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BUREAU OF PUBLIC ROADS

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NATIVE PLANTING ON SLOPES INACCESSIBLE TO MECHANICAL MOWERS ON ROAD NEAR ELDORA, IOWA

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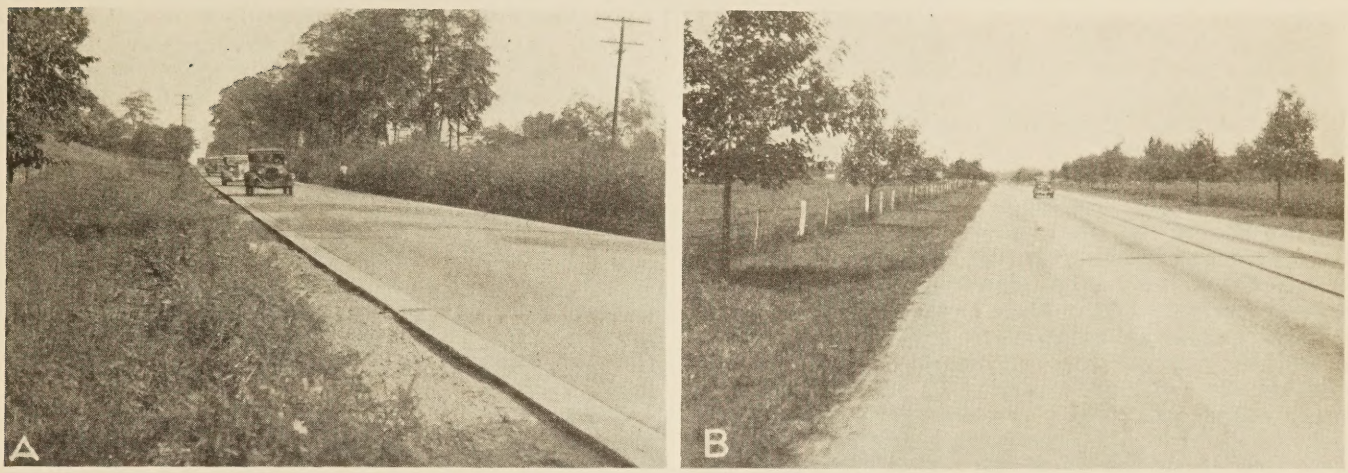
WEED CONTROL AND ERADICATION ON ROADSIDES

A STUDY OF PRESENT PRACTICES AND THEIR PRACTICAL APPLICATION

Reported by O. K. NORMANN, Assistant Highway Engineer, Division of Construction, Bureau of Public Roads



A, Uncontrolled Weed Growth on the Roadside. B, Pleasing Appearance of a Roadside Where Weeds Are Controlled.

WEED CONTROL and eradication on roadsides is an important function of State and local road maintenance organizations. One midwestern State highway department has spent an average of $639,286 per season or 18.8 percent of its total maintenance expenditures during the past 3 years for eliminating and controlling undesirable weed growth along State highways.

The increasing demand for broad, well-kept highways on ample rights-of-way has given increased importance to the problem of weed control and eradication. Without adequate methods of eradicating or controlling weeds it is not possible to have roadside attractiveness developed to its full extent. Simplicity and neatness are among the first requirements in roadside treatment. A rank growth of tall weeds may partake of simplicity but such a growth continuously along the highway can never be neat.

During the fall of 1935 a survey was begun by the Bureau of Public Roads to obtain data on the weed-control practices of each State highway department and other agencies. A compilation of such information should be useful to maintenance organizations in more effectively meeting the problems involved.

Reports were received from maintenance engineers covering the procedure, cost, effectiveness, and extent of weed prevention and eradication methods in use by all State highway departments. Information was also obtained from leading authorities on weed control either through correspondence or review of their publications. After a detailed study and analysis of all available material, this report, covering mowing, blading, burning, tillage, planting of smother crops, and application of herbicides, was prepared.

A road supervisor or patrolman directing operations to control or eradicate weeds should first observe and classify existing vegetation to determine the types to be considered weeds, as judged by their advantages and disadvantages. It is usually possible then to plan field operations that will tend to discourage or eliminate objectionable types and leave unharmed or encourage preferred types of growth.

By definition a weed is "any harmful or useless plant; a wild plant which hinders the growth of cultivated ones; anything useless or troublesome." Any plant that is or may become undesirable in its particular location, injurious to crops, or people, can be considered a weed. A plant that is very useful in one location may be harmful in another. In the United States poppies are not considered weeds, yet in France they have become one of the worst weeds.

Weeds on roadsides help to prevent erosion by water, wind, or traffic. Their usefulness in this respect may easily be overestimated unless other factors are considered. Most weeds, particularly those on newly constructed roads, are annuals having a luxurious top growth during the late spring and summer months. Their root systems, however, do not afford the same protection as the more extensive root systems of perennials. From late fall to well into the spring months, the period of greatest erosion in most localities, root systems of annuals afford little protection.

Recent studies by the United States Department of Agriculture have shown that for each climatic or soil condition there is a type of desirable vegetation that requires little or no encouragement to grow and that will prevent soil erosion equally as well as undesirable varieties do. The pioneering annual or early ruderal types of vegetation are usually most valuable as temporary forerunners of more permanent plants that are desirable as ground-cover protection. Weeds give way to more desirable vegetation on roadsides where proper maintenance methods are practiced.

WEED CONTROL ESSENTIAL FOR WELL-KEPT ROADSIDES

Every State highway department has the objective of keeping its roadsides free from trash and debris, neatly mowed, and of a generally pleasing appearance.

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Extensive planting and landscaping cannot be done immediately on all the main highways but clean-up of debris and control of undesirable growth is a possibility on all main roads and on many secondary roads. The improved appearance of roadsides produced by weed control is sufficient to warrant the expenditures made and the highway officials need seek no further for justification. However, there are a number of other benefits.

Some of these benefits relate to the highway itself. Tall weeds may lessen the sight distance on curves and at intersections. Even low-growing weeds may hide culvert headwalls, guardrails, markers, and other obstructions. Culverts and drains may become clogged with weed growth causing washouts or other damage.

Weeds may cause drifting of snow, and in a few areas the drifting of soil, that blocks the highway. They may also cause desirable drifting that protects the road. In such cases a permanent planting of selected material is to be recommended in place of the weeds.

Weed control on highways is of definite benefit to agriculture. Seeds from uncontrolled weeds on the roadside are continually carried to adjacent fields by wind, water, and birds. Passing automobiles carry them to distant points to infest new areas. Agricultural specialists and progressive farmers attach considerable importance to the control of weeds along fence rows and roadsides. Laws have been enacted in many States making highway officials responsible for destroying weeds but these laws are seldom rigidly enforced. The spread of any kind of weed to farm fields is damaging and certain kinds of weeds have rendered valuable land almost worthless.

Weeds such as wild lettuce, Russian thistle, dock, and wild mustard often harbor insects that invade field crops during certain seasons. The weeds shelter the insects during the winter months when they might otherwise be destroyed.

The pollen from some weeds causes hay fever. Contact with poison ivy, and poison oak, often results in severe skin injury.

Dry weeds are a fire hazard to adjacent fields, woods, and structures. The hazard is accentuated by the danger of burning cigarettes and cigars thrown from cars.

That weed control is desirable is now generally accepted among highway officials and some effort at control is made on practically all of our main highways. However, the effort is not always made at the right time or by the best methods. It is believed that wherever control is attempted, it should be made sufficiently effective to prevent reproduction of undesirable growth, thus lessening the amount of future control work.

In deciding upon the most effective or practical method of control it is necessary to consider the weed's habits, habitat, and distribution. It is important to know the time and conditions under which seeds germinate; how much time is required to mature seeds; whether the plant dies at the end of 1 or 2 years, or lives several years; and whether it reproduces and spreads only by seeds or also by vegetative propagation. Such information will often enable the supervisors and patrolmen to check or stop natural reproduction of weeds.

Weeds may be classified into four general groups as follows:

1. *Annuals.*—Plants that complete their growth and die in 1 year. They depend upon seeds for reproduction. Examples are puncture vine, ragweed, Russian thistle, and wild oats.

2. *Winter annuals.*—Plants having seeds that germinate in the fall and complete their growth the following spring. Examples are chickweed and shepherd's purse.

3. *Biennials.*—Plants that require 2 years to complete their growth, storing up food during the first year and completing growth and seeding the second year. Most biennials depend entirely upon seeds for propagation. Examples are bull thistle, burdock, and wild carrot.

4. *Perennials.*—Plants that live 3 or more years and reproduce from both seeds and roots. Examples are bindweed, Canada thistle, dock, oxeye daisy, and Johnson grass.

SEVERAL METHODS USED TO CONTROL AND ERADICATE WEEDS

Annuals, winter annuals, and biennials can be effectively controlled and finally eradicated by preventing the formation of seed. Methods that will kill the roots must be used to eradicate perennials, but preventing the formation of seed will help confine them to a limited area.

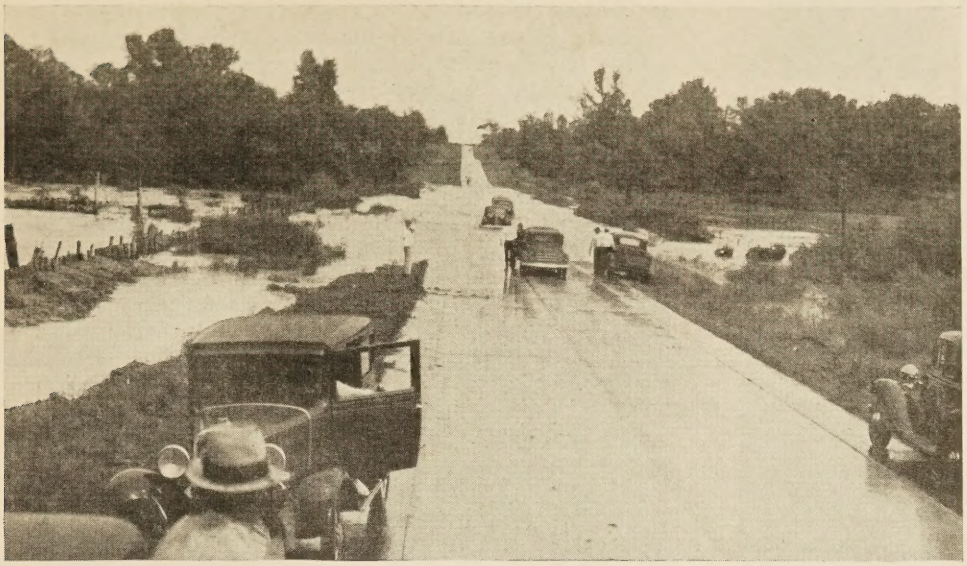
Methods for controlling weeds are mowing, burning, blading, dragging, steaming, hand pulling, hoeing, smothering, and killing with herbicides. Each of these methods has certain advantages and disadvantages that must be considered before it is possible to determine the most effective method to use under given conditions. Maintenance personnel must recognize fully the importance of all factors that influence the effectiveness of the various methods and must take advantage of all favorable conditions to make the methods used as efficient as possible.

Timely mowing is an effective method of controlling most annual weeds. By thus preventing seeds from maturing, their only means of propagation is destroyed. Mowing is the most practical method of discouraging objectionable weed growth and encouraging desirable permanent types of vegetation on roadsides and large areas where funds for weed eradication are very limited.

Complete eradication of perennial weeds by mowing is difficult, and satisfactory results are obtained only by monthly cuttings during the growing season over a period of years. Mowing often enough to prevent the formation of seed will confine the perennial weeds to a limited area.

Unless mowing is done at the proper time, it may actually spread the growth of weeds. As a rule, it is best to mow when weeds have reached the bloom stage. All too frequently weeds are mowed when they are in seed and the plants are left on the ground to dry. The flowers of many plants are formed over a period of several weeks, and although the plant has the appearance of being in flower, it may have mature seeds or seeds developed far enough to mature. Early destruction is desirable if reseeding is to be prevented. It is impossible to specify the best date for the mowing of all weeds in all localities, as different species produce seeds at different seasons and the same species mature at different dates in various locations. For this reason, each highway patrolman or supervisor should be familiar with the weeds in his section and should know the proper time to cut or destroy the weeds of each variety to prevent seed formation.

Mowing the roadsides one or more times each season is a common procedure and in many States this is all that is done to control weeds. The number of mowings

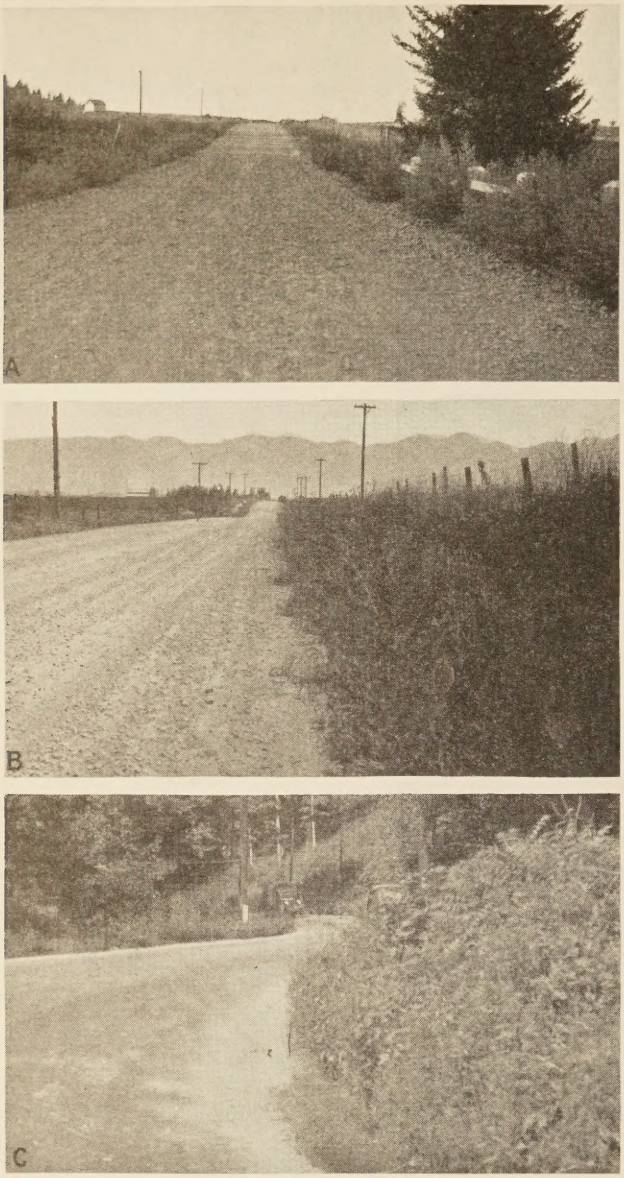


Overflow Caused by Weeds and Silt Blocking Ditch on Left Side of Roadway.

Tumbleweeds Caught Along Fence Lines May Cause Snowdrifts Across the Roadway During Winter Months.

Ditches Filled with Drift Sand and Soil Deposited Along Fences Where Tumbleweeds Were Allowed to Collect.

WEEDS MAY MAKE ROADS IMPASSABLE BY CAUSING WASHOUTS, SNOWDRIFTS, OR DEPOSITS OF SAND AND SOIL.



WEEDS MAY BECOME A MENACE TO TRAFFIC: A, BY REDUCING THE EFFECTIVENESS OF GUARDRAIL; B, BY CONCEALING MARKERS AND OBSTRUCTIONS OUTSIDE THE TRAVELED WAY; AND C, BY SHORTENING SIGHT DISTANCES AT CURVES.

per season, the width covered, and the main purpose of the mowing operations vary greatly between States. The number of mowings varies from 1 to 8; the width varies from one swath on the shoulders to the entire right-of-way.

The general practice by a majority of highway departments is to mow and remove weeds in the fall during the yearly clean-up of the entire right-of-way after the weeds have completed their growth. This clears the roadside of dead growth that might clog the ditches and culverts and cause formation of snowdrifts on the roadway during the winter and spring months, but helps very little in the control or permament eradication of undesirable vegetation.

In addition to mowing over the entire right-of-way in the fall, the majority of State highway departments also mow over the shoulders one or more times during the growing season. A few mow over the entire right-of-way 2 or 3 times, the shoulders 4 to 8 times, and supplement these mowings by hand cutting of weed patches as needed to keep seeds from maturing.

The equipment used for the mowing operation includes truck- or tractor-drawn hay mowers, power mowers, ordinary horse-drawn farm mowers, and hand scythes. When mechanical mowers are used, weeds around headwalls, guard rails, fences, signs, highway markers, and other obstructions where the mechanical unit cannot be used are cut by laborers using scythes.

The most effective type of mechanical mowing unit depends largely upon the width and roughness of the roadside to be cut over and the number of headwalls, highway markers, or other obstructions present. The type preferred by maintenance superintendents in a majority of States, especially when cutting over the entire right-of-way, is the common, horse-drawn farm mower. Two of the reasons for this preference as given by men in charge of maintenance operations on State highways are as follows:

1. The units can be operated efficiently over comparatively rough ground and close to obstructions, thus reducing to a minimum the amount of hand work required.

2. Farm-owned mowers can be rented at reasonable rates, thus reducing the amount of State-owned equipment required and efficient operators experienced in maneuvering mowers in and out of ditches and over rough slopes can usually be hired from local farms.

The horse-drawn farm mower costs less to operate and the consensus of opinion is that better work is done than with other types of mowing units.

MECHANICAL MOWING CHEAPER THAN HAND MOWING

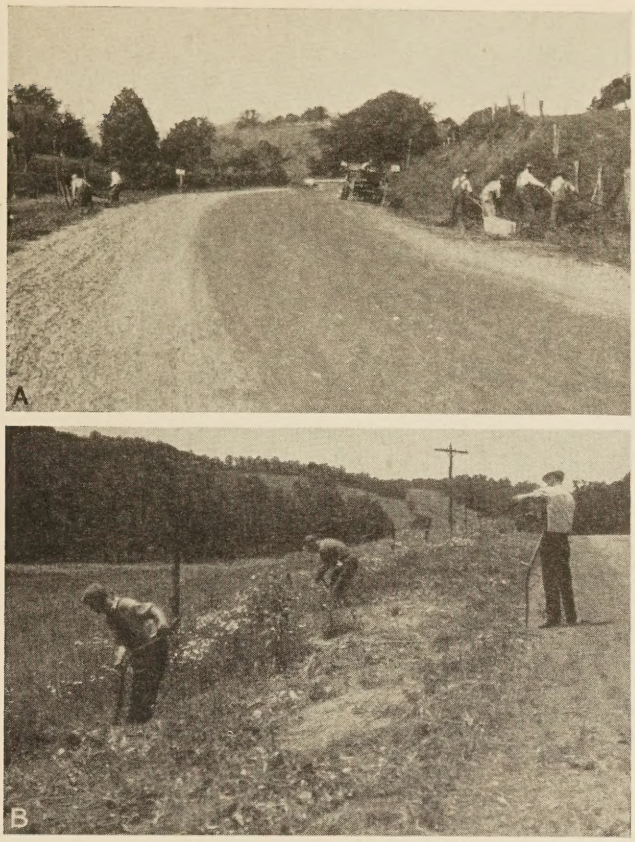
Hourly rates for hired mowers, including two horses and the operator, varied from 60 cents to 1 dollar during 1935 in the States that furnished cost data for this operation. The resulting costs varied from $1.20 to $2.43 for a round trip over 1 mile of highway or $0.99 to $2 per acre. One State hiring mowers on a mileage basis paid $1.30 per round trip over 1 mile on old roads and $1 on roads recently graded where the cutting was easier because of modern design.

Mowers drawn by light trucks are very effective on shoulders and other places where there are few obstructions. Some States, however, prefer to use two mowers drawn by a light tractor as they have found that truck gears require frequent replacing when the truck is used continuously at speeds of 4 or 5 miles per hour. One man is able to operate a tractor and mower unit while two are usually required with a truck unit.

Numerous special types of self-propelled machines have been built by State forces for cutting roadside weeds. These include mowers attached to tractors with power take-offs and mowers attached at the side of a truck. Equipment manufacturers have also placed on the market several types of self-powered mowers especially designed for roadside work.

All of the self-powered units and truck-drawn mowers have been tried by various State highway departments. Many have been discarded in favor of the horse-drawn mower. In sections where it is impossible to obtain sufficient teams when desired, the power units have been developed to a point where they are considered very satisfactory.

Hand mowing with labor at $0.40 per hour costs about $5 per acre. This is considerably higher than the cost of cutting with horse-drawn or engine-powered



A, Cutting Weeds by Hand Around Obstructions and on Slopes Inaccessible to Mechanical Mowing Units. B, Cutting Patches of Weeds Before They Form Seed and Spread to Adjoining Fields.

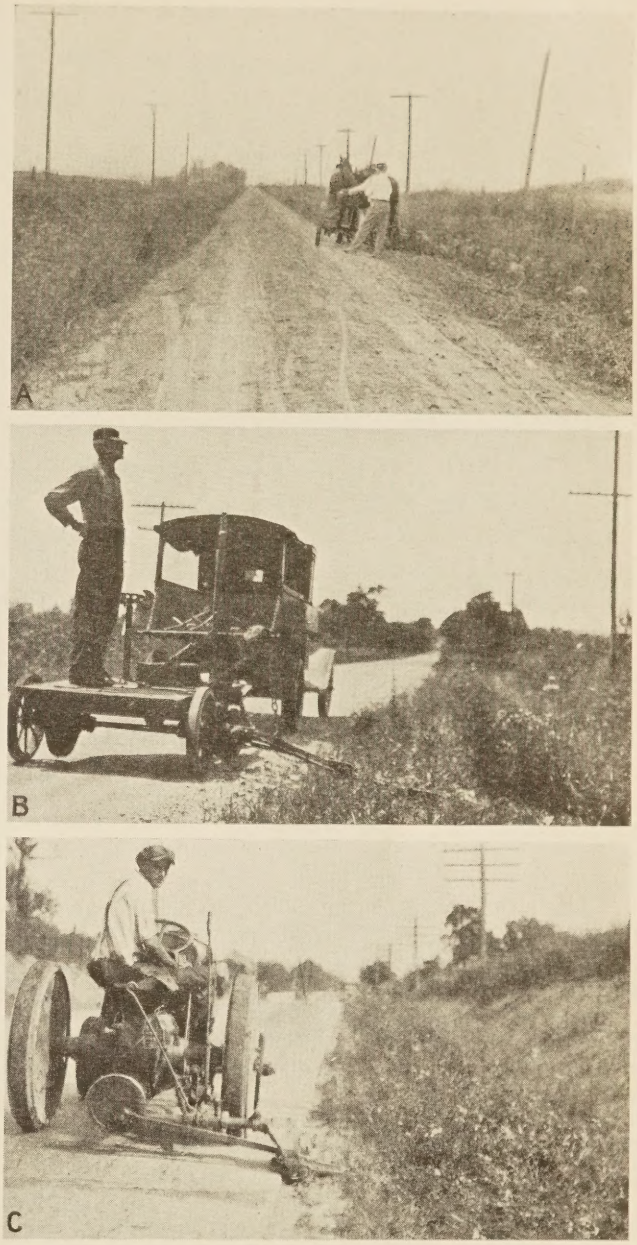
mowers. Some States prefer to use mechanical units on accessible sections first and then finish with hand scythes. Others precede mechanical mowing with hand cutting around all obstructions, trees, and desirable plants so that they will be in plain view of the operators of mechanical units.

Recent designs for highway cross sections have features, intended primarily to improve roadside appearance, that greatly facilitate mowing. Flatter slopes and rounded shoulders, gutters, and ditches have made a greater portion of the rights-of-way accessible to mechanical mowers.

Cooperation between maintenance personnel and landscape engineers is essential for economical roadside development. Volunteer growth that will develop into good shade or ornamental trees can be saved during the mowing operation if they are properly identified. Arranging roadside plantings so that weeds can be cut with a minimum of hand work will help materially in developing roadsides without increasing expenditures for grass and weed cutting.

Some States prefer to mow roadside weeds frequently, the cuttings being left on the right-of-way. Where tumbleweeds are removed from shoulders primarily to prevent snow drifts, cutting to pieces with a disk harrow has been satisfactory. Leaving vegetation to decay increases the fertility of the soil and eliminates damage from burning, provided accidental burning does not occur.

Weeds can be burned with a flame while they are green, as they stand after forming seeds, in piles after being cut, or after being sprayed with gasoline, oil, or

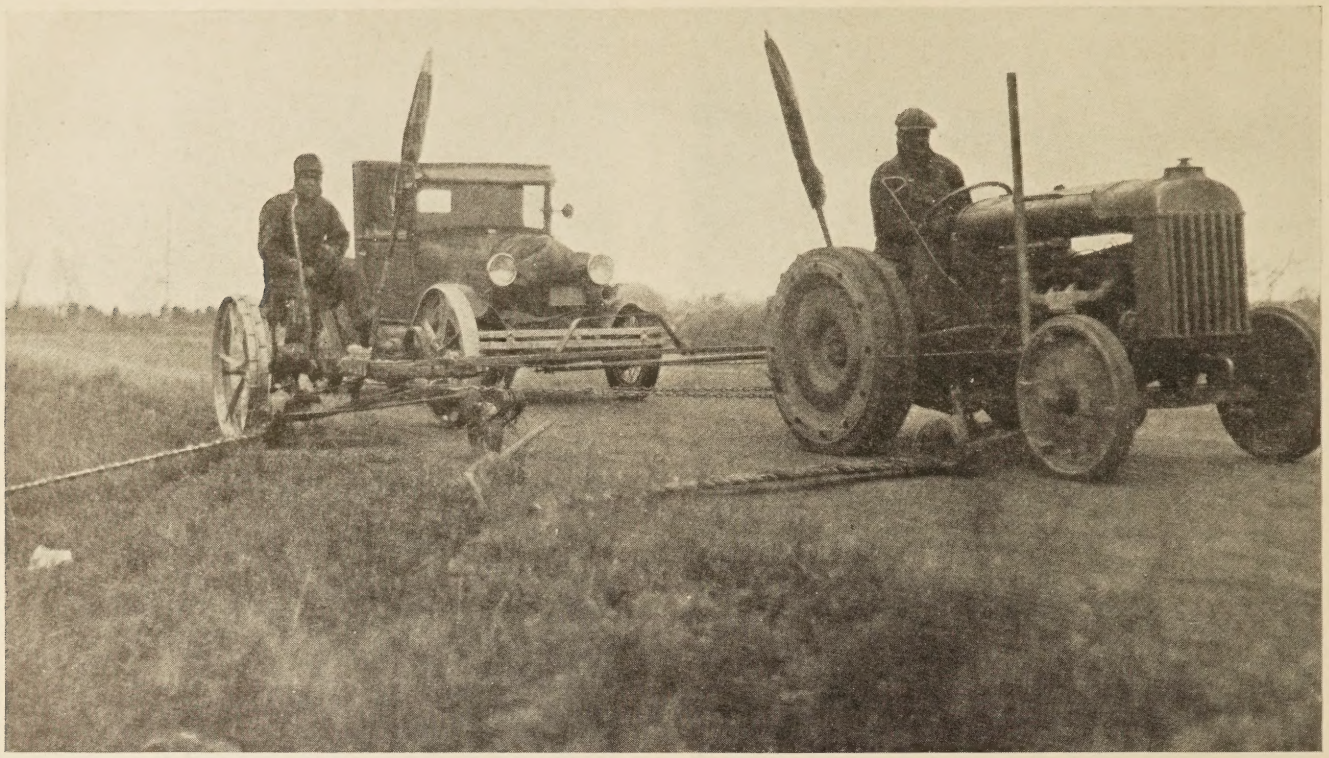


A, the Horse-Drawn Farm Mower is Still the Most Commonly Used Mowing Unit on Roadsides. B, Mower Being Pulled by a Light Truck. C, Tractor With Power Take-Off for Operating Mower.

other herbicides. Adequate control is assured if both plants and seeds are destroyed. The principal objections to burning are the fire hazard, particularly in timbered and grain-raising country, and the hazard to traffic from blinding by smoke.

Special care must be taken to see that adjoining property, fence posts, trees, etc., are protected, and provision must be made for warning traffic.

There are two general types of burners for green vegetation—the oven burner and the extended burner. The oven burner confines the heat and flame in an oven which is mounted on wheels or on the side of a truck. The extended burner is equipped with one or more burners on extended arms which may be operated individually or collectively and are controlled by the operator. Single burners are manufactured that will



DUAL MOWERS PULLED BY TRACTOR.

shoot a flame for several feet and can be carried and operated by one man. These have been found to be useful in burning small scattered patches of weeds.

To be effective, burning should give the vegetation a thorough scorching. The great amount of heat required makes burning impractical on large areas of green weeds over 6 inches high.

Burning is a method of last resort applicable to roadsides on which weeds have been allowed to mature a crop of seeds. Dry weeds with attached seeds are best burned as they stand. Mowing before burning merely scatters the seeds and those on the surface of the soil are seldom exposed to a sufficiently high temperature to be destroyed.

After mowing dense vegetation or weeds that are beyond the full-bloom stage, it is advisable to pile and remove them from the roadside to prevent clogging of drainage facilities and the ripening of seeds starting to mature. Burning the piles when dry is the cheapest method if it can be done without injuring desirable growth or causing unsightly scars along the right-of way.

SPECIAL PRECAUTIONS NECESSARY WHEN ROADSIDE WEEDS ARE BURNED

It is also possible to burn green weeds after spraying with oil or killing with certain herbicides.

Present burning practice of the State highway departments is extremely varied. Some departments, Indiana for example, allow no burning on the right-of-way because of the danger to traffic. The majority of the departments do allow burning on the right-of-way, especially when the growth is heavy, but issue detailed instructions to the patrolmen prescribing methods that must be followed to safeguard persons and property.

Burning is accomplished in New Mexico and Nevada by a steel drag with a fire ball attached that is pulled along the shoulders and ditches by a truck. The fire ball sets the loosened weeds on fire as it moves along. Old tires are sometimes used as the kindling material.

New Jersey permits burning only in the spring while the ground is still wet enough to protect the grass roots. Minnesota permits burning only on sandy areas, because of the danger of peat-bog fires, and only after May, so that nests of partridges and pheasants on the right-of-way will not be destroyed.

Below are listed a few of the suggestions in regard to burning operations as given by State highway officials to patrolmen in States where burning is allowed:

1. Unless there is a natural firebreak adjoining the right-of-way, burn only on the windward side of the highway so that the road surface will act as a firebreak. This necessitates exposing motorists to smoke and fumes.

2. Make adequate provision for warning traffic to slow down and stay on the right side of the road while passing through smoky areas.

3. Conduct the burning operation in such a manner as to avoid the formation of dense smoke.

4. Make adequate provision for protecting desirable vegetation from intense heat.

5. Any burning with mobile equipment should be closely followed by fire-extinguishing equipment. This is best done by a patrol equipped with knapsack fire extinguishers or a tank truck with sufficient water hose to reach beyond the area being burned.

6. In forest areas, cooperation between patrolmen and forest rangers is highly desirable.

Only three States reported the cost of burning operations. These are listed below:

California—Burning vegetation about 2 weeks after treating with oil costs $20 per mile for two 9-foot strips.

New Mexico—One man at 40 cents per hour can burn tumbleweeds on both sides of one-half of a mile of road in 1 day at a cost of $3.20. With a drag and

Burning Weeds Along Highways. A, Mechanical Weed Burner; the Individual Oil Burners Can Be Operated Singly or Collectively. B, Warning Traffic of Weed-Burning Operations, Which Are Hazardous to Both Traffic and Desirable Vegetation.

truck costing $7 per day and two men to control the burning and each paid 40 cents per hour, the cost was $4 per acre.

Idaho—The cost to pile weeds ready for burning was $5 per mile of road.

The cost of using burners on 24,618 miles of single track by five railroads during 1934 averaged $4.47 per mile including all labor, materials, equipment, and overhead charges.

Blading.—While scraping with a blade grader is considered to be an inexpensive means of destroying numerous young weeds on the roadside, it serves only to spread the plants if done after seeds are formed. Any blading operation has the disadvantage of disturbing and loosening the soil to wind and water erosion so that the ultimate cost, considering damage done and discomfort caused by the dust, may well exceed the cost of more satisfactory methods. Blading mixes the weeds and earth together so that the weeds cannot be burned satisfactorily.

Many State highway departments prohibit the use of blades on ditches, shoulders, and slopes, as they

desire these areas to become covered with vegetation. Some States even haul in material to keep the shoulders smooth rather than use a blade. In the arid regions of such States as Arizona, New Mexico, and Nevada, and in places where firebreaks are desired, blading has been used quite extensively to remove weeds. Even in these sections there is an increasing tendency to mow the weeds and allow growth of vegetation in harmony with the surrounding country. Mowing allows the soil humus to be built up to support desirable vegetation sooner than if blading is practiced. Removing weeds with a blade pulled by a truck or tractor costs about the same per cutting as by mowing but the seasonal cost is less as blading is not required so often.

DRAGGING, HAND PULLING, AND SMOTHERING OF WEEDS USED TO A LIMITED EXTENT

Dragging.—A number of improvised drags are used by highway departments for clearing weeds from the right-of-way. In New Mexico frames of 4-by-4-inch timber 12 feet long and 7 feet wide faced with old grader blades extending three-fourths of an inch below

Pulling Dry Weeds on a Desert Road by Means of a Weighted Wire Mesh.

the timbers are used in the fall to gather tumbleweeds along shoulders. The drags are pulled by light trucks and are automatically dumped when full of weeds. One man with this equipment can cut and pile the weeds on both shoulders of a highway ready for burning over an average length of 15 miles of road per day.

In South Dakota A-frames are used to clear weeds from the right-of-way, and in Wyoming cables or chains weighted with pieces of iron serve the same purpose. Other States use harrows for cutting and piling the weeds.

These methods tend to spread the seeds but are effective in removing tall weeds which may cause snowdrifts, especially in the semiarid sections where the run-off from the surfaces causes an abnormal growth of weeds on the shoulders. Little damage is done to desirable grasses.

Steam.—Although a number of railroads have used steam in keeping down the weeds along their tracks, there is no record of similar practice on roadsides. The probable reason is that the railroads have equipment on hand that can readily be adapted to this purpose. Superheated steam does not actually destroy weeds and will not kill hardy or fibrous vegetation; it merely wilts the tops and keeps them down temporarily. The less hardy types are killed. A first application at 600 to 900° F. during the early growing season while the vegetation is tender, followed by a second application 3 or 4 weeks later has been found by the railroads to give the best results. Steam boxes 20 feet long are moved at 2½ miles per hour where the growth is thick and at 4 miles per hour over areas with small weeds.

The average cost per treatment including labor, materials, equipment, and overhead is reported as $10.93 per mile over 6,272 miles or approximately 1 dollar per mile per foot of width. Four treatments per year are usually required.

Hand pulling.—Hand pulling, spudding, and hoeing, although very effective methods of weed eradication, are too costly to be used to any great extent on roadsides. Their use is confined to the control of special areas or to the supplementing of mechanical methods in spots not reached by the equipment. A few scattered weeds that are very undesirable can be removed by hand with little work, whereas if allowed to mature they may thoroughly seed a larger area and make more trouble in the future.

The best time to pull or hoe weeds is while the ground is moist and while they are in full bloom, as the roots are then the weakest. This is especially true for annuals and biennials that are largely exhausted.

Smothering.—Smothering of undesirable vegetation can be done by covering with burlap, paper, or other material, to exclude the light or by planting or making conditions favorable for vegetation that will crowd out the objectionable plants by either root or top growth. The first of the two methods is impractical for large areas but has been used to a very limited extent on patches of poison ivy and other vines.

Any grass, plant, vine, or shrub that has no undesirable tendencies and is hardy enough to withstand or predominate over the weeds by making conditions unfavorable for them can be used as a smother crop. In cultivated fields, millet, Sudan grass, oats, corn, peas, and sorghum have been successfully used to reduce the number of weeds prior to planting other crops. Native perennials or annuals that will reseed themselves are more desirable for smothering weeds on roadsides. Some State highway maintenance departments favor suitable low-growing ground covers like colorful wild flowers and dwarf grasses by raising the mower blade sufficiently to permit the low-maturing plants to reseed themselves naturally, without competition from high-growing, objectionable species like Johnson grass.

Maintenance supervisors should not, however, permit attractive blooms or misleading names to prevent the early destruction of such weeds as the oxeye daisy, toad flax, Jimson weed, wild carrot, and flowering spurge if they are adjacent to cultivated fields. Common misnomers of these weeds are white daisy, wild snapdragon, devil's trumpet, Queen Anne's lace, and baby's breath, respectively. The Shasta daisy is bigger and showier and should be encouraged in place of the oxeye daisy, as it does not have the tendency to become harmful.

VARIOUS CHEMICALS USED TO KILL WEEDS

Many States cover steep slopes that are impossible or difficult to mow with appropriate woody, ground-cover vegetation like native vines, Japanese honeysuckle, wild grapes, dwarf flowering locust, low forms of sumac, and even dwarf varieties of cacti. In addition to increasing the esthetic benefits, such plantings should have as their objective a reduction in maintenance expenditures. Garden shrubs placed on high

PILES OF WEEDS THAT HAVE FORMED A CARPET OVER THE EDGES OF THE PAVEMENT. THESE WEEDS, ABOUT 6 MONTHS OLD HAVE BEEN CUT AT INTERVALS OF 10 OR 15 FEET AND ROLLED UP PREPARATORY TO REMOVAL.

banks and struggling for existence against uncut weeds are not effective and should not be planted.

The present knowledge of the use of chemicals for controlling weeds has been developed during the past 45 years, though the most progress has been made during the last 10 years. Except for a few chemicals such as arsenical compounds, salt, or oil used to kill weeds along paths, driveways, and roads, the development of their use has been primarily for agricultural purposes. Many important facts concerning the use of chemicals for weed eradication and control that have been brought out in these developments should be known by highway maintenance departments.

Numerous examples are available to show that the use of herbicides in the control of weeds along highways is both practicable and economical under certain conditions. In one political subdivision the use of chemicals on roadsides for 4 years has made it possible to reduce the expenditures for weed control to one-sixth the amount formerly spent when only cutting and mowing were practiced. Further reduction in cost is anticipated by their continued use. Several of the larger railroads favor chemical treatment in preference to repeated mowing or cultural methods which are slow and difficult to effect.

The following is a list of the most important herbicides:

Ammonia compounds.	Formaldehyde.[1]
Arsenic acid.	Hydrochloric acid.[1]
Carbolic acid.[1]	Iron sulphate.
Carbon bisulphide.	Kerosene.
Caustic soda.	Mercuric chloride.[1]
Common salt.	Nitric acid.
Copper nitrate.	Sodium arsenite.
Copper sulphate.	Sodium chlorate.
Crude oils.	Sodium nitrate.
Cyanide compounds.	Sulphuric acid.

[1] Use limited to experiments so far as is known.

Chemicals suitable for killing weeds along highways must be effective, easily applied, and cheap enough to be more economical for the particular work than other methods. They may be grouped into three types:

1. Chemicals that produce soil sterility for a period of several months.

2. Chemicals that kill all vegetation but do not produce sterility of the soil for any appreciable time.

3. Chemicals used in selective sprays to kill certain weeds without permanent injury to other vegetation growing among the weeds.

Some chemicals may be used to make a solution that will fall in any one of these classes by properly controlling the concentration or the rate of application.

The herbicides falling in group one may be used on the traveled way of highways, driveways, and walks, on patches of weeds, and sometimes on shoulders, along fences, under guardrails, and around culvert headwalls and route markers. Those of the second group are used chiefly on areas where it is desired to replace the present growth with more suitable vegetation. Chemicals of the third group, now used chiefly in the treatment of grain fields, might possibly be used in the treatment of lawns and grass-covered roadsides.

Table 1 lists the weeds killed, the chemicals used, the solutions or rates of application, and general information regarding effective experimental or practical applications of herbicides by various State and Federal agencies, commercial firms, and individuals as reported in publications on chemical weed control. The bibliography at the end of this report shows the source of all information presented in table 1.

Ammonium sulphate.—Although ammonium sulphate is one of the best chemicals for the control of weeds on

121624—37——2

TABLE 1.—*Summary of effective herbicidal applications*

[As obtained by review of publications on chemical weed control]

Bibliographical reference number	Authors' classification of weeds reported killed	Chemical	Rate of application: Pounds of chemical: Per 100 gallons of water	Rate of application: Pounds of chemical: Per 1,000 square feet	Rate of application: Gallons of solution per 1,000 square feet	Remarks
37	Dandelions in lawns	Ammonium sulphate	125	8.4	6.7	Apply dry or in solution 3 to 5 times 2 weeks apart during early spring or late fall on cloudy, damp days while the grass is dry. Chemical acts as fertilizer to lawn grass.
52	Lawn weeds	do	50	3.0	6.0	
52	All vegetation	Ammonium thiocyanate	200	8.0	4.0	No toxic effect after 3 months when sulphur is added to the soil. Converted into ammonium sulphate, which is a good source of nitrogen for plants. Best results if applied in solution.
29	Deep-rooted weeds	do		22.0		
29	Canada thistle, poison ivy, quack grass, and sow thistle.	do		14.7		
22	All vegetation	Copper sulphate	20–30	0.28–.42	1.4	Use spray in clear weather.
52	Wild mustard and radish	do	[1] 25			Saturate plants. Used as selective spray for grains.
22	All but grass and grains	Iron sulphate	200			Spray while plants are growing, on clear, bright day.
3	Buttercup, chickweed, dandelion, heal all.	do	150	5.0	3.3	Use on warm, dry days. Injures clover but not grass.
17	Dandelions in lawns	do	150–200	4.4–5.8	2.9	Spray 4 or 5 times 1 month apart.
37	do	do	125	8.4	6.7	Apply 3 to 5 times 2 weeks apart in spring when grass is dry, on cloudy, damp days. Will not hurt lawn. Mow lawn before applying.
38	Dandelions	do	150	4.5	3.0	
52	Dandelions in lawns	do	200	5.0	2.5	
17	Moss in lawns	do	125	1.4	1.1	
11	Annual weeds	Arsenic acid	8.4			
49	Hard-fern	Arsenic pentoxide	3			Spray during December to April.
49	Hoary cress	Arsenite	50	2.2	4.4	Spray during warm, dry weather.
24	All vegetation	Arsenic trioxide		6.9		Spray, adding 4 pounds soap per 100 gallons of solution.
24	Wild morning glory	do	4			Roots killed best in fall. Spray during moist weather.
52	Bindweed	Arsenite	1	.12	11.5	Mix chemicals in quantities indicated.
		Sulphuric acid	5	.6		
52	Shrubs	Arsenite	10			2 to 4 gallons per shrub, depending on size.
63	All weeds—average conditions	Sodium arsenite	10	1.4	13.8	2 or 3 applications for perennials, 1 application for annuals.
63	All weeds—in Idaho	do	3.3–4.2	.45–.58	13.8	
22	Most weeds	Caustic soda	4	.46	11.5	Large vegetation should be mowed before spraying. Mix chemicals in quantities indicated.
		White arsenic	8	.92		
1	All weeds	Caustic soda	5–6			Mix chemicals in quantities indicated.
		White arsenic	18–20			
36	Canada thistle, quack grass, and wild morning-glory	Caustic soda	1.1			Caustic soda and white arsenic are mixed in concentrated solution and added to water with sulphuric acid as needed. Apply as spray when plants are dry and wilted but when air is moist.
		White arsenic	4.4			
		Sulphuric acid	5.6			
52	Lawn weeds	Lead arsenate		5.0		Apply dry. Results are not certain.
52	All types	Carbon bisulphide				Apply at roots.
57	Perennials	Carbon disulphide				Apply in holes 2 feet apart. Make holes 12 to 18 inches deep.
63	All; especially grasses	Oil		[2] 6.9		Kills seed.
11	Annual weeds and seeds	Diesel oil		[2] 6.9		
61	Roadside vegetation	do		[2] 11.1		Used to provide firebreak in California.
22	All vegetation	Petroleum oil		[2] 6.9–9.2		
52	Annual weeds	Sulphuric acid	25–84	.6–1.2	1.4–2.9	Spray when atmosphere is dry.
14	Most weeds	do	17–84			(Experiments in Arizona).
14	Puncture vine	do	17			Do.
10	Wild mustard	do	84	2.5	3.0	For use during normal weather.
10	do	do	125	2.6	2.1	For use during damp days.
30	Canada thistle, morning glory, poverty weed, quack grass, etc.	Calcium chlorate or magnesium chlorate.		11.0		(Experiments in Idaho). Use 18.4 pounds per 1,000 square feet in irrigated soil.
30	Blue flowering lettuce, sow thistle, white top.	do		22.0		(Experiments in Idaho). Use 29.4 pounds per 1,000 square feet in irrigated soil.
30	Yellow toad flax	do		14.7		(Experiments in Idaho).
30	Leafy spurge	do		25.7		Do.
6	Canada thistle	Potassium chlorate	54			
51	do	do		5.5		Apply dry in late fall.
4, 5, 30, 39, 50, 60, 63, and 67.	Common perennials	Sodium chlorate	100			
62	Annuals and biennials	do	100	5.0	5.0	
5	Perennial weeds	do		7.4		Apply dry when tops are dead.
62	Perennials	do	150	7.5	5.0	
33 and 56.	Most weeds	do		11.0		Use dry or in solution during cool weather.
28	Most vegetation	do	200	7.4	3.7	One application only at blossom time.
28	Most vegetation including bindweed and perennials.	do	100	2.3	2.3	First application at blossom time, rest after new growth starts, 2 or 3 applications necessary.
62	Arkansas bedstraw, cypress spurge, leafy spurge and St. John's wort.	do	150		Saturate	Spray when 4 to 5 inches high and repeat in a month's time.
53	Bermuda grass	do		4.6		Two applications necessary in Oklahoma.
62	Bindweed	do	100–150		Saturate	Spray during flowering stage or late June and repeat in a month's time.
22	Bindweed: Heavy growth	do	100	3.4	3.4	Apply on moist days. Soil not sterile long.
	Bindweed: Ordinary growth	do	100	2.3	2.3	
68	Bindweed: First treatment	do	100	3.4	3.4	3 treatments. First treatment before plants bloom.
	Bindweed: Second and third treatments	do	100	2.3	2.3	
37	Bindweed	do	100–300	9.2–11.0		Soil conditions govern solution to be used.
40	Bindweed: First treatment	do	100	3.4	3.4	2 or 3 treatments necessary when weeds are in full bloom.
	Bindweed: Second and third treatments	do	100	2.3	2.3	
4	Bindweed: First treatment	do	100	4.6	4.6	First treatment latter part of June when there is a heavy growth. Second treatment 6 weeks later.[3]
	Bindweed: Second treatment	do	100	2.3	2.3	
30	Bindweed, Canada thistle and quack grass.	do	100	11.0	11.0	Experiments in irrigated sections of Idaho.

[1] Amount for dry regions. In moist climates use 42 pounds of copper sulphate per 100 gallons of water.

[2] Gallons.

[3] One-half teaspoon of sulphuric acid and 1 teaspoonful animal glue to each gallon makes solution more effective. Acid hastens diffusion through cuticle. Glue keeps solution in contact with the weeds longer.

TABLE 1.—*Summary of effective herbicidal applications*—Continued

Bibliographical reference number	Authors' classification of weeds reported killed	Chemical	Rate of application			Remarks
			Pounds of chemical		Gallons of solution per 1,000 square feet	
			Per 100 gallons of water	Per 1,000 square feet		
30	Blue flowering lettuce, leafy spurge, perennial sow thistle, white top.	Sodium chlorate	100	18.4	18.4	(In Idaho). In irrigated sections use 22 pounds per 1,000 square feet.
30	Canada thistle, morning glory, poverty weed, quack grass, and Russian knapweed.	do	100	7.3	7.3	(In Idaho). In irrigated sections use 14.7 pounds per 1,000 square feet.
62	Brush	do	125–150			Spray young shoots in spring after cutting during winter.
11	Canada thistle	do		4.0		Apply dry during fall. (Experiments in New York)
19	Canada thistle:					
	First treatment	do	150			
	Second treatment	do	250			
51	Canada thistle	do		3.7		Apply dry in late fall.
41	Canada thistle, European bindweed, Johnson grass, quack grass, sow thistle.	do	[4] 100			Respray in 6 weeks.
52	Chickweed, growing ivy, speedwell, and other broad-leaved, shallow rooted weeds.	do	9.4	.94	10.0	Will not injure grass. Kills crabgrass seedlings.
3	Chickweed, ground ivy, ironweed, oxeye daisy, speedwell, poison ivy.	do	12.5	1.25	10.0	Apply during cool weather. Does not injure grass.
62	Goldenrod	do	100			
26	Johnson grass	do		2.3		2 treatments required in Oklahoma.
5 and 51	Leafy spurge	do		7.3		Apply dry in late fall. (Experiments in New York.)
66	Oxeye daisy	do	50			No injury to grass during July. (Experiments in Ohio.)
62	Perennial sow thistle	do	100			Spray thoroughly and repeat in a month.
17	Poison ivy	do	100			Soak soil; 2 or 3 treatments may be needed.
28	do	do	200	7.4	3.7	1 application usually sufficient.
62	do	do	100			Saturate plants; 1 spraying usually effects 100 percent kill.
5	Quack grass	do		7.4		Apply dry in fall.
19 and 60	do	do	100	11.0	9.1	(Experiments in Washington and New Jersey.)
58	do	do		5.7		2 applications necessary (experiments in Virginia.)
66 and 67	Quack grass and Canada thistle	do	100	7.3	7.3	Total of all treatments—17.7 to 18.4 pounds per 1,000 square feet.
62	Ragweed	do	50–75			Spray just before coming into blossom.
54	Rifes petrolare	do	42–84			
22	All vegetation	Sodium chloride [5]	300	3.3–24.0	1.1–8.0	92 to 459 pounds per 1,000 square feet if applied dry. Apply on hot dry days. Removes all growth for a season.
52	Barberrybush, dandelions, poison ivy, and poison sumac.	do	300			Spray thoroughly. First application when leaves are full grown. Second and third as new leaves appear.
16 and 37	Bindweed	do		1,000		Almost permanent detrimental effect on soil.
68	do	do		918		Very expensive.
63	Most vegetation	do		1,000		5 to 10 tons per acre on large areas.
17	Poison ivy	[6]	300			Soak soil. Repeat in 2 weeks if necessary.
28	do	Sodium chloride [5]		1,000		Place ¼-inch thick on ground.

[4] Quantity for large plants. Use 150 pounds per 100 gallons of water as a respray. [5] Common salt. [6] Rock salt.

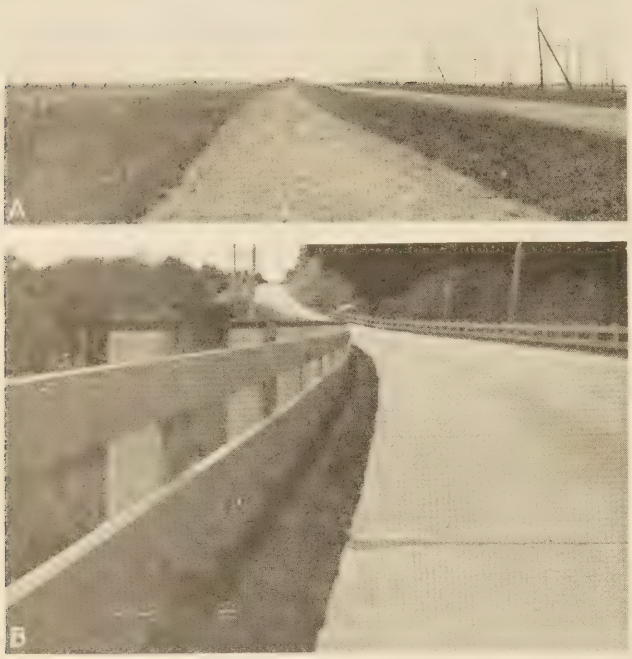
lawns, it is too expensive to be used to any great extent on roadsides. Traffic circles, center islands, parkings, and landscaped areas where the grass is kept mowed short and a dense turf is desired may be benefited by the use of ammonium sulphate. It is not only harmful to dandelions and many other common lawn weeds but also acts as a fertilizer to the grass. However, repeated use tends to make an over-acid soil that may be detrimental to the grass. The lawn should be well watered not sooner than 24 hours and not later than 48 hours after each treatment to prevent the grass from being burned.

Ammonium thiocyanate.—Ammonium thiocyanate, a byproduct of coke plants, acts on all vegetation very rapidly, but does not sterilize the soil for more than a few weeks. It is highly soluble, noninflammable, absorbs moisture from the air, and decomposes in a few weeks, liberating desirable fertilizers. These features, together with the fact that stock will not eat sprayed vegetation because of its repellent taste, make it a desirable herbicide for treating small areas of vegetation. Its cost—17 to 20 cents per pound during 1935—prohibits its use on large areas.

Copper sulphate.—Copper sulphate solution is sometimes used as a selective spray for killing young weeds, especially those such as wild mustard and wild radish plants, in localities where iron sulphate and sulphuric acid are not readily available. For best results, it should be used while the plants are still young and tender. It should be applied as a fine spray on clear days when there will be no rain for several hours.

Iron sulphate.—Iron sulphate has much the same destructive effect on dandelions and broad-leafed lawn weeds as copper sulphate and is a little lower in price. Grasses and grains are very resistant to the spray, and although it slightly blackens them at first they will soon recover.

Iron sulphate can be applied dry or in solution. A fine spray applied on humid days when rain is not likely to fall soon is most effective. Small patches can be sprayed with a sprinkling can or the chemical can be applied dry. If rain falls soon after spraying, the chemical will be washed off before the weeds are damaged. When application is made in dry weather the solution will dry and the residue falls off of the leaves before they are affected. The first application should be made in early spring and the other three to six necessary applications at intervals of 10 days to 2 weeks. Spraying should not be done in midsummer when the grass is inactive and the soil very dry. Lawns should be mowed 2 or 3 days both before and after spraying. Undesirable stains are produced when the solution comes in contact with buildings, walks, or clothing.



A, Firebreak Strip Formed by Treating Vegetation With Sodium Chlorate. B, Appearance During the Summer of Area Around Guardrail Where Sodium Chlorate Was Sprayed the Previous Fall.

SPECIAL CARE NECESSARY IN USE OF CHEMICALS THAT ARE POISONOUS TO MAN OR ANIMALS

Arsenicals.—Arsenicals have been used extensively as contact sprays for killing weeds along railroad tracks, highways, and, to some extent, in fields. Many commerical weed-killing solutions contain sodium arsenite.

The principal objection to arsenic and all its compounds is that they are very poisonous to both man and beast. When sprayed upon weeds they give them a brackish, sweet taste that is attractive to grazing animals. The greatest care must be exercised not to inhale the dust or fumes or to bring the hands near the face or mouth while using this chemical. Arsenicals should not be used near playgrounds or where they can be reached by children or animals. Utensils used in preparing them should always be thoroughly washed and should never be used for cooking purposes. Vegetation deadened by arsenic compounds should be burned.

A few years ago the use of arsenic sprays was replaced to a great extent by sodium chlorate solutions to eliminate the danger of poisoning livestock. Sodium chlorate solutions are several times as expensive as arsenic solutions and there is always the danger of fire. During the last year or two arsenicals have come back into more general use because of the development at the University of California of an acid arsenical solution and improved knowledge of its use.

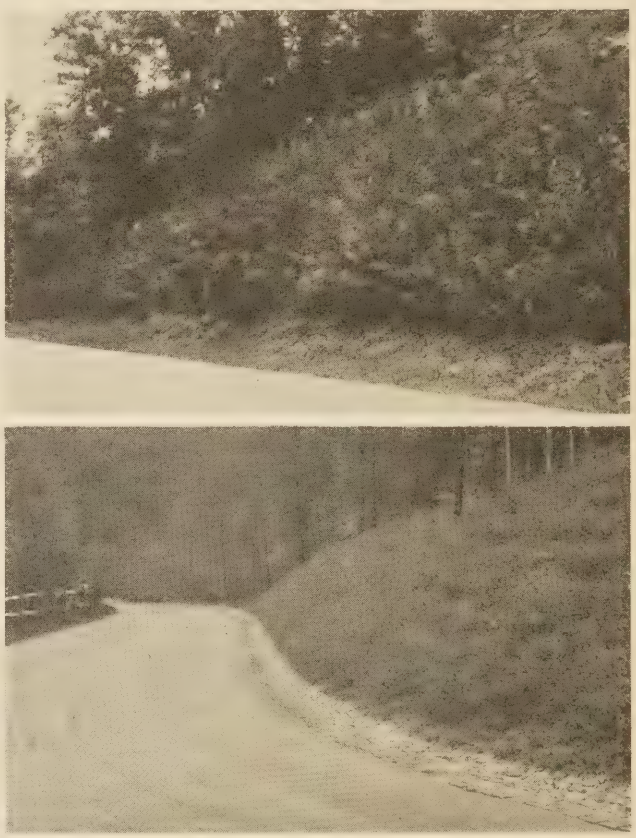
The method of preparing and applying the acid arsenical solution as given by L. W. Kephart, senior agronomist of the United States Department of Agriculture, is becoming standard practice because of the low cost and the relatively high efficiency in killing very troublesome perennial weeds. This method is as follows:

Stir the following solution until dissolved—

White arsenic	4 parts by weight.
Caustic soda	1 part by weight.
Water	2½ parts by weight.

When required for use add 1 part by weight of the solution to 100 parts of water. After mixing thoroughly, add 5 parts by weight of a commercial grade of sulphuric acid slowly while stirring constantly.

It is highly important that the plant be in proper condition to take the chemical into its tissues when the spray is used. This condition occurs when the plants are wilted after hot, dry weather, but when the atmosphere is moist so that evaporation is not high. Under such conditions, a solution sprayed on the foliage is taken up by the leaf tissues and drawn downward into the stem by reason of the negative pressure within the plant cells. The acid in the solution makes the leaf surfaces more permeable. Broad-leafed weeds are affected to a greater extent than grasses.



Slopes Covered With Desirable Vegetation Make the Roadsides Attractive and Reduce Maintenance Costs.

In practice it has been found that the best kill is obtained when full-grown plants are sprayed towards night after a few hot, dry days. Several authorities recommend the addition of 3 or 4 pounds of soap to each 100 gallons of solution for waxy-coated foliage where the spray has a tendency to collect in drops.

While arsenic makes soil very toxic when applied in large quantities, as in the root-absorption method, the amount required for the leaf-absorption method is so small that no ill effects to the soil can be detected after several applications. It is the cheapest and most effective herbicide to use when permanent sterilization is desired on areas where there is no danger of poisoning people or livestock.

Applying Chemical Weed Killer.

Truck equipped with U-Shaped Device for Spraying Around Posts and Under Rail. Weeds Behind Rail Are Being Sprayed Using a Pipe Attachment.

APPLYING CHEMICALS TO KILL WEEDS.

Carbon bisulphide.—The use of carbon bisulphide as an herbicide has been limited by the cost, especially the labor cost, and the danger of handling this inflammable and explosive chemical. The present method of application by making a large number of holes in the soil, pouring a small quantity of the chemical into each, and capping with earth is practical only for small areas of weeds when large regions of weed-free land are in danger of being invaded.

Complete killing of perennial weeds, for which this chemical has been chiefly advocated, depends upon favorable conditions which as yet are not fully understood. The depth of the holes, the distance between them, the amount of liquid used, and the porosity of the soil are variable factors that affect the results obtained. Dense soils do not allow the distribution of the liquid and gases that is necessary to kill the roots.

CORROSIVE EFFECT OF CHEMICALS ON EQUIPMENT MUST BE CONSIDERED

Sulphuric acid.—Sulphuric acid in dilute solutions has been used quite extensively as an herbicide in Europe, especially France, where its use has been most energetically carried on for a number of years. Owing to the difficulties of handling this highly corrosive chemical which burns clothing and flesh, it has rarely been recommended in the United States although it is entirely safe if handled with reasonable care.

Sulphuric acid is a very active and efficient herbicide as a spray for killing annual weeds. It is not effective on grasses or perennials with extensive root systems unless several applications are made. Other advantages of using sulphuric acid on roadsides are that it is not poisonous to animal life, does not injure the soil, and is one of the most inexpensive herbicides.

Dilute solutions of sulphuric acid may be applied under all conditions of humidity, but best results have been obtained in a dry atmosphere and in hot weather. Dilute solutions are, therefore, very useful in the more arid regions where other sprays are not so effective. They do not dry up, and destroy weeds in a short time. Rain falling 2 or 3 hours after the sulphuric acid spray has been applied does not destroy its effectiveness.

The necessary concentration of the solution depends not only on the species but also on the age and size of

the weeds and on the temperature. Usual practice is to spray the foliage with a 3 to 10 percent solution at the rate of 50 to 100 gallons per acre. The solution does not affect the germination of seeds and it is most effective when applied to young plants so as to kill them before they form seed.

The use of sulphuric acid as an herbicide has been retarded largely by lack of sprayers that will resist corrosion. Standard types of spraying equipment are quickly damaged by sulphuric acid solutions. The concentrated acid will not attack steel but is very destructive to rubber hose. Dilute solutions, on the other hand, will corrode steel and wrought iron but will not affect rubber. Standard spraying outfits may be readily converted into satisfactory equipment for applying acid solution by injecting the concentrated acid contained in steel drums directly into the rubber spray line by means of a simple venturi tube. Special injectors of suitable sizes similar to a venturi tube are obtainable from plumbing dealers. Recently, the venturi-tube method has been replaced to a large extent by the acid pump method. The latter does not require as high a pressure.

The cost of sulphuric acid during 1935 was approximately $1.40 per 100 pounds when bought in 100-gallon lots. Using a 10 percent solution or 6.05 gallons of concentrated acid per acre, the acid costs $1.50 per acre. The labor and equipment for spraying and the cost of hauling water are usually about $1.50 per acre, making the total cost around $3 per acre. This figure may be reduced or increased depending on the distance water must be hauled and the rate at which the solution is applied.

Chlorates.—Chlorates of calcium, magnesium, potassium, and sodium have been used successfully as herbicides. At the present time sodium chlorate or commercial compounds or other mixtures containing sodium chlorate are probably the most widely used herbicides. Oils and chlorates are practically the only herbicides now being used by State maintenance departments on roadsides. Sodium chlorate is not a magic weed destroyer; it has its limitations. Like most herbicides, it affects all vegetation, so it cannot be used as a selective spray except in rare instances when a thorough knowledge of the amount required to kill each type of vegetation is known.

The chief objection to sodium chlorate is the fire hazard associated with its use. The chemical in itself is not dangerous, inflammable, or explosive, but a mixture of it with organic matter is even more dangerous than gasoline, since it can be ignited by friction, sparks, shock, or spontaneous combustion under favorable weather conditions. Solutions in containers or on clothing and vegetation are not inflammable while wet but, unfortunately, they dry rapidly, causing fire hazards.

Experiments by Dr. W. H. Cook of the National Research Council, Ottawa, Canada, indicate that at relative humidities above 75 percent materials treated with sodium chlorate solutions are noninflammable because of the moisture content always present. The moisture content decreases rapidly at relative humidities slightly below 75 percent, making inflammable any treated organic material.

Experiments and practical applications have definitely shown that sodium chlorate solutions are not as effective in arid regions where humidity is low as in moist climates. In arid regions the leaves do not have sufficient time to absorb the solution before it dries. A practical criterion to follow is that the solutions will not be effective in killing weeds unless applied during periods when dew forms on the vegetation at night.

RELATIVE HUMIDITY IMPORTANT CONSIDERATION WHEN SODIUM CHLORATE SOLUTIONS ARE USED

One method of reducing the fire risk is to mix sodium chlorate solution with chemicals of high water-absorbing ability such as calcium chloride or with other nonoxidizing chemicals of good herbicidal power, the latter acting as a diluent and fire preventative when in contact with organic material. Calcium chloride and sodium carbonate are the two substances most commonly used with sodium chlorate in commercial herbicides. The chief function of the calcium salt is to reduce the fire hazard by absorbing moisture from the air although the claim is made that it improves the herbicide by preventing the solution from drying on the leaves and blowing off. The reason for using sodium carbonate is not definitely known, but it may retard the spreading of flames by the evolution of carbon dioxide or increase the herbicidal power of the chlorate.

Dr. W. H. Cook recommends the following herbicides as being safe at relative humidities of 40 percent and no more than doubtful hazards at 30 percent relative humidity. Proportions of all chemicals are on an anhydrous basis.

1. One-half sodium chlorate plus one-half calcium chloride.
2. Two-thirds sodium chlorate plus one-third magnesium chloride.
3. Two-thirds barium chlorate plus one-third calcium chloride.
4. Two-thirds barium chlorate plus one-third magnesium chloride.

The toxicities of these four mixtures expressed as percentages of the toxicity of pure sodium chlorate as determined by the chlorate ion content of the hydrated material are 33.5, 48.3, 34.2, and 32.9 percent, respectively. To obtain solutions with the same herbicidal power that sodium chlorate alone has, the total amount of chemical per 100 gallons of solution must be approximately doubled if the second combination is used and tripled when the others are used.

Before attempting to use sodium chlorate solutions it is well to consider the relative humidity at the time and place that application is to be made. This will help to reduce both the fire hazard and chances of unfavorable results.

Figure 1, prepared from data furnished by the United States Weather Bureau, illustrates the variation throughout the United States in the average minimum relative humidity during the month of July over a period of years. The chart may also be considered as being typical for the months of June through September. More important than average relative humidity is the frequency with which the humidity falls below certain minimum values. Data were obtained by determining from Weather Bureau reports the number of days each month that the relative humidity fell below 30 percent during the 4 months of June through September for the years 1930, 1931, 1932, and 1933 at 34 typical stations throughout the United States. These data are shown as circled figures on figure 1.

There is no portion of the United States where the use of sodium chlorate would not constitute a fire hazard at the period of minimum relative humidity during

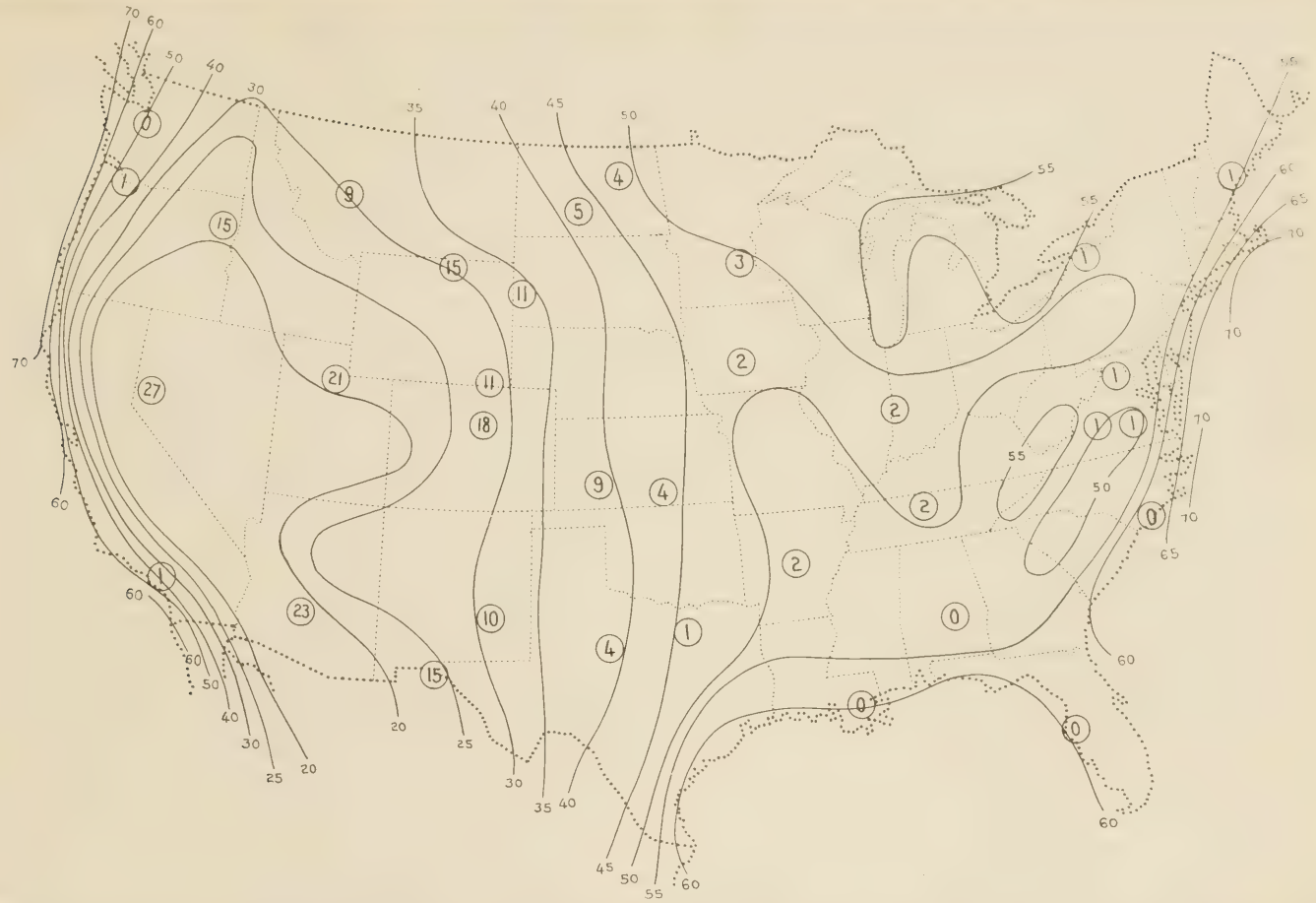


FIGURE 1.—AVERAGE RELATIVE HUMIDITY FOR JULY. CIRCLED FIGURES SHOW THE AVERAGE NUMBER OF DAYS PER MONTH THAT THE RELATIVE HUMIDITY WENT BELOW 30 PERCENT DURING JUNE, JULY, AUGUST, AND SEPTEMBER FROM 1930 THROUGH 1933.

the majority of days from June through September. Even with a protecting agent that reduces the herbicide to a doubtful hazard at 30 percent relative humidity, it could not be considered safe if applied on roadsides in the western and midwestern States, as the relative humidity frequently falls below 30 percent. A chlorate herbicide safe at relative humidities below 30 percent requires such a large portion of protecting chemical that its use is impracticable owing to the cost and loss of herbicidal power.

The absolute amount of moisture in the air or the vapor pressure usually varies only slightly in a given locality during any one day. The relative humidity varies almost inversely as the temperature—being highest at low temperatures and lowest at high temperatures. This is illustrated by figure 2, which shows the hourly changes of temperature and relative humidity in four cities located in various parts of the country.

The temperature usually reaches a maximum for the day between 1 and 5 o'clock in the afternoon at most locations throughout the United States. This is therefore the most hazardous time of the day to apply chlorate solutions. As a general rule, the relative humidity is also lowest on warm days. The preferable time to apply sodium chlorate solutions is therefore on cool, humid days. The same precautions should be taken with commercial herbicides containing sodium chlorate, as the majority produce distinct fire hazards at low relative humidities although manufacturers rightfully claim that the danger is greatly reduced.

SODIUM CHLORATE CAN BE APPLIED DRY OR IN SOLUTION

The following precautions should be taken by the operators using solutions of sodium chlorate:

1. While spraying, use rubber boots. Clothes saturated with the solution should be well rinsed before they dry.
2. After using pails or other utensils, wash them out thoroughly before setting them away.
3. Trucks, wagons, and other equipment being used should be washed off 2 or 3 times a day, particularly in warm weather.
4. Do not smoke while handling chlorates.
5. Warn the public as to the danger of walking through treated areas by placing "KEEP OFF" notices. After 2 or 3 rains have fallen most of the fire hazard will have been eliminated.

Best results are usually obtained by application while the foliage is fully developed and the plants are still growing vigorously. Sprayed plants should not be burned or cut immediately after the solution has been applied. Burning destroys the chlorate and cutting prevents the roots from being poisoned.

It is impossible to determine in advance just how much chlorate will be required. The amount varies with climate, soil fertility, root growth, and soil texture. A fibrous rooted annual or biennial requires less chemical than a perennial with a deep, underground root stock. It is general practice to spray a solution containing 1 pound of sodium chlorate per gallon until the leaves are well covered. This requires from 100 to

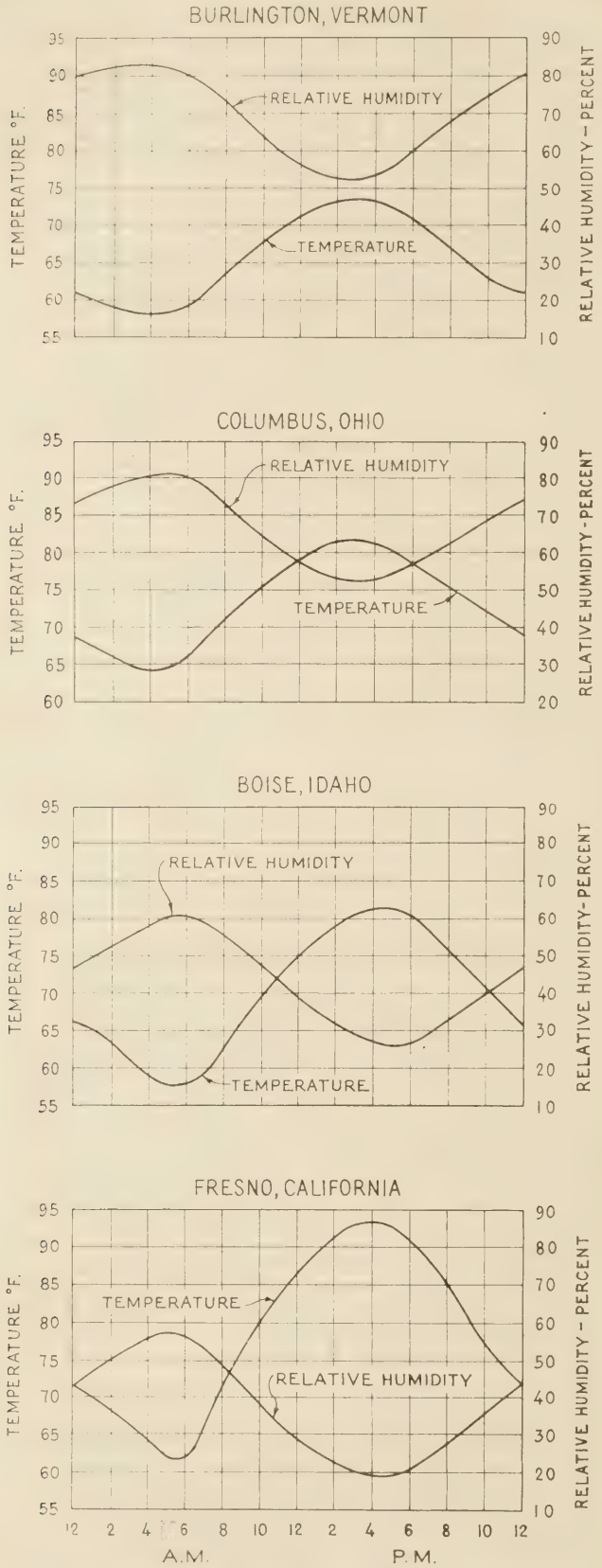


FIGURE 2.—TYPICAL HOURLY CHANGES IN TEMPERATURE AND RELATIVE HUMIDITY DURING SUMMER MONTHS.

200 gallons of solution per acre. High-pressure spray guns ejecting a fan-shaped, mist-like spray, are the preferable means of application although for small areas sprinkling cans may be used.

The present tendency in the use of sodium chlorate is toward dry applications. Though most results indicate that sprays are somewhat more effective, they are always much more erratic than the dry applications. Applying pure sodium chlorate on the ground after removing the mowed weeds would be safe almost anywhere. Besides eliminating the fire hazard, other advantages of this method are: (1) No spraying equipment is required; (2) it is not necessary to prepare a solution or transport large quantities of water; (3) the cost of application is reduced; and (4) only one application is usually required. The principal drawback to dry applications at present is the lack of good distributing equipment for large areas. Chlorate either dry or as a spray has been ineffective on alkali soils. The character of the soil is an important consideration, especially for dry applications. Better results have been obtained on soils of medium texture than on sandy or heavy clay soils.

The present cost of sodium chlorate varies from 6 to 9 cents per pound. One railroad applied 21,850 pounds at a total cost of 14.4 cents per pound, including material, labor, and equipment charges.

Sodium chlorate or compounds containing this chemical have been tried for the eradication of weeds by only a few State maintenance departments. Most of the applications have been made as experiments during the last year or two so the results, although generally quite satisfactory, are not conclusive. Some maintenance departments have become discouraged and discontinued the use of this chemical.

In a maintenance district in the State of Washington sodium chlorate has been used for the past 2 years on weeds under and around guardrails with very good results. The cost was only half the cost of cutting weeds by hand, and a very neat appearance was obtained. The solution used was 1 pound of chemical to a gallon of water applied with a U-shaped spray bar for straddling the guardrail and attached to a pressure pump on a tank truck. The total cost was one-half cent per lineal foot on a strip approximately 2 feet wide. Good results were also obtained on patches of weeds along the right-of-way.

A Canadian investigator found that weeds could be completely killed on a strip 25 feet wide at a cost of $4 to $6 per mile. Bindweed was also completely eradicated for $20 per acre where it was growing in sod. The investigator believes that the cost of weed control on the treated areas will be negligible as compared to the amounts now being expended for weed cutting and more satisfactory results together with cleaner roadsides will be evidenced. In Ontario, Canada, where the experiments were made, climatic conditions are generally more favorable for the use of sodium chlorate than in most sections of the United States.

Sodium chloride —Common salt will kill weeds when applied at the rate of 1 pound per square foot. The large amount required and its permanently detrimental effect on the soil and surrounding vegetation where the salt may be washed make it impractical for roadside use except where there is no objection to rendering the soil unfit for plant growth. The Utah Road Commission has found that in certain districts common crushed rock salt was less expensive and equally as effective as any other chemical treatment.

TANK TRUCKS AND EQUIPMENT FOR SPRAYING OIL.

OILS FOUND EFFECTIVE IN KILLING WEEDS

Oils.—Oils are effective in controlling all types of annual weeds and preventing biennials and perennials from seeding. Oils have great penetrating power and are the only herbicide that will destroy the viability of seeds. For this reason they have been widely utilized in puncture vine control. Oils are top killers and when applied as a spray do not ordinarily penetrate underground tissue.

All oils are destructive to vegetation, but the mineral oils are the only ones cheap enough for general use. Coal-tar creosote oils sometimes sold as "crude carbolic acid" are excellent weed killers for small areas but are too expensive for large-scale operations. The most promising of the oils tested for weed control are those least refined, such as crude oil, waste cylinder oil, slop distilate, Diesel oil, and stovepipe oil. Stovepipe oil is a local name for a byproduct at cer-

tain western oil refineries. The two most widely used products are Diesel oil and stovepipe oil. One is probably as efficient as the other for destroying vegetative growth, but if an emulsion is desired to reduce the cost for large-scale treatments only Diesel oil in the commercial state will give satisfactory results.

Usually oils are applied at the rate of 300 to 400 gallons per acre—a quantity sufficient to cover the vegetation and soil with a thin film. A spray pump providing a pressure above 80 pounds is recommended. Rubber parts of the spray outfit, readily attacked by oil, should be replaced by metal wherever possible.

Diesel oil is an effective herbicide for destroying vegetation in ditches, fences, firebreaks, roadsides, or similar locations. It also aids in burning vegetation.

A few authorities recommend Diesel oil as a selective spray for controlling crab grass in lawns. The danger of injuring the bluegrass is, however, very great even under favorable conditions.

Heavy applications of oil on roads and railroads act in the dual capacity of weed killers and dust layers. The amount required when acting as a weed killer alone is obviously much less than that needed as a dust preventative unless permanent sterilization is desired.

A great many State highway departments eradicate weeds with oil as an incident in stabilizing or preventing dust on shoulders and roadway surfaces. California probably exceeds all other States in its use for the sole purpose of weed eradication for fire protection. Since 1929 oil applications have been a regular part of the highway commission's maintenance program with an annual expenditure of about $80,000 on about 1,100 miles of the State highway system. The roadsides are sprayed and burned to provide a firebreak between the highway and adjoining property as well as to prevent erosion damage by protecting the natural cover from uncontrolled fires. Generally no spraying is done opposite locations where an effective natural or artificial firebreak exists adjacent to or within a reasonable distance of the right-of-way. Spraying is considered unnecessary for fire control adjacent to orchards, vineyards, plowed land, railroads, streams, or bare cut slopes 5 feet or more in height which parallel the highway, as reasonable protection already exists.

The material applied, equipment used, and methods followed in California were adopted after considerable experimentation. The most effective nonpoisonous material was found to be Diesel oil having the following specifications:

Specific gravity (A. P. I.) at 60° F.—not less than 27° Baumé.

Flash point (Penskey-Martin closed cup)—not less than 150° F.

Viscosity (Saybolt Univ.) 100° F.—not over 50 seconds.

Distillation (90 percent point)—not over 680° F.

Water and sediment—not more than a trace.

The Diesel oil is applied at an average rate of one-tenth gallon per square yard by a tank truck equipped with a pressure pump and orchard-type nozzles on a spray bar that can be raised or lowered and extended to varying distances from the truck.

For most effective and economical results the oil is sprayed on a strip 9 feet wide adjacent to the fence line when the vegetation is about 2 inches high. At this time the area is uniformly covered, practically a perfect kill of the tender growth is assured, and no burning is required. This treatment also permits burning of the section between the shoulder and sprayed area at a later date, if desired.

The chief objections to using oils are the appearance of the treated areas and the cost. Accidents have been reported by drivers who at night have mistaken the dark surfaces of treated areas for portions of the roadway or shoulders. In California the spraying cost averages from $50 to $60 per mile of highway when two 9-foot strips are treated. An additional cost of $20 per mile is incurred when burning is required. The initial cost of fire protection by blading, disking, or mowing averages about $6 per mile for a reasonable width but the ultimate cost, considering all factors involved, may well exceed the cost of spraying.

In one maintenance division of the State of Washington fuel oil and used crankcase oil were applied under guardrails with good results. The total cost was 3 cents per square foot and compared favorably with the cost of hand cutting. There was the added advantage that the treatment was good for the entire season whereas cutting was only effective for 1 or 2 months.

Another division found kerosene very effective in eliminating a dense growth of blackberry bushes that obstructed vision. They were very difficult to cut or burn prior to being sprayed but were completely eradicated by spraying with kerosene and burning 2 weeks later.

SUMMARY

Marked progress has been made in the control of weeds on our highways. Each year weeds are cut or killed by various treatments along a large mileage of road but the work is still in the transition stage. There is already available a variety of methods most of which are suitable for control work in any part of the United States. Improvements will undoubtedly be made in the existing methods and new ones will be discovered but effective control is now possible with the weapons already at hand.

The most important recommendation to be made at this time is that all work be done as part of a permanent control policy with particular emphasis on the prevention of new weed growth. Cutting weeds or killing them by other methods should not be regarded as a job to be done at some convenient time to remove unsightly objects but as a job that must be done at such times as will prevent reproduction. The major part of the problem is to prevent reseeding but some special attention must be given weeds that propagate from root growth.

Elimination of reproduction is important not only because it will make possible diminishing expenditures for control but because it is the only method by which the highways can be given the appearance of being well kept at all times.

Machine mowing is the most generally used method of weed control. In general, the costs per acre by this method are lower than by other methods. However, machine mowing is not a complete method in itself and must be supplemented by methods that are effective at places not reached by the mower. It is important that effective work in mowing not be vitiated by seed from places not reached by the machine.

Modern cross-section design with slopes that can be reached by a mowing machine and side ditches that can be mowed over greatly increase the effectiveness of machine mowing.

Burning is practiced largely to dispose of cut or killed weeds. Oil and sodium chlorate are the materi-

als that have been applied most often as weed killers in highway work, and are effective. They are useful for general applications, as supplements to mowing and to kill weeds not reached by the mower.

Every State highway department should decide upon a definite policy of weed control, equip its forces in accordance with the methods selected and fully instruct its maintenance personnel why and when different operations must be performed. The character of the work and the time it should be done will vary from year to year depending upon the effectiveness of the work of preceding years and how the weather affects the maturing of weed growth.

The objective should be the replacement of all weeds with suitable low growth. Most highway departments now have a landscape architect to supervise roadside-improvement work and his knowledge of plant habits and growth makes it desirable that he have close contact with the planning of weed-control work.

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STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF JANUARY 31, 1937

STATE	APPORTIONMENT	COMPLETED			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 7,872,980	$ 51,600	$ 25,800	9.0	$ 937,481	$ 468,740	36.9	$ 801,590	$ 400,780	46.5	$ 6,977,660
Arizona	5,394,661	1,855,670	1,435,570	102.5	1,059,678	839,446	40.4	508,266	358,421	20.7	2,761,224
Arkansas	6,463,681				690,901	689,793	22.3	1,970,706	1,970,239	109.8	3,803,649
California	14,366,891	5,743,330	3,299,695	148.5	8,297,414	4,754,356	207.8	1,616,266	902,036	41.6	5,410,805
Colorado	6,911,198	3,665,727	1,956,513	146.0	2,954,576	1,632,551	97.3	1,118,551	626,203	60.0	2,695,930
Connecticut	2,388,339	777,897	388,949	14.2	705,928	350,556	8.7				1,648,834
Delaware	1,843,750	439,127	219,348	34.4	292,582	146,030	7.7	407,854	192,008	12.3	1,286,364
Florida	5,020,323	826,514	407,878	27.5	1,075,355	537,673	40.2	1,241,670	620,835	22.3	3,453,937
Georgia	9,569,722	1,145,317	535,720	86.2	2,378,207	1,189,089	124.9	643,840	321,920	30.1	7,522,994
Idaho	4,635,991	2,692,632	1,582,237	256.6	754,240	451,335	52.9	759,789	454,503	40.2	2,147,916
Illinois	15,564,720	8,271,649	4,130,594	134.5	4,435,496	2,183,273	116.3	3,807,885	1,880,790	104.4	7,370,062
Indiana	9,333,269	5,396,075	2,691,320	179.1	2,486,425	1,242,424	65.5	2,919,490	1,459,058	68.1	3,940,466
Iowa	9,757,950	6,889,355	3,330,098	466.7	2,958,216	1,472,725	113.8	2,695,257	1,240,104	79.8	3,715,023
Kansas	10,005,211	2,987,962	1,493,019	606.5	5,098,601	2,522,847	394.6	3,429,964	1,714,964	173.8	4,274,381
Kentucky	6,961,271	2,232,017	1,090,976	149.8	988,987	494,493	28.7	1,234,422	617,210	32.6	4,758,592
Louisiana	5,387,420	1,855,608	925,151	66.1	810,147	405,072	28.0	870,287	430,845	17.6	3,626,352
Maine	3,299,867	1,911,144	954,774	58.7	838,968	419,484	21.7	731,560	365,780	23.6	1,559,829
Maryland	3,094,808				1,069,427	534,678	17.5	442,610	221,305	6.3	2,338,825
Massachusetts	5,255,300	333,935	166,968	3.1	4,322,180	2,161,090	20.3	477,660	238,830	2.3	2,688,412
Michigan	11,562,296	9,135,716	4,531,544	327.9	5,020,619	2,509,406	128.0	957,750	478,250	29.2	4,043,096
Minnesota	10,344,485	8,180,055	3,844,163	532.8	2,320,208	1,160,105	127.2	1,376,989	688,495	46.8	4,651,723
Mississippi	6,635,344				913,040	456,820	55.9	2,677,871	1,338,185	128.3	4,840,339
Missouri	11,479,090	4,065,899	2,028,370	439.3	7,178,579	3,580,796	258.8	2,810,218	1,397,763	115.1	4,472,160
Montana	7,744,061	3,752,814	2,100,650	384.1	2,608,183	1,460,321	172.3	647,433	324,306	29.2	3,858,784
Nebraska	7,809,353	2,740,846	1,368,005	170.2	2,902,005	1,456,585	288.6				4,984,763
Nevada	4,821,864	1,571,360	1,355,536	272.2	567,128	487,083	11.5	9,600	8,300	.5	2,970,945
New Hampshire	1,843,750	857,796	422,345	24.8	192,933	96,014	2.3				1,325,391
New Jersey	5,054,295	2,466,551	1,233,124	34.7	2,257,052	1,051,231	24.9	19,989	9,994		2,759,545
New Mexico	6,030,708	3,414,419	2,097,613	273.2	1,873,692	1,139,563	122.2	146,499	89,100		2,704,432
New York	18,565,567	8,076,035	3,979,167	167.7	14,504,484	6,951,397	226.2	3,801,300	1,339,850	65.4	6,295,153
North Carolina	8,877,837	2,258,254	1,128,251	301.0	3,128,312	1,556,358	230.2	2,670,300	1,220,000	83.7	4,973,228
North Dakota	5,914,683				384,820	204,581	.4				5,710,102
Ohio	13,771,548	2,480,549	1,236,370	44.3	5,838,641	2,761,206	56.5	1,747,550	819,275	20.5	8,954,697
Oklahoma	8,880,547	2,671,532	1,388,452	92.1	1,935,244	1,014,710	75.5	1,131,868	585,100	27.0	5,892,286
Oregon	6,182,079	2,919,052	1,764,466	110.5	2,700,632	1,599,127	115.6	1,187,562	701,448	25.6	2,117,039
Pennsylvania	16,129,804	6,651,795	3,325,205	111.3	7,270,667	3,627,506	99.3	2,964,560	1,475,236	49.9	7,701,857
Rhode Island	1,843,750	213,888	106,944	3.4	678,336	339,168	5.6	173,727	86,864	2.1	1,310,774
South Carolina	5,103,525	216,108	85,500	22.2	3,999,480	1,649,420	255.6	1,104,382	407,700	97.1	2,960,905
South Dakota	6,162,747	1,396,263	784,004	188.6	127,860	80,869	36.5	772,488	423,492	57.4	4,874,382
Tennessee	7,949,380	2,159,870	1,077,805	94.2	695,856	347,923	22.4	885,780	442,890	31.0	6,080,762
Texas	23,506,431	10,972,590	5,470,692	640.4	5,700,331	2,846,035	288.2	8,130,141	3,939,494	505.5	11,250,209
Utah	4,274,740	2,072,641	1,476,890	138.1	922,190	664,334	66.5	273,583	198,217	18.7	1,935,299
Vermont	1,843,750	1,319,301	655,718	62.9	814,359	380,260	23.7	243,300	121,650	8.0	686,122
Virginia	6,887,569	2,752,896	1,373,608	109.8	1,948,680	974,336	101.1	1,824,685	912,343	51.6	3,627,283
Washington	5,907,615	3,881,697	2,038,263	149.9	1,967,306	1,033,271	84.2	543,954	284,800	4.4	2,551,281
West Virginia	4,107,201	785,955	392,977	41.1	816,556	408,266	18.9	737,725	368,862	17.1	2,937,095
Wisconsin	9,197,557	4,098,859	1,966,662	164.7	3,977,710	1,934,584	129.7	748,658	373,275	18.4	4,923,037
Wyoming	4,722,322	2,835,092	1,744,404	354.0	1,127,677	689,037	130.2	728,456	448,624	56.5	1,840,257
Hawaii	1,843,750				537,793	265,921	9.8	421,060	210,195	8.4	1,367,634
Puerto Rico	625,000										625,000
TOTALS	368,750,000	141,023,392	73,611,338	7,744.8	127,065,182	65,221,888	4,613.3	64,415,095	32,709,539	2,389.4	197,207,235

CURRENT STATUS OF UNITED STATES WORKS PROGRAM HIGHWAY PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF JANUARY 31, 1937

STATE	APPORTIONMENT	COMPLETED			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	
Alabama	$ 4,151,115	$ 3,036,662	$ 3,036,362	97.7	$ 1,042,170	$ 1,042,170	40.6				$ 72,582
Arizona	2,569,841	2,547,433	2,205,206	162.9	526,730	300,064	25.6	$ 100,643	$ 30,137	7.3	34,433
Arkansas	3,352,061	2,497,841	2,480,129	260.5	800,798	798,995	87.6	29,715	29,499	10.9	43,437
California	7,747,928	5,808,360	5,621,952	228.4	2,062,739	2,045,845	26.8				80,131
Colorado	3,395,263	1,970,108	1,961,044	97.9	153,510	153,494	7.0				1,280,725
Connecticut	1,418,709	402,033	382,928	4.3	423,251	397,410	5.1	272,331	256,831	8.1	381,541
Delaware	900,310	417,640	410,683	45.4	451,442	353,856	21.4				135,771
Florida	2,597,144	1,427,880	1,424,043	65.1	1,069,251	1,069,251	34.0	38,957	38,957		64,893
Georgia	4,988,967	479,047	472,243	29.1	831,616	831,616	54.1	266,889	266,889	22.0	3,418,218
Idaho	2,222,747	2,209,717	2,141,178	182.9	56,927	56,927	2.7				24,642
Illinois	8,694,009	7,362,520	7,301,509	418.3	1,352,408	1,352,408	52.9				40,092
Indiana	4,941,255	2,745,166	2,517,673	115.7	2,322,341	2,322,341	112.8	37,925	37,925	6.3	63,317
Iowa	4,991,664	2,569,468	2,477,319	322.3	2,644,540	2,492,895	198.3	37,723	21,450	2.9	
Kansas	4,994,975	2,157,487	2,157,018	226.1	2,849,966	2,831,762	149.0	6,195	6,195	.6	
Kentucky	3,726,271	2,611,265	2,595,839	308.5	719,658	719,658	36.4	213,797	213,788	7.1	196,986
Louisiana	2,890,429	1,095,899	940,741	67.3	1,799,448	1,598,347	97.9	204,077	204,077	9.5	147,264
Maine	1,676,799	1,271,208	1,270,368	55.4	344,642	344,642	15.6	52,100	52,100	1.7	9,689
Maryland	1,750,738	378,205	376,029	17.6	555,725	555,725	10.7	477,247	377,817	12.8	441,168
Massachusetts	3,262,885	203,614	203,614	2.5	2,554,270	2,200,910	15.5	130,110	130,110	.4	728,251
Michigan	6,301,414	6,106,242	6,031,562	287.9	291,871	246,871	4.8	5,765	4,650		18,331
Minnesota	5,277,145	5,171,181	4,391,532	815.7	1,147,311	743,325	85.5	137,137	120,248	2.3	22,039
Mississippi	3,457,552	1,884,824	1,880,934	139.3	1,447,716	1,446,347	92.8	48,500	48,500	3.0	81,772
Missouri	6,012,652	3,436,242	3,399,960	696.1	2,216,469	2,100,512	80.0	523,893	429,968	1.7	82,211
Montana	3,676,416	3,351,841	3,348,936	185.1	245,028	245,028	10.2				82,451
Nebraska	3,870,739	2,235,485	2,192,111	240.1	1,314,598	1,313,095	117.6	114,733	114,733	12.2	250,801
Nevada	2,243,074	1,773,592	1,719,315	79.7	287,205	287,205	12.3	134,698	121,548	.3	115,006
New Hampshire	945,225	655,002	629,312	26.7	180,697	178,504	7.6	108,084	107,219	3.3	30,191
New Jersey	3,129,805	667,788	664,788	14.0	2,310,652	2,297,497	16.9	85,946	76,977	2.9	90,543
New Mexico	2,871,397	2,301,821	2,300,502	179.2	375,715	375,715	13.9	83,314	83,314	5.2	111,866
New York	11,046,377	7,643,658	7,353,467	130.2	3,509,260	3,381,360	37.7	295,300	295,300	2.4	16,250
North Carolina	4,720,173	2,221,485	2,221,485	146.9	2,291,590	2,229,801	121.2	232,071	196,131	10.6	72,755
North Dakota	2,867,245	1,381,290	1,379,329	209.3	1,131,196	1,127,760	96.3	159,667	159,611	20.2	200,545
Ohio	7,670,815	3,043,625	2,983,062	138.2	3,621,427	3,571,031	117.8	966,060	962,530	41.4	154,192
Oklahoma	4,580,670	2,302,597	2,277,659	213.5	1,614,966	1,606,776	149.5	476,141	471,282	30.4	224,953
Oregon	3,038,642	2,054,423	2,035,590	149.3	1,161,326	799,892	8.0	69,992	69,992	9.5	133,169
Pennsylvania	9,347,797	1,816,909	1,751,221	91.0	2,334,510	2,284,672	63.1	1,649,173	1,643,359	51.9	3,668,545
Rhode Island	989,208	990,131	979,535	18.8	9,520	9,520	.6				153
South Carolina	2,702,012	1,017,081	959,962	97.0	1,231,900	1,194,365	118.5	318,449	305,141	16.3	242,543
South Dakota	2,976,454	1,950,262	1,949,444	383.0	734,747	734,747	80.5	93,620	93,620	18.2	198,643
Tennessee	4,192,460	2,200,158	2,193,276	92.0	937,611	937,611	34.6	523,573	523,573	16.6	538,000
Texas	11,989,350	10,695,387	9,749,194	989.2	2,446,619	2,123,997	126.7	76,061	60,475	6.0	55,685
Utah	2,067,154	1,612,126	1,475,251	163.5	431,344	399,980	26.2	90,221	90,221	3.5	101,702
Vermont	924,306	835,878	734,174	20.5	206,848	157,545	1.6	21,062	20,930	.9	11,657
Virginia	3,652,667	2,814,645	2,740,481	904.4	612,103	598,369	109.4	120,635	113,567	27.3	200,249
Washington	3,026,161	2,565,627	2,304,314	157.7	835,386	721,608	6.8				239
West Virginia	2,231,412	484,483	481,279	24.5	1,597,597	1,596,526	65.1	149,621	119,620	5.2	33,987
Wisconsin	4,823,884	4,992,340	4,433,853	328.1	509,195	368,403	15.1				21,629
Wyoming	2,219,155	1,630,454	1,630,369	123.1	542,569	523,701	17.0				65,085
District of Columbia	949,496	930,398	930,398	8.6	19,098	19,098	.2				
Hawaii	926,033	244,040	228,652	4.0	688,277	681,181	13.3				16,201
TOTALS	195,000,000	122,202,568	117,326,825	9,764.5	58,845,783	55,770,358	2,644.8	8,351,425	7,898,284	380.9	14,004,533

CURRENT STATUS OF UNITED STATES WORKS PROGRAM GRADE CROSSING PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF JANUARY 31, 1937

STATE	APPORTIONMENT	COMPLETED					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
				NUMBER					NUMBER					NUMBER			
		Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 4,034,617	$ 1,922,172	$ 1,922,172	27	1	4	$ 1,907,753	$ 1,907,753	21			$ 10,140	$ 10,140			8	$ 194,552
Arizona	1,256,099	825,527	821,292	9			359,694	348,249	4								86,558
Arkansas	3,574,060	1,322,674	1,318,539	30	4		2,000,062	1,996,729	24	2	1	214,670	214,400	2		28	44,392
California	7,486,362	4,266,085	4,115,169	25	8		3,148,136	3,054,767	19								316,426
Colorado	2,631,567	1,074,662	1,052,372	19			1,132,441	1,132,431	10	1							446,764
Connecticut	1,712,684	73,479	73,479		1		779,991	758,630	5		1	76,314	76,314		1		804,261
Delaware	418,239						130,000	130,000	1								288,239
Florida	2,827,883	1,248,356	1,246,045	10	5		1,139,547	1,139,204	18	1		178,000	178,000	2			264,634
Georgia	4,895,949	30,706	30,706		2		725,457	725,457	16	1		188,098	188,098	7		1	3,951,688
Idaho	1,674,479	899,847	896,674	14	1	2	370,886	370,773	5	1		25,265	25,265			15	381,767
Illinois	10,307,184	3,373,645	3,372,768	40	1		5,532,107	5,428,907	28	5		1,454,100	1,454,100	8	1		51,409
Indiana	5,111,096	1,422,488	1,419,963	17	7		3,445,155	3,322,036	25	5		399,720	363,120			162	5,977
Iowa	5,600,679	1,988,651	1,929,919	49	6		3,417,373	3,394,668	55	3		325,615	253,980	3		8	22,112
Kansas	5,246,258	774,057	774,057	11		3	4,542,745	4,470,102	47	1		2,099	2,099			1	
Kentucky	3,672,387	395,465	395,465	8	1		2,358,176	2,068,444	14	2		252,078	252,078	3	4		956,399
Louisiana	3,213,467						1,656,948	1,656,948	18	1		756,712	712,247	4	3		844,272
Maine	1,426,861	490,074	489,812	12		2	584,695	584,103	8			77,464	77,464	1			275,482
Maryland	2,061,751	274,706	274,706	2	3		595,787	595,787	4		17	606,404	583,936	2	2	2	607,323
Massachusetts	4,210,833	884,661	884,661	7	2		2,052,433	2,052,433	16	1		350,743	350,743	1	1		922,996
Michigan	6,765,197	3,322,775	3,278,275	34	4		3,454,277	3,454,277	11	4							32,645
Minnesota	5,395,441	2,846,823	2,715,906	59	9	38	2,509,840	2,323,459	26	3	3	58,428	58,428		1	1	297,647
Mississippi	3,241,475	712,987	712,839	20	3	1	1,874,273	1,874,273	33			15,070	15,070			4	639,293
Missouri	6,142,153	367,844	367,844	7			5,620,522	5,424,278	41	1		367,252	253,300	1		2	96,731
Montana	2,722,327	2,469,975	2,469,470	35	6		178,582	178,582	2								74,275
Nebraska	3,556,441	1,521,673	1,520,188	55	1	1	1,577,178	1,577,178	22	1	5	397,665	397,665	4	1	18	61,410
Nevada	887,260	690,197	690,197	9	1		211,658	193,432	1			3,630	3,630			5	
New Hampshire	822,484	341,748	341,748	3	3		160,490	160,490	4	1	1	264,177	264,132	3			56,114
New Jersey	3,983,826	508,289	508,289	3	2		2,135,406	2,124,361	15	1		542,474	542,474	2	4		808,702
New Mexico	1,725,286	1,010,150	1,010,135	12	1		716,430	713,740	7								1,410
New York	13,577,189	2,273,973	2,269,173	12	8		9,485,651	9,229,605	28	30		1,057,230	1,057,230	1	8		1,021,181
North Carolina	4,823,958	741,865	741,865	12	7		2,751,656	2,732,105	29	9	46	481,680	481,680	7	1	15	868,308
North Dakota	3,207,473	515,132	515,132	16			1,988,284	1,987,284	31	3		343,730	343,730	10	1		361,327
Ohio	8,439,897						5,370,694	5,147,201	34	5		2,560,560	2,403,502	20	2	3	889,194
Oklahoma	5,004,711	1,477,537	1,477,467	30	3		1,784,915	1,784,915	19	3		416,024	416,024	5	3	2	1,326,306
Oregon	2,334,204	878,991	878,451	8	5	2	1,491,605	1,410,005	8	1		34,950	34,950	1			10,798
Pennsylvania	11,483,613	1,765,034	1,560,946	26	6		5,952,432	5,553,640	39	10	9	1,968,219	1,857,444	7	1		2,511,584
Rhode Island	699,691	655,074	654,008	4	1		25,386	25,386		1		39,260	12,812		1		7,485
South Carolina	3,059,956	483,603	475,951	12	2	3	1,400,825	1,389,482	25	7		354,682	354,682	4		55	839,841
South Dakota	3,249,086	734,402	734,402	21	1	14	1,444,779	1,444,779	31	3	11	285,205	285,205	8	1	6	784,700
Tennessee	3,903,979	513,125	513,125	10	1	15	1,467,277	1,467,277	21	1	2	1,261,366	1,261,366	10	1	6	662,211
Texas	10,855,982	3,585,848	3,585,660	66	9		6,322,832	6,316,455	63	4		499,270	499,263		1	176	454,605
Utah	1,230,763	87,218	85,828	1	1		1,107,705	1,107,705	16			2,700	2,700			1	34,529
Vermont	729,857	491,155	485,556	7	5	10	238,930	194,630	3	1	4						49,671
Virginia	3,774,287	1,524,744	1,453,879	30	6	1	751,170	712,172	7	7		552,742	552,741	13	2	17	1,055,496
Washington	3,095,041	1,014,754	1,009,922	15	5	7	1,824,355	1,823,930	8	6		7,788	7,788			2	253,401
West Virginia	2,677,937						1,549,493	1,549,491	19	3		189,362	189,362	4		4	939,084
Wisconsin	5,022,683	2,031,168	2,003,071	25	4		2,935,206	2,843,954	12	3							175,658
Wyoming	1,360,841	464,745	464,638	6			648,627	648,624	6								247,579
Dist. of Columbia	410,804						425,564	396,804	3								14,000
Hawaii	453,703						522,380	453,703	5								
TOTALS	196,000,000	54,298,084	53,541,764	818	136	103	103,807,808	101,380,638	907	132	100	16,620,886	16,037,162	133	40	542	25,040,436

PUBLICATIONS of the BUREAU OF PUBLIC ROADS

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Department and as the Department does not sell publications, please send no remittance to the United States Department of Agriculture.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1927. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1928. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1929. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

DEPARTMENT BULLETINS

No. 583D . . Reports on Experimental Convict Road Camp, Fulton County, Ga. 25 cents.

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

TECHNICAL BULLETINS

No. 265T . . . Electrical Equipment on Movable Bridges. 35 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.

Federal Legislation and Regulations Relating to Highway Construction. 10 cents.

Supplement No. 1 to Federal Legislation and Regulations Relating to Highway Construction. 5 cents.

No. 191 . . . . Roadside Improvement. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

Single copies of the following publications may be obtained from the Bureau of Public Roads upon request. They cannot be purchased from the Superintendent of Documents.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

A complete list of the publications of the Bureau of Public Roads, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to the U. S. Bureau of Public Roads, Willard Building, Washington, D. C.

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

AS OF JANUARY 31, 1937

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$ 8,370,133	$ 4,259,842	$ 15,583,537	$ 8,301,392	$ 3,764,471	770.5	$ 233,955	$ 52,665	$ 181,290	6.4		$ 285,822	1.5	$ 16,076	$ 28,258
Arizona	5,211,960	2,641,935	8,981,820	5,204,512	2,605,035	542.9	12,500		12,500					7,448	24,400
Arkansas	6,748,335	3,428,049	10,949,302	6,631,484	3,347,962	619.9	139,416	70,019	62,922	3.9	$ 41,829	7,200	13.5	5,003	9,965
California	15,607,354	7,932,206	30,627,453	15,583,782	7,768,675	758.7	115,898		115,836					23,572	47,695
Colorado	6,874,530	3,486,006	11,283,637	6,873,735	3,459,071	639.0	6,362		6,360					795	20,576
Connecticut	2,865,740	1,454,868	4,514,512	2,758,269	1,312,770	74.0	59,618	59,618		.1				47,854	142,098
Delaware	1,819,088	923,395	2,733,715	1,818,804	868,109	128.8	49,363		49,363	1.2				284	5,923
Florida	5,231,834	2,661,343	8,910,496	5,175,534	2,344,563	305.6	332,979		308,665	4.0	56,300		.5		8,116
Georgia	10,091,185	5,113,491	13,294,173	9,269,813	3,256,698	754.2	1,013,512	408,690	604,822	72.2	84,072	218,875	3.1	328,611	1,033,096
Idaho	4,486,249	2,277,486	7,098,072	4,477,339	2,185,517	501.4	54,194		52,034	.1		1,886		8,910	38,049
Illinois	17,570,770	8,921,401	26,228,301	17,182,552	7,998,840	715.4	1,337,417	325,149	885,007	13.5	17,560	7,100	7.5	45,509	30,453
Indiana	10,037,843	5,088,963	15,472,436	9,896,355	4,803,874	479.1	267,993	129,083	138,910	5.7		58,728		12,405	87,452
Iowa	10,055,660	5,118,361	15,455,458	10,055,161	4,797,361	1,222.2	340,072		321,000	5.1	499				
Kansas	10,089,604	5,117,675	15,427,787	10,089,600	5,010,191	1,132.3	110,336		86,598	13.1				4	20,885
Kentucky	7,517,359	3,818,311	12,036,657	7,504,619	3,574,952	811.3	205,881		205,881	4.2	10,217	27,640		2,523	9,838
Louisiana	5,828,591	2,963,932	9,168,831	5,787,557	2,718,108	259.5	215,480		215,459	11.5				41,034	30,365
Maine	3,369,917	1,711,586	5,253,290	3,047,261	1,676,308	193.5	43,100	15,000	26,540	1.4				7,655	8,738
Maryland	3,564,527	1,810,058	5,659,409	3,475,617	1,103,885	152.2	68,343		68,343	1.5		285,453	7.3	88,910	352,377
Massachusetts	6,597,100	3,350,474	10,388,667	6,552,734	3,094,370	115.5						91,944	.1	44,366	164,160
Michigan	12,736,227	6,452,568	20,694,553	12,736,227	6,306,320	768.1	96,788		96,788			40,000	.4		9,460
Minnesota	10,656,569	5,425,551	16,235,971	10,514,422	4,870,955	1,641.9	374,082	58,110	270,314	7.2		34,800	.6	84,037	249,482
Mississippi	6,978,675	3,540,227	12,728,665	6,763,926	2,994,079	723.3	674,062	165,696	491,245	21.9	3,960	15,123	.8	45,092	39,780
Missouri	12,180,306	6,173,740	18,179,234	12,105,337	4,962,661	1,441.2	1,130,984		1,127,050	6.4		27,356		74,969	56,673
Montana	7,439,748	3,769,734	11,764,936	7,425,476	3,649,311	1,058.4	56,546		56,546					14,273	63,877
Nebraska	7,828,961	3,964,364	12,837,282	7,812,918	3,613,533	1,018.4	272,820		265,495	27.7		68,900	5.9	16,043	16,437
Nevada	4,545,917	2,302,356	7,065,551	4,545,917	2,268,591	758.8	25,004		25,004			1,650			7,111
New Hampshire	1,909,839	969,462	3,003,039	1,904,951	950,488	78.3	4,174		4,174					4,888	14,800
New Jersey	6,346,039	3,220,879	9,096,652	6,045,652	2,452,166	85.9	1,218,088	120,518	663,430	10.3	88,486	9,212	.6	91,384	96,071
New Mexico	5,792,935	2,941,700	8,784,010	5,731,884	2,813,448	743.9	107,130		107,130	5.9		2,695		61,051	18,426
New York	22,330,101	11,327,921	39,446,868	21,773,149	10,493,822	821.3	1,131,180	416,110	631,049	2.6	139,503	139,675	1.4	1,339	63,374
North Carolina	9,522,293	4,840,941	14,957,895	9,210,800	4,520,731	1,345.8	582,880	291,910	257,207	19.6				19,582	63,004
North Dakota	5,804,448	2,938,967	8,612,636	5,593,423	2,250,890	2,127.0	230,303	106,183	124,120	16.3	15,703	153,680	27.6	89,139	410,276
Ohio	15,484,592	7,865,012	24,746,655	15,379,719	7,519,093	792.1	276,268	40,500	206,851	4.0	34,023	87,639	4.3	30,350	51,429
Oklahoma	9,216,798	4,685,180	14,628,257	9,212,943	4,313,159	805.5	105,855		105,855	1.1		174,301	.2	3,855	91,864
Oregon	6,106,896	3,097,814	9,901,295	6,037,198	2,940,828	468.0	75,530	11,308	64,222	.8	55,000	26,981	.7	3,391	65,783
Pennsylvania	18,891,004	9,590,788	28,769,839	18,536,705	8,741,885	1,053.5	473,357	53,214	377,896	3.1	168,454	190,960	4.6	132,630	280,048
Rhode Island	1,998,708	1,014,572	3,150,270	1,998,708	1,012,094	89.1									2,478
South Carolina	5,459,165	2,770,954	7,999,242	5,222,052	2,460,815	618.6	359,440	161,981	196,174	9.5	46,320	60,613	1.7	28,812	53,353
South Dakota	6,011,479	3,047,643	9,267,271	5,834,666	2,856,363	1,571.5	207,802	77,600	130,202	29.5		26,146	6.1	99,213	34,933
Tennessee	8,492,619	4,302,991	13,667,902	8,490,706	4,135,256	492.7	102,910		102,910	3.6		46,727	5.9	1,913	18,098
Texas	24,244,024	12,291,253	37,992,724	24,189,662	11,882,478	2,780.0	97,693	14,797	82,576	.7		211,401	8.5	39,565	114,797
Utah	4,194,708	2,132,691	7,408,593	4,193,208	2,132,691	590.9								1,500	
Vermont	1,867,573	948,007	3,166,359	1,867,452	940,847	141.0								121	7,160
Virginia	7,416,757	3,765,387	11,635,946	7,292,347	3,408,105	614.5	298,632	82,461	210,539	30.5	9,045	64,762	3.7	32,903	81,982
Washington	6,115,867	3,106,412	9,399,840	6,112,042	3,027,370	302.7	46,596		46,596			14,823	.3	3,825	17,622
West Virginia	4,474,234	2,280,335	6,474,665	4,342,391	1,796,306	212.9	375,487	54,892	297,549	9.4		66,425	.7	76,951	120,055
Wisconsin	9,724,881	4,941,837	15,438,317	9,720,705	4,895,799	619.7					4,176	15,050			30,988
Wyoming	4,501,327	2,287,712	6,891,444	4,451,923	2,230,541	1,037.7	5,781	5,780		.3	11,818	21,300	2.5	31,806	35,871
District of Columbia	1,918,469	973,842	2,887,584	1,918,469	968,979	22.3						4,863			
Hawaii	1,871,062	949,778	2,680,983	1,857,812	264,953	51.1	650,838		646,859	4.7		14,000		13,250	23,966
TOTALS	394,000,000	200,000,000	628,582,031	388,808,910	183,365,317	35,052.1	13,586,649	2,721,284	9,929,311	359.0	786,965	2,503,730	110.0	1,682,841	4,201,642