 grass mixture is sown at 60 lb/acre, 20 lb is Banner Chewings fescue, 20 lb is Fortress spreading fescue, and 20 lb is Kenblue Kentucky bluegrass. The application of Type A-2 grass mixture provides 40 lb of fine fescue seed. The application of the old Type A grass mixture provides 35 lb of fine fescue, i.e., Pennlawn red fescue. The additional 5 lb of the Type A-2 grass mixture spread over 43,500 ft<sup>2</sup> would not create excessive grass plants and smothering conditions.

### Substitute Grasses

The report Better Grasses for Roadsides (2) concluded that fine grasses, which include spreading fescue, Chewings fescue, and common-type Kentucky bluegrass, provide a more acceptable cover with less mowing than coarse hay-type grasses. The report specifically recommended Fortress, Banner, and Kenblue cultivars and suggested the grasses listed

below as alternatives for any one of these three if the primary cultivars are not available:

| <u>Primary Cultivar</u> | <u>Alternative</u>    |
|-------------------------|-----------------------|
| Spreading fescue        | Pennlawn -<br>Ruby    |
| Chewings or hard fescue | Jamestown<br>C-26     |
| Kentucky bluegrass      | South Dakota<br>Delta |

It is recommended that substitutes be seeded at the same rate as the Banner, Fortress, or Kenblue. The preferred cultivar is listed above the less desirable cultivar.

### Seeding Rate

The Bureau of Landscape Architecture had seeded the Type A grass mixture at 100 lb/acre for several years before the implementation of the Type A-2 grass mixture. The 100-lb rate provides better coverage on poor soils where overseeding is necessary for an adequate turf.

## SUMMARY AND CONCLUSIONS

The implementation objectives were to evaluate the newly developed Type A-2 grass mixture, compare that mixture with the previous New Jersey standard Type A grass mixture in large roadside plots, and develop any changes in components of the mixture or in recommended application rates that might be needed to permit continued, standardized use of the A-2 grass. The new grass was evaluated for reduced mowing, better appearance, and better establishment characteristics.

The Division of Construction and Maintenance, the Division of Research, and the Bureau of Landscape Architecture established five large roadside plots and monitored the plots for the study objectives. Grass height measurements, subjective analysis, and photographs were made to evaluate the establishment characteristics and mowing requirements.

The 1979 gasoline crisis, the 1980 drought, and the 1981 department restrictions on mowing limited data collection and mowing evaluation. Data collection and evaluation continued despite these restrictions, and sufficient data were collected for a subjective evaluation of the plots.

The previously used Type A grass mixture, which is dominated by Kentucky-31 tall fescue, has been established adequately on roadsides and medians for several years. However, its turf is clumpy and less dense than the Type A-2 fine fescues even though it produces a dense, abundant foliage. Tall fescue does not establish well on slopes where fine fescue dominates.

The height measurements of the Type A grasses indicate that the tall fescue grows more vigorously after initial establishment and requires more mowing to maintain an acceptable appearance than the Type A-2 grasses. The tall fescue grows twice the height in the same time as the Type A-2 fine fescues. The Kentucky-31 tall fescue is a tough, wide-blade grass that requires excessive mowing energy. Its excessive vigorousness after establishment is not essential for an acceptable roadside.

The Type A-2 grass mixture, which is dominated by fine fescues, establishes adequately on roadsides and slopes and on loamy and sandy soils. The fine fescues develop a dense, more uniform turf than the tall fescues and establish a significantly better turf for slope protection. The fine fescues provide an improved unmowed appearance over the tall fescues.



The fine fescue grasses appear initially to green up (germinate) and establish slower than the Type A grasses. This slow green-up and the slow establishment are attributed to the nature of the fine fescues and the absence of quick-germinating ryegrass in the Type A-2 grass mixture.

The height measurements of the Type A-2 grass indicate that the fine fescue grows less vigorously after establishment and requires less mowing to maintain an acceptable appearance than the tall fescue Type A grass mixture. The fine fescue grasses grow approximately half as fast as the tall fescues. However, the fine fescues are not initially vigorous enough to restrict weed intrusion. An initial mowing or an application of 2-4D chemical herbicide is sufficient to assist the Type A-2 grass for initial establishment. The small investment in the initial mowing and chemicals pays off with reduced future mowing.

The research consultant for the initial roadside vegetation study estimated that the Type A-2 grass mixture would require two to three less mowings per year, depending on the environment and soil fertility. In 1970 the department required six mowings per year by contractors to control the tall fescue grasses. However, in 1982, due to fiscal restraints, the department mowed only critical safety areas that were warranted by roadside conditions as determined by appropriate maintenance personnel. Mowing contractors and maintenance personnel now mow 6 ft of the shoulder and 12 ft on either side of the median. Crossovers and jug-handled areas are mowed to provide adequate sight distance for safety. The policy of mowing a certain number of times during the growing season is no longer in force.

The fine fescues on sandy soil did not withstand the 1980 drought, as the consultant had predicted. The drought susceptibility of the fine fescues is attributed to the immaturity of the grasses. If the grasses were more mature, the root system would have been better developed and more able to withstand the drought.

The fine fescue grasses on small maintenance renovation sites are not sufficiently vigorous to exclude the tall fescues from surrounding areas. Tall fescues eventually dominate the area seeded with fine fescue.

The fine fescue established an adequate dense turf on a sandy soil mulched with Camden composted sludge. The tall fescue turf was sparse and clumpy. The composted sludge provided adequate moisture and nutrients for the grasses on the arid, sandy soil.

Seed certification and seed sampling would guarantee the quality, purity, and quantity of seed mixture portions. It would clarify seed germination and establishment problems and serve to enforce the department's seed specification. It would also clarify future claims against the seed mixture.

#### RECOMMENDATIONS

1. The Type A-2 grass mixture should be modified with a 10 percent addition of Manhattan ryegrass to provide quick green-up of seeded areas. The modified Type A-2 grass mixture should be specified as follows (all seed should be blue-tag certified):

| <u>Cultivar</u>            | <u>Percentage of<br/>Total Weight</u> |
|----------------------------|---------------------------------------|
| Kenblue Kentucky bluegrass | 30                                    |
| Fortress spreading fescue  | 30                                    |
| Banner Chewings fescue     | 30                                    |
| Manhattan ryegrass         | 10                                    |

The blue-tag certification is a guarantee of the quality and variety of seed. At the time of har-

vest, grass seed is sampled and tested for quality and variety under the Federal Seed Act. A blue tag is then attached to sealed bags of seed to certify its contents. This certification attests to the fact that strict controls have been adhered to through establishment, growth, and harvesting to ensure against contamination of the seed.

2. The modified Type A-2 grass mixture should be used for all roadsides and slopes on major highway landscape projects. The Type A-2 fine fescues require less mowing, provide a superior appearance, and establish well on roadsides and slopes on loamy and sandy soils of New Jersey.

3. The report *Better Grasses for Roadsides* (2) recommends alternative cultivars for the spreading fescue, Chewings fescue, and common-type Kentucky bluegrass, as previously discussed.

4. Kentucky-31 tall fescue should not be used in grass mixtures for New Jersey roadsides. Sufficient varieties of initially vigorous grasses are available for quick initial green-up and establishment. The Kentucky-31 tall fescue is excessively vigorous and requires excessive mowing to maintain an acceptable appearance. It grows poorly in sandy soils and does not sufficiently dominate slopes or poor soils.

5. The modified Type A-2 grass mixture should be sown at 100 lb/acre. Most test plots and landscape seeding projects were seeded at 60 lb/acre. However, overseeding was necessary in most areas of projects. The 100-lb/acre rate should eliminate the need to overseed established areas.

6. A seed sampling plan should be initiated to identify and guarantee the seed specification quantities and grass species.

7. Camden composted sludge successfully assisted the establishment of fine fescue grasses on arid sandy soils. However, the serious potential of harmful carcinogens exists in some sludges. The Camden composted sludge was certified free from dangerous carcinogens, but fear of the sludge was expressed by the people who worked with it. The department should investigate the use of safe, carcinogenic-free composted sludge for roadside landscape maintenance. The sludge assists the establishment of grasses on sandy arid soils and prevents costly erosion.

8. The modified Type A-2 grass mixture should be more appropriate for maintenance renovation sites than the Type A-2 (without Manhattan ryegrass). The modified Type A-2 grass mixture should be used and evaluated at such locations.

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The opinions, findings, and conclusions expressed in this paper are mine and not necessarily those of NJDOT or FHWA. This paper does not constitute a standard, specification, or regulation.

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# Wildlife Values and Management of Gravel Pits in Forest Ecosystems

JOHN E. MATHISEN

Gravel pits in forest ecosystems provide unique habitats for a variety of wildlife species due to features such as steep banks, storage piles of excavated material, exposed mineral soil, and surface water. In north central Minnesota there are 51 species associated with these characteristics. Gravel-pit management and rehabilitation can be coordinated to meet wildlife management objectives by providing dead and dying trees for cavity-nesting species, shallow areas of surface water, and downed logs and by maintaining vertical banks and areas of bare ground.

An open area in a forested ecosystem is recognized as a vitally important habitat that contributes to faunal diversity and to the welfare of many wildlife species (1-5; 6, pp. 189-197). Most forest habitat management programs emphasize the significance and management of these habitats, often referred to as wildlife or permanent openings (2,7).

Due to their structural characteristics, gravel pits--both operational and abandoned--provide opening types differing in wildlife values from those originating from homesteads, old fields, or frost pockets. The purpose of this paper is to assess the value of gravel-pit openings to those wildlife species who use them for feeding and breeding and to provide recommendations that land managers can use to enhance and manage these habitats in a forest ecosystem.

## CHARACTERISTICS OF GRAVEL PITS

Gravel pits occur throughout the forested area of the Lake States in relatively small land units ranging in size from an acre or less to 20 acres or more. On the Chippewa National Forest in north central Minnesota, they account for about 10 percent of the opening type of community and vary from 1 to 10 acres in size (8). Most of these pits originate when relatively small quantities of gravel are extracted for local road construction or for timber-sale haul roads. Abandoned sites, unless totally depleted, are often reopened after many years of inactivity.

The diversity of vegetation and structure of gravel pits depend on activity status, age, soil conditions, and rehabilitation treatment. Unfortunately, from a wildlife-habitat perspective, abandoned sites are often degraded by leveling and reforestation practices. A typical abandoned pit consists of a mixture of grasses, shrubs, and forbs interspersed with bare ground. A steep slope or bank (usually occurring from excavation) is a typical structural feature. Occasionally water resulting from excavation below the water table will be present.

Although gravel-pit openings proceed through vegetative succession very slowly after abandonment, they will eventually disappear, if unmanaged, due to the encroachment of the forest.

## ORIENTATION OF WILDLIFE TO PERMANENT OPENINGS

Although the data presented here apply specifically to the Chippewa National Forest, the concepts and values are generally applicable throughout the forested region of the Lake States.

To provide a systematic way of simultaneously displaying the effects of habitat alteration on all

species of wildlife, a habitat association data base was assembled (9). The data base also facilitates the ranking and assessment of various vegetative communities in terms of richness of vertebrate species. Used to evaluate gravel pits in terms of the wildlife community, these data will also provide a rationale for management.

## Description of Data Base

The data base consists of 9 interrelated elements correlating 310 vertebrate species with habitat, season of use, and status. The habitat types (communities) described by Niemi and Pfanmuller (10, pp. 154-177) were modified to accommodate the conditions and vertebrate species on the Chippewa National Forest. These 24 communities reflect a combination of vegetation, successional stage, and structure. The permanent opening is one of these communities.

Each species was categorized by the communities it uses for feeding, breeding, or both. Because most species are oriented to more than one community, an attempt was made to designate one of these communities as particularly important. This was termed the critical community for the species. It was impossible to assign a critical community to the more ubiquitous species.

The 310 vertebrates were also classified into 16 life forms, adapted from work by Thomas and others (11, pp. 60-77).

Eight categories were used to relate special habitat requirements to each species (man-made structure, edge, decaying log, snag, riparian area, mast, and bank or bare ground). Those species having a special requirement of a bank or bare ground are particularly germane to the subject of this paper. Each species was also categorized as to season of use (migration, summer, winter, permanent resident) and status (threatened, endangered, sensitive, game or fur, indicator). The data were entered on an IBM OS/6 word processor for storage and manipulation and to facilitate updating.

A gravel pit is a type of permanent opening, so the information in the data base concerning the species associated with openings can be generally applied to this assessment. A more specific and detailed analysis can then be made based on the unique habitat features of gravel pits and their relation to the special requirements of the associated vertebrate fauna.

Although permanent openings account for less than 5 percent of the upland communities on the Chippewa National Forest, there are 158 vertebrate species (51 percent of 310) that have a primary orientation to them; i.e., they feed, breed, or both in permanent openings:

| Group                           | No. of Species |       |      |       |
|---------------------------------|----------------|-------|------|-------|
|                                 | Feed           | Breed | Both | Total |
| Birds                           | 71             | 6     | 34   | 111   |
| Mammals                         | 15             | 0     | 21   | 36    |
| Herps (reptiles and amphibians) | 3              | 2     | 6    | 11    |
| Total                           | 89             | 8     | 61   | 158   |

Among the 158 species associated with permanent openings, 22 are game or fur species, 7 are classified as sensitive, 2 are considered by the federal government to be endangered or threatened, and 5 are management indicator species.

A further refinement of these data can be displayed by considering only those species that have the opening community designated as their critical community:

| Group            | No. of Species | Total Species in Class (%) |
|------------------|----------------|----------------------------|
| Birds (N = 233)  | 38             | 17                         |
| Mammals (N = 57) | 15             | 26                         |
| Herps (N = 20)   | 8              | 40                         |
| Total (N = 310)  | 61             |                            |

#### Unique Qualities of Gravel Pits

Gravel pits, considered as a type of permanent opening, could potentially accommodate all of the species listed above. The animal community associated with specific gravel pits will depend on characteristics of the vegetation, presence of water, and structural features.

The uniqueness of gravel pits as compared with other openings in a forest ecosystem is due to the presence of steep banks, storage piles of excavated material, and exposed mineral soil. There are 21 species (13 percent of the 168) oriented to openings that have these features (Table 1). This group of vertebrates includes bank-nesting birds, such as the belted kingfisher and bank swallow; fossorial mammals such as the badger and woodchuck; and reptiles such as the snapping turtle that require bare ground for excavating a nest.

Unvegetated banks and mounds of surplus material created by excavation are favored rendezvous sites for the threatened gray wolf (12,13) and are frequently used by other canids (personal communication from Bill Berg, Minnesota Department of Natural Resources). Deer and other mammals are also attracted to exposed soil typical of gravel pits, possibly for mineral content.

Clearly, gravel pits are important and valuable components of wildlife habitat, and if species di-

versity is a management goal, land managers should be aware that they deserve thoughtful and careful consideration.

#### MANAGEMENT OPPORTUNITIES

Of the 158 species associated with openings, 132 have one or more special requirements considered in the data base. These special requirements are directly related to habitat management strategies for gravel pits. Again, the wildlife habitat association data base provides information (Table 1) and focuses on the importance of various structural features to vertebrates associated with gravel-pit habitat.

#### Snags

Thirty-four (22 percent) of the species associated with openings also require snags or cavities for nesting, roosting, hibernation, or perching. Examples are American kestrel, eastern bluebird, red-headed woodpecker, big brown bat, and white-footed mouse. Three are primary excavators (14, pp. 214-225) that initiate holes for secondary users.

Normal gravel-pit operations will generally preclude the presence of snags within the clearing, although this may be possible in some instances by reserving islands, or clumps of trees, at the time of land clearing. Snags, however, can be provided along the edges of the clearing to accommodate the 34 species that require them. By using the method of Thomas and others (11, pp. 60-77) for determining snag densities by community type, a density of about two hard snags per acre [diameter at breast height (dbh), 16 in. or larger] will accommodate the primary excavators and the associated secondary users at the 100 percent management level (Table 2). Nesting boxes for secondary users may be substituted for snags if trees of suitable size are not present.

#### Water

Clearly, surface water or wetland habitat within or adjacent to a gravel pit enhances its value to wildlife. If a gravel pit contains surface water due to excavation below the water table, an additional community (pond) is established. Depending on depth and permanency of the water and whether fish are present, animal diversity is significantly affected. The presence of a pond within a gravel pit will potentially accommodate 30 additional species, consisting of 18 birds, 6 mammals, and 6 reptiles and amphibians. Fifty-eight (37 percent) of the species associated with gravel pits are also associated with riparian environments. Examples are spotted sandpiper, eastern kingbird, killdeer, coyote, little brown bat, and eastern garter snake.

When possible, excavation procedures should provide for digging below the water table to produce permanent or temporary aquatic habitats. Water-filled excavations should not be filled in as part of the reclamation activity. In order to produce a varied and productive aquatic plant community, excavations should produce gently sloping and shallow edges and should not exceed 3 ft in depth unless a

Table 1. Special requirements of species associated with openings.

| Group               | No. of Species <sup>a</sup> |      |          |     |      |      |             |
|---------------------|-----------------------------|------|----------|-----|------|------|-------------|
|                     | Snag                        | Edge | Riparian | Log | Mast | Bank | Bare Ground |
| Birds               | 23                          | 60   | 34       | 8   | 9    | 5    | 6           |
| Mammals             | 11                          | 24   | 16       | 21  | 8    | 6    | 0           |
| Herps               | 0                           | 0    | 8        | 7   | 0    | 0    | 4           |
| Total               | 34                          | 84   | 58       | 36  | 17   | 11   | 10          |
| Percentage of total | 22                          | 53   | 37       | 23  | 11   | 7    | 6           |

<sup>a</sup>Total number of species = 158.

Table 2. Hard snags required to support various percentages of maximum populations of primary excavators associated with openings.

| Species                  | Minimum Dbh (in.) | Snags/100 Acres by Management Level |            |            |            |            |
|--------------------------|-------------------|-------------------------------------|------------|------------|------------|------------|
|                          |                   | 100 Percent                         | 80 Percent | 60 Percent | 40 Percent | 20 Percent |
| Common flicker           | 12                | 50                                  | 40         | 32         | 20         | 10         |
| Red-headed woodpecker    | 16                | 200                                 | 160        | 120        | 80         | 40         |
| Yellow-bellied sapsucker | 10                | 100                                 | 80         | 60         | 40         | 20         |

fishery is planned. The pond habitat can be further enhanced by planting willows along the edges.

#### Downed Logs

Downed, decaying trees are used as cover or foraging sites by 36 (23 percent) of the species associated with openings. Examples are common flicker, red fox, masked shrew, and red-bellied snake.

Prescriptions for gravel-pit rehabilitation or management should provide for this structural feature by dropping trees into the pit area along the edge or hauling logs into the interior. At least two logs per acre are recommended (15, pp. 78-95). Logs should also be placed on the periphery of ponds to provide waterfowl roosting sites and places for amphibians and reptiles to sun and hide.

#### Mast

Seventeen (11 percent) of the vertebrates associated with openings also use mast, such as acorns and nuts. Examples are white-tailed deer, black bear, and eastern chipmunk.

Managers should strive to perpetuate oak adjacent to gravel pits and promote mast-producing shrubs such as American hazel within the clearing.

#### Banks and Bare Ground

Unvegetated banks and mounds of surplus material created by excavations should be retained and not leveled as a rehabilitation technique. Rehabilitation plans should also provide for patches of bare ground on at least 50 percent of the area to benefit species such as nighthawks, killdeer, snapping turtles, and green snakes.

The open character of depleted or abandoned gravel pits should be maintained, and vegetation plans should not provide for reforestation. Seeding and fertilizing to restore vegetative cover on portions of the area should be done with grasses and legumes suitable to the soil and site. In some situations, planting of native shrubs may be appropriate to enhance habitat structure, although natural invasion may accomplish the same objective over time. In order to control the invasion of trees, maintenance treatments with herbicide, hand cutting, or burning may be required.

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