Report No. FHWA-RD-76-5

Dept. of Transportation
JUL 8 1976
Library

HIGHWAY-WILDLIFE RELATIONSHIPS

Vol. 2. An Annotated Bibliography

D.L. Leedy, T.M. Franklin, and E.C. Hekimian

DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA •

December 1975
Final Report

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D.C. 20590

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof

The contents of this report reflect the views of Urban Wildlife Research Center, Inc., which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification, or regulation.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of the document.

TE
662
.A3
no. FHWA-
RD-
76-5

Dept. of Transportation
JUL 8 1976
Library

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-76-5		

4. Title and Subtitle	5. Report Date
Highway-Wildlife Relationships Volume 2. An Annotated Bibliography	December 1975
	6. Performing Organization Code
7. Author(s) Daniel L. Leedy, Thomas M. Franklin, and Edyce C. Hekimian	8. Performing Organization Report No.
9. Performing Organization Name and Address Urban Wildlife Research Center, Inc. 12789 Folly Quarter Road Ellicott City, Maryland 21043	10. Work Unit No. FCP 33F2-182 11. Contract or Grant No. P.O. 5-3-0189 13. Type of Report and Period Covered Final Report
12. Sponsoring Agency Name and Address Offices of Research and Development U.S. Federal Highway Administration U.S. Department of Transportation Washington, D.C. 20590	14. Sponsoring Agency Code E0150

15. Supplementary Notes

FHWA contract manager: Douglas L. Smith (HRS-42)

16. Abstract This study assesses, primarily through an extensive literature review, what is known about highway-wildlife relationships and suggests research and management approaches to protect and enhance fish, wildlife, and environmental quality. A cooperative effort to this end among natural resource and highway agency personnel is needed on a continuing basis from the initial planning stages for new highway construction through operation and maintenance. The 20 million or more acres in highway rights-of-way have been largely neglected as wildlife habitat. Opportunities exist for creating valuable fish and wildlife impoundments during construction, yet the minimal effort needed to locate and design such impoundments has generally not been made. The Nation's four million miles of streets and highway often create "edges" conducive to wildlife. Many millions of wild vertebrates are killed annually, but apparently most wildlife populations are not seriously affected by such losses. Highway construction through limited ranges of endangered species can be a serious problem, as can erosion, wetland drainage, stream alteration, structures which block the passage of anadromous fish, and pollutants resulting from highway maintenance and use. Better measures for mitigating habitat losses, predicting effects of highways on fish and wildlife, reducing animal-vehicle accidents, and enhancing highway environment for fish, wildlife, and people are sorely needed.

This Volume is volume 2 of a two volume report.
Volume 1. A State-of-the-Art Report.
Volume 2. An Annotated Bibliography.

17. Key Words	18. Distribution Statement
Highway, Wildlife, Fish, Right-of-way, Vegetation-management, Highway-plantings, Pollutants, Wildlife-mortality, Erosion, Environmental-quality Planning, Research-needs, Bibliography	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161. Also for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	427	

Form DOT F 1700.7 (8-69)

PREFACE

This two-volume work, consisting of a State-of-the-Art Report and an Annotated Bibliography on Highway-Wildlife Relationships, was prepared by the Urban Wildlife Research Center, Inc. for the Department of Transportation, Federal Highway Administration. The primary purpose of the project was to assess what is known about the effects of highways, their construction, maintenance and operation on fish, wildlife and their habitat. In addition, the effects of wildlife on highway structures, vehicular use, and rights-of-way vegetation were considered. Also, suggestions were made as to what might be done, especially with respect to research, to promote the protection and enhancement of fish and wildlife and of environmental quality in the conduct of the Department's program.

The report was written not only with highway planners, engineers, landscape architects, and others in the transportation field in mind, but, also, for fish and wildlife agency administrators, biologists, ecologists, and others concerned with natural resources and environmental quality. The project involved an extensive review of the literature in both the transportation and natural resource conservation fields. This literature review was supplemented by personal observations and by information derived from discussions and correspondence with individuals in both of these fields. This approach showed a surprising lack of understanding of each others' problems in these areas and little appreciation of what might be accomplished through research and a cooperative management effort.

In order to set the stage for such cooperation and understanding among highway and natural resource personnel, certain references concerning highway construction and maintenance operations, and some references on ecology, hydrology and wildlife were cited in the State-of-the-Art report or abstracted in the Bibliography which do not deal directly with highway-wildlife relationships. They do have relevance, however, in that they provide information on highway pollutants, for example, or deal with food and cover requirements of, or pollutant effects on, fish and wildlife.

Of the 794 references abstracted in the Annotated Bibliography, 489 are cited in the State-of-the-Art Report. Although some of the references cited in the Report utilize a considerable amount of the material included in the respective abstracts, many of them contain only a fraction of the information available in the Bibliography. Likewise, the reader will find much relevant information in the remaining 305 uncited bibliographical items.

As a convenience to the reader, the Bibliography has been arranged under headings and sub-headings which correspond, generally, with the subject matter headings in the State-of-the-

Art Report. In addition, because some articles dealt with more than one subject and required cross-referencing, a dual system of identifying the reference was used.

Each reference in the Bibliography was given a number and listed consecutively. This number was used along with the author's name and date of publication for those articles cited in the State-of-the-Art Report. Thus, the reader can locate, immediately, the reference in the Bibliography and obtain any additional information provided therein.

The authors have been impressed with the opportunities and challenges that exist for closer cooperation and more effective exchange of information among highway and natural resource agency personnel at all levels on matters concerning highways and the environment. Environmental laws, administrative directives, memoranda of understanding and some guides exist for such cooperation and coordination of effort, but much more effective implementation is needed. This is particularly true at local levels in the construction and maintenance of township and county roads. If this report leads to more scientific input from biologists and ecologists, beginning at the earliest stages of planning and selecting a route for a highway and continuing through the construction, operation and maintenance of the highway; and if some of the needs and opportunities for research which are identified, can be pursued, we shall consider our time spent on the project worthwhile.

ACKNOWLEDGMENTS

The assistance and cooperation of many individuals and organizations in the preparation of the State-of-the-Art Report and the Annotated Bibliography is acknowledged with sincere thanks. Stephen R. Seater, Administrative Director of the Urban Wildlife Research Center, Inc., was a constant source of inspiration and support, as was Douglas Smith, Contract Manager for the Federal Highway Administration. Fredia Rafferty and Katherine Appler deserve special thanks for typing the manuscript and the extensive bibliography. Charles R. Anderson, Chief, and Bluett Green of the Bureau of Landscape Architecture, Maryland State Highway Administration, were most cooperative in making available pertinent references assembled by them for a wildlife guide being prepared for the American Association of State Highway and Transportation Officials' Task Force for Environmental Design.

References and information were also provided by Richard Banks, Kenneth J. Chiavetta, Clyde Jones, Chandler Robbins, and Lucille Stickel of the U. S. Fish and Wildlife Service; John L. Buckley of the U.S. Environmental Protection Agency; Mason Hale of the Smithsonian Institution; John S. Gottschalk of the National Association of Game, Fish and Conservation Commissioners; Fred G. Evenden, Executive Director, the Wildlife Society; Kenneth Taylor of the California Native Plant Society; the

Reference Department of the Library of Congress; and Oliver B. Cope of the Fish and Wildlife Reference Service, Denver Public Library.

Nancy L. Dagenhart, Retrieval Specialist for the Transportation Research Board, National Research Council, was especially helpful in providing summaries of completed research and descriptions of current research related to highways and their effects on fish and wildlife and the environment. Likewise, the Smithsonian Institution's Science Information Exchange provided computer printouts of descriptions of recent or on-going research projects relating directly or indirectly to the impacts of highways on fish and wildlife and the environment; and the Water Resources Scientific Information Center, U. S. Department of the Interior provided abstracts of pertinent published reports.

Permission to quote or reprint information from certain copy-righted or restricted publications is gratefully acknowledged. Complete reference citations for these publications or reports are provided in the Bibliography for the following numbered references and the publishers, copyright owners and/or authors granting this permission are listed accordingly: 7, 741 and 739, Doubleday & Company, Inc.; 182 and 216, The American Chemical Society; 183, Frank P. Grad of Columbia University; 242, the State of California Department of Transportation; 268, Charles Scribners Sons; 402, TIME, the Weekly Newsmagazine, Copyright Time Inc.; 453, Franklin J. Svoboda, State of Minnesota, Department of Highways; 520, Mrs. Edward H. Graham, Vienna, Virginia; and 780, W. B. Saunders Company.

TABLE OF CONTENTS

PART IV

PART V

BIBLIOGRAPHY OF HIGHWAY-WILDLIFE RELATIONSHIPS

INTRODUCTION

This annotated bibliography is based as much as possible upon examination of original articles, particularly from the wildlife literature. However, liberal use was made of abstracts and summaries obtained from Wildlife Review (WR), Sport Fishery Abstracts, and the Water Resources Scientific Information Center (WRSIC) of the U.S. Department of the Interior; and from the Highway Research Information Service (HRIS) of the Transportation Board, National Academy of Sciences. The number and source of most such abstracts and summaries are shown.

The subject matter headings and sub-headings for this bibliography are arranged, to the extent feasible, in accordance with the headings in the state-of-the-art report. When a publication dealt with two or more categories of interest with respect to this report, we attempted to include it in the category of greatest relevance. Thus, we included in category I-B, "Highways and Highway Rights-of-Way and Their Use by Wildlife," primarily articles describing use of the highway system, rather than those articles which focused on highway mortality (I-D-4) or on right-of-way vegetation management with specific reference to wildlife (II-C-1). Also, in the case of category I-C-1, "Erosion, Channelization, and Sedimentation," the articles listed generally describe the extent and the effects of erosion and stream alterations caused by highways and highway construction, whereas I-D-5 deals largely with erosion control by means of vegetation management, and II-B deals primarily with other means of erosion control and ways of rehabilitating altered streams for fish and wildlife.

There is, nonetheless, some overlap in the various categories. Although the references are arranged alphabetically and by date of publication within each category, they are numbered consecutively at the right side from 1 through 794. As an aid to the reader, a dual system of identifying the references is used in the state-of-the-art report which permits ready cross-referencing among the categories dealing with similar subjects.

We make no claims that this bibliography is exhaustive. We did, however, make it as complete as possible within the time available. Also, we included some articles which, although not dealing directly with highways, may have relevance and be of use to highway and natural resource agency personnel.

Among the articles reviewed at first hand were those published in the Journal of Wildlife Management, Transactions of the North American Wildlife and Natural Resources Conferences, Proceedings of the International Association of Game, Fish and Conservation Commissioners, and Transactions of the American Fisheries Society of which journals whole or lengthy series were examined article by article for pertinent material. Likewise, selected articles appearing in such publications as Science, the Journal of Mammalogy, Ecology, the Auk, the Wilson Bulletin, the Journal of Range Management, and the Journal of Forestry were abstracted from the original.

In many instances, the author's abstract was supplemented by additional material gleaned from the article in order to provide readers without ready access to the literature as much relevant information as possible short of reproducing the entire article. In other instances -- identified in the bibliography -- only portions of the author's abstract which were pertinent to this subject were used so as to conserve space.

BIBLIOGRAPHY ON HIGHWAY-WILDLIFE RELATIONSHIPS

I. THE HIGHWAY SYSTEM: EFFECTS ON AND RELATION TO FISH AND WILDLIFE

A. EXTENT OF HIGHWAYS AND STREETS.

Council on Environmental Quality (1)

1974. The fifth annual report of the Council on Environmental Quality. Pages xxxvii +597. (U.S Government Printing Office, Washington, D.C. 20402. Price $5.20, Stock No. 4000-00327).

In Chapter 1 (Land Use) of this report, with respect to highways, the Council on Environmental Quality pointed out that "Each mile of interstate highway consumes up to 48 acres; over two-thirds of the land area in some cities is consumed by streets, roads and parking; 26 million acres of America's rural land is consumed by the transportation system.

..."The earth moving required in the construction of such systems is a major source of soil erosion and increased sediment loads in rivers and streams. The paved area results in increased stormwater runoff, which can be heavily polluted with organic materials, oil, nutrients and toxic substances..."

Jordan, Robert Paul (2)

1968. Our growing interstate highway system. National Geographic 133(2) 194-219.

In the words of Mr. Jordan, whose illustrated article describes some of the challenges, problems and accomplishments in constructing the 41,000 mile National System of Interstate and Defense Highways. "...largest public works program in history...the super-roads are gobbling up 1.6 million acres for right-of-way, an area larger than the State of Delaware. Enough material is being excavated to bury Connecticut knee-deep. The sand, gravel, and stone going into the roads would build a wall 9 feet thick and 50 feet high around the world."

Note: According to a June 3, 1975 letter from Newton V. Blakeslee. the exact figure for acreage in the total area taken up by this system, as provided by the then Bureau of Public Roads, Washington, D.C., was 1.602 million acres and was understood to include the actual concrete paving, the median strip, the shoulder and the 100 feet or so on each side of the road.

Of further relevance to the present report was reference to the problem for landowners whose property was divided by the highway (and, in our case, hunters and recreationists) of limited access afforded by these super highways; and on the beneficial side, the dredging of some of the sand and gravel from the wayside, for roadbeds and embankments, which resulted in water-filled areas. The author states with respect to I-80 across Nebraska: "Now a chain of more than 100 lakes and ponds, the largest 43 acres in area, sparkles along the road. Motorists can pause beside them to fish and swim, picnic and relax. In the golden autumn, ducks and geese -- their cries hoarse and lonely in the chill prairie area -- wing down the Platte River flyway and alight by the thousands on the gleaming lakes."

Mayer, Harold M. (3)

1958. Cities, transportation and technology. In Yearbook of Agriculture, 1958, pages 493-502. U.S. Department of Agriculture, Washington, D.C.

Points out that the program of Federal interregional highways authorized by the Congress in 1956 provided for 41,000 miles of modern highways, a substantial part of which would be in metropolitan areas with rights-of-way 250 to 300 feet wide. They state, page 501, "At the interchange between expressways and other arteries, vast areas of land must be taken and hence made unavailable for other development."

Miller, J. Paul, and Burwell B. Powell (4)

1942. Game and wild-fur production on agricultural land. U.S. Department of Agriculture. Circular No. 636, 58 pages, illus.

Miller, a biologist of the U.S. Fish and Wildlife Service, and Powell, an agricultural economist, report on a nation-wide investigation made in 1936 and 1937. The authors indicated that at that time, more than 85% of the huntable land was in private ownership or control and that economic necessity for its most efficient use reduced wildlife production to an incidental, if not accidental, status. They reported that more than 75% of our game and wild fur is produced and harvested on agricultural land of which land more than 80% is privately owned. Pertinent to the present literature survey are tables indicating that public highways occupied 17,787,000 acres of .7% of the total land area of the United States (excluding Alaska and Hawaii); that 75% of the highway areas was providing food and cover for wildlife; and that, on an estimated 75% of these highway lands, it was economically feasible to improve food and cover for wildlife. Percent of the total area in highways is given for each of the then forty-eight states.

U.S. Department of Transportation (5)

1973. Highway statistics - 1973. U.S. Department of Transportation, Federal Highway Admniistration, Highway Statistics Division, Office of Highway Planning. Pages viii +270. (Supertintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $4.90, Stock No. 5001-0008).

This document, 29th of an annual series, and composed largely of tables, presents 1973 statistical and analytical information..."of general interest on motor fuel, motor vehicles, driver licensing, highway-user taxation, state highway finance, highway mileage, and Federal aid for highways; and 1972 highway finance data for municipalities, counties, townships, and other units of local government."

The total road and street mileages, classified by system, are shown for each of the 50 states on page 210 of the report. The total rural and municipal mileage as of December 31, 1973, compiled from reports of state authorities was listed as 3,806,883 of which 3,175,654 miles were classified as rural roads and 631,229 as municipal mileage. The mileage built on roads <u>not on state highway systems</u> in 1973 totaled 75,538 graded and surfaced (Page 223) and 4,712 miles were listed as graded and drained. Mileage <u>built on primary state highways</u>, including municipal extensions, totaled 19,088; and 28 miles were reported to have been graded and drained (page 223). For all secondary state roads, including county roads under state control, the total mileage reported graded and surfaced was 7,686 and the total mileage graded and drained, 29 (page 225). Within the National

System of Interstate and Defense Highways, rural - there were 5,720 miles of surfaced, undivided highways and 28,062 miles of surfaced, divided highways reported as of December 31, 1973. Approximately 46% of the undivided highways had surface widths of between 24 and 26 feet and most of the divided highways had surface widths of 48 feet or more. In the case of the divided highways, the states exercised full control over access to the highways, i.e. "authority to control access is exercised to give preference to through traffic by providing access connections with selected public roads and streets only and by prohibiting crossings at grade or direct private driveway connections" (pages 267-268).

Van Dersal, William R. (6)

1943. The American land - its history and uses. Oxford University Press, New York xvi +215 pages, illus.

The author calculated in 1943 that of the total land area of the United States (1,903 million acres) 20,000,000 acres were in highways and roads and 4,000,000 acres in railroad rights-of-way. Page 29.

White, Gilbert F. (7)

1966. Arid lands. Pages 172-184 in "Future environments of North America -- transformation of a continent. Edited by F. Fraser Darling and John P. Milton. Record of a conference convened by the Conservation Foundation in April, 1965, at Airlie House, Warrenton, Virginia. The Natural History Press/Garden City, New York. Pages xv +767.

White included construction of roads and airstrips as one of five great instruments of change at work in arid lands and pointed out that road building into mesquite lands is associated with possible intensification of both grazing and seasonal residential uses and may stimulate mineral development and additional demand for water. For 11 western states the total rural and municipal mileage in highways and streets increased from 753,678 miles in 1946 to 896,232 miles in 1961. Road building, he indicated, involves an interruption of drainage channels and concentration of feeder flows at the infrequent times when rain causes surface runoff. "...A combination of road and trail transport has led to easy and ephemeral access to large sectors of the arid lands which previously were touched only rarely by humans."

Wooten, Hugh H. and James R. Anderson (8)

1958. The uses to which we put our land. *In* Yearbook of Agriculture 1958, pages 53-62. U.S. Department of Agriculture, Washington, D.C.

Relative to this report, the authors stated that the acreage of land in urban areas, highways, airports and reservoirs increased an average of about 831,000 acres a year from 1945 to 1954 with the area occupied by highways increasing by an average of 78,000 acres per year.

B. HIGHWAYS AND HIGHWAY RIGHTS-OF-WAY AND THEIR USE BY WILDLIFE.

Alsop, Fred J. (9)

1970. Cliff swallows nesting in Knox County. The Migrant - a quarterly journal devoted to Tennessee birds, 41(4): 78.

The author reported finding nests of the cliff swallow under two concrete bridges near Concord in Knox County, Tennessee on May 16, 1970. This constituted the first nesting record of this species for this county. The nests were attached to the underside of the bridges where supporting concrete beams met at right angles to each other thus forming solid supports for the nests on both sides and above.

Baker, Rollin H. (10)

1971. Nutritional strategies of myomorph rodents in North American grasslands. Journal of Mammalogy 52(4): 800-805.

In this article Baker points out that because such rodents as the voles or meadow-mouse (*Microtus*) and cotton rats (*Sigmodon*) occupy lands highly prized by man, farming, ranching and suburbanization have encroached on their habitats in many areas; but, on the other hand, forest clearing, irrigation, encouragement of grasses along highway and railroad rights-of-way, and introduced grasses such as bluegrass (Poa), quackgrass (Agropyron) and brome (Bromus) which provide attractive foods, have opened new territory to these grass-eaters.

Baxter, William L., and Carl W. Wolfe (11)

Undated. The ring-necked pheasant in Nebraska. Nebraska Game and Parks Commission. 30 pages.

This publication describes the life history of the ring-necked pheasant in Nebraska. In addition, sections are presented on hunting, methods of management and background and prospects for the ringneck in Nebraska. A ten year study on pheasant life history and ecology in south-central Nebraska is cited which indicates that hens preferred roadsides, wheat and alfalfa as nesting cover. Most of the chicks (approximately 77 percent) were hatched from nests in roadsides and wheat. Roadsides are particularly important as pheasant nesting cover. While this cover type makes up approximately one percent of the total land area, it consistently produces more than 25 percent of all chicks hatched. The relatively high production from such a restricted area results primarily from the permanency of this cover type. Roadsides are not worked from year to year. Therefore, they contain residual cover as well as new growth. Generally roadsides with well developed, solid stands of warm-season native grass or smooth brome are not preferred types. Rather, hens selected roadsides with an abundance of early maturing grasses such as western wheatgrass or bluegrass, mixed lightly with annual weeds. Hen pheasants also showed a definite preference for nest placement within the roadside profile. The bottom area was preferred as a site to establish a nest by the slope adjacent to the fence. Winter feeding programs are discouraged since grain is generally distributed in areas where humans have easiest access - along open roads and highways or near farmsteads. These are not generally the areas of greatest need and can even be detrimental to birds attracted there. For example, many birds drawn to roads by a handout are subsequently killed by passing autos.

Beule, John D., and Allan T. Studholme (12)

1942. Cottontail rabbit nests and nestlings. Journal of Wildlife Management 6(2): 133-140, 1 plate, 7 figs.

In this study conducted in central Pennsylvania during two rabbit breeding seasons, four of 121 rabbit nests found were in roadside cover. Nine sets of embryos were obtained from rabbits that had been struck by automobiles.

Broadbooks, Harold E. (13)

1958. Northward extension of the kangaroo rat in Washington. Journal of Mammalogy, 39(2): 299-301.

The author indicates that for many years the northward dispersal of the kangaroo rat (Dipodomys ordi) apparently was blocked by the Columbia and Snake Rivers. He first observed signs of this mammal north of the Snake River in the triangle formed by the Snake and Columbia in April, 1956. He speculates that perhaps both the kangaroo rat and the ground squirrel (Citellus beecheyi) may have entered Washington via bridges over the Snake and Columbia Rivers, but there are other possibilities, also.

Buss, Irven O., and Carl V. Swanson (14)

1950. Some effects of weather on pheasant reproduction in southeastern Washington. Transactions, 15th North American Wildlife Conference, pages 364-378.

The authors state, page 368: "The highways of southeastern Washington are of special attraction to pheasants. During the harvest season, combining wheat fields causes the birds to seek other covers which are at a premium. Eventually many pheasants reach the roadsides where they find wheat scattered and spilled by trucks that ply between fields and elevators; grit is available on the shoulders, and herbaceous cover remains in ditches. As a result, roadside concentrations develop, and automobile fatalaties to pheasants are excessive in the heavily traveled routes." From data collected by the authors in 1949 relative to the average number of young pheasants per brood and adult-juvenile ratios,

juvenile pheasants did not appear to be more vulnerable than adults to automobiles.

Campbell, Howard (15)

1954. Use of oil dust baths by quail. Journal of Wildlife Management, 18(4): 543.

Observations made in New Mexico first on a "gallinaceous guzzler" construction site where oil had been spilled on the ground accidentally, and then on sites where a gallon or so of old motor oil was deliberately poured as an experiment, showed frequent use was made of the oily places by scaled quail, and perhaps other birds as well, for dusting. The author indicated that the birds were selective in choosing oily spots in favorable dusting areas and stated: "It would appear that quail find the 'de-lousing baths' of definite benefit (to discourage ectoparasites), and return to them time and again for treatment."

Chesness, Robert A., Maynard M. Nelson, and William H. Longley (16)

1968. The effect of predator removal on pheasant reproductive success. Journal of Wildlife Management, 32(4): 683-697.

In this study, conducted in southern Minnesota during 1960-64, road ditches and roadgrades constituted 2.9 percent of the cover area available for pheasant nesting. Road ditches with an average of 1.42 pheasant nests per acre ranked next to fencerows (2.46 nests per acre) in density of nests located by careful searching. It was noted that striped skunks (Mephitis mephitis) and other wild predators as well as dogs and cats frequented roadsides or used the ditches as travel lanes and apparently destroyed many of the nests, but even so, the number of successful nests in road ditches ranked second to those found in agricultural crop fields and produced a significant part of the pheasant crop.

Dalke, Paul D. (17)

1938. Amount of grit taken by pheasants in southern Michigan. Journal of Wildlife Management 2(2): 53-54, 2 tables.

Provides information on amount of grit found in pheasants of different ages and in the different months of the year. Pheasants experience little difficulty in obtaining grit in southern Michigan where, even in the winter, during periods of snow, grit usually is available along drainage ditches, embankments, or highways.

Dalke, Paul D., Robert D. Beerman, F. J. Kindel, R. J. Robel, and T. W. Williams (18)

1965. Use of salt by elk in Idaho. Journal of Wildlife Management, 29(2): 319-332.

It has been suspected that deer will come to a salted highway for salt, thus increasing the likelihood of accidents. This article, which delved into the history of big game salting programs, listed as one of the justifications given for salting, to "...hold game away from snow-cleared railroads,..." No further detail on this aspect of salting were provided.

Dalke, P. D., D. B. Pyrah, D. C. Stanton, J.E. Crawford, and E. Schlatterer (19)

1960. Seasonal movements and breeding behavior of sage grouse in Idaho. Transactions, Twenty-fifth North American Wildlife and Natural Resources Conference, pages 396-407.

In this study of the sage grouse (Centrocercus urophasianus) conducted in Jefferson, Clark, and Fremont counties, Idaho, strutting grounds -- areas used by sage grouse for display and mating -- were found in roadside sheep bedding grounds and old burns where openings have been created in otherwise nearly solid cover of sagebrush, and, in some cases, the road itself was used as a strutting area. In such cases, the authors observed, the strutting birds are highly vulnerable to fast-moving vehicles and to poachers. Sage grouse in the vicinity of Sand Creek game management area showed a preference for strutting sites associated with waterholes.

Dambach, Charles A. (20)

1951. Roadside use has a part in the conservation program. In the tenth short course on Roadside Development. Published by the Department of Landscape Architecture, Ohio State University, and Ohio Department of Highways. Pages 16-22, 2 photos.

"Ohio's roadsides total some 250,000 acres, more than state forests. Well vegetated roadsides provide wildlife cover that is much needed in an intensively farmed state. 'Mile for mile and acre for acre, Ohio's roadsides are next to farm fence rows, probably the most productive areas of wildlife lands in the State.' Several things can be done to improve roadsides for conservation purposes. Roadsides should be kept vegetated with native plants adapted to the site. Low herbaceous vegetation should be next to road, woody cover at outside of right-of-way. If woody plants are used, clumps of them should not be planted opposite each other on both sides of the road, for such an arrangement increases the tendency of animals to cross the road. Mowing should be delayed until as late in the season as possible so first broods and litters can be brought off. Mowing should be done as late as possible to reduce amount of nesting cover next spring. Herbicides should be used with caution to avoid damage to plantings of wildlife value. Pullouts should be planned where highways pass spots that are of special interest for their game concentrations or are conservation demonstration areas. Such spots should be used not merely for sight-seeing, but also to help popularize conservation."
WR #87

Davis, Russell, and E. Lendell Cockrum (21)

1963. Bridges utilized as day-roosts by bats. Journal of Mammalogy, 44(3): 428-430.

The authors stated that as of October, 1972, they knew of 20 bridges used as day-roosts by bats in Arizona. Although they indicate that most bridges apparently furnish sufficient shelter for night-roosting of bats, only two types which are illustrated by drawings in their article seem to provide the necessary conditions to allow them to serve as day-roosts one is an open expansion joint bridge which has one to several open transverse expansion joints which are closed above with paving material but are open below and thus accessible to bats; and the other type, rare in Arizona, which has "...inspection openings at each end which open into rather large cavelike chambers formed within the terminal foundations of the bridge." Eight different species of bats were reported as using the highway bridges of Arizona for day-roosts. The authors state: "Because of a recent trend toward the use of metal longitudinal undersupports, most newer bridges are not suitably constructed to serve as day-roosts."

Denton, J. Fred (22)

1967. The barn swallow nesting in Columbia and Lincoln Counties, Georgia. The Oriole - a quarterly journal of Georgia ornithology XXXII(3): 32-33.

The author reported seeing on June 3, 1967, three active nests of the barn swallow (Hirundo rustica) under the Broad River Bridge, Georgia Highway 79, on the Lincoln-Elbert County line and discussed observations made the previous fall at another bridge near Lincolnton where 15 barn swallow nests were noted on the flanges of the several I-beams.

Dopson, C. William, Jr., and Richard H. Peake (23)

1967. The cliff swallow, a new breeding bird for Georgia. The Oriole - a quarterly journal of Georgia ornithology XXXII(3): 29-31.

The authors reported on nests of cliff swallows found at Hartwell Dam under the fishing ramp over the dam's tailwater and confirmed that the cliff swallow had become established as a breeding bird in Georgia.

Eklund, Carl R. (24)

1942. Ecological and mortality factors affecting the nesting of the Chinese pheasant (Phasianus colchicus torquatus). Journal of Wildlife Management 6(3): 225-230., 4 tables.

In this pheasant nesting study conducted in Oregon in 1935, 11 of 145 nests found were located in roadside cover. Only fence rows and hayfields had more nests.

Emlen, John T., Jr. (25)

1954. Territory, nest building, and pair formation in the cliff swallow. The Auk, 71(1): 16-35, 4 plates.

Reporting on a study of cliff swallows made in Wyoming in 1950 and 1951, Emlen stated: "...Of eighteen colonies observed in the Jackson Hole area, eight were under the eaves of buildings, four were under concrete culverts, three were under ledges in large concrete bridges or dams, one was on steel girders under a steel-wood bridge, one was on a natural limestone cliff, and one was on a sand bank...In all cases, the essential features of the site seemed to be: a) a vertical surface beneath a ledge or overhang, and b) clearance below of at least three feet if over water and eight feet if over land...Almost any site possessing these features was explored by hovering flocks of swallows at the beginning of the nesting season...In one place where the birds were unable to secure a perch, the placement of narrow board strips below the overhanging eave resulted in the prompt establishment of a nesting group..."

Ferris, Craig R. (26)

1974. Effects of highways on red-tailed hawks and sparrow hawks. West Virginia University, Morgantown, West Virginia, M.S. Thesis, 60 pages, 25 tables, 2 figures.

"The effects of high-speed, limited-access highways, and their rights-of-way areas on red-tailed hawks (Buteo jamaicensis) and sparrow hawks (Falco sparverius) were studied along a 34.3 kilometer (21.3 mile) section of Interstate 79 in northcentral West Virginia.

During late fall, winter, and early spring, a drive census was used to determine the distribution and abundance of hawks along the highway. Both species were observed within the right-of-way more frequently than would be expected by random distribution alone. This was probably due to the availability and vulnerability of prey within the right-of-way. Sparrow hawks made greater use of the right-of-way than did red-tails due to the availability of perch sites.

Red-tails made limited use of the right-of-way in late spring and summer. Observations of the activity of sparrow hawks revealed that, while only 14.2 percent of the time was spent in the right-of-way, 46.2 percent of the strikes (attempts at catching prey) were made there. This was due in part to the abundance of insects in the right-of-way.

Little use was made of the right-of-way by either species in early fall. Lack of birds during early fall was attributed to migration.

Hawks were disturbed very little by moving traffic and would tolerate vehicles in their immediate vicinity. Highway rights-of-way could be of importance to red-tails and sparrow hawks if suitable vegetation is planted to encourage prey populations, and if perches are left during construction." (Author's abstract)

Hammond, Merrill C. (27)

1941. Fall and winter mortality among Hungarian partridges in Bottineau and McHenry Counties, North Dakota, Journal of Wildlife Management 5(4): 375-382.

In fall and winter studies of resident game species on the Lower Souris National Wildlife Refuge, North Dakota, Hammond reported graded and graveled roads to be important locally to the welfare of Hungarian partridges (Perdix). He stated: "...They provide the only supply of grit ordinarily available during the winter months...When the snow is deep the windswept roads are apparently utilized also as feeding areas.

"...Of 85 partridge deaths or injuries noted during the period from August 1938 to March 11, 1941, 68 were attributed to automobiles..."

Hanson, Lynn E., and Donald R. Progulske (28)

1973. Movements and cover preferences of pheasants in South Dakota. Journal of Wildlife Management, 37(4): 454-491.

In this study in which radiotelemetry was used to determine movements and cover preferences of ring-necked pheasant (Phasianus colchicus) hens in east-central South Dakota from June to October in 1969 and 1970, alfalfa was the most extensively used cover type both day and night and was preferred in all months of the study. Road and drainage ditches were next in order of preference during all periods, especially during darkness.

Haverlack, Edward G., Edwin D. Michael, and Craig R. Ferris (29)

Undated. Song bird occurrence around highway interchanges. Scientific Paper No. 1321, West Virginia University, Agricultural Experiment Station, 17 pages, 4 tables, 2 figures.

"This study determined passerine bird use of five interstate interchanges on Interstate 79 near Morgantown, West Virginia. Birds were censused by direct count during June, July, and August 1973. Interchanges were classified into four zones extending outward from the center of the roadway. Most species were found in the zone just beyond the right-of-way fence. Wildlife values can be enhanced within the right-of-way by planting shrubs and by modifying mowing practices. Interstate highways may create a desirable environment for some bird species." (Author's abstract)

Huey, Laurence M. (30)

1941. Mammalian invasion along the highway. Journal of Mammalogy, 22(4): 383-385.

There is some evidence that the range extension of certain mammals, as well as of plants, has been influenced by highways. Huey traces the history of road development across a 50-mile section of arid sandy desert between the High-line Canal, 10 miles east of Holtville in Imperial County, California, and the Colorado River near Yuma, Arizona -- an area originally unsuitable for pocket gophers (Thomomys), but suitable for desert mammals such as kangaroo rats (Dipodomys), two or more species of pocket mice (Perognathus), and a ground squirrel (Citellus tereticaudus). The road, when first seen by the author in 1960, consisted of "...two deeply scored wheel tracks in the sandy silt..." which led to an experimental plank road across seven miles of rolling sandy hills. This road was replaced in 1920 by a corduroy road made of heavy planks and the road over the silty plain was oiled. The present concrete road was completed in 1928. The writer indicated that he had seen no signs of the spread of gophers in the days of the old oiled road but had observed their advance 37 miles eastward from the canal 37 years subsequent to construction of the concrete road. He attributed this expansion of range to increased moisture content of the soil by the roadside (rain drained off the hard surface of the road to the side) and to the fossorial habits of the pocket gopher and consequently to less highway mortality than that suffered by the kangaroo rats. The increased moisture along the road created conditions suitable for the pocket gopher including more luxuriant plant growth on which to feed. He suggested that the oiled road did not have the same effect because it was more porous and did not result in as much moisture beside the road. Furthermore, he reasoned that the heavy black crude oil type pavement would have become so softened by heat during summer that the pounding wheels of traffic would collapse any burrows beneath it, preventing the passage of gophers.

Kopischke, Earl D., and Maynard M. Nelson (31)

1966. Grit availability and pheasant densities in Minnesota and South Dakota. Journal of Wildlife Management, 30(2): 269-275.

There is some indication of an association of pheasant distribution and abundance in the United States with the availability of calcium. In this study of 137 hen pheasants (Phasianus colchicus) collected by shooting in different areas of Minnesota and South Dakota, no significant difference was found between areas in the quantity of grit consumed by laying hen pheasants nor in the relative calcium and magnesium of this grit. Laying hens were found to have consumed about 50 percent more grit by weight than did nonlaying hens. "...Grit of the size commonly used by hen pheasants was abundant on secondary roads in each area but was comparatively scarce in field soils of the loess soil area. There was more calcium and magnesium in the grit from roads in southeast Minnesota than in grit from the other areas because crushed limestone is used in this area; glacier gravel is used in the other areas...Pheasants can selectively pick calcium -- and magnesium-bearing grit and differences in availability of these elements in the grit is believed not to limit pheasant densities in the areas studied." The size of grit particles most often used by hen pheasants was about 0.84 to 4.69 mm in diameter.

Lehmann, V. W. (32)

1968. The Attwater prairie chicken, current status and restoration opportunities. Transactions, Thirty-third North American Wildlife and Natural Resources Conference, pages 398-407.

A survey by the author in 1967 on special assignment to the U.S. Fish and Wildlife Service revealed 1,070 Attwater prairie chickens (Tympanuchus cupido attwater) a then all-time low. In discussing effects of flooding -- and, in particular, Hurricane Beulah -- on this species, he indicated that after the September 1947 floods, 55,000 acres of the Aransas-Refugio-Goliard prairie in Texas were checked for these birds by helicopter and only 49 were found -- all on or near elevated roads, knolls, ridges, and/or inside brushland.

Although it might be observed, parenthetically, that elevated roads provide a means of keeping them out of flood water, the birds' presence there subject them to highway mortality and one of the questions the author said needed to be answered by research is: "Can birds be attracted away from heavily-used roads and airstrips with artificial booming grounds created by mowing, fertilization, or controlled burning? What are the value of shelterbelts of various types and sizes; how much will water improvement contribute to chicken welfare?"

Linder, Raymond L., D. L. Lyon, and C. P. Agee (33)

1960. An analysis of pheasant nesting in south-central Nebraska. Transactions, Twenty-fifth North American Wildlife and Natural Resources Conference, pages 214-230.

The authors state that on their study area in south-central Nebraska, investigations from 1955-1959 indicated roadsides, which comprised less than 1.5 percent of the total acreage, had 23.6 percent of the total observed pheasant nests. They stated: "One of the reasons roadsides assumed this importance was the presence of cover remaining from the previous year which was available for early nesting...In dry years, fireweed (Kochia sp.) became abundant and during the fall and winter was blown into roadside ditches. This additional cover resulted in greater density of nests as well as higher rate of success of those nests. The increased success was not thought to have resulted from improved concealment but from the fireweeds' serving as a deterrent to mammalian predators that normally used roadsides as travel lanes..."

In discussion following presentation of this paper, Dr. Lindner stated: "Our roadsides as they stand probably would be hard to improve because they are not mowed. They are burned once in a while, often enough to keep them in constant fluctuation of cover, but most of them are in forbs or revert to native grasses. Western wheat grass is fairly important."

Martin, Robert F. (34)

1974. Syntopic culvert nesting of cave and barn swallows in Texas. The Auk, 91(4): 776-782.

The cave swallow (Petrochelidon fulva) was at one time considered by some United States students to be potentially endangered because of its geographically and restricted breeding habits, i.e., in Texas, it was thought to have breeding sites restricted to sink holes and caves. Recently the cave swallow has been found nesting in culverts which are used also by barn swallows (Hirundo rustica) and cliff swallows (Petrochelidon pyrrhonata). The author states: "This altered relationship offers several potential hazards to the species involved and provides an excellent opportunity to study competitive equilibria." More specifically, these hazards were suggested to be increased competition, vulnerability to disease or parasitism and breakdown of reproductive isolating mechanisms.

Michael, Edwin D. (35)

1971. Starling nesting in rocky cliffs. Bird-Banding 42 (2): 123.

"Starlings (Sturnus vulgaris) were observed feeding young in nests in cavities on rock faces formed in highway construction." W R No. 143:78.

Miller, John W. (36)

1975. Much ado about starlings. Natural History 84(7): 38-45.

In describing the introduction, acclimatization and spread of the European starling from its point of release in New York City's Central Park in 1890, throughout the United States and into Canada, the author indicated that the automobile age has proved to be a boon to this species. He observed that use of cars made the suburbs accessible to migrating urbanites and that starlings were provided with replicas of their Old World foraging grounds -- the close-cropped pastures of England and the Continent -- by lawns kept cut by power mowers and which were abundant in seeds, insects, worms, and grubs -- and that the superhighways that cover the American landscape have also enlarged the starlings' foraging area with thousands of miles of wide, grassy shoulders and median strips.

He states, page 41, "In addition to the bountiful harvest they glean from the edges of the roads, starlings add to their diet by dashing out into traffic lanes to snatch insects killed by cars."

On page 43, he states: "The architects of today's elevated expressways, overpasses, roadway ramps, and bridges now provide drier shelter and more ample perching space than the birds had in Victorian times. Horizontal steel I-beams, supporting wide slab roofs of cement, make excellent sleeping quarters protected from wind and rain...What is so striking about New York's starlings is that in a square half-mile of intersecting traffic arteries over the Harlem River -- marked by a jumble of cement ramps, elevated cloverleafs, concrete columns, and a canopy of steel struts and girders -- the birds have discovered an area with fewer humans afoot than any within miles of the city. The constant traffic from the Major Deegan Expressway, Harlem River Drive, Cross-Bronx Expressway, and the twelve-lane superhighway from the George Washington Bridge has drawn away pedestrians and turned the area into a sanctuary for birds able to tolerate engine noise and exhaust fumes." Information the author had from a bridge painting contractor indicated that the painters, in 1973, "had to use cold chisels and hammers to crack off eighteen-inch-thick cakes of guano that had accumulated on beams and gusset plates."

Milonski, Mike (37)

1958. The significance of farmland for waterfowl nesting and techniques for reducing losses due to agricultural practices. Transactions, Twenty-third North American Wildlife Conference, pages 215-228.

This paper reports on a waterfowl nesting study conducted along the border of, and south of, the Delta Marsh, Manitoba. Roadsides along the study area contained one nest per 0.68 miles in 1956 and one nest per 0.56 miles in 1957 and ranked next to stubble fields in total number of nests found in farmland cover.

Oetting, Robert B., and J. Frank Cassel (38)

1971. Waterfowl nesting on interstate highway right-of-way in North Dakota. Journal of Wildlife Management, 35(4): 774-781.

Author's abstract: "We studied 630 acres of roadside along 23 miles of Interstate 94 in Stutsman County, North Dakota to assess wildlife values of highway rights-of-way. We found 422 duck nests that had an overall success of 57 percent in 1968, 1969, and 1970. Mammalian predators were responsible for 85 percent of the destroyed nests. To test the effect of mowing on duck nest initiation and success, alternate 1-mile blocks of the study area were not mowed in the fall of 1968. In 1969 and 1970, significantly more ducks chose unmowed vegetation in preference to mowed vegetation for nest sites. Mallards (Anas platyrhynchos), pintails (A. acuta), and gadwalls (A. strepera) were especially responsive to unmowed vegetation. Success of duck nests in unmowed vegetation was 62 percent compared with 51 percent in mowed vegetation. Sixteen percent of the nests were unhatched by July 5, the beginning mowing date previously recommended by the North Dakota Highway Department. Wildlife killed by traffic did not increase when half the mile blocks were unmowed, and no significant difference was observed in the build-up of snow between mowed and unmowed blocks in the winter of 1968-69. Of 182 motorists interviewed in the study area, 82 percent had not noticed the unmowed rights-of-way. We strongly recommend no mowing of ditch bottoms or back slopes, minimal mowing of inslopes, and no mowing before July 20 to enhance waterfowl nesting and to reduce maintenance costs of highway rights-of-way in duck-producing regions."

The authors report that the 789,000 acres of highway-rights-of-way and the 70,600 acres of railroad rights-of-way are double the combined acreage (425,000) of state game management areas and Federally owned waterfowl production areas and wildlife refuges in North Dakota and they urge increased attention to rights-of-way for wildlife. Wildlife observed in the study area, in addition to ducks, included the killdeer (Charadrius vociferus), mourning dove (Zenaidura macroura), American bittern (Botaurus lentigenosus), gray partridge (Perdix perdix), and upland plover (Bartramia longicauda) -- all of which nested in the rights-of-way -- sharp-tailed grouse (Pedioecetes phasianellis), white-tailed jack rabbit (Lepus townsendii), ring-necked pheasant (Phasianus colchicus), striped skunk (Mephitis mephitis), Richardson's ground squirrel (Citellus richardsonii), white-tailed deer (Odocoileus virginianus), long-tailed weasel (Mustala frenata), and a variety of gulls, hawks, shorebirds, mice, voles and songbirds. Highway mortality of wildlife was noted daily along the entire highway in the study area during May, June and July. When all vegetation was in the mowed condition in 1968, wild animal victims observed included 23 striped skunks, 5 white-tailed deer, 4 raccoons, and 4 ducks. During the same period in 1969, when half the right-of-way was mowed, dead animals recorded were 16 ducks, 12 jack rabbits, and 3 white-tailed deer.

Although 82 percent of the motorists intervived had not noticed the unmowed vs. mowed portions of the roadside in 1969, when this condition was called to their attention, 72 percent preferred the mowed strips because they were neater; many of the respondents, however, wanted to change their initial answers after the interview when the study was explained, because they feared their first answers might jeopardize wildlife using the rights-of-way.

The interest of the North Dakota Highway Department in the study, their cooperative attitude and their willingness to alter maintenance methods, including the delay of mowing on primary and secondary roads from July 5 to July 15 to allow more nests to hatch, is noted.

Owens, R. A. and M. T. Myers (39)

1973. Effects of agriculture upon populations of native passerine birds of an Alberta fescue grassland. Canadian Journal Zoology 51:697-713, 4 figs. In English with French summary. (F. F. Slaney and Co., Ltd., 402 West Pender Street, British Columbia, Canada.)

"Abstract: The effects of several forms of agricultural use of native fescue (Festuca scabrella) grasslands upon population of native passerine birds were studied in the Hand Hills of southern Alberta in 1970. Censuses of avian populations were carried out on twelve 40-acre (16.2 km) study plots as well as on two 10-mile (16.1 km) long roadside routes. The vegetation on the study plots and along the roadside routes was described. Native fescue grasslands, undisturbed for three years, supported a passerine community consisting of Baird's sparrow (Ammodramus bairdii), Sprague's pipit (Anthus spragueii), savannah sparrow (Passerculus sandwichensis), clay-colored sparrow (Spizella pallida), and western meadowlark (Sturnella neglecta). Incomplete disturbance of fescue grasslands, by mowing for hay or grazing by cattle, reduced or eliminated Baird's sparrow and Sprague's pipit but permitted the ingress of horned lark (Eremophila alpestris) and chestnut-collared longspur (Calcarius ornatus). Total elimination of the native grassland by ploughing and cultivation for cereal crops, eliminated all passerine species except

the horned lark. Peripheral disturbed areas resulting from cultivation, such as field boundaries and roadside ditches, may have benefitted several species that tend to occur in ecotonal habitats: savannah sparrow, clay-colored sparrow, and vesper sparrow (Pooectes gramineus). W. R. No. 150:75.

Page, J. Frank (40)

1971. Waterfowl nesting on a railroad right-of-way in North Dakota. Journal of Wildlife Management, 35 (3): 544-549.

The authors point out that, in North Dakota, acreage in rights-of-way approximates one million and that this represents an unstudied resource of high potential for nesting habitat. A 21.5 mile section of the Northern Pacific Railway's main line right-of-way in west central Stutsman County was studied for waterfowl production. Of 240 acres searched for duck nests, 105 acres had been hayed the previous season and 135 acres had at least a year's growth of dead vegetation. Nest densities were 9.6 nests per 100 acres on hayed areas and 55.6 nests per 100 acres on unhayed areas. The acres mowed for hay produced 0.64 duckling per acre; the unmowed portion, 3.93 ducklings per acre. The authors suggested that for waterfowl production, consideration be given to stopping all annual cover removal on managed areas and allowing only periodic burning to alter plant succession.

Robinson, Cyril S. (41)

1935. Truck trails and firebreaks; their use by deer on the Santa Barbara National Forest. Journal of Forestry 33 (11): 940-942.

Indicates deer are not driven out by trail invasion of their habitat. Rather, the change in ecological conditions produces a new mixed growth of which the deer are quick to take advantage. W. R. No. 4.

Snyder, Warren D. (42)

1974. Pheasant use of roadsides for nesting in northeast Colorado. Special report No. 36, Colorado Division of Wildlife. 24 pages, 11 tables, 11 figures.

Abstract by author: "This study compares ring-necked pheasant (Phasianus colchicus) nesting and production under existing roadside conditions (farmed and unfarmed) with production where grass and grass-legume covers were seeded in roadsides in northeast Colorado. One nest was found per 0.58 linear mile (0.94km) of seeded roadside, per 0.93 mile (1.50 km) of unfarmed (natural weedy) roadside, and per 2.04 miles (3.28 km) of farmed roadside. On the average, one nest was found per 1.25 acres (0.51 ha) of seeded roadside, per 2 acres (0.81 ha) in unfarmed roadside, and per 5 acres (2.02 ha) of farmed roadside. Nesting density differences were highly significant among all three types. Predators destroyed about 55 percent or more of the roadside nests and about 11 percent were lost to abandonment. As a result, annual production was relatively low, with one successful nest observed per 2.42 miles (3.90 km) of seeded roadside (0.19 nest per acre), per 3.54 miles (5.70 km) of unfarmed roadside (0.14 successful nest per acre), and per 12.23 miles (19.70 km) of farmed roadside (0.04 successful nest per acre) over the four year (1970-1973) study interval. Seeded cover containing alfalfa (Medicago sativa) and alfalfa-grass mixtures contained significantly higher nest densities than did grass stands alone. A combination of alfalfa and tall wheatgrass (Agropyron elongatum) was recommended as one of the best combinations for nesting cover in northeast Colorado. The impact of habitat and pheasant production loss due to current practices of farming roadsides is discussed."

Stewart, Robert E., and Harold A. Kantrud (43)

1973. Ecological distribution of breeding waterfowl populations in North Dakota. Journal of Wildlife Management, 37 (1): 39-50.

The authors studies breeding waterfowl populations on various wetland habitat types in North

Dakota during 1967-69. The data are based on counts of breeding pairs on the various types of wetland within sample units that were selected by stratified random sampling techniques. The total wetland acreage in North Dakota was estimated to be about 3.2 million acres consisting of about 2.5 million acres designated as natural basin wetlands and 0.7 million acres as "other wetlands." Although road ditches and drainage channels were the most numerous of the other wetlands, they represented less than 0.5 percent of the total wetland; however, they attracted about 2 percent of the breeding pairs.

Tabor, R. (44)

1974. Earthworms, crows, vibrations and motorways. New Scientist, IPC Magazines (66-69 Great Queen Street, London WC2E 5DD, England). 62(899): 482-483.

"Observations suggest there is a positive factor drawing crows and rooks to the freeway compared with levels in fields and on other roads. This factor seemed to be dependent on the moisture of freeway banks, and sensitivity to frosts. Variations in vibration were possibly causing different numbers of earthworms to "surface", and this factor, in turn, was possibly the source of the different crow/rook counts along the M4. In dry conditions, earthworms burrow deeper into the soil, and as traffic vibrations are largely a surface effect, they remain there unmolested. For a given soil, exposed to a 5 HZ square wave excitation signal at 0.025 mm peak-to-peak amplitude, the moister the soil conditions the more earthworms emerged on the surface. HRIS No. 262464.

Trautman, Carl G. (45)

1960. Evaluation of pheasant nesting habitat in eastern South Dakota. Transactions, Twenty-fifth North American Wildlife and Natural Resources Conference, pages 202-213.

In a study in Brookings County, South Dakota roadsides were found to have 2.82 pheasant nests per acre, ranking relatively high among the various cover types searched for nests. The author stated: "The benefits to pheasant production by delaying the mowing of roadsides should be impressed upon public road agencies."

Upgren, Ted (46)

1974. Winter energy problems of North Dakota Huns. North Dakota Outdoors 37 (5): 8-13.

The author discusses the survival problems of the exotic Hungarian or gray partridge during North Dakota winters. It is mentioned that "Roadsides are important components of winter partridge habitat, particularly in years when heavy snow conceals gravel and grit required for food digestion. Bladed shoulders offer spilled grain, weed seeds, and sprouts. These open stretches also absorb heat and probably are very comfortable loafing sites on cold, but sunny days."

Wallace, Gary O. (47)

1970. Cliff swallows nesting in Grainger County. The Migrant - a quarterly journal devoted to Tennessee birds, 41 (4): 77-78.

In June, 1970, the author reported seeing 216 nests of cliff swallows (Petrochelidon pyrrhonata) under 6 bridges in Grainger and Jefferson Counties, Tennessee and indicated that this was the fourth location reported for this species in East Tennessee. Under most bridges in Grainger County were old mud rings indicating that cliff swallows had been nesting in the area prior to 1970.

Wright, Vernon, and Paul Otte (48)

1962. A central Iowa pheasant nesting study, 1961. Proceedings, Iowa Academy of Scinece 69: 252-259, illus. (From Biol. Abstr.) 45 (2), 1964.

"A study of nesting success of pheasants (Phasianus colchicus) on three areas in central Iowa in 1961 showed that the peak of nest establishment occurred between May 16 and May 30 ..... Roadsides sheltered the highest percentage of nests on a per acre basis (46 nests/100 acres), followed by hayfields (24 nests/100 acres) and oatfields (4.7 nests/100 acres) ..... Most nests were located in cover from 16 to 22 inches in height ...." After W. R. No. 116.

C. EFFECTS OF HIGHWAYS AND HIGHWAY CONSTRUCTION ON FISH AND WILDLIFE.

1. Erosion, Channelization and Sedimentation

American Association of State Highway Officials, (49)
Operating Subcommittee on Roadway Design

1973. Guidelines for hydraulic considerations in highway planning and location.

Amercian Association of State Highway Officials Publication, 1973, 4 pages, 2 references, Ref. Highway Drainage Guidelines: Vol. 1.

Abstract: "Water and related climatic factors are important considerations in planning and locating highways. The effect of the highway construction on the existing drainage pattern and on the potential flood hazard, as well as the effect of floods on the highway, must be assessed in the preliminary planning and design stages. Often hydraulic factors are closely related to the environmental, ecological and economic aspects of the location of a new highway and critical evaluations must be made in the planning process, requiring compromises and a searching for alternatesolutions and routes. Some drainage, flood, and water quality problems can be easily recognized and resolved; others may require extensive investigation before an adequate and satisfactory solution can be developed. Specialists experienced in hydrology and hydraulics can contribute substantially to the planning and location of a highway project by recognizing potentially troublesome locations, making necessary investigations, and recommending practical solutions. Hydrologic and hydraulic data, preliminary calculations and analyses, all information used in developing conclusions and recommendations related to drainage requirements, including estimates of structure size and location, should be compiled in a report. Such a report serves as documentation and back up for decisions on route location and is an excellent reference for more detailed studies needed in preparing construction plans. (See also W73-10658) (Woodard-USGS)" WRSIC Accession No. W73-10657.

Note: Another volume (2) deals with guidelines for hydrology.

Anderson, Henry W. (50)

1974. Sediment deposition in reservoirs associated with rural roads, forest fires, and catchment attributes. Pages 87-95 in Proceedings of the Paris Symposium - "Effects of man on the interfaces of the hydrological cycle with the physical environment," IAHS-AISH Publication No. 113.

Author's abstract:
"Deposition of sediment was measured in 48 northern California reservoirs having catchment areas exceeding 5 km^2. The measurements were related by principal components analysis to four categories of variables: catchment, streamflow, snow, and land use. Intensity of land use was characterized by roads built for timber harvesting, mining, and recreation, and by uses not primarily related to roads such as grazing and forest fires. Roads were of five classes -- ranging from highways to dirt roads -- and three locations: ridge top, slope, and streamside. Forest fire variables included current fire history and the extent of high-elevation brushfield associated with burning and grazing. Explained variance in sediment deposition ranged from 78 to 83 percent, depending on the model used in the analysis. Variables contributing the most to explained variance were, in decreasing order, snow, geology, streamflow, forest fires, roads, and reservoirs. Roads located near streams contributed the most to deposition, twice as much as did roads located elsewhere. And improved secondary roads near streams were the single greatest contributor."

In his conclusions, the author stated: "Historically, the common practice has been to upgrade dirt (earth roads) to improved secondary roads; this practice may reduce sediment at slope locations by as much as 44 percent. However, upgrading of dirt roads at streamside locations can increase sedimentation by 4.8 times."

Barns, R. A. (Biological Station, Nanaimo, British Columbia, Canada). (51)

1969. Adaptations of sockeye salmon associated with incubation in stream gravels. H. R. MacMillan Lectures in Fisheries, Symposium on Salmon and Trout in Streams, University of British Columbia, Vancouver, Canada, February 1968, pages 71-87.

"Successful development in and escape from the intergravel environment poses scientific problems to salmonid larvae. Adaptive responses have developed to cope with these problems. They include behavioural responses, such as ventilation swimming, coughing, negative phototaxis and directed emergence, as well as physiological responses, such as early hatching, branchial respiration, gill cleaning by mucous secretion, and 'spontaneous' initiation of emergence behaviour. Some implications associated with development in the gravel and optimal time of lake entry illustrates the extent, complexity, appropriateness and sensitivity of adaptation required to fit the animal for its way of life." (Authors) Sport Fishery Abstracts No. 12434.

Bayless, Jack, and William B. Smith. (52)

Undated. The effects of channelization upon the fish populations of lotic waters in eastern North Carolina. Division of Inland Fisheries, North Carolina Wildlife Resources Commission, Raleigh, N. Carolina. 14 pages.

"This paper concerns an evaluation of the effects of habitat alteration associated with stream channelization in eastern North Carolina. The evaluation was based upon a comparison of fish populations found in 23 channelled streams, and 36 proximate natural streams within the Chowan, Neuse, Northeast Cape Fear, Pimlico, Perquimans, and Tar River Watersheds. These comparisons indicated that reductions in magnitude of 90 percent occurred both in weight of game fish per acre, and in number of game fish exceeding six inches total length per acre, following channelization. The data further revealed that no significant return towards the natural streams populations occurred with a 40-year period following channelization." (Authors) Sport Fishery Abstracts No. 8368.

Briggs, William M.-Soil Conservation Service, Madison, Wis. (53)

1969. Roadside erosion survey. Soil Conservation, 35 (2): 27-28, 1 figure, 1 photo, 1 table.

Abstract: "A survey was made of roadside soil erosion in Wisconsin. Over 21,000 sediment-producing sites on 87,000 miles of road total 3,711 miles of erodible roadside. Town and county roads account for 97 percent of the erosion. Erosion control recommendations include seeding, mulching, sediment-control structures, and property acquisition. (KNAPP-USGS)" WRSIC Accession No. W70-02327

Briggs, William M. (54)

1973. Inventory of roadside erosion in Wisconsin. Pages 77-81 _in_ Soil Erosion: Causes and Mechanisms, Prevention and Control, Special Report 135. Highway Research Board (Washington, D. C.) 141 pgs.

"Highways have an important effect on our environment. Runoff from highways frequently drains directly into lakes and streams. For years observers recognized roadside erosion caused by construction and maintenance as one of the principal contribution factors to sedimentation."

In 1967, a statewide inventory of erosion on all of Wisconsin's state, county, and town roads, was taken. Seventy-three percent of erosion was found to occur along town roads and twenty-four percent along county roads. Three percent of erosion sites occurred along state roads."
The following benefits are expected from the roadside erosion control program (which Wisconsin has, as a result, initiated):

1. Improvement in the quality of our environment,

2. Reduction in lake and stream sedimentation,

3. Improvement in highway safety,

4. Enhancement of natural beauty and wildlife habitat, and

5. Reduction in maintenance and reconstruction costs." Bibliography of 1 title.

Brown, G. W. -Oregon State University, Corvallis. School of Forestry. (55)

1972. Logging and water quality in the Pacific Northwest. Pages 330-334 in: Watersheds in Transition; proceedings of symposium held at Fort Collins, Colorado, June 19-22, 1972; American Water Resources Association Proceedings Series, No. 14, 1 figure, 10 references.

Abstract: "The impact of logging and road construction on water quality in the steep, densely forested watersheds of the Pacific Northwest is summarized. The forests of the Pacific Northwest are among the most productive in the world. In Oregon, some 536 billion board feet of standing sawtimber annually supply 9.1 billion board feet to national and international markets. In the past, management of the area's forested watersheds has focused primarily upon the production of timber. Many of the streams in these watersheds are also the spawning and rearing sites for a valuable anadromous fishery and, in many instances, the source of water for northwest municipalities. Management of these watersheds is in a state of transition. Recent research findings have shown that clear-cut logging can significantly affect stream temperature, and sediment and dissolved oxygen concentration. Water quality standards prescribed for interstate waters are being extended to small, forested streams. Oregon for example, is now in the process of instituting a new Forest Practices Act which will prescribe logging practices and standards of operation and enforcement to meet these water quality criteria. (see also W73-03536) (WOODARD-USGS)" WRSIC Accession No. W73-03551

Brown, G. W. and J. T. Krygier - Oregon State University, Corvallis. (56)

1971. Clear-cut logging and sediment production in the Oregon coast range.

Abstract: "The impact of road construction, two patterns of clear-cut logging, and controlled slash burning on the suspended sediment yield

and concentration from three small watersheds in the Oregon coast range was studied for 11 years. Sediment production was doubled after road construction but before logging in one watershed and was tripled after burning and clear-cutting of another watershed. Felling and yarding did not produce statistically significant changes in sediment concentration. Variation in the relation between sediment concentration and water discharge on small undisturbed streams was large. (Knapp-USGS)" WRSIC Accession No. W72-01129

Cywin, Allen, and Ernest L. Hendricks (57)

1970. An overview of U. S. Department of Interior's role in sediment control. Federal Water Quality Administration, Washington, D. C. Division of Applied Science and Technology; and Geological Survey, Washington, D. C. In: Proceedings of National Conference on Sediment Control, September 14-16, 1969, Washington, D. C., Environmental Planning Paper, Department of Housing and Urban Development, pages 34-40.

Abstract: "Objectives of the following organizations within the USDI having programs related to sediment pollution and its control are reviewed: (1) Federal Water Pollution Control Administration, (2) Geological Survey, (3) Bureau of Reclamation, (4) Bureau of Mines, (5) Bureau of Sport Fisheries and Wildlife, (6) Bureau of Outdoor Recreation, (7) Bureau of Land Management, (8) Office of Water Resources Research, and (9) National Park Service. Sediment represents a heavy economic drain in loss of valuable topsoil. It also makes water unfit for use as municipal and industrial sources of supply unless the water undergoes expensive treatment. It also interferes with navigation, destroys esthetic values and injures aquatic life. As a nutrient carrier, it promotes algal growths which degrade water quality and in turn accelerates the aging process of lakes and reservoirs. Utilization of existing techniques and development of new techniques for sediment control that are tailored specifically for use in urban or urbanizing areas are musts if adequate control of sediment problems is to be achieved and these in turn

must consider ecology and water quality requirements. (See also W71-04146) (WOODARD-USGS)" WRSIC Accession No. W71,04147

Fredricksen, R. L. (58)

1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. Forest Service, Portland, Oregon. Pacific Northwest Forest and Range Experiment Station. Forest Service Research Paper PNW-104, 15 pages, 5 figures, 4 tables, 15 references.

Abstract: "In two steep headwater drainages in Oregon landslides were the predominant source of increased sedimentation of streams following timber harvest. Patch-cut logging with forest roads increased sedimentation relative to a control by more than 100 times over a 9-year period. Landslide erosion was greatest where roads crossed high gradient stream channels. In an adjacent clearcut watershed with no roads, sedimentation increased three times that of the control. (KNAPP-USGS)" WRSIC Accession No. W71-09655

Henegar, Dale L., and Keith W. Harmon (59)

1973. A review of references to channelization and its environmental impacts. North Carolina Division American Fisheries Society, Special Publication 2, pages 79-83.

"Available literature is briefly reviewed under the following headings: downstream flooding, drainage outlets, sediment damage, groundwater recharge, fishery losses, wildlife losses. A bibliography of 63 titles is presented. All of The papers in the bibliography are not reviewed.

Abstracted by John L. Funk. Sport Fishery Abstracts No. 17092.

Herr, Lester A. - Bureau of Public Roads, Washington, D. C. (60)

1970. The control of erosion and sediment in highway construction. in: Proceedings of

National Conference on Sediment Control, September 14-16, 1969, Washington, D.C., Environmental Planning Paper, Department of Housing and Urban Development, pages 41-47.

Abstract:
"This report emphasizes the importance of prudent planning in highway construction to control erosion and sediment problems that deteriorate our natural resources. Erosion and scour of the banks and beds of streams and rivers are problems both during design and construction of our highways and for years after they are built. Rivers change course and meanders move downstream which make our bridge piers and abutments vulnerable to attack by the main current. In some cases, the initial main river bridge becomes ineffective as a waterway. In such a case expensive revetment or additional openings must be constructed. Channel changes made downstream from our highway structures cause degradation of streambeds which make foundations of existing bridges unsafe and have caused failures. Suggestions for approaching these and other related problems are presented. (See also W71-04146) (Woodard-USGS)" WRSIC Accession No. W71-04149.

Irizarry, Richard A. (61)

1969. The effects of stream alteration in Idaho. Idaho Fish and Game Department, Federal Aid in Fish and Wildlife Restoration Project F55-R-2, 26 pages, 5 tables, 8 figures, literature cited, photos.

"Investigations were conducted to evaluate the number of stream miles subjected to artificial alteration and compare the standing crop of game fish between equal areas of altered and unaltered stream sections.

In the physical inventory phase of this project, 1,138 miles of stream were studied during a two-year period (Fig. 1). The number of altered stream miles were calculated at being approximately 434 miles, which converted to percentage, revealed that an average of 38 percent alteration had occurred within the 45 study streams. This was an occurrence of 1-1/4 alterations per stream mile, with the average length of a channel alteration being 1,935 feet.

Encroachment of road materials was responsible for 55 percent of the alteration, 20 percent was due to channel relocation, 13 percent to mining, 11 percent to channel clearance, and 1 percent to riprapping (Table 1). Sixty percent of the alterations were associated with road-building activities, nineteen percent with flood control projects, thirteen percent with mining, six percent with railroad construction, and two percent with agriculture and other miscellaneous activities (Table 2).

Biological sampling in 29 different streams found that there were almost seven times as many catchable-sized trout and almost ten times as many catchable-sized whitefish censused in unaltered (natural) stream sections as in altered stream sections. The undisturbed areas out-produced the altered areas, ranging from 1.4 to 112 times greater in poundage of game fish. In some instances, the altered areas produced no game fish whatever.

Average fish production, in poundage was 8 times greater in undisturbed stream sections; while in numbers of game fish, the natural areas out-produced the altered areas 6 to 1." (Author's abstract)

Khanna, S. D. (62)

1973. Effects of highways on surface and subsurface waters. Public Works, 104 (11): 71-73, 123-124, 2 figures.

Abstract: "The construction of highways can create serious environmental problems in surface waters. Such problems need to be identified and solutions considered during the design and location stage of highway construction. Several general problem areas are discussed and solutions are offered to either minimize detrimental effects or maximize beneficial effects. The general problem areas considered are: (1) quantity of water, (2) water resources projects, (3) storm drainage systems, (4) channel relocations, (5) flood controls and flood plains, (6) groundwater, (7) water recreation, (8) community utilities, and (9) water quality. (Mortland-Battelle)"
WRSIC Accession No. W74-03607

Kingsburg, A. P., Alaska Dept. of Fish & Game, Juneau. (63)

1973. Relationship between logging activities and salmon production. Available from the National Technical Information Service as COM-73-11630; $5.00 in paper copy, $1.45 microfiche. National Marine Fisheries Service Report No. NOAA-730-90605, April 1973. 59 pages, 13 figures, 1 table, 33 references, 10 appendices. 5-24-R.

Abstract:
"Effects of logging and road building on stream flow, water temperature and debris on salmon egg and fry production were assessed quantitatively and additional data obtained on sediment content of spawning gravel, intra-gravel, dissolved oxygen and salmon abundance. Studies were conducted at 108 Creek and Kadashan Creek in southeastern Alaska. Spawning bed sediment and dissolved oxygen and pink salmon survival data were assembled and are discussed in relation to logging and road building. Fine sediment in three 108 Creek study areas increased somewhat irregularly over the first six years of the study and did not change appreciably in the following three years. Analysis of the relationship between amount of fine sediment and dissolved oxygen content within the gravel in the streams was inconclusive. Decreases in fine sediments were usually associated with high stream flow and high spawner density. Estimates of over-winter survival of pink salmon were too imprecise and are affected by too many factors for use as a measure of land use effects on pink salmon production. Intra-gravel sediment and dissolved oxygen data were highly variable within and between Kadashan Creek study areas. Effects of logging and roading on the pink salmon production were difficult to demonstrate. (Jones-Wisconsin)" WRSIX Accession No. W74-07468.

Kopperdahl, F. R., J. W. Burns, and G. E. Smith. (64)

1971. Water quality of some logged and unlogged California streams. Administrative Report No. 71-12, 19 pages, 8 tables, 23 references.

Abstract:
"Water quality surveys of four stream which had been logged or had road construction, and two undisturbed streams were conducted in 1968 and 1969.

The effects were evaluated of logging on water quality and to predict capacities of the streams to rear salmon IDS. No abnormal concentrations of dissolved oxygen, alkalinity, hardness, dissolved solids, phosphates, chlorides, sulfate, nitrate, tannin, lignin, or pH were detected. Carbon dioxide was low in all streams except in South Fork Caspar Creek, in which 8 mg/l were observed during decomposition of logging debris. Turbidity was high when bulldozers were working in the stream. Alternating cut and uncut blocks on one stream, and retaining a buffer strip along another, kept temperatures low in the two streams. Temperatures increased after logging. (Katz-Washington)" WRSIC Accession No. W72-12248.

Lanyon, R. F. (65)

1972. Impact of highways on surface waterways. Metropolitan Sanitary District of Greater Chicago, Ill., 21 pages, 3 figures, 1 table, 9 references.

Abstract:
"The modern highway has a high efficiency of stormwater drainage which is beneficial to the highway, but detrimental to the waterways into which the runoff is discharged. The associated landscaping near the highway often reduces the natural storage of rainwater and reduces the rate of rainwater infiltration, causing additional problems of increased flow in the waterways. Further problems are encountered when highways are built in floodplains, occupying land which previously was used for stormwater storage. During construction of the roadway, erosion can be a serious problem. Sediment yields have been estimated at 500 to 1,000 tons per year per mile of 100-foot wide construction, or 40 to 80 tons per acre per year. Sediment yields between 0.3 to 0.5 tons per acre per year are cited for undeveloped land. The construction of a roadway across a stream can be a potential flood hazard if debris is allowed to collect at the bridge. Highways can also be detrimental to waterways as a result of pollution from deicing chemicals, oil on the pavement and ordinary surface dirt. Detention storage of stormwater runoff is recommended as a means of controlling many of these problems. Runoff flow rates can be reduced, sediments settled out and additional flood plain storage provided. Detention storage can provide other important benefits such as groundwater replenishment, and recreational and open space facilities. Detention of runoff

can also reduce the cost of drainage facilities in comparison to conventional facilities." (Poertner) WRSIC Accession No. W73-08894.

Megahan, W. F., and W. J. Kidd. (66)

1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. Journal of Forestry, 70(3): 136-141.

Abstract:
"Erosion plots and sediment dams were used to evaluate the effects of jammer and skyline logging systems on erosion and sedimentation in steep, ephemeral drainages in the Idaho Batholith of Central Idaho. Plot data collected periodically over a 5-year period indicated that no differences in erosion resulted from the two skidding systems as applied in the study. Concurrent sediment dam data were used to show that the logging operations alone (excluding roads) increased sediment production only about 0.6 times over the natural sedimentation rate. Roads associated with the Jammer Logging System increased sediment production an average of about 750 times over the natural rate for the 6-year period following construction." WRSIC Accession No. W73-09374.

Menendez, Raymond. (67)

1968. Survey of dredging and bank stabilization practices in Hampshire County, West Virginia. Pages 6-10 in Inter-agency Stream Disturbance Symposium Proceedings (Charleston, West Virginia), 47 pages.

"The 19 projects, inspected during this (dredging and bank stabilization) survey involved a total of 22,400 feet of stream alterations, encompassing a total area of 27.20 acres." Seven of these projects were on the North River and involved 6.11 acres. "In the past, much of the headwaters (of the North River) have been channelized for road maintenance purposes by the State Road Commission (F-10-R-6, District II, D-J Report). No estimate was made of this damage. Much of the drainage has been depredated by floods and bulldozing.

"The total losses attributable to this project (the entire 19) include the loss of 27.2 acres of water valued at $81,600.00, annual fish population losses valued at $3,517.22, plus additional expected losses of $1,679.04. Additionally, there is a loss of 140 man/days of angling per acre per year valued at $1,522.80.

Packer, Paul E. and Harold F. Haupt. (68)

1965.. The influence of roads on water quality characteristics. Proceedings, Society of American Foresters, Detroit, Michigan, 1965, pages 112-115. Forest Service (USDA), Logan, Utah. Intermountain Forest and Range Experiment Station.

Abstract:
"Road systems needed to serve inter-regional traffic as well as local uses, including those for timber harvesting, increase the potential for damaging the high quality of water. Examples are cited where poorly-built roads produce large amounts of sediment. Well-built forest roads contribute some sediment after construction; but, because of good location and design characteristics with respect to drainage, erosion scars heal rapidly. The importance of keeping even small quantities of sediment out of stream channels has been stressed repeatedly by fishery biologists. Turbid streamflow may drastically reduce aquatic fauna and the hatchability of fish eggs. Watershed scientists have observed that, when well-constructed roads are located some distance from streams, muddy over-land flow does not reach the stream, but infiltrates harmlessly into the undisturbed intervening protective strip. Road location, drainage design, and nature of the protective strip, therefore, are essential factors in water-quality control on managed forest lands. Guides for locating and draining roads have been developed from investigations in specific locations where soil and terrain factors were studied. Similar study techniques would be valuable for determining the influence of roads on water quality characteristics under other conditions of soil and terrain. This article has 17 references." WRSIC Accession No. W69-05886.

Parizek, R. R. (69)

1971. Impact of highways on the hydrogeologic environment. In: Environmental Geomorphology, Proceedings of 1st Annual Geomorphology Symposia Series, held at Binghamton, N. Y., Oct. 16-17, 1970. State University of New York at Binghamton, Publications in Geomorphology; pages 151-199, 9 figures, 7 tables, 61 references.

Abstract: "Highways may have favorable or unfavorable influences on our environment. The presence or absence of deep cuts and extensive fills can produce a large variety of transformations on the terrain and in the hydrogeologic environment. Such possible changes include beheading of aquifers, development of extensive groundwater drains, damage and pollution of water supplies, changes in groundwater and surface-water divides and basin areas, reduction of induced streambed infiltration rates, siltation of channels, obstruction of groundwater flow, and changes in runoff and recharge. Changes occur by economic activity stimulated by the highway. Sanitary, industrial, and solid wastes may be disposed of in an unsatisfactory manner. Pullution may result from maintenance procedures used to control weeds, insects, snow and ice, and from exposed stock piles of chemicals used for these purposes. (see also W72-08510) (KNAPP-USGS)" WRSIC Accession No. W72-08516

Patric, James H. (70)

1970. Logging roads and water quality. Proceedings Forest Engineering Workshop on Forest Roads, W. Va. University, 1970, pages 11-16.

Abstract: "Soil from eroding logging roads is the most common and harmful pullutant of forest streams in West Virginia. Some consequences of pollution by soil and other contaminants from logging roads are reviewed. Forest managers can avoid most of this damage to water quality by applying known methods of water control on logging roads. (PATRIC-FOREST SERVICE)" WRSIC Accession No. W70-10417

Patrick, Ruth (The Academy of Natural Sciences of Philadelphia) (71)

1973. Effects of channelization on the aquatic life of streams. Pages 150-154 in "Environmental considerations in planning, design, and construction." Highway Research Board, Div. of Engineering, National Research Council, National Academy of Sciences - National Academy of Engineering Washington, D. C., Special Report 138. 161 pages. (Price $5.00)

"The chief effects of channelization are as follows:

1. Removes the natural diverse substrate materials that allow the development of many types of habitats for aquatic organisms;

2. Increases sediment load that decreases light penetration and primary production;

3. Creates a shifting bed load that is inimical to bottom - dwelling organisms;

4. Simplifies the current pattern and eliminates habitats of diverse currents;

5. Lowers the stream channel and often drains adjacent swamp areas and aquifers that help to maintain stream flow during times of low precipitation;

6. Destroys floodplain ponds that are the breeding ground for aquatic life and that act as a reservoir of species for the river proper; and

7. Reduces the stability of the banks and causes cave-in of trees and other overhanging vegetation that are an important food source for stream life and whose shade reduces high stream temperatures during the summer months."

Dr. Patrick points out that usually channelization is done to increase the rate of flow in streams but sometimes to obtain road - building materials. She indicates that snagging and removing vegetation from the banks produce profound changes in the ecosystems of the stream and that removal of floating debris eliminates an important habitat for aquatic organisms. The removal of sand and gravel from the stream bed for road improvement often is done without regard to the gradient of the stream and to natural bed contours. Large holes may result in areas where stagnant water accumulates without the necessary oxygen for aquatic life... "When a channel is straightened the banks are often riprapped with quarried stone at a vertical angle. The result is that the sun reaches the water surfaces for an insufficient period time to support algal growths that are important as food for animals in the ecosystem. If the banks were riprapped at an angle of 30 to 45 degrees with natural water - worn stones, current patterns would be produced that favor native stream organisms... If dredging is done, attempts should be made to restore the natural contour of the channel bed, for example, create pools and slackwaters in shallow streams or restore the roughness of the channel bed. That would interfere very little with the carrying capacity of the channel under flood conditions, but would greatly improve the bed habitats for species occupancy."

Peters, John C., and William Alvord. (72)

1964. Man-made channel alterations in thirteen Montana streams and rivers. Transactions, Twenty-ninth North American Wildlife and Natural Resources Conference, pages 93-102.

Reports on 1961 and 1962 inventories of man-made stream channel alterations in 768 miles of 12 Montana streams. For comparative purposes, standing crop estimates of the fish population were made in both natural and altered channels in the streams surveyed. There were 1,987 individual alterations in the 768 miles of streams surveyed. These man-made alterations involved 251 miles of streams and resulted in shortening the length of the channels by 68 miles. Relocation of channels, riprapping, diking and channel clearance were the principal causes of channel alteration. Standing crops of game fish were several times more abundant in natural, meandering channels than in altered channels. Agricultural activities accounted for the greatest length of channel alteration followed in order by railroad construction -- mostly done prior to 1920 -- state, county, and federal road construction of more recent occurrence, and urban and industrial development.

Plass, William T. - Forest Service (USDA), Princeton, W. Va. Northeastern Forest Experiment Station (73)

1966, 1967. Land disturbances from strip mining in eastern Kentucky. USDA Forest Service res. notes: NE-52, 1966, 7p; NE-55, 1967, 8 p; NE-68, 1967, 6 p; NE-69, 1967, 7 p; NE-71, 1967, 7 p; NE-72, 1967, 8 p.

Abstract: "The six research notes covering specific coal reserve districts gives information about the amount, location, and general characteristics of areas disturbed by strip-mining. It is useful for determining economic impact, for planning reclamation programs, and for determining research needs and priorities. Aerial photographs were used to obtain reliable estimates of acreage disturbed by mining and associated coal haul roads n eastern Kentucky as of October, 1964. Over 55,000 acres were disturbed by strip-mining and an additional 3,900 acres were disturbed by coal haul roads. (Curtis-Forest Service)" WRSIC Accession No. W70-02213

Platts, William S. (74)

1968. South Fork Salmon River, Idaho, aquatic habitat survey with evaluation of sediment accruement, movement, and damages. U.S.D.A. Forest Service (Boise, Idaho) 135 pages, 36 tabs., 55 figures, glossary.

"The major causes of death or low production in anadromous salmon, steelhead trout, and resident salmonid populations can be summed up in five areas.

1. Reduction of population size by extreme floods.

2. The status of water levels during early stages of incubation and its effects on the survival of deposited eggs.

3. The rate of permeability of the intragravel waters in the spawning area and resulting fry production.

4. The loss of carrying capacity due to decreased rearing and production potential from adverse conditions within the watershed.

5. Restriction of passage and access of both adults and juveniles between their rearing and production areas..."

"Much of the South Fork Salmon River sediment accruement is due to landslides and slumps which are generally associated with intensive storms coupled with disturbed lands. Road construction, mining, logging, fire, and domestic livestock have all contributed to the accelerated sediment loads the South Fork Salmon River has received."

"Sediment (all streambed or water suspended solids 9.51 mm or less in diameter)..., especially in spawning areas, can cause serious mortalities among salmonid embryos, alevins, and fry still in the gravel. The crusting of sediment over spawning areas kills the alevins by filling the interspaces and thus not allowing them to emerge to surface waters. Sediment has great effect on the permeability and rate of water interchange through spawning gravels and food rearing areas. Sediment also clogs up the spaces within the gravel, decreasing permeability and adversely affecting the survival of salmonid embryos and other aquatic organisms."

"The amount of oxygen available to embryos and fry in the gravel depends on the oxygen interchange from atmosphere to surface waters to subsurface waters, which sediment restricts by forming a barrier between the surface water and subsurface water, and also between the subsurface water and the embryos and fry. Very fine sediment and clay (.050 mm and under in diameter), because of small size and colloidal and electrostatic properties, can be most damaging to eggs, alevins, and fry."

"The amount of food available for fish in fresh waters depends ultimately upon the growth of green plants (aquatic) which sediment destroys. The food potential of a stream is also directly related to the underneath exposed area of boulders, rubble, gravel, etc., that is available for aquatic insect production. Available food production in a stream,... has great influence on carry capacity."

Shifting sediments create unstable conditions for the benthic organisms. "With the decimation or elimination of benthic organisms, the food chain is broken. Overwintering salmonids use the interspaces of the gravel-rubble-boulder streambottom to survive conditions caused by low water temperatures. A sediment build-up eliminates these interspaces."

A recommended means to improve aquatic habitat, other than the stopping of watershed and stream activities, is the use of in-river sediment containment traps. Sediment traps constructed to meet standards required by the particular stream, would help to eliminate surface sediment to allow better aquatic habitat conditions downstream. Bibliopraphy of 47 titles and appendix.

Platts, William (75)

1974 (a). Stream channel sediment conditions in the South Fork Salmon River, Idaho. Progress Report IV., U.S.D.A., Forest Service, Boise, Idaho, 38 pages, 18 tables, 4 figures.

Abstract: "During 1952-1965, the South Fork Salmon River (SFSR) was incapable of discharging the accrued bedload sediment as fast as it was being recruited. This period corresponded with the increase in logging and road construction activities. During 1966-1972, the SFSR discharged from its system bedload sediment faster than it was being recruited. During this period, there was decreased logging and road construction, finalizing in a complete non-log moritorium. During 1973, monitoring areas continued to show improvement, but the river stations did not.

Factors such as an extremely low waterflow year (1973) resulting in low energy for moving sediment, and pools acting as sediment traps even during fairly high flows could be the reason for the increase of channel fine sediment readings. In Progress Report II, it was predicted that without any large storms and no additional logging or disturbance, along with rehabilitation of the present road system and logged areas, the river should return to near-natural status within the next decade. Even though all the 1973 information does not follow this trend, I believe that the information does not warrant any changes in past predictions of the river's return to near-natural conditions." Bibliography of 6 titles.

Platts, William S. (76)

1974 (b). Geomorphic and aquatic conditions influencing salmonids and stream classification. U. S. Forest Service (SEAM Program), xiii + 199 pages, 44 tables, 28 figures.

This publication concerns itself with investigations that were conducted from July 1970 through September 1972 concerning "(1) the physical structure of aquatic environments in granitic, mountainous lands in Idaho, (2) the relationship between physical stream structure and fish populations, (3) the influence of geomorphic process of aquatic ecosystems, (4) the relation of order within landforms in relation to uniformity in aquatic environments, and (5) the potential for classifying aquatic environments from land classification systems." It is stated that certain aquatic structural characteristics controlled with the density of fish populations and the composition of fish species "... Stream depth, width, and the elevation of the stream channel were the most important such characteristics. Variations in water chemistry did not seem correlated with the density of fish populations. The fish population total density decreased or increased in a uniform manner as certain variables in the aquatic structure changed...The variables that described the structure of the study streams often proved to be directly related. If one changing variable was identified, most other structural variables responded in a predictable manner...

This study provides information from mountainous aquatic environments that can be used to examine further the relationship of order and control in specific geologic and geomophic settings." Bibliography of 120 titles.

Ringler, Neil H. and James D. Hall (77)

1975. Effects of logging on water temperature and dissolved oxygen in spawning beds. Transactions of the America Fisheries Society, 104 (1): 111-121, 3 tables, 8 figures, references.

"The temperature and dissolved oxygen content of intragravel water were measured in three Oregon coastal streams between June 1968 and June 1969. In 1966, the watershed of one stream had been completely clearcut, and that of a second stream partially clearcut in staggered settings. A third watershed was left unlogged.

"Clearcut logging resulted in increased temperature in intragravel water in salmon and trout spawning beds and decreased concentrations of dissolved oxygen. The changes were related largely to reduced forest cover over the stream surface and to deposition of fine sediment in the gravel.

"No serious reduction in survival to emergence of coho salmon occurred along with the observed changes in terperature or dissolved oxygen. A decrease in the resident population of cutthroat trout after logging may have been related to these changes." (Author's abstract)

Schneberger, Edward and John L. Funk (Editors) (78)

1973. Stream Channelization: a Symposium. North Carolina Div., American Fisheries Society, 1319 - 18th Street, N.W., Washington, D.C. 20036. $2.00 per copy.

"Eight papers presented at a symposium held at the 33rd Midwest Fish and Wildlife Conference in Omaha, Nebraska in December, 1971. One deals with the general status of stream channelization in the Midwest. One each presents the viewpoints of the U.S. Army Corps of Engineers and the Soil Conservation Service on the subject. Four

deal with the effects of channelization on the biological productivity and recreational values of streams. One presents a brief literature review and bibliography." John L. Funk. Sport Fishary Abstracts No. 17210.

Schubel, J. R., A. H. Auld, and G. M. Schmidt. (79)

1974. Effects of suspended sediment on the development and hatchery success of yellow perch and striped bass eggs. Chesapeake Bay Institute, the Johns Hopkins University Special Report 35, Ref. 74-2, 12 pages.

"Yellow perch and striped bass eggs were incubated in suspensions of different concentrations of natural, fine-grained sediments. The results showed that in the laboratory concentrations of up to 500 mg/l did not significantly affect the hatching success of yellow perch or striped bass eggs, but that concentrations of 1000 mg/l did significantly affect their hatching success. (Authors) --Sport Fishery Abstracts No. 17768.

Shannon, Walter S. (80)

1967. Forest practices and watershed management in California. American Forests, 73 (5): 6-7, 48, 50, 52-55.

"Data on 33 streams damaged by 1962 logging. A total of some 55 stream miles were damaged mainly by phys cal destruction of the stream channel or by sedimentation of gravels. Logging roads, skid trails, and landings located in the streambed or on its banks are particularly bad. Sediment fills the spaces among the rocks in the riffles, the main food-producing area of a stream. Sport Fishery Abstracts No. 9250.

Shapley, S. Phillip, and Daniel M. Bishop (81)

1965. Sedimentation in a salmon stream. Journal Fish. Research Board, Canada, 22 (4): 919-928.

"Sediment was artificially added to a small southeastern Alaska salmon stream. Observations in sedimented and control riffles indicate that the amount of sediment settling to the stream bottom decreases exponentially with distance

downstream. The dissolved oxygen content of intragravel stream water remained high in sedimented riffles. The added sediment was removed from streambed gravels by fall freshets and floods." (Authors) Sport Fishery Abstracts No. 8393.

Sherk, J. Albert, Jr., and Eugene L. Cronin. (82)

1970. The effects of suspended and deposited sediments on estuarine organisms: an annotated bibliography of selected references. Natural Resources Institute, University of Maryland, Reference No. 70-19, April, 1970, 62 pages, 179 references. Contract No. DACW 73-70-C-0013 by U.S. Corps of Engineers; Selected Water Resources Abstracts, 3 (20): 42 1970.

"This annotated bibliography was prepared by screening approximately 1200 published and unpublished articles, papers, and books. Abstracts of 161 references are presented for all papers on the effects of suspended loads and deposited sediments on estuarine organisms. Articles are classified into 9 categories (annelid worms, crustaceans, benthic species, engineering activities, mollusks, offshore disposal, fish, primary production, and sediment effects on water quality). Also included is a list of 18 references constituting a bibliography of bibliographies. (Sjolseth) -- Sport Fishery Abstracts No. 12925.

Slotta, L. S., D. A. Bella, D. R. Hancock, J. E. McCauley, and C. K. Sollitt. (83)

1974. An examination of some physical and biological impacts of dredging in estuaries. Abstract in Weekly Government Abstracts of Environmental Pollution and Control, National Technical Information Service (Springfield, Virginia). 264 pages. PB-240 742/7WP.

"The report presents the major research achievements of the NSF-RANN dredging research group at Oregon State University during the first ten months of its activity, February-November, 1974. The research focused on four major topics: (1) the effects of dredging on estuarine systems, (2) the system properties of estuaries, (3) the ways in which estuarine research can be used e effectively by user groups, and (4) the development of concepts and techniques for monitoring impacts of dredging and other alterations to estuaries. The various kinds of impacts discussed in the study include: Impacts of dredging and marine traffic; impacts of sediment turnover; impacts of sediment physical changes; impacts of turbidity; impacts of release of toxins from sediments."

Tarplee, William H., Jr., Darrell E. Louder, and (84)
Andrew J. Weber. (N. C. Wildlife Resources Commission, Raleigh, North Carolina)

1972. Evaluation of the effects of channelization on fish populations in North Carolina's coastal plain streams. Proceedings, 25th Annual Conference, Southeastern Association of Game and Fish Commissioners, October 17-20, 1971, pages 431-446.

"This research study was designed to determine the degree of damage, if any, to fish populations resulting from channelization, and to determine the rate of recovery, if the damage was significant. This study points out the detrimental effects stream channelization has on fish populations and on the flora and bottom fauna of streams. The study also indicates that following channelization, and with no channel maintenance, nature can ultimately restore a coastal plain stream and its fish population to a stage reasonably near its natural condition, providing no further alterations of the stream bed, banks, forest canopy, or aquatic vegetation occur." (Authors) Sport Fishery Abstracts No. 15502.

Taylor, John L., and Carl H. Soloman (Bureau of (85)
Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Florida)

1969. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida. U. S. Fish and Wildlife Service Fish Bulletin, 67 (2): 213-241, illustrated.

"Filling of 1,400 hectares (3,500 acres) of bay by hydraulic dredging has reduced the area of Boca Ciega Bay, Florida, by about 20 percent since 1950. An estimate of the annual standing crop destroyed is 1,133 metric tons (798 kg per hectare, dry weight) of sea grass and about 1,812 metric tons (1,277 kg per hectare, dry weight) of associated fauna. In terms of annual production, the loss of biological resources is far greater -- minimum estimates are 25,841 metric tons of infauna exclusive of meiofauna. Natural areas remaining in the Bay support local and offshore fisheries and are of value for recreation, public utilities, commerce and industry. At an estimated value of $988.00 per hectare per year, worth of the estuarine area already eliminated is $1.4 million annually. In addition, inestimable secondary losses occur, principally from sedimentation, turbidity, and domestic sewage." (Authors) Sport Fishery Abstracts No. 11894.

Tebo, L. B., Jr. (N.C. Wildlife Resources Com.) (86)

1955. Effects of siltation, resulting from improper logging, on the bottom fauna of a small trout stream in the southern Appalachians. Progressive Fish Culturist 17 (2): 64-70.

This research, done on the Coweeta Experimental Forest, Macon County, North Carolina was concerned with effects of siltation on bottom organisms of Shope Creek, a small trout stream which receives the drainage from a 212-acre logged watershed. Roads (2.2 miles) and skid roads were built parallel and adjacent to the stream channel. No surfacing material and no drains were used. During storm periods the turbidity of Shope Creek was appreciably increased by the highly turbid waters from the logged area -- primarily from the roads and skid trails. A significantly lower standing crop of bottom organisms was found at the collecting station below the mouth of the logged watershed. A flood on February 21, 1953 -- about five years after termination of the original logging in 1948 -- reduced the bottom fauna at the lower station to 7.3 organisms per square foot, as compared with 25.5 organisms per square foot at the upper station, which had not been subject to siltation from the logged watershed.

Thomas, Harold E. (U.S. Geological Survey, Menlo Park, Cal.) (87)

1969. Water as a resource and as a nuisance. Pages 17-28 _in_ "Planning conservation of the physical environment," (papers presented at a 1969 conference on this subject), Highway Research Board, Div. of Engineering, National Research Council, National Academy of Sciences -- National Academy of Engineering, Highway Research Record No. 271, 47 pages.

With respect to effects of roads on surface water the author stated, "Historically roads and other means of communication have modified the natural land surface and therefore the poo-portions of water that infiltrate, accumulate, or run off from the area. Infiltration is reduced because of impermeable road surfaces; accumulation may be prevented by development of suitable gradients. The resulting runoff is greater than natural, and may require gutters and drain for control. Where cuts, fills, and embankments, are made during road construction, the artificial slopes are subject to erosion during storms, and to deposition of sediment at the foot of the slope or beyond, unless the slope is protected by vegetation or paving. Some roads use flood plains, canyons, gaps, dry lakebeds, shorelines, and other landforms created by water, and they require protection during exceptional periods when the water is 'reclaiming its own.' Other roads cut across the natural drainage systems, and may obstruct the natural flow in some places and accelerate or redirect the flow in other places."

Thompson, J. R. (88)

1970. Soil erosion in the Detroit Metropolitan Area. Journal of Soil and Water Conservation, 25 (1): 8-10, 3 figures, 4 tables, 4 references.

Abstract: "A study was made in the Detroit Metropolitan area to evaluate the rates and amounts of erosion from urban construction sites. In the summer of 1968, 2.1 percent of an urban zone was under development. This zone produced about the same amount of eroded soil material as the remaining 97.9 percent of the area. Erosion from the developing areas averaged 69 tons per acre per year, compared with an overall average erosion rate for the Metropolitan area of about 3.0 tons per acre per year and an overall average erosion rate for southeast Michigan of 2.6 tons

per acre per year. (KNAPP-USGA)" WRSIC Accession No. W70-04557

U. S. Department of the Interior, Office of Water (89) Resources Research, Washington, D. C. Water Resources Scientific Information Center

1971. Urbanization and sedimentation - a bibliography. Available from NTIS as PB-203 188, $3.00 in paper copy, $.95 in microfiche. October 1971. 116 pages, WRSIC 71-203.

Abstract: "The bibliography is a compilation of 116 abstracts of current and earlier pertinent reports, journal articles and other publications on urbanization and sediment problems. The abstracts include full bibliographical citations and a set of descriptors from the Water Resources Thesaurus. The bibliography was produced by computer retrieval from the information base of selected Water Resources abstracts (SWRA), which had 31,244 abstracts at the time of the retrieval. The KWIC method of indexing is used in which each significant work in the title is filed in alphabetical place. Using a few keywords describing the subject matter of interest, one scans the middle rank for their presence, then the remainder of the title to determine relevance. The bibliography is arranged in ascending WRSIC accession number sequence.(LANG-USGS)" WRSIC Accession No. W71-13432

Vice, R. B., H. P. Guy, and G. E. Ferguson (90)

1969. Sediment movement in an area of suburban highway construction, Scott Run Basin, Fairfax County, Virginia, 1961-64. U. S. Geological Survey Water-Supply Paper 1591-E, 41 pages, 13 figures, 11 tables, 10 references.

Abstract: "Movement of sediment during a period of intensive highway construction was studied in the Scott Run Basin, Fairfax County, Va., from 1961 to 1964. The 4.54 square mile drainage basin, which empties into the Potomac River about 6 miles above the head of the Potomac estuary, was the scene of highway construction covering 11 percent of the basin; other types of urban construction in the basin during this

time were minor. Sediment was measured at the gauging station by a system of representative samples. These samples made it possible to document the sediment yield for 88 storm events representing the overland runoff. The 88 events accounted for 37 percent of the runoff and 99 percent of the sediment movement in 3 percent of the time. The highway construction areas, varying from less than 1 to more than 10 percent of the basin at a given time, contributed 85 percent of the sediment; 38 percent of the sediment movement occurred during April, May, and June, and only 11 percent occurred during July, August, and September; and on the basis of residual soil and stream-sediment particle sizes, the amount of sediment eroded from areas of construction was about twice that transported from the basin. Sediment yield is about 10 times that normally expected from cultivated land, 200 times that expected from grassland, and 2,000 times that expected from forest land. (KNAPP-USGS)" WRSIC Accession No. W69-09683.

Voutyras, Constantine - Ministry of Public Works, Caracas (Venezuela) (91)

1969. Reverse and direct reservoir routing method sets highway grade. Civil Engineering, 39(10):56-58, 4 figs. 1 photo.

Abstract: "Combined overflows from the Orinoco and Apure Rivers in Venezuela produced unprecedented flooding in the vicinity of a highway that was under construction. The partially built embankment acted as a dam, and because the flood was without precedence, the drainage system designed for the highway proved inadequate. The problem of providing proper drainage was aggravated by a lack of topographic and hydrologic data for the area. Information was gathered on water levels, high water marks and topography in the vicinity. By treating the embankment as a broad-crested weir, a rating curve for the 2.5 km (1.6-mile) spillway was developed, and an outflow hydrograph constructed from stage-discharge relationships. Then, employing reverse routing methods, an inflow hydrography was established. Repeated routing of this hydrograph was used in developing one graph of water elevation and total waterway span, from which the total drainage waterway opening required to prevent overtopping of the road was determined. (KNAPP-USGS)" WRSIC Accession No. W70-01660.

Whitney, Arthur N. and Jack E. Bailey (92)

1959. Detrimental effects of highway construction on a Montana stream. Transactions, American Fisheries Society 88 (1): 72-73.

Comparison of results of electric shock censuses of trout and whitefish on a 300 foot section of Flint Creek, Granite County, Montana is made for 1955, prior to channelization accompanying highway improvement, and for 1957, following the new highway construction. In its original condition Flint Creek averaged about 20 feet in width and six inches in depth, had holes up to four feet deep, and average flow of about 15 cubic feet per second, good trout cover provided by overhanging willows, and undercut banks. During construction, which began in the fall of 1956 and continued through the summer of 1957, a bulldozer was used to remove brush, scour the stream bed and straighten the channel. Numbers of large-sized trout -- rainbow (*Salmo gairdneri*), cut-throat (*Salmo clarki*), and eastern brook (*Salvelinus fontinalis*) captured were 75 and 69 in 1955 and 1956, respectively, compared with 6 large-sized trout in 1957. Reductions in the game fish of the area, including the trout and mountain whitefish (*Prosopium williamsoni*) amounted to 94 percent in both numbers and weight of the large-sized fish and to 85 percent in number and 76 percent in weight of the small sized game fish.

YOUNKIN, Larry M. (93)

1973. Effects of highway construction on sediment loads in streams. Pages 82-93 *in* Soil Erosion: Causes and Mechanisms, Prevention and Control, Special Report 135. Highway Research Board, (Washington, D. C.) 141 pages.

"A study has been conducted to obtain the relationship between highway construction and change in suspended sediment yield in stream systems ...
This paper describes an investigation

of the effects of rainfall, construction phases, and proximity of construction to the stream system on the quantity of sediment transported...Results indicate that the sediment supply to the streams increases with rain energy, clearing and grubbing, embankment work, and proximity of construction to stream. It is concluded that the results of the study may be employed as a means of predicting whether highway construction would be a significant pollution source for a particular site, a criterion to be considered by an engineer during location studies, and a basis to evaluate the effectiveness of attempts to control sediment yield from construction areas...

"An equation has been developed that may be employed to predict the suspended sediment load carried by a stream system during the period of rainfall-induced erosion of disturbed soils common to highway construction." Bibliography of 13 titles.

2. Other Detrimental Effects of Highway Construction

Berryman, Jack H., et al. (94)

1963. Road construction and resource use. A contribution of the College of Forest, Range, and Wildlife Management. Utah State University, Extension circular 297, pages 7-15.

"Perhaps the most obvious effect of highway construction is the direct loss of land, especially farm land -- an incipient erosion of a National resource. For example, the new Federal Freeway Program requires 30 acres per mile of highway... Of even greater importance is the indirect loss. Residential, business and industrial expansions follow new highways...These developments consume a vast acreage and modify the use of adjacent lands...There are many other impacts including direct destruction of scenic, recreational and wildlife values as well as the more subtle influence upon animal behavior, especially wildlife movements.

"Highways are increasingly hazardous to game animals. Two features may be effective in considering game needs: road location, and type of construction, including fencing." Frequently in the West, roads cross directly over semi-annual migration routes. Also, deer may become entangled in right-of-way fences or jump over them into traffic. "These losses may be minimized by advance planning, (road location change and more adequate fencing)."

"The direct and indirect loss of farm lands is imporant to upland game, especially pheasants and quail." If isolated islands of habitat are created, game management and harvest is impractical.

"Drainage of swamps and marshes (for highways and related development) eliminates fish habitat and ultimately the fishery along with waterfowl and furbearer resources.

"Only through carefully integrated, long range planning can resource waste be minimized...The broad resource picture and the needs and requirements of all resource users cannot be considered until there is adequate representation of all interests in the earliest planning stages of highway construction."

Brunna, Joe (95)

1969. The effects of State and Federal programs upon fish and wildlife resources as seem from a wildlife department's viewpoint. Proceedings, 60th Convention, International Association of Game, Fish and Conservation Commissioners, pages 28-39.

In this paper the author stated with respect to highways, page 32: "Interstate and access roads constructed under the Appalachia Program will destroy some fish and wildlife and result in easier access to recreation areas. (Highway lakes can be constructed under this program and cost-shared under the Land and Water Conservation Fund.) In this steep terrain, care must be taken in constructing highways and bridges so that some of our fine streams are not damaged by silt. Kentucky was the first state to develop a plan of review between the Highway Department and Fish and Wildlife Department, even before it became a national policy."

With respect to the Department of Commerce, Bureau of Public Roads, he stated, page 32: "This Department if responsible for accelerating the construction of interstate roads. Each mile of interstate highway utilizes approximately forty acres of land. Kentucky's 510 miles of partly completed and proposed interstate road systems will have destroyed approximately 21,000 acres of largely agricultural land by 1972. Secondary roads will utilize additional lands. Many of these acres supported good populations of quail and rabbits."

And in commenting on State agencies he said of the Highway Department, page 35, "This department affects wildlife resources through the large acreages of agriculture and forested lands required for highway construction. State plans call for a total of 647 miles of toll roads to be completed by 1971. Along with the proposed and nearly completed interstate system, Kentucky will have 1,157 miles of major highways. With an average of 40 acres required for each mile of four-lane road, 46,280 acres of land will be paved and in right-of-way. Figured at a minimum population of one rabbit per five acres and one covey of quail per 40 acres, this destruction will have cost the sportsmen the loss of 9,256 rabbits and 1,157 coveys of quail annually."

DeLeonardis, Salvatore (96)

1970. Industrialization of the north and its effects on wildlife resources. Transactions Thirty-fourth Federal-Provincial Wildlife Conference, Yellowknife. Northwest Territories, July 14-16. Pages 46-49.

The author summarized some of the probable environmental impacts of the then "proposed" 800-mile, 48-inch pipeline for moving oil from the North Slope of Alaska to market, and of the transportation corridor to be built to link the North Slope to the existing ground transportation network. He mentioned the following problems or potential problems: (1) Although the actual physical "take-out" of habitat is relatively insignificant, human activity may influence a much larger area; (2) stream bed gravel, perhaps the best source of gravel for pods on which construction may be accomplished without melting the permafrost, if extracted improperly can cause degradation of downstream spawning beds and trap downstream-migrating smolts in poorly designed temporary stream-side pits; (3) garbarge dumps attract bears, foxes and other furbearers which must be removed or destroyed when they become pests; (4) harassment and excessive take of wildlife, legal or illegal, could have severe consequences for wildlife populations; (5) the network of roads and connecting feeder pipelines, built on elevated gravel pads may tend to restrict caribou movement along the slope; and (6) oil spills on the tundra could have long-lasting detrimental effects. The author pointed out that field operations in the late 1940's and early 1950's, in connection with oil operations under Government contract had demonstrated some of the possible consequences of development on the environment. "Permanent gullies, slumping slopes, sunken and undulating roads and trails, (presumably due to melting of the permafrost), offer dramatic testimony to improper use of these northern lands. In some areas, trails cut by a single passage of a tracked vehicle are still visibile after twenty or more years. Trash and discarded oil drums litter the landscape and will continue to do so because of the slow rate of decomposition in this arctic environment." The author recognized... "that political and economic pressures may dictate that the loss of some wildlife and wildlife habitat is not too high a price to pay for the oil."

Dryden, R. L., and C. S. Jessop (97)

1974. Impact analysis of the Dempster Highway Culvert on the physical environment and fish resources of Frog Creek, Environ, Canada, Research Management Branch, Central Region Technical Report Series No. Cen/T-74-5, 59 pages. From author's abstract:

"The impact of improper culvert design and effects on the hydrology and fish biology of Frog Creek, N.W.T. are discussed. Fish migration discharge design, as required by Fisheries and Marine Service, Environment Canada for northern highway culverts, is defined. At this or lower discharges, flow conditions within the culvert must allow for the upstream passage of fish. Fish migration discharge for Frog Creek, N.W.T. is calculated as 22.4 m^3/s (800 cfs). If the culvert at Frog Creek had been designed to allow fish passage at this discharge, the delay to fish migration would have been only 3 to 4 days. Water velocities in the Frog Creek culvert during 1973 exceeded the maximum allowable velocity of 1.5 m/s (5 fps) for 40 days from May 26 to July 5. Bank erosion downstream from the culvert caused retreat of the river bank at a rate of 15 cm (6 inches) per day. Siltation of the stream resulting from construction was evident, but appeared to be insignificant. During the peak discharge period, extensive ponding occurred upstream of the culvert. Ice buildup inside the culvert occurred primarily during early spring as a result of over-ice flow. High water velocities within the culvert blocked the spawning migration of approximately 600 northern pike, Essox lucius (Linnaeus) and appeared to block movements of some broad whitefish, Coregonus nasus (Pallas). Fish passage did not become generally possible until July 5, when water velocities of less than 1.5 m/s (5fps.) were attained. After passage became possible, both pike and broad whitefish dispersed equally in upstream and downstream directions. It was estimated that only a small proportion of the total pike population of the Frog Creek drainage was blocked by the culverts. No physiological effects of culvert delay on ripe pike were evident..." Sport Fishery Abstracts No. 18133.

Gilbert Bill (98)

1975. The devaluation of Alaska. Audubon 77 (3): 64-80.

In writing of the environmental impacts of the Alaska pipeline, Gilbert stated (p. 76): "There is growing realization that, while the pipeline will bring oil out of the north, in the long run, people spillage may present a more serious threat than oil spillage," i.e. the construction of the highway in connection with the pipeline would bring recreation and other development -- people who would put pressure on wildlife and wildlife habitat.

Griffith, Chuck (99)

1975. Road projects run over wetlands. Conservation News 40(10): 10-12.

The author states: "Highway departments already exercise stringent control over their rights-of-way to protect their integrity against incompatible uses. Tilling, grazing and other encroachments, by adjoining landowners are no-no's and the highway departments take a non-nonsense attitude towards such incursions."

He then asks: "Why not, then, a similar hard-nosed attitude towards farmers who use the roadside ditches as dumping place for their ditched wetlands? Certainly the end result of such drainge tie-ins is a troublesome to the highway budget planners as it is destructive to wetlands."

He then suggested that levels of such pollutants as lead, salt, sand, hydrocarbons from tires, fuel residues and lubricants, and other pollutants should.

be identified and listed in any such required permits, along with the anticipated volume of water to be carried by the road drainage system into any receiving waters and recommends that the highway agencies at all levels should be required to obtain amendments to the regular permits to increase water volumes and to add to contaminants. He indicates that the public has as much interest in, and concern for, natural wetlands as it does in highways and states: "Federal funding of highways could provide the lever for better protection of wetlands and water quality."

Hancock, Norman V. (Utah State Department Fish and Game) (100)

1963. Impact of interstate highways upon the wildlife resource. Proceedings, 43rd Annual Conference, Western Association, State Game and Fish Commissioners, pages 183-187.

"Federal highways planned to be completed by 1973 in Utah will use 28,950 acres of land. Present hunter-access roads will be made useless through access restriction of freeways. Increased high speed traffic will account for increased mortality of game. Fences built along these highways will interfere with migrations of big game and pose major law enforcement problems as a result of migrating game congregating at fences." WR No. 112.

Harmon, Keith W. (101)

1971. Prairie potholes. National Park & Conservation Magazine 45(3): 25-28, illus.

Discusses the nature and importance of the pothole area of the Dakotas, western Minnesota and parts of Manitoba, Saskatchewan and Alberta to wildlife -- particularly waterfowl. The author points out that the prairie pothole country contains only about 10 percent of the available duck nesting habitat in North America but produces 50 percent of the ducks raised in North America in an average year. He indicates that by 1950 about half of the United States' share of the pothole country had been drained, much of it with Federal assistance. He further states: "Private drainage surveys made in the Dakotas and Minnesota by the Bureau of Sport Fisheries and Wildlife show that approximately 125,000 acres of shallow marshes, deep marshes, and open-water areas were drained from 1965 to 1968. Channels constructed in small watershed projects and flood control projects of the Army Corps of Engineers, local highway ditches, and other ditching systems were used as outlets for draining these wetlands.

"New highway construction in the prairies threatens vast numbers of wetlands. Less obvious a threat than ditches dug solely for drainage, these projects can place drainage outlets within easy reach of most landowners. Federal funds go to both county and state highway departments to help expand the road system. Along with the money comes certain engineering specifications conducive to increased drainage.

"As part of these construction projects, roadside ditches are reshaped so runoff reaching the ditches will move to the nearest creek or river. Since it was completed in 1970, landowners have already ditched many permanent wetlands into the highway outlet."

He goes on to explain how "a single road construction project, six miles in length, is now in the process of eliminating waterfowl habitat that produced more than 2000 ducks per year."

Higbee, Edward (University of Delaware) (102)

1959. Rural shrinkage. Transactions, Twenty-fourth North American Wildlife Conference, pages 93-101.

In speaking of urbanization and the shrinkage of rural areas, the author stated "...not at all by coincidence, but rather because the best agricultural sections of New Jersey are also the most highly urbanized, the New Jersey Turnpike was constructed on some of the state's best soils. This toll road causes some of the heaviest interurban traffic in the country. Along its route it is breeding new residential and commercial zones. Fortunately they have only limited access to the turnpike, but nevertheless the great convenience of this road has prompted such development, particularly near the interchanges.

"From the standpoint of New Jersey's agriculture the selection of this particular route has been disastrous. With four-fifths of the state covered with non-arable soils, it is unfortunate that some of the poorer lands were not chosen for the right-of-way even though it might have involved running the road a few miles longer. It is time to recognize that a highway may not only consume arable land itself, but it can foster additional losses through the urban and suburban development that it engenders..."

Klemmedson, James O. (University of Arizona) (103)

1967. Big-game winter range -- a diminishing resource. Transactions, 32nd North American Wildlife and Natural Resources Conference, pages 259-269.

Discusses construction of roads and highways as one of several activities or land uses which is reducing wintering range for big game. He pointed out that year by year forest roads are penetrating deeper into the unroaded back country and indicated that if only 5 percent of then planned national forest development program calling for nearly 70,000 miles of roads in the six western regions passed through game winter range, an estimated 19,000 acres would be lost. He stated also: "New super and interstate highways occasionally pass through winter range. When they do, habitat is destroyed at the rate of several acres per mile. To minimize winter maintenance, highways are more often than not located on south-facing slopes, much to the detriment of the winter range. Encroachment of highways and roads on winter range is gradual, but in some instances it can spell immediate disaster to local game populations. The new divided interstate highway west of Denver, Colorado has eliminated at least 40 percent of the winter range for the resident band of bighorn sheep near Georgetown, Colorado." (After unpublished report, Intermountain Forest and Range Experiment Station, Boise, Idaho).

With respect to mitigation for lost winter range, he pointed out that it is not enough for the construction agency to grant x number of dollars for purchase of other land or for rehabilitation, and sit back feeling that the job is done because shrub generation takes a long time and the technical know-how to accomplish mitigation of damages to winter range is inadequate for many areas. He states: "... Additional research is needed to develop new and better species, to learn more about range pests, to learn how to restore depleted ranges and create new range. We must learn to manipulate and manage winter range as a crop in diverse environmental situations, to effectively coordinate game and livestock grazing, and to integrate big game habitat management with timber management..."

Sutton, John G. (104)

1955. Outlet ditches, slopes, banks, dikes, and levees. In Yearbook of Agriculture 1955, pages 521-528. U.S. Department of Agriculture, Washington, D.C.

As related to this state-of-the-art report, the author stated that to have effective drainage systems, farmers need to give special attention to outlet ditches, side slopes and banks, and levees and dikes. "Outlet ditches must have ample capacity to dispose of runoff. They must be deep enough to drain low fields and to serve as outlets for tile drainage systems. Often, it is necessary to survey a natural channel well below the point of outlet to determine whether the channel is big enough to handle the flow from the drainage system and whether the land along the channel will not be subjected to increased flooding hazards."

"...The most common type of drainage ditch structure is a culvert or bridge. Difficulty has been encountered where highway, road or railroad culverts were placed too high or were too small. Their replacement often has been difficult and costly. Culverts and bridges should be carefully planned to meet the future drainage requirements so as to avoid unnecessary expense later.

"The Ohio Turnpike exemplifies planning for future requirements. It crosses 13 counties in northwestern Ohio, nearly all of which is flat, drained land. The width of right-of-way was generally 250 to 600 feet. The highway crossed many tile systems, with laterals spaced not more than 60 feet apart, and many open ditches. Engineers at the outset planned for adequate birdges and culverts to take care of existing drainage systems and provide for future installations."

"...The engineers worked out plans for the installation of collector mains in places that needed drainage but had no other outlets. Some of the mains are below existing tile systems, or may be sealed at both ends, so as to provide for future drainage needs."

U.S. Department of Agriculture, Forest Service (California Region) (105)

1974. An inventory of fish and wildlife habitat improvement needs, 14 pages.

This illustrated booklet discusses briefly the four basic elements required for successful existence of fish and wildlife: food, cover, water, and a place to reproduce. An inventory of sites needing habitat improvement in the National Forest lands of California is given. In connection with barriers to fish migration the authors state: "Many fishes in the course of their life cycle, migrate upstream at certain times of the year to reach suitable spawning or feeding areas. Their access to these waters is often prevented by various stream crossing structures installed by man such as culverts, weirs, dams, and certain types of bridge abutments. Most such barriers can be modified at reasonable expense to provide adequate fish passage. Elimination of these barriers is an important factor in restoring and maintaining our trout and salmon resources. Inventories of all such blockages are currently underway in all the National Forests in California. Corrective action is then planned."

U.S. Department of the Interior (106)

1975. Sea turtles to be added to threatened list. U.S.D.I. News release (May 21, 1975), 2 pages.

This news release states that three more species of sea turtle -- the green (Chelonia mydas), loggerhead (Caretta caretta) and Pacific ridley (Lepidochelys olivacea), have been pushed closer to extinction by increased development of coastal shorelines and overuse for commercial purposes. These species have been proposed in the Federal Register to be added to the U.S. List of Threatened Wildlife.

The release states: "Sea turtles, which can grow to 1,500 pounds, rarely come on land except to lay eggs. Human development of coastal areas for industry and tourism has destroyed many of these nesting sites. Along shorelines, bright city and highway lights confuse hatchlings and attract them inland where they die."

U.S. Department of the Interior, Fish and Wildlife Service (107)

1975. Task force report on effects of road construction on wetland wildlife habitat. Fish and Wildlife Service (Federal Building, Fort Snelling, Twin Cities, Minnesota 55111).

A report to provide information on effects of road construction on wetland wildlife habitat. Recommendations made not to be construed as representing approval or disapproval by the Secretary of the Interior or the Director of the Fish and Wildlife Service.

Based upon a sampling of the 28,953 miles of highways -- 2,777 state and federal, 9,797 county, and 16,379 township -- in 19 western Minnesota counties, it was estimated that 99,292 acres of wetland had been drained as a result of highway construction at the rate of 2.33, 2.62 and 4.10 acres, respectively, per mile of highway.

The task force stated: "Wetland destruction has been most severe where neither NEPA nor the Department of Transportation Act apply. Generally, but not exclusively, locally financed township and county roads which are not part of the federal and state highway system have successfully circumvented environmental safeguards."

The task force recommendations were to: "1. Request legislation or an Executive Order or a U.S. Department of Transportation Policy that would require state and local governments to maintain right-of-way integrity by prohibiting the use of road ditches for the indirect drainage of wetlands. Failure to prohibit this use of public rights-of-way should result in loss of Federal highway funds to that state. 2. Request legislation that requires a percentage of Federal Aid Highway funds be used for wildlife enhancement to offset damage to wildlife habitat in highway corridors. 3. Determine if NPDES (National Pollution Discharge Elimination System) permits are required for discharges of high runoff waters. 4. Conduct an intensive educational program to publicize the destruction of wildlife habitat that results from county and township road projects. 5. Promote 'Effects of Road Construction on Wetland Wildlife Habitat' as a major topic thrust on the agenda of conservation and land use planning conferences."

D. EFFECTS OF HIGHWAY MAINTENANCE AND OPERATION ON THE ENVIRONMENT.

1. De-Icing Chemicals and Their Effects

Adams, Franklin S. (108)

1973. Highway salt: social and environmental concerns. Highway Research Board #425. Highway Research Board (Washington, D.C.) pages 3-13.

"There is little question that under many meteorological and environmental conditions, chloride salts are effective agents for melting ice and snow. Yet problems of management, safety, and potential environmental damage are obviously more serious than simply melting snow. To calculate the true costs and real benefits of an expanding salt-based technology requires that a great deal of vital research be conducted. In the meanwhile, persistent efforts to expand the use of salt as an assumed most efficient, safe, and cheap alternative method of snow removal need to be strenously questioned."

"Dissolved salt entering streams, rivers, ponds, and lakes acts as a weak electrolyte, thereby changing the electrical conductivity of the aquatic system. In concentrations greater than 1 percent, all freshwater species of bacteria, algae, invertebrates, fish,and higher plants are placed in immediate jeopardy. Science simply does not know what the long-term effects of small amounts of artificially induced salt are on species of freshwater organisms. We need to know which species are relatively resistant and which species are slightly or seriously affected, and most of all we need to know the effect of salt on fundamental evolutionary processes of selection and adaption...The most obvious effect of salt on roadside vegetation is that susceptible species such as white pine, hemlock, sugar maple, red maple, and most ornamentals respond with symptoms of chronic toxicity, burned or browning foliage. Salt apparently interferes with noraml photosynthesis and respiratory processes and, at acute levels of toxicity, will kill the leaves directly. Small amounts of salt absorbed through roots or exposed vegetation will lead to premature coloration of leaves and early leaf fall in the next year. With acutely toxic doses, the plant dies, and, unless the dead portions are removed, the salts contained therein will be recycled to the roadside environment...in all probability, salt has the potential for acting as a selection agent in the natural environment." Bibliograohy of 13 titles.

Anderson, R. C., and C. Auster (109)

1974. Costs and benefits of road salting. Boston College, Environmental Affairs 3(1): 128-144.

"At the current levels of salt usage for highway de-icing, the gains to society appear to be far less than the costs. Most if not all of the benefits are immediate, while costs such as the pollution of water supplies and damage to vegetation and highway structures may accrue over relatively long periods of time. Although it was shown that the cost in terms of automobile depreciation alone exceeds the benefits due to reduced travel costs, this does not necessarily imply that all salting should be discontinued. Rather, one is interested in applying salt until the gains from the last ton applied are just balanced by the additional costs incurred. Given the findings in this study, it appears that the use of salt for de-icing should be curtailed. The extent of the reduction can be determined only through a more detailed and comprehensive analysis of the various benefits and costs." HRIS No.219191.

Anonymous (110)

1971. Do de-icing salts constitute a health hazard? Bauwirtschaft, Weisbaden/Germany 25(6) 1525-1526, 1 fig.

"Arguments presented at the 14th World Road Congress, in Prague in the autumn of 1971, on the effect of a mixture of de-icing salts and fuel oil on ground water, drinking water and vehicle corrosion are outlined." /TRRL/ HRIS No. 219189.

Anonymous (111)

1971. County reshapes hill into pollution-control salt storage. Rural and Urban Roads 9(12): 14-16, 6 photographs.

From Summary:
"Ecology-conscious Hennepin County officials have reshaped a hill in their storage yard into a non-polluting salt storage area. Co-designers of the square, u-shaped structure worked out the plan because a satisfactory storage unit could not be found from commercial suppliers..." HRIS No. 218961.

Anonymous (112)

1972. Experiment with a salt substitute. Publiv Works 103(11): 96, 1 ref.

Synopsis:
"For ecological reasons, fly ash produced at a coal-burning power plant, was used as an alternative to salt. The fly ash consists of tiny, black sharp-edged angular chips. The black, chemically inert material is coarser than sand and absorbs heat from the sun. The grit improved traction and reduced accidents. The fly ash does not run off when the snow melts and must be swept up promptly since the grit damages tires somewhat. The material leaves the streets with a dirty appearance in winter." HRIS No. 219091.

Anonymous (113)

1973. Low cost ecologically safe antidote to grass brownout from salt. Better Roads 43(10): 24, 1 photograph.

"Research indicates that gypsum applied to roadsides subject to winter road salt, effectively reduces the sodium level in soil. High concentrations of sodium ions are not toxic to plants but can also cause dispersion and cementing of the clay. Chloride ions can also be too toxic to plants. Details are outlined of the research project in which three plots of ground adjacent to the Maine highways were treated with gypsum applied in different amounts to a maximum rate of 14 tons per acre. A technologicaly breakthrough by United States Gypsum is expected to make the application of gypsum more efficient in the future." HRIS No. 262490.

Bazarth, F. M. (114)

1973. Implementation package for use of liquid calcium chloride to improve de-icing and snow removal operations. Federal Highway Administration, Offices of research and development. Final Report, 19 pages.

"This implementation package presents highlights of the methods developed by the Iowa State Highway Commission for accelerating the de-icing of roadways by using salt prewetted with liquid calcium chloride. Solutions are sought to the following problems: 1) how to reduce the over $1 million annual cost of salt used on Iowa highways; 2) how to obtain effective melting action at temperatures below 20 degrees F.; 3) how to reduce the roadside pollution potential due to salt; and 4) how to reduce overtime labor costs on winter maintenance work." (FHWA), HRIS No. 218091

Bried, R. (115)

1973. The great salt controversy. Yankee, 37(3): 94-114, 1 figure, 3 photographs.

Abstract:
"Over 9 million tons of salt are dumped on the nation's highways for ice control each winter. Salt spray from treated roads often injures roadside vegetation. A decided relationship was found between salt injury symptoms and the distance of trees from the road and their elevation above or below it. Analysis of leaves and twigs of 150 trees showed between 577 and 732 ppm sodium for those witin 30 feet of the road as contrasted with 327 to 280 ppm for those farther back. Contamination of water resources is also a problem. The State Highway Department of New Hampshire has been forced to replace a number of wells over the years that have suffered chloride damage. Some have shown counts from 3,550 to 3,800 ppm chloride. In 1964 they replaced 37 wells. Banox, a rust inhibitor sometimes added to salt, contains sodium hexametaphosphate. It has the potential, as a nutrient source, of stimulating excessive aquatic plant growth in lakes and ponds. Where high-speed travel is not a factor, salting can often be reduced to a negligible minimum or, as in the case of Burlington, Vt., eliminated altogether. (Woodard-USGS)"
WRSIC Accession No. W73-05970.

Bubeck, Robert C., et. al. (116)

1971. Runoff of de-icing salt effect on Irondequoit Bay, Rochester, New York. Science 172 (3988): 1128-1132.

"Salt used for deicing the streets near Rochester, New York, has increased the chloride concentration in Irondequoit Bay at least five-fold during the past two decades. During the winter of 1969-70, the quantity and salinity of the dense runoff that accumulated on the bottom of the bay was sufficient to prevent complete vertical mixing of the bay during the spring. Comparison with 1939 conditions indicates that the period of summer stratification has been prolonged a month by the density gradient exposed by the salt runoff...the fact that the chloride levels are rising rapidly suggests that they should be monitored carefully and that serious attention should be given to the fraction of de-icing salt that is being stored in the groundwater. The need for more detailed statistics as to the local distribution of deicing salt is also evident."

Butler, J.D. (117)

1972. Salt-tolerant grasses for roadsides. Highway Research Record #411. Highway Research Board (Washington, D. C.) Pages 1-6.

"An accelerated use of sodium chloride and other salts for deicing highways has caused widespread destruction of roadside vegetation. Satisfactory alternatives to salting have not yet been devised; thus the need for plants that are tolerant of a drastically changed environment must be considered. This discussion is limited to several grasses found in the United States, which have demonstrated good salt tolerance. Specific growth characteristics and habitats of the grasses pertinent to roadside use are discussed. Research with specific grasses is cited, and the need for further in-depth research and development with salt-tolerant grasses is noted." Bibliography of 15 titles.

Chance, R. L. (118)

1974. Corrosion, de-icing salts, and the environment. Materials Performance; National Association of Corrosion Control, 13(10):16-22.

"This digest of a part of their literature review discusses one phase of the work of NACC's task group T-3N-5 on the use and effects of deicing salts. The corrosion environment in North America is reviewed here and some specific effects of the environment are discussed. A rationale for deicing salt usage, alternative means of deicing, and the effect of inhibitors are presented. Corrosion preventive measures recommended by the Society of Automobile Engineers are reviewed." HRIS No. 264705.

Connecticut University (119)

1968. Symposium: Pollutants in the roadside environment, pp. 1-68, figures, tables, references.

"The effects are discussed of salt deicing chemicals on plants and croplands bordering highways. In all, nine papers were devoted to (1) the problems, (2) snow removal, (3) salt migration in soil, (4) the relationship of road salt application to sodium and chloride ion levels in the soil bordering major highways, (5) movement of dissolved salts in groundwater systems, (6) effect of deicing chemicals on grassy plants, (7) effect of deicing chemicals on woody plants, (8) salt tolerance on roadside vegetation, and (9) air pollution in the roadside environment." HRIS No. 204132.

Dickinson, W. E. (120)

1968. Snow and ice control - a critical look at its critics. Highway Research Record, Highway Research Board No. 227, pp. 48-49.

Summary:
"Salt is the principal tool in a highly essential operation financed with tax funds to control snow and ice on highways. Most commonly voiced criticisms of deicing chemicals are discussed. Salt causes auto corrosion, kills trees, grass and shrubs, pollutes water supplies and can pollute local wells, ponds and streams. Most pollution problems result from improper storage of deicing salts. Chemical producers are ready to assist public works officials in planning proper storage facilities. However, the positive aspects of deicing salt use show by accident statistics, the great decrease in accidents and saving of lives because of its use. Chicago estimates that its snow removal program prevented 15,250 accidents that would have cost $3.71 million." HRIS No. 218399.

Feick, G., R. A. Horne, and D. Yeaple (121)

1972. Release of mercury from contaminated freshwater sediments by the runoff of road de-icing salt. Science 175 (4026) 1142-1143.

"A recent report of the contamination of freshwater by the runoff of $CaCl_2$ and NaCl used for deicing roads raised the possibility that road salt could release mercury from bottom sediments. The results tabulated (in this report) show such to be the case, with the addition of NaCl or $CaCl_2$ increasing the relative amount of mercury in the water in equilibrium with the sediments by two to five or more orders of magnitude. The effect tends to increase as the mercury burden of the sediments increases. The pH changes consequent upon salt addition probably also contribute to the release of mercury.

"In addition to being a serious contaminant itself, road salt in natural waters can acerbate contamination by mercury and undoubtedly by other toxic heavy metals. The results presented here are also of interest in connection with the chemistry of heavy metals in the estuarine environment where sediment-laden freshwater and saltwater are mixed." Bibliography of 4 titles.

Field, Richard, Hugh E. Masters, Anthony N. Tafuri, and Edmund J. Struzeski, Jr. (122)

1974. Water pollution and associated effects from street salting (abridgement of 1971 EPA report, Environmental Impact of Highway Deicing), Transportation Research Record 506, Transportation Research Board (Washington, D.C.), pages 40-42.

From abstract:

"Most of the sodium chloride and calcium chloride (salt) used for deicing purposes eventually has a detrimental effect on our environment. The high levels of salt in our drinking water and the effect of the salt on the flora adjacent to highways and roadways have produced doubts about the heavy use of salt to provide 'bare pavement'.

"Currently about 9 to 10 million tons of sodium chloride, 0.3 million tons of calcium chloride, and 11 million tons of abrasives are used annually. Highway salting rates range from 400 to 800 pounds of salt per mile of highway per application, and many roads annually receive more than 50 tons of salt per mile.

"Deicing salts are often stockpiled in open areas without suitable protection, and if covers exist they are often not properly fastened. The resulting salt-laden drainage often has easy access to nearby water supplies. Treatment of the drainage and the use of covered dome-like structures, like the one called the 'beehive,' could eliminate salt storage pollution dangers.

"Large amounts of accumulated snow and ice, some containing up to 10,000 mg/litre of sodium chloride, 100 mg/litre of oils, and 100 mg/litre of lead, are dumped into nearby waters, or else the snow melts and then runs off and enters the body of water via the sewer system...In addition, the sodium from road salts entering streams and lakes can overstimulate the growth of blue-green algae. Sodium and calcium ion exchange with mercury could, under special conditions, release highly toxic mercury or other heavy metals to the overlying fresh waters.

"Ferric ferrocyanide and sodium ferrocyanide (anti-caking additives), common in road salt, are soluble in water and can generate cyanide in the presence of sunlight: 15.5 mg/litre of sodium ferrocyanide can produce 3.8 mg/litre of cyanide after 30 minutes, as compared with public health limits of 0.1 to 0.2 mg/litre. Further research is needed to establish the ultimate fate of these cyanides in the environment.

"Widespread damage to roadside soils, vegetation, and trees has been attributed to liberal application of road salt. Sugar maples...have deteriorated extensively within a 5-year period."

The Environmental Protection Agency has initiated several projects to attempt to better understand and control the road salt problem. One project has three objectives. They are: (1) to determine the best current method of optimum salt use, (2) to develop a practical guide for salt storage and handling, (3) to examine the ecological effect of dumping large quantities of snow from streets and highways into water bodies or water supply watersheds. Samples will be analyzed for chloride, nitrogen, nitrates, sodium, phosphorus, lead, mercury, chromium, oxygen demand, oil and grease, and other solids. Bibliography of 1 title.

Field, R., E. J. Struzeski,Jr., H. E. Masters, and A. N. Tafuri (123)

1973. Water pollution and associated effects from street salting. (Edison Water Quality Research Lab., N. J.) Copy available from GPO Sup. Doc as EP1,23/2:73-257, $.85; Microfiche from NTIS as PB-222 795, $1.45. Environmental Protection Agency, Technology Series Report, EPA-R2-73-257, 48 pages, 28 figures, 11 tables, 109 references.

Abstract

"A state-of-the-art review is presented of highway deicing practices and associated environmental effects. The bare pavement policy has resulted in a great increase in the use of deicing salts. They are more efficient and economical than abrasives. However, there is excessive application leading to environmental problems. Besides chemical melting, various methods for deicing exist. Some of these are stationary and mobile thermal melting units, alternate deicing compounds, snow adhesion reducing pavements, electromagnetic energy for ice shattering, and drainage systems designed to capture snowmelt for treatment or control. Salt storage facilities often become a major contributing source of local groundwater and surface water salt contamination. Coverage of salt piles is becoming more prevalent. Types of enclosed structures are illustrated, and cost consideration given. High chloride concentration levels have been found in roadway runoff. The special additives in deicing salts may create more severe pollutional problems than the chloride salts. Serious groundwater contamination has occurred in many locations, for example, Maine, Massachusetts, New Hampshire, and Michigan. Widespread damage of roadside soils and vegetation has been observed in areas of liberal salt usage. (EPA)". WRSIC Accession No. W73-13471.

Field, R., E. J. Struzeski, Jr., H. E. Masters, and A. N. Tafuri (124)

1974. Water pollution and associated effects from street salting. Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 100, No. EE2, Paper 10473, pages 459-477, 9 figures, 3 tables, 100 references.

Abstract

"Excessive application of deicing salts to streets leads to environmental problems. Besides chemical melting, various methods for deicing exist. Some of these are stationary and mobile thermal melting units, alternate deicing compounds, snow adhesion reduction, electromagnetic energy for ice shattering, and drainage systems designed to capture snowmelt for treatment or control. Salt storage facilities often become a major contributing source of local groundwater and surface water salt contamination. High chloride concentration levels have been found in roadway runoff. The

special additives in deicing salts may create more severe pollutional problems than the chloride salts. (Knapp-USGS)" WRSIC Accession No. W74-08306.

Hanes, R. E., L. W. Zelazny, and R. E. Blaser (125)

1970(a). Effects of de-icing salts on water quality and biota. National Cooperative Highway Research Program Report #91. Highway Research Board (Washington, D.C.), 70 pages.

"The findings indicate that the chloride concentration on major rivers in Northcentral and Northeast United States is not seriously affected by salts applied to highways for de-icing purposes. However, from available data, it seems that deicing salts can contaminate surface runoff, soil moisture, local wells, ponds, small streams, and maybe groundwaters along roadsides. Water volume is usually small near roadside areas, and dilution is not always sufficient to prevent high salt concentrations. However, the magnitude of the seriousness of such contamination is uncertain... Concentration of de-icing salts that would affect man, animals, fish and wildlife is restricted to the roadside area where dilution is small. Within the roadside area, high salt concentrations are likely to occur in the effluent from the terminal points of roadside drainage and especially in runoff from salt stockpiles...Other substances are often added to de-icing salts to prevent caking or inhibit corrosion. Sodium ferrocyanide, often added to de-icing salts to prevent caking, is not itself very toxic. However, upon photodecomposition it releases cyanide ions, which are extremely toxic, especially to fish...A rust inhibitor containing a source of phosphorus, serves to stimulate excessive aquatic plant growth in freshwater lakes. This may produce objectionable water plants, such as algal "blooms," that are toxic to fish life and produce objectionable odors." Also discussed is the effect of salts on plants with recommendations for further research.

Hanes, R. E., L. W. Zelazny, and R. E. Blaser (126)

1970(b) Salt tolerance of trees and shrubs to deicing salts. Highway Research Record #335. Highway Research Board. (Washington, D.C.) Pages 16-18.

"The purpose of this paper is to summarize the findings of a study intended to determine the tolerance of several deciduous trees and shrubs and several evergreen trees and shrubs, to the commonly used de-icing salts -- sodium and calcium chlorides...salt tolerance was based on plant injury symptoms and survival after salt treatment under field conditions...The average tolerance values across all sodium chloride and calcium chloride treatments showed salt tolerance of the deciduous trees to increase in the following order: tulip poplar $<$ green ash $<$ redbud-sugar maple $\lesssim$ white birch $<$ honey locust. For the deciduous shrubs salt tolerance increased in the following order: rose-spirea $<$ weigela $\lesssim$ forsythia $<$ honeysuckle $\lesssim$ privet. Salt tolerance for the evergreens increased in the following order: hemlock $<$ Norway spruce $<$ white pine $<$ creeping juniper $<$ Adams's needle $\lesssim$ pfitzer juniper."

Hawkins, R. H. (127)

1971. Street salting -- urban water quality workshop. Steet Salting -- Urban Water Quality Workshop Proceedings, State University College of Forestry at Syracuse University, May 6, 1971, 94 pages.

Abstract

"The 12 papers included in this volume concerning water pollution and related environmental effects from highway deicers, were given at the Street Salting -- Urban Water Quality Workshop, held at the State University College of Forestry at Syracuse University, on May 6, 1971. Current annual use of highway deicers is around 9 million tons of sodium chloride, about one-third million tons of calcium chloride, and about 8 million tons of abrasives. Leading states in deicer use are Pennsylvania, Ohio, New York, Michigan, and Minnesota. Specific data and information are presented regarding: (1) methods, equipment and materials used for snow and ice removal; (2) chlorides found in rainfall and municipal sewage during the winter; (3) salt runoff from streets and highways; (4) deicing compounds found in surface streams, public water supplies, groundwater, farm ponds and lakes; (5) special additives incorporated into deicing agents; (6) vehicular corrosion and deterioration of highway structures and pavements; and (7) effects on roadside soils, vegetation and trees. (See also W71-13434 thru W71-13441) Woodard-USGS." WRSIC Accession No. W71-13433.

Hawkins, R. H., and J. H. Judd (128)

1972. Water pollution as affected by street salting. Water Resources Bulletin, 8(6): 1246-1252, 1 figure, 3 tables, 12 references.

Abstract

"The use of salt to melt ice and snow on streets and roads has become prevalent throughout the northeast U.S. Several states apply as much as 20 tons per lane-mile. Eventually the salt reaches streams and lakes. In Meadowbrook, New York, the chloride content reached a high of 11,000 ppm in December 1969. The runoff from the watershed was emitted in several surges. Chloride concentrations declined with the onset of summer, but still remained high, suggesting that some of the salt applied during the past winter appeared in the summer streamflow. Salt runoff entered a small lake, and flowed directly to the lake bottom. The buildup of high density saline water in the lower portion of the lake prevented complete mixing in the spring. Incomplete mixing led to anoxic conditions in the lower lake strata. The population of benthic fauna of the lake was changed by the flow of salt water into the lake. From a total of 10 species of dipteran larva and oligochaetes, only 4 species remained. (Knapp-USGS)" WRSIC Accession No. W73-04789.

Hofstra, G. and R. Hall (129)

1971. Injury on roadside trees; leaf injury on pine and white cedar in relation to foliar levels of sodium and chloride. Canadian Journal of Botany 49: 613-622.

"Severe injury was observed on white cedar and several species of pine adjacent to highways in southern Ontario in the spring of 1970. Foliar injury, measured quantitatively as the ratio of brown to total leaf tissue, and foliar levels of sodium and chloride higher than background levels occurred on trees up to 120m from the highway, particularly on the downwind side of the highway, on the windward side of the tree, and on trees in exposed positions. Injury and foliar levels of sodium and chloride progressively declined at greater distance from the highway. For a given level of sodium or chloride more damage occurred on the windward side than on the sheltered side

of the tree. The data suggest that salt applied to highways in the winter is whipped up in a spray by traffic, blown onto vegetation, and contributes to leaf injury. Wind and lower than average temperatures also appeared to contribute to the injury observed in 1970. At similar foliar concentrations of sodium and chloride white pine showed twice as much injury as white cedar. Of the pines close to the highway, damage was greatest on white pine and red pine, intermediate on Scotch pine, and least on Austrian and Mugo pine. At similar levels of damage all pines contained similar foliar levels of sodium and chloride." Bibliography of 7 titles.

Huling, Edwin E. and Thomac C. Hollocher (130)

1972. Groundwater contamination by road salt; steady-state concentrations in east central Massachusetts. Science 176 (4032):288-290.

"The average steady-state contamination of groundwater by road salt in the suburban area around Boston, on the assumption that current rates of application of salt will continue, is about 160 milligrams pf sodium chloride per litre of water (100 milligrams of chloride per liter). This value is compared with values of 50 to 100 milligrams of chloride per liter found rather commonly now in town wells in eastern Massachusetts. These salt concentrations may be of concern to persons on low-sodium diets and to persons who obtain water from wells in the vicinity of major highways where salt concentrations could be several times higher than average." Bibliography of 16 titles.

Hutchinson, F. E. (131)

1968. Effect of highway salting on the concentration of sodium and chloride in rivers. Research in the Life Sciences, 3 pp., 2 tables.

From summary:
"Parallel and subsequent to a study that measured sodium and chloride ion concentrations along the roadsides of Maine highways, an analysis was made of ion concentrations in seven Maine rivers. When

averaged over all sites, the sodium content of the water was lowest in October and highest in April, following the winter period. However, the average chloride value was highest in July and lowest in April. Since there is no apparent reason why the trends for the two ions should be different, it is concluded that highway salting has no influence on the concentration of these ions in the rivers sampled. The fact that more ions are entering the rivers during and immediately following the winter months is offset by the increased volume of water in the sysytem at that time. The concentrations of these ions in the rivers studied are generally low and not a problem..." HRIS No. 218721.

Hutchinson, F. E. (132)

1970. Environmental pollution from highway deicing compounds. Journal of Soil and Water Conservation, 25(4):144-146, 1 figure, 3 tables, 7 references.

Abstract

"During the period 1965-1969, a study was made to determine what environmental pollution, if any, resulted from the average annual application of 25 tons of sodium chloride to each mile of paved highway in Maine. Analyses of water samples indicated that wells and farm ponds were seriously contaminated with chloride ions. Soil sample analyses revealed that soils contiguous to highways contained sodium levels that threaten vegetation and soil drainage. Concentrations of these ions in rivers apparently were not influenced by this practice. (KNAPP-USGS)" WRSIC Accession No. W70-09844.

Hutchinson, F. E. (133)

1971. Disposal of sodium ions in soil. Maine State Highway Commission; Materials and Res. Div. TP 71-10C, 23 pp., 14 tables, 1 figure.

From summary:

"Limestone and gypsum were surface applied to three sites along Maine highways where sodium levels had been raised appreciably by road salting for deicing purposes during previous winters...Calcium levels in the soil at all sites were significantly increased by limestone application, but the sodium levels remained unchanged. Magnesium levels tended decrease with increased rate of liming, while potassium and pH values remained relatively constant. Gypsum treatments significantly increased the calcium levels in the soils, although less than limestone. At the 6-inch depth, sodium levels were significantly reduced by the treatment..." (Author) HRIS No. 238032.

Hutchinson, F. E., and B. E. Olson (134)

1967(?) The relationship of road salt applications to sodium and chloride ion levels in the soil bordering major highways. Highway Research Record No. 193, Environmental Considerations in Use of Deicing Chemicals, 5 reports, National Highway Research Board, Division of Engineering, National Research Council, National Academy of Sciences - National Academy of Engineering, pp. 1-7, 6 tables, 2 figures.

"Sodium and chloride levels in soils adjacent to salted highways were measured during July and October 1965, and April 1966 at 27 sites to determine the effect of salting for periods ranging from zero to 18 years. Levels of both ions were raised as a result of this practice, with the effect greatest at the edge of the road embankment and also where salting had been practiced for the longest period of time. Salting increased sodium and chloride levels more at the 6-inch than at the 18-inch depth, and sodium levels were raised to a higher value than were the chloride levels. Although levels of these ions were highest at the edge of the highway, the levels were raised at a distance of 60 ft. from the highway in some instances. Wells near some of the highways contained chloride levels in excess of the recommended maximum." Author's abstract.

Kunkle, S. H. (135)

1972. Effects of road salt on a Vermont stream. Journal of the American Water Works Association, 64(5): 290-295, 6 figures, 6 tables, 16 references.

From Abstract:
"Deicing roads by salting them may or may not reduce accidents, but salting roads definitely does raise the salt level of streams that flow nearby. Highway deicing chemicals, especially sodium chloride,

are used liberally during winter months in many areas. The total volume of deicing chemicals used in the U.S. probably exceeds 2 million tons per year. Road salt investigations were carried out in the Sleepers River Basin, Vermont, between 1968 and 1970... A 4 km section of the U.S. Highway 2 traverses the research basin just west of St. Johnsburg, Vt. Salt concentrations in the highway-influenced stream peaked during summer baseflow, not during winter or spring as might be expected. Peak chloride concentrations during the summer dry period indicated that some of the road salt found its way into soils, then into subsurface flows, and finally emerged in summer's groundwater inputs into the stream. Individual seeps sampled near the highway showed chloride levels exceeding 200 mg/liter. Problem concentrations could arise where a salt-contaminated stream empties into a town water-supply reservoir. (KNAPP-USGS)" WRSIC Accession No. W72-08808.

Kyser, J. O. (136)

1971. Liquid road treatment for ice control. ASHTO Proceedings, pp. 56-62.

"A discussion is given of the use of liquid salt solution by the North Dakota State Highway Department for control of icy road conditions. Some advantages of the use of this solution over dry chemicals are presented, and a cost comparison is made. Overall, it appears that the amount of chloride used for snow and ice removal, while increasing some, will not increase to a degree where it could have any ecological effects on plant growth." HRIS No. 219124.

McConnell, H. (137)

1972. De-icing salts and the environment. Habitat Sch. of Environment, 55 pp., 5 tables, 1 figure, 88 references, 3 appendices.

From summary: "...Most of the information available to the public has been supplied by organizations promoting the sale of deicing salts, although the U. S. Environmental Protection Agency has published a review of the existing literature. The present report is another such review, treating the following topics: the chemistry and application of deicing salts, damage to public works, automobile corrosion, water pollution, effects on vegetation and wildlife, the effectiveness of salting, alternatives, and the economics of salting." HRIS No. 218985.

Meredith, Dale D., Ralph R. Runner, Jr. Calvin C. Chien, and Robert P. Apmann (138)

1974. Chlorides in Lake Erie Basin, Department of Civil Engineering, State University of New York at Buffalo, Water Resources and Environmental Engineering Research Report No. 74-1 (Completion report for Project B-044-NY). Pages v + 82.

Authors' Abstract

"The deicing salt runoff from Buffalo, New York and selected nearby communities has been measured and it was found that, in the case of Buffalo, approximately 90% of the deicing salt applied is recovered by the combined sewer system. The Lake Erie drainage basin was subdivided into regions and a search of the literature was made to establish the historical data for chloride discharge from each region. Time-dependent equations were estimated for the annual chloride discharge from each source region and used in conjunction with a mathematical model for chloride balance in Lake Erie. It was possible to fairly reproduce the historical trend of chloride build-up in Lake Erie by this method. The calibrated model projects a chloride concentration in Lake Erie of 135 ppm by the year 2050. The effects of a few selected salt management programs on future chloride levels in Lake Erie are examined utilizing the model."

The authors indicate that there has been a threefold increase in the chloride concentration in Lake Erie (from 9 mg/l to about 28 mg/l in the period of 1911 through 1960 and that although the present concentration has no identifiable effect on current water use, the increasing concentration may be a threat to some uses in the future.

They attribute (page 34) approximately 35.8% ot the chloride discharge from Buffalo to deicing salt runoff and estimate that the total chloride deicing salt runoff into Lake Erie from the Lake Erie basin was as much as 831,800 tons of chloride in 1972. They recommended that more efficient application techniques be developed and explained to local government officials who are in charge of ice control because the use of deicing salt is not likely to be abated in the near future.

Murray, D. M., and M. R. Eigerman (139)

1972. A search: new technology for pavement snow and ice control. ABT Associates, Inc., EPA#-R2-72-125, 62 pp, tables, figures, 65 references.

From Summary:
"A study was undertaken to search for new approaches to the problem of snow removal and ice control in vehicular and pedestrian usage areas. Proven techniques of technology transfer were applied for the purpose of identifying technologies that have not yet been utilized for deicing purposes. Contacts with specialists and a 'brainstorming session' were used to determine strategies for searches of computerized data banks. Although several approaches were identified, none are immediately usable..." HRIS No. 260727

O'Toole, M. L. (140)

1972. Effective methods for storing and using salt. Public Works 103(10):76-78, 2 photographs.

"Maintenance departments in the northern states are caught between motorists and shippers charging unsafe roads on the one hand and environmentalists charging ground and stream pollution on the other. Steering a middle ground begins with salt storage, which, in all cases, must not be permitted to occasion environmental damage. Precautions for indoor and outdoor storage are discussed. The key to reduced pollution from salt application is maximum removal of snow and ice before application, together with control over salt-application rate, adjustment of quantity to average daily traffic, salting as close to the crown as possible, conversion of the pavement from wet to dry as soon as feasible; better application can also be realized through better understanding of storm characteristics, the local weather cycle, and daily traffic patterns. Proper equipment is essential. Foreman and operators must be trained in the department's approach to winter maintenance. HRIS No. 219035.

Relph, E. C., and S. B. Goodwillie, Toronto University, Ontario, Canada, Department of Geography (141)

1968. Annotated bibliography on snow and ice problems. Natural Hazard Research Working Paper No. 2, 1968, 13 pp.

Abstract: "This paper, a bibliography of 126 references on snow and ice problems, is one in a series on research in progress in the field of human adjustments to natural hazards. It is intended that these papers will be used as working documents by the group of scholars directly involved in hazard research as well as inform a larger circle of interested persons. The annotated bibliography lists publications including bibliographies and general studies, meteorological and climatic studies, studies of the impact of snowfalls, perception of the snow hazard, methods and costs of snow removal and ice control, and methods of snow removal. (KNAPP USGS)" WRSIC Accession No. W71-06719

Rich, Avery E. (142)

1973. Some effects of de-icing chemicals on roadside trees. Highway Research Record #425. Highway Research Board (Washington, D. C.) Pages 14-16.

"...The amount of salt used on highways in the United States has increased from ½ to 6 million tons during the past 20 years. Its use appears to be increasing at the rate of about 1 million tons per year, and predictions are that it may level off at 10 to 12 million tons. It is estimated that 95% of the salt used is sodium chloride (NaCl) and 5% is calcium chloride ($CaCl_2$)." The results of several studies "suggest that salt is an important contributing factor to the decline of roadside maple trees. Other factors, such as drought, pavement, mechanical root damage and possible air pollution should have remained relatively constant for the salted and unsalted roads." Tree species intolerant to salt include the sugar maple (Acer saccharum), red maple (Acer rubrum), basswood (Tilia americana), American elm (Ulmus americana), Canadian hemlock (Tsuga canadensis), balsam fir (Abies balsamea), white pine (Pinus strobus), and red pine (Pinus resinosa). Tree species tolerant to salt include the red oak (Quercus rubra), white oak (Quercus alba), white ash (Fraxinus americana), black locust (Robinia pseudo acacia), quaking aspen (Populus tremuloides), black cherry (Prunus serotina), black birch (Betula lenta), gray birch (Betula populifolia), yellow birch (Betula alleghaniensis), Norway maple (Acer platanoides), and red cedar (Juniperus virginiana). The recommendations for reduced tree damage are: use of properly calibrated salt spreaders, the mixing of sand and salt when possible, construction of a ditch between the edge of the road and the nearest row of trees for salt to drain into, selection of tolerant species for new plantings, and the mixing of gypsum with the soil at planting time to improve soil structure and reduce salt injury. Bibliography of 12 titles.

Riddle, J. R. (143)

1972. Environmental considerations in snow removal, mowing and spraying of roadsides. Ohio Highway Engineering Conference Proceedings 4 April '72, pp. 265-270.

"Damages to trees and shrubs and water contamination result from the use of salt for snow removal. The environmental effects of mowing and spraying, referred to as vegetation control, are also discussed. Recommendations are made for salt storage, and several rules to follow for a uniform weed brush roadside management program are presented." HRIS No. 219176.

Roberts, Eliot C. and Edward L. Zybura (144)

1967. Effect of sodium chloride on grasses for roadside use. Highway Research Record No. 193, Environmental Considerations in Use of Deicing Chemicals - 5 reports, Highway Research Board, National Research Council, National Academy of Sciences - National Academy of Engineering, pp. 35-42, 5 figures, 5 tables.

"More than 24,000 lbs. of sodium chloride per mile of four-lane highway have been used per year for ice removal on some sections of Interstate 80 in Iowa. Salt applied at this rate during the winters of 1963-64 and 1964-65 affected median and foreslope soil structure and prevented satisfactory establishment of grass cover. Injury to grass seedlings and established turf has been greatest on heavy soils with little organic matter - i.e., glacial till. Soluble salt determinations made on soil samples taken along I-80 indicate concentrations of sodium chloride sufficiently high to restrict grass growth up to 10 ft. from the pavement. Kentucky 31 fescue, slender wheatgrass, intermediate wheatgrass, western wheatgrass, Russian wild rye and reed canarygrass have enough seeding vigor for rapid establishment and enough tolerance to clipping at a 3-in. height to be used effectively on roadsides. Of these grasses, Kentucky 31 fescue and western wheatgrass are the most salt tolerant. Up to about 600 ppm sodium chloride stimulated growth of all grasses tested, but injury became evident and increasingly more pronounced as salt levels increased from 1000 to 5000 ppm. Of the 10 grasses studied, Kentucky 31 fescue is best suited for use where roadside soils are contaminated by salt."

Sharp, R. W. (145)

1971. Road salt as a polluting element. In: Street Salting - Urban Water Quality Workshop Proceedings, State University College of Forestry at Syracuse University, May 6, 1971; Syracuse, N.Y., State College of Forestry, pages 70-73, July 1971; 5 references.

Abstract: "The use of salt for snow and ice control on northern streets and highways has grown rapidly since the 1940's. In the winter of 1964-65, the city of Milwaukee, Wisconsin, used 33,000 tons of sodium chloride and 200 tons of calcium chloride. In the same winter, the Wisconsin Highway Department used 160,000 tons of sodium chloride, or 15.8 tons per mile of highway. The chlorides, being highly soluble, are carried by runoff water to lakes and streams. The question arises as to possible damage to the aquatic and terrestrial environment. Environmental effects appear to be localized near large urban centers and along heavily used freeway routes. Diamond Lake, in Hennepin County, Wisconsin, which receives the discharge of a major storm sewer, now has a chloride content of 2,270 ppm, equivalent of 3,780 ppm sodium chloride. To place these values in the perspective of fish tolerance, bluegills will tolerate 10,000 ppm, sodium chloride. Rainbow trout sustained 20% mortality at 12,000 ppm. A build-up of sodium chloride can cause complete soil sterility. Studies show a substantial build-up in chloride content of domestic wells located adjacent to main highway systems. Chloride levels exceeding the potable water supply standard of 250 ppm have been found in many states during recent years as a result of road salt application. (see also W71-13433) (Woodard-USGS)" WRSIC Accession No. W71-13440

Schaufnagel, F. H. (146)

1967. Pollution aspects associated with chemical deicing. Highway Research Record No. 193, Environmental Considerations in use of Deicing Chemicals - 5 reports, Division of Engineering, National Research Council, National Academy of Sciences - National Academy of Engineering, pp. 22-33, 4 tables.

This paper points out that about the only requirements of deicing chemicals are that the substance be soluble in and lower the freezing point of water. Therefore, there are a number of chemicals used, from urea to rock salt. Cost is a big factor in the selection of deicer and this alone points to the widespread use of salt. The paper discusses the use and some environmental effects of chlorides, nitrogen and phosphorus and other deicers.

Various harmful and non-harmful levels of chloride are cited for several fish and wildlife species. During the winter of 1958-1959 wildlife mortality occurred in Wisconsin which was attributed to salt poisoning from sodium chloride used for deicing highways. Salt poisoning was diagnosed in wild rabbits, pheasants, a quail and a pigeon. There were additional reports of rabbit mortality due to deicing. Heavy snows and cold weather of that winter created "salt hunger" with restricted water intake. Laboratory experiment on adult pheasants and rabbits produced disorders similar to the symptoms observed in the wild. Ferrocyanides used as additives to rock salt and calcium chloride to prevent caking, inhibit corrosion and for marking, are cited as being particularly toxic to fish. Sodium ferrocyanide releases cyanide due to photo-decomposition. Nitrogen and phosporus compounds are discouraged as deicers due to potential over-fertilization effects on water areas. Some of the alcohols used with gasoline and ethylene glycol used on windshields to clear ice, have potential for reducing water's dissolved oxygen thereby endangering fish life. Various other harmful effects of chemicals due to sewage and waste are discussed.

Struzeski, Ed - Edison Water Quality Lab., New Jersey (147)

1971. Environmental impact of highway deicing.

Copy available from GPO Supt. DOC as SN-5501-0127, $1.25; microfiche from NTIS as PB-203 493, $.95 EPA Program 11040 GKK 06/71.

Abstract: "Deicing agents for removal of ice and snow from highways and streets are essential to wintertime road maintenance in most areas of the U.S. Due to the ever-increasing use of highway deicing materials, there has been growing concern as to environmental effects resulting from these practices. This state-of-the-art report critically reviews the available information on methods, equipment and materials used for snow and ice removal; chlorides found in rainfall and municipal sewage during the winter; salt runoff from streets and highways; deicing compounds found in surface streams, public water supplies, groundwater, farm ponds and lakes; special additives incorporated into deicing agents; vehicular corrosion and deterioration of highway structures and pavements; and effects on roadside soils, vegetation and trees. Highway deicing can cause injury and damage across a wide environmental spectrum. Recommendations describe future research, development and demonstration efforts necessary to assess and reduce the adverse impact of highway deicing. (Struzeski-EPA)"
WRSIC Accession No. W71-13898

Trainer, D. O. and Lars Karstad (148)

1960. Salt poisoning in Wisconsin wildlife. Journal of the American Veterinary Medical Association 136 (1): 14-17.

"Salt (NaCl) poisoning was diagnosed in Wisconsin in wild rabbits, pheasants, quail, and a pigeon during the winter of 1958-1959. fected animals showed signs of severe derangement of the central nervous system. A similar disease picture was experimentally produced by the administration of sodium chloride to wild rabbits (1,100 to 1,200 gm.) and pheasants

(1,200 to 1,400 gm). The source of sodium chloride in the naturally occurring disease was found to be salt spread on highways to control slippery road conditions. It is believed that unusually severe weather and heavy snowfall predisposed to poisoning of wildlife by creating "salt hunger" and restricting water intake in affected animals...the number of fatalities may be increased when the only source of water is snow, which animals must eat. Salt poisoning in wildlife is, therefore, considered to be an accidental disease. Due to the difficulties encountered in detecting and estimating mortality in wildlife populations, its frequency of occurrence is unknown. Bibliography of 12 titles.

Transportation Research Board (149)

1974. Minimizing de-icing chemical use. National Cooperative Highway Research Program. Synthesis of Highway Practice #24. Transportation Research Board, (Washington, D.C.) 58 pages.

"...Salt-calcium chloride ($CaCl_2$) mixes can increase melting effectiveness and reduce quantity of salt used. Several agencies are using liquid $CaCl_2$ to prewet salt as it is spread. Prewetting has been estimated to reduce the amount of salt used by up to 40%. Aqueous $CaCl_2$ solutions have also been used alone successfully...Optimum application rate depends on level of service required, weather conditions, chemical used, time of application, traffic, topography, and type of road surface. Actual rates for a single application of salt vary from 100 to 800 lb. per lane-mile (30 to 230 kg/km) in rural areas and up to 2,000 lb. per lane-mile (560 kg/km) on city expressways. Annual use reaches up to 40 tons per lane-mile (23,000 kg/km) on heavily traveled roads in high-frequency snow areas...Only urea, formamide, and TKPP (tetrapotassium pyrophosphate) have been used," in practical applications as alternatives to the use of chlorides.

"Approaches to minimizing de-icing chemical use include:

1. Prewetting salt with liquid chemicals.
2. Direct application of liquid chemical.
3. Calibration of spreaders.
4. Better management control.
5. Training of personnel.
6. Adequate weather forecasts.
7. Use of abrasives.
8. Snowplowing."

Bibliography of 71 titles and appendix of chemical and sand use by State.

van de Voorde, H., M. Nijs and P. J. Van Dijck (150)

1973. Effects of road salt in winter. Environmental Pollution. 5(3):213-218

"The salt concentration in three streams and soils was studied during a two-year period in order to discover the effect of salt treatment of roads in winter. Scattered salt enhances slightly, for a 24 hour period, chloride concentration in the river which crosses a city. In a rural stream the salt concentration reaches a high level for a short period. In the rivers or streams the scattered salt is quickly diluted so that the normal chloride level remains unchanged. The amount of salt deposited on the banks of the roads filter down to the phreatic water and locally enhances the chloride concentration of the groundwater but not to a concentration which can be considered harmful to the health of consumers. Other minor disadvantages of road salt are damage to ornamental vegetation and corroding effect on metallic surfaces. The hazards of the use of road salt are, however, negligible compared with traffic safety." Bibliography of 10 titles.

Verghese, K. G., R. E. Hanes, L. W. Zelazny, (151)
and R. E. Blaser

1970. Sodium chloride uptake in grasses as influenced by fertility interaction. Highway Research Record #335. Highway Research Board (Washington, D.C.). Pages 13-15.

"Field and greenhouse experiments were conducted with sodium chloride to study the effects of de-icing salts on grasses along highways. Bromegrass (Bromus inermis), red rescue (Festuca rubia), Kentucky bluegrass (Poa pratensis L.), and Kentucky 31 fescue (Festuca arundinacea) were used in an experiment at Warsaw, Virginia, to compare the responses of these grasses with similar salt treatments. Rock salt was applied at rates of 2,4, and 6 tons/acre in 6 split applications during the winter months of 1967-68 on all grasses seeded in 1966. In the early spring, 50 lb./acre of nitrogen was applied on half of each plot. The grasses were harvested in June and analyzed for sodium and chloride...These investigations show that there was less rock salt damage to plants with certain fertilizer salt nutrients than when rock salt was applied alone... Before salt mixtures are used for de-icing, the effectiveness of salts as ice-melting agents, the costs of the material and the polluting potentials must be considered."

Westing, Arthur H. (152)

1969. Plants and salt in the roadside environment. Phytopathology 59 (9):1174-1181.

"This past winter, some 6 million tons of salt (95% sodium chloride and 5% calcium chloride) were applied to the highways of our northern states. The use of salt is now increasing by about 1 million tons a year, and is expected to level off at perhaps 10 or 12 million tons." The author discusses the fate of this salt in roadside soils and plants and the weather conditions, soil and plant types which influence the effects of salt. Solutions to reduce the problem of roadside salt are given." Bibliography of 120 titles.

Wilmoth, B. M. (EPA, Wheeling, W.Va.) (153)

1972. Salty ground water and meteoric flushing of contaminated aquifers in West Virginia. Ground Water, 10(1):99-105, 8 figures, 6 references.

Abstract; "Salty groundwater is commonly encountered at relatively shallow depths of 100 to 300 feet beneath the major stream channels in the western half of West Virginia. It is difficult to distinguish natural contamination from that caused by industrial activities. Histories of some water well developments show large-scale changes in salt content from various industrial activities that affect the fresh water zones. Heavy pumping of well fields in Charleston during 1930 to 1956 accelerated migration upward of salt water. Pumpage has declined greatly since 1956 and chloride content has decreased below 200 mg/liter at some of the contaminated wells. Road salt piles contaminated a carbonate aquifer in Monroe County. Chloride concentrations in wells located 1,500 feet from the piles increased from 185 mg/liter to 1,000 mg/liter in 5 years. The greatest change was 1,000 mg/liter in 1969 to 7,200 mg/liter in 1970 when the salt storage area was enlarged. All salt piles were removed in late 1970 and within 2 months chloride content decreased to 188 mg/liter. (KNAPP-USGS)" WRSIC No. W-72-04801

2. Roadside Rest Areas and Parks: Waste Disposal

AASHTO (154)

1973. Rest areas, National Cooperative Highway Research Program. No. 20, Synthesis of Highway Practice, Highway Research Board, Division of Engineering, National Research Council, National Academy of Sciences - National Academy of Engineering, 38 pages, 33 figures, 3 tables.

This publication points out that rest areas are providing motorists with a greater measure of safety and comfort on limited access and other highways. States are providing complete facilities, including ample parking spaces, toilet buildings, lavatories, hand dryers, and drinking water; picnic tables and benches; shelters; cooking grills and fire places; public telephones; lighted, landscaped grounds; and the necessary systems for power supply, water supply, and sewage disposal. Multiple use of sites is feasible in many locations where additional lands may be acquired with the cooperation of other public agencies. An example is cited in Montana where access is provided from the rest area to an adjacent U.S. Forest Service campground with fishing and boat facilities. Maintenance of rest areas is discussed whereby if a rest area is properly designed, it will operate in a safe manner with a minimum of supervision.

Anderson, C. V. (155)

1974. Zero discharge sanitation system. 34 pp., 13 fig., 5 tab., photos. Western Association of State Highway and Transportation Off; AASHTO, 341 National Press Building; Washington, D.C. 20004

From summary:
"A study was conducted to evaluate the usage of a zero discharge waste treatment unit for a highway safety rest area...It is concluded that zero discharge system is another technical advancement which allows highway authorities to provide necessary comfort facilities, which would be impossible using conventional methods to meet modern environmental requirements." HRIS No. 260295.

Baumgardner, R. H. (156)

1972. Rest area sewage disposal and water supply. Am. Assoc. State Highway Officials Proc. 48 pp., 26 fig., 2 tab., 18 ref.

Summary:
"The section on water supply considers wells, surface waters, and municipal sources. As the last is rarely close enough and the second requires a complete water treatment plant, most of the discussion is about the design and construction of wells, with special attention given assuring sanitary supply. With respect to sewage treatment, the advantages and disadvantages of three types are discussed: septic tanks, extended aeration package plants, and stabilization ponds." HRIS No. 205233.

Kamber, D. M. (157)

1970. New York State Thruway accomplishes pure water program objectives. Public Works 101(4): 92-93, 3 fig., 2 tab.

Summary:
"The New York State Thruway authority initiated a study in 1964 to determine the condition and adequacy of its service-area sewage treatment facilities. As a result of this study, a comprehensive maintenance and operation program was established. Studies disclosed that extended aeration process would be best for satisfying the established criteria in treatment of sewage at the Thruway owned plants. The design of extended aeration treatment facilities at primary plants was completed. Planned improvements of the primary plants will offset increased flows and will substantially reduce the contribution of these two primary plants to the receiving stream organic loading. With the construction of the added facilities, the New York State Thruway Authority will conform with the requirements of pure waters program and accomplish its role in water pollution control while continuing to utilize existing facilities in the most efficient manner." HRIS No. 204790.

Parker, C. E. - Virginia Highway Research Council, Charlottesville. (158)

1974. Feasibility of water reuse at highway rest stations.
Journal of the American Water Works Association, 66(4):247-249, 4 tables, 9 references.

Abstract: "A study was made of the current effluent quality from an existing rest station, the treatment required to upgrade the waste water from the rest area for recycle, the requirements of the rest area, and the response necessary for a recycle system to meet peak demands. Water use was correlated with rest area use and traffic flow. Waste water was examined from an area employing an extended aeration system and a holding pond, and evaluated regarding requirements for toilet flushing at

peak needs. It appears that by changing the flow scheme and storage and disinfection scheme, the present effluent could be used for flushing toilets. Capital costs were compared with the necessary system for effluents which are free from phosphorus and low in organic carbon. This recycling alternative would save about $35,000 per rest area. On a test basis, it is indicated that waste water reuse for flushing toilets at highway rest areas offers an alternative to releasing high-quality effluent to a stream. Further demonstration projects are needed. (Prague-Firl)" WRSIC Accession No. W74-11134

NOTE: It may be observed that holding ponds would have wildlife values.

Solomon, D. (159)

1974. Environmental research and highways. Public Roads (a journal of highway research and development), 37(8):297-305, 6 figures.

Astract: "Environmental research completed, underway, or planned under the Federally coordinated program of Research and Development in Highway Transportation is described. Three major research areas are involved in efforts to reduce significant water pollution from highway sources. One is to provide requirements for the quantity of water to be treated and criteria for treatment of wastes at roadside rest areas. Physical, chemical, and biological tests of the water and sewage will determine water quality and effectiveness of the sewage treatment process. A second area of research involves determination of the type and amount of pollutants, their impact on the environment, and methods for controlling pollutants contributed by the highway system. Included are such pollutants as rubber, lead, grease, and oil which collect on the pavement surface and wash into drainage facilities. A third task has as its objective the reduction of damage of water resources through accidental spills of chemicals and other materials. Research on air quality, noise, esthetics and visual quality, and ecological problems is also discussed. (Merritt-Firl)" WRSIC No. 74-08251

Stuart, Leslie B. (Tenn. Tech. Univ. Cookeville) (160)

1970. Development of design parameters for interstate rest area sewage treatment systems. Master of Science Thesis, Engineering Research Series, August 1970. 90 pages, 17 tables, 12 figures, 22 references, 2 appendices.

Abstract: "A research project was conducted to establish design parameters for application to interstate rest area sewage treatment facilities. This study was conducted at the Smith County Rest Area, located on I-40, Tennessee where the sewage treatment system consists of a 20,000 gpd package-type extended aeration plant installed in February 1969 on recommendation of private consultants. The investigation indicates that current design of interstate rest area sewage treatment systems in Tennessee is much too conservative and uneconomical. The results of this study indicate that hydraulic loading is the critical factor in sizing package-type treatment facilities for interstate rest areas. The Smith County plant was designed on the basis of 10.68 gallons per vehicle (gpv) but tests showed that the actual flow is only 5.52 gpv and the organic loading is only 200 mg/liter while it was designed for 240 mg/liter. (ELLIS-TEXAS)" WRSIC No. W71-06040

Sylvester, R. O. and R. W. Seabloom - Washington University, Seattle (161)

1972. Rest area wastewater disposal. Available from the National Technical Information Service as PB-208 522. $3.00 in paper copy, $.95 in microfiche. January 1972. 72 pages, 10 figures, 16 tables, 20 references.

Abstract: "The development of alternative methods of wastewater disposal in Highway Department safety rest areas was investigated. Existing and planned rest area installations were studied to establish critical operating parameters and relative effectiveness of existing waste disposal systems. State-of-the-art systems and various additives were examined and tested to determine if system efficiency can be increased. Recommendations were made as to disposal systems which were suited to the conditions existing in rest areas including the desirable and undesirable features of each system considered. (Galwardi-Texas)" WRSIC No. W72-14382

U.S. Department of Transportation, Federal Highway Administration (162)

1971. Water supply and waste disposal series: volume 1. Terminology standardization and microbiology. Department of Transportation - Federal Highway Administration Staff Report 72R-106S-1, 51 pages, 16 figures, 12 tables, 141 references, appendices.

Abstract: "This is the first volume of a series of reports on water supply and waste disposal published by the Federal Highway Administration. This series emphasizes water supplies, water-carriage waste treatment, and solid waste disposal, particularly as they relate to roadside rest areas. Because definitions, classifications and terminology concerning microorganisms and bilogical terms sometimes lack uniformity among the disciplines, this volume defines and standardizes the terminology that will be used in all volumes of the series. Information on diseases that might be transmitted at rest or recreation areas is presented. The capability of individual species of microorganisms to survive in the soil, on the soil, in water, and in other situations is indicated. A bibliography containing 14 references is included. (Woodard-USGS)" WRSIC No. W72-14363

U. S. Department of Transportation, Federal Highway Administration (163)

1972. Water supply and waste disposal series volume 6 - oxidation ditch sewage waste treatment process. 52 pp., 31 fig., 6 tab., 17 ref., app.

Summary: "The Federal Highway Administration is publishing a series of reports on water supply

and waste disposal, of which this one presents the step-by-step procedure for designing an oxidation ditch sewage treatment process. Information from research and field investigations indicates that the oxidation ditch process is the most suitable for many roadside rest and recreation areas. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification, or regulation." (FHWA) HRIS No. 206037

3. Other Pollutants Resulting from Highways

Anonymous (164)

1972. Toxic metals along roads. Science News 102(18):280.

"The lead industry and others are still trying to claim that toxic metals emitted into the air from automobiles are harmless. While there is still doubt about the harm to humans of breathing the contaminated air, there appears to be less doubt that dangerous amounts of the metal get into roadside soil. Now the Interior Department's Fish and Wildlife Service reports that analysis of earthworms taken from soil 10,20,40,80, and 160 feet from U. S. Highway 1 and from the Baltimore-Washington Parkway, both in Maryland, show high levels of several toxic metals. Lead and zinc were in quantities that would be fatal to birds that consumed the earthworms, even when the worms were 160 feet from the roads in the case of zinc. Other metals found in the worms were nickel and cadmium. The FWS researchers say the metals evidently came from auto emissions. Zinc is used in motor oil, lead in gasoline, cadmium in tires, and nickel in both gasoline and oil.

Lead at levels higher than the 200 parts per million (ppm) level known to be fatal for mallard ducks was found only within 10 feet of the roads and in lesser amounts beyond 10 feet. Cadmium was not found at known lethal levels at any distance from the roads. Nickel was found at 34.5 ppm 10 feet from the roads, but toxicity levels for nickel are not known." HRIS No. 205221

Anonymous (165)

1972. How polluting is storm runoff from unpaved roads? Civil Engineering ASCE 42(7):91

Summary:
"The impact of storm-water runoff from unpaved roads on stream quality is reported. It was found that while the turbidity of a stream in undeveloped areas remains unchanged, that besides a 2-lane country gravel road jumped two orders of magnitude. This increase may have harmful effects on plankton, benthos and other organisms. The composition of bottom sediments influences the quality of the overlying water. Nutrient materials are released into overlying waters through stirring up of muds, transfer at the interface, and ingestion of living animals. Toxic metal dumped into a stream can have a drastic effect on fish life many miles downstream. The example is described of an 80-year long pollution of a major waterway by waste-water laden with mercury. Twelve years ago, a dam was built just upstream from this waterway, creating $40 million dollars in commercial fishing. A method is being developed whereby oils found in water and sediment may be identified by means of infrared spectra or by using atomic absorption spectrophotometry to analyse the oils nickel-vanadium ratio." HRIS No. 204513

Atkins, P. R. (166)

1969. Lead in a suburban environment. Journal Air Pollution Control Association, 19(8):591-594, 14 references.

Abstract: "The lead content of air, rainfall, and dry fallout samples taken at several sites in Palo Alto, California are reported and discussed. Major source of lead pollution apparently is the high-speed, high-density freeway traffic in the area. The natural atmospheric cleansing processes of sedimentation and raindrop scavenging remove large quantities

of lead particulate matter. Nucleation probably occurs on the submicronic lead compound particles in exhaust streams, making droplets which impact on the larger airborne particles. This could explain the wide size distributions range reported in the literature as well as the large amounts of lead found in the samples analyzed. (LANG-USGS)" WRSIC No. W70-09251.

Bini, G. (167)

1973. Lead in the rural environment - 1. Lead in the urban environment - 2. International Journal of Environmental Studies. (July 9, 1973).

"Internal combustion engines, industrial emissions, and open burning of lead paint coated wood are the main sources of lead pollution of the atmosphere. Lead accumulates downwind, i.e. on the leeside of traffic congested motorways, reaching concentrations of up to 700 ppm. in the needles of conifers flanking roads with a traffic density of 1000 cars per hour. Emphasis is placed on the direct connection of lead pollution with the food chain. A possible remedy appears to be a reduction in lead content of gasoline and its replacement with high octane rating isoparaffins. Airborne lead concentration, overwhelmingly due to automotive traffic, is now ranging from 0.5 to more than 10 g/cu m in European cities." HRIS No. 224507

Bullock, J. and W. M. Lewis (168)

1968. The influence of traffic on atmospheric pollution. The High Street-Warwick. Atmospheric Environment, 2:517-534, 13 fig., 9 tab., phot., 5 ref.

From summary:
"Details are given of an investigation into air pollution caused by traffic in the High Street at Warwick which is frequently congested and carries a large number of both private and commercial vehicles...The concentration of

atmospheric lead was not high enough to be a health hazard..." (TRRL) HRIS No. 239692.

Chow, Tsaihwa J., Kenneth W. Bruland, Kathe Bertine, Andrew Soutar, Minoru Koide, and E. D. Goldberg (169)

1973. Lead pollution: records in Southern California coastal sediments. Science 181: 551-552, 2 figures, references.

Author's abstract: "The present anthropogenic lead fluxes into sediments from the Santa Monica, San Pedro and Santa Barbara basins of Southern California are respectively, 0.9, 1.7, and 2.1 micrograms of lead per square centimeter of sea bottom per year, the natural (prepollution) rates for these three basins were, respectively, 0.24, 0.26 and 1.0 microgram of lead per square centimeter per year. Studies of isotopic composition indicate that lead pollutants in coastal sediments are derived mainly from the combustion of lead additives in gasoline."

Chow, T. J., and J. L. Earl (170)

1970. Lead aerosols in the atmosphere: increasing concentrations. Science 169(3945): 577-580.

From summary:
"The concentrations of atmospheric lead round San Diego, California have been determined and their geographic and seasonal variations are explained..." (Author) HRIS No. 239986.

Cook, R. S. and D. O. Trainer (University of Wisconsin, Madison) (171)

1966. Experimental lead poisoning of Canada geese. Journal of Wildlife Management, 30(1): 1-8.

From author s abstract: "Canada geese (Branta canadensis) were experimentally exposed to known amounts of lead. The course of the lead and of the disease was followed, utilizing established laboratory procedures. Gross signs

of lead poisoning first appeared 5-7 days following ingestion...Normal lead levels of blood for Canada geese were found to be 0.018-0.037 mg/100g blood. The lead levels of blood of lead-poisoned geese reached a peak between the third and tenth day, and ranged from 0.320-1.680 mg/100g..."

Daines, R. H., H. Motto, and D. M. Chilko (172)

1970. Atmospheric lead: its relationship to traffic volume and proximity to highways. Environmental Science and Technology 4(4): 318-323.

"These studies show that a relationship exists between traffic volume, proximity to the highway, engine acceleration vs. constant speed, wind direction, and the amount of lead in the air. At locations near the highway, the effect of traffic density on the lead content of the air is at a maximum, but, at distances greater than 250 feet, the effect of the traffic density is largely lost. More than 65% of the lead in the air from 30-1750 feet from a well traveled highway (48,000 cars daily) consists of particles under 2 micron in diameter, and more than 85% consists of particles under 4 micron in diameter." HRIS No. 239962.

Davidson, C. I., J. J. Huntzicker, and S. K. Friedlander (173)

1974. The flow of trace elements through the Los Angeles area: effect on non-urban areas.

<u>In</u>: Preprints of papers presented at the 167th National Meeting of the American Chemical Society, April 1-5, 1974, Los Angeles, Calif: American Chemical Society, Division of Environmental Chemistry, 14(1):251-255, 1 figure, 1 table, 9 references.

Abstract: "The effects of Los Angeles as a pollutant source on the surrounding non-urban areas are described. Of particular interest are the coastal waters, which are of economic, recreational and aesthetic importance to the

area as a whole. The mass flows of Pb, Zn, Cd and Ni to these waters and also to the mountains and deserts surrounding the Los Angeles basin were studied. At least 3 of the 5.8 tons of Pb which are blown out of the urban basin each day are transported large distances from Los Angeles before being removed from the atmosphere. The effect of the urban basin as a pollutant source extends well beyond the geopolitical boundaries and what is an output for one geographical region is an input for the neighboring region. (see also W74-10947) (KNAPP-USGS)" WRSIC No. W74-10988.

Deubert, Karl H. (174)

1974. Impact of human activities on the quality of groundwater and surface water in the Cape Cod area. Water Resources Research Center, University of Massachusetts at Amherst. Publication No. 42 (Completion report for Project A-043-Mass), 30 pages + 28 pages of tables.

This study focused on the impact of cranberry production and of traffic volume on the quality of groundwater and surface water and on the relation of population density to groundwater quality. Although neither automobile traffic nor cranberry production appeared to have a measurable impact on water quality, the study confirmed results of other studies in that concentration of lead, nickel, cadmium, and zinc in surface soil decreased rapidly with increased distance from roads and highways. Vertical movement of lead in the top 1 to 4 inches of soil appeared to be slower than the movement of zinc.

Eisler, Ronald (National Marine Water Quality Labs., U.S. EPA, West Kingston, Rhode Island 02892). (175)

1973. Annotated bibliography on biological effects of metals in aquatic environments. National Environmental Research Center, E.P.A.-R3-73-007, Ecological Research Series, 287 pages. U.S. Government Printing Office, $3.20.

Author's abstract: "A total of 567 references on biological effects of metals to aquatic organisms were annotated and subsequently indexed by metal and by taxa. Preference was given to articles on toxicity of heavy metals to marine, estuarine, and anadromous species." Sport Fishery Abstracts No. 18796.

Fimreite, Norvald (H. G. Acres Limited, Niagara Falls, Ontario) (176)

1974. Mercury contamination of aquatic birds in northwestern Ontario. Journal of Wildlife Management 38(1): 120-131.

Author's abstract: "A total of 184 specimens of fish-eating and aquatic birds were collected on or near five different lakes of the Wabigoon and English River systems in northwestern Ontario and analyzed for total mercury in liver. Mercury concentrations were highest in specimens collected on Clay and Ball lakes, about 50 and 80 miles downstream from Dryden where a chlorine plant is believed to be the source of contamination. The concentrations reached or approached 100 ppm in some scavengers and fisheaters like turkey vulture (Cathartes aura), common merganser (Mergus merganser), raven (Corvus corax), and common loon (Gavia immer), while concentrations in typical surface feeding ducks, mallards (Anas platyrhyncos) and pintails (A. acuta), were generally below 10 ppm." Mercury pollution was suspected in resulting in the lack of young loons on Clay and Ball lakes, although 21 adult loons were observed in the contaminated area. The "safe" limit of 0.5 ppm mercury in food stuffs was exceeded by all but one of the mallards and pintails collected from these lakes. The methyl form of mercury in relation to total mercury was found to vary considerably and inasmuch as the methyl mercury is recognized as the most dangerous form, the author suggested that wildlife monitoring for mercury be focused on this form rather than the total content.

Fimreite, Norvald, and Lincoln M. Reynolds (177)

1973. Mercury contamination of fish in northwestern Ontario. Journal of Wildlife Management, 37(1): 62-68.

Author's abstract: "Mercury levels were determined in lateral musculature of fish from northwestern Ontario in specimens taken upstream and downstreat from a chlorine plant, and a number of lakes not contaminated from any known source. The maximum mercury levels in Northern pike (Esox lucius), burbot (Lota lota) and walleye (Stizostedion vitreum) were 27.8 24.8 and 19.6 ppm respectively, measured in specimens taken 50-60 miles downstream from the plant. They decreased proportionally to the distance from the plant but were clearly elevated even 200 miles downstream. The levels in specimens from suspected uncontaminated lakes were generally well below 1 ppm but frequently above the 0.2 ppm often considered as the maximum background concentrations. The latter finding may possibly be explained on the basis of the oligotrophic conditions characteristic of these lakes."

The authors suspect, on the basis of information obtained from an Indian trapper who reported that mink (Mustela vison) and otter (Lutra canadensis) had disappeared from the Clay Lake area and on reports from Sweden concerning impairment of reproduction in mink consuming fish with lower mercury levels than reported here, that these fish-eating mammals have been adversely affected in the area.

Freestone, F. J. - Edison Water Quality Research Lab. (178)

1972. Runoff of oils from rural roads treated to suppress dust.
Environmental Protection Agency National Environmental Research Center Report EPA-R2-72-054, 29 pages, 6 figures, 7 tables, 3 references.

Abstract: "Oil runoff from two rural roads in Readington Township, Hunterdon County, New Jersey, which are treated with waste crankcase oils, was studied to determine whether or not the oil leaves the road. Roughly 1% of the total oil estimated to have been applied remains in the top inch of road surface material, oil penetration below the top inch of road was minimal, and lead was concentrated in the top inch of road material. Laboratory weathering experiments indicate that estimated maximum weathering loss of oil from a road would be approximately 18%. Runoff studies on simulated rural road surfaces indicated two mechanisms by which oil is transported from the road: Leaching of the oil by flotation, and flotation of oil-wet soil particles. The greatest oil transport is during the first few rains after oil application with continuous, low-level leaching during each subsequent rain. Analysis of soil samples taken from a field subjected to runoff from an oiled road showed significantly higher lead content than soil taken from a field 150 feet from the road. (KNAPP-USGS)" WRSIC No. W74-08236.

Frybourg, M. (179)

1972. Inquiry into the impact of the motor vehicle on the environment. OECD, Paris, France. TPP figs; tabs:35 ref.

From summary:
"This inquiry into the public policy implications of the impact of the motor vehicle takes into consideration a wide range of economic, social and environmental concerns. A study of the problem of automotive air pollution and noise involved an estimation of the trends in growth of motor vehicle emissions in urban areas; an identification and evaluation of alternative approaches to reducing the levels of automotive air pollution and noise; an examination of the technology and costs of emission control; and an assessment of the impact of present and contemplated automotive emission control requirements on government, the economy, the users and international trade...Details are given of the costs and effectiveness of vehicle emission and land use control strategies, and the use of lead in motor fuel. Information on the health effects of airborne lead and other environmental problems is provided in appendices."
HRIS No. 224467.

Gamble, Hays, B., C, John Langley, Jr., (180)
Robert D. Pashek, Owen H. Sauerlender,
Richard D. Twark, and Roger H, Downing

1974. The influence of highway environmental effects on residential property values. Research Publication No. 78, Institute for Research on Land and Water Resources, The Pennsylvania State University, (University Park). Pages xii + 9 Chapters of 11; 25;11; 28; 70; 33; 50; 30; and 26 pages, respectively, plus a 7-page bibliography and 5 appendices (supported by Federal Highway Administration).

Author's abstract: "Four residential communities bisected by interstate highways were examined to determine the effects of regional accessibility and highway generated disturbances on property values. Disturbances measured within each community included noise, carbon monoxide, oxides of nitrogen, hydrocarbons, and particulates. Data on traffic mix, volume and speed were obtained simultaneously. Residents were interviewed to determine their perceptions of highway disturbance and other pertinent information. Data were gathered on all valid property sales from 1969-1971.

"NPL contour lines and CO isopleths were plotted for each community. Residents objected to noise more than any other highway originating disturbance. The NPL regression coefficient was significant in explaining variation in property values in all communities, and showed an average loss of $2,050 per highway and property.

"The relationship of NPL, distance from highway, and property value loss was determined. There was a high degree of correlation between measured noise (NPL) and perceived noise. Property value increases due to regional accessibility amounted to $5 million in one community, while highway induced property value losses were $300,000. Total losses for all properties in all communities amounted to $2.3 million, or an average of $1,120 per property."

Methods of sampling and of collecting data -- and data collected on study areas -- on highway traffic effects on air quality and on noise pollution might be helpful to wildlife biologists and ecologists in assessing effects on wildlife. Methods of determining the mix and volume of traffic might be useful, also.

Giles, F. E., S. G. Middleton, and J. G. Grau (181)

1973. Evidence for the accumulation of atmospheric lead by insects in areas of high traffic density. Environmental Entomology 2(2): 299-300, 1 table, references.

The authors state that plants and insects were collected in close proximity to Baltimore city's major north-south freeway (I-83) and compared to collections from a control area 480 meters from the freeway. Both collection areas are in a zoned residential-farming district free of industrial pollution. Plants were cut with a stainless steel knife and sealed in plastic bags. Insects, which were collected by sweeping, were placed in plastic bottles containing 95% ethanol. A lead assay was performed using a Beckman[R] Atomic Absorption Spectrophotometer (Model 444) and Concentration Converter.

The authors found significantly higher concentrations of lead in wild carrot (*Daucus carota* L.); and evening primrose (*Oenothera biennis* L.), growing near the freeway. Japanese beetles (*Popilla japonica* Newman) feeding on plants near the highway did not differ significantly from those collected from the control area.

The damselfly (*Agrion maculatum* Beauvois) collected near the highway showed significantly higher lead concentrations in July, but showed no difference from the control in August.

The authors suggest that perhaps various aspects of the life cycles of these insects affect lead concentration.

The most striking differences in lead concentration were exhibited by the European mantid (*Mantis religiosa* L.). All freeway samples of this species showed significantly higher concentrations of lead than control samples, but nymphs collected 13 August had higher lead concentrations than did samples of teneral imagos taken 31 August. Since many of these tenerals were collected within sight of the soft exuviae, there exists the possibility that lead pollutants are stored in the ecoskeleton, which upon being shed, would cause a lower lead reading. From the data obtained from samples of this species, it is presumed that measurable amounts of atmospheric lead are being concentrated by insect predators, at least during the later part of the season.

Gish, Charles D., and Robert E. Christensen (182)

1973. Cadmium, nickel, lead, and zinc in earthworms from roadside soil. Environmental Science and Technology 7: 1060-1062.

Authors' abstract:

"Cl, Ni, Pb, and Zn in soils and earthworms along two Maryland highways decreased with increasing distance (10,20, 40, 80 and 160 ft.) from the roadway. Metals were quantified by atomic absorption spectrophotometry. Metal residues were higher at the location along each highway where traffic volume was greater. Correlations between residues in earthworms and soil decreased with decreasing atomic weights (Pb is greater than Cd which is greater than Zn which is greater than Ni). Metal residues in soils were positively correlated with quantities of soil organic matter. Earthworms accumulated up to 331.4 ppm of Pb and 670.0 of Zn, concentrations which may be lethal to earthworm-eating animals."

The authors point out that earthworms are food items for many birds as well as certain amphibians, reptiles and mammals, and that the toxicity of metal residues in worms to such animals has not been studied. Other studies have indicated that elevated levels of heavy metals along highways may be attributed to operation of motor vehicles - the Pb and Ni to gasoline and the Cd and Zn both to tires and motor oil.

Grad, Frank P., Albert J. Rosenthal, et al. (183)

1974. The automobile and the regulation of its impact on the environment. RANN Report NSF/RA/-74-023. Copyright 1975 by the Trustees of Columbia University in the City of New York. Composed and printed by the University of Oklahoma Press, Norman, Oklahoma. Available from NTIS # PB-237232/4ST.

A study prepared by the Legislative Research Fund of Columbia University. Pages xiv +481.

Part 1, consisting of 9 chapters totaling 423 pages, deals largely with air pollution from automotive sources including noise pollution, water pollution problems related to the automobile, and solid waste problems. For example, as indicated on page 457, crankcase oil presents a problem because its disposal, after use, may damage the environment. It may coat the surface of water thereby preventing oxygen from reaching the water and sunlight from penetrating to the plants below, thus retarding photosynthesis and, hence, decreasing the DO in water. In addition, calcium and several heavy metals are found in most used motor oils. Waste oil sprayed on roads to suppress dust may also, through seepage and runoff, contaminate water and plant life.

The authors stated, page 458, "An estimated 100 million gallons of waste oil are disposed of in this manner annually" - i.e. are sprayed on roads. An unknown amount is dumped into rivers and sewers. They state, page 459, "Oil may pollute waterways and the oceans and its metal additives may harm fish and plant life."

Huntzicker, J. J., C. I. Davidson, and
S. K. Friedlander (184)

1974. The flow of trace elements through the Los Angeles Basin: Zn, Cd, and Ni.

In: Preprints of papers presented at the 167th National Meeting of the American Chemical Society April 1-5, 1974, Los Angeles, Calif: American Chemical Society, Division of Environmental Chemistry, 14(1): 245-250, 3 figures, 1 table, 14 references.

Abstract:

"The two major sources of atmospheric Zn in the Los Angeles area are tire dust and metallurgical emissions. Tire dust contains approximately 1.5 percent by weight Zn. Most of the tire dust is associated with very large particles which settle close to the source. The primary source of airborne Ni is probably the combustion of fuel oil by power plants. The Ni content of fuel oil fly ash from the Pasadena Power Plant is 2 percent. The total emission of Ni is 260 kg/day. Cd is usually present in Zn ores and is emitted to the atmosphere during Zn smelting operations. Cd

fallout rate is about 5 kg/day. (See also W74-10947) (Knapp-USGS)" WRSIC No. W74-10987.

Jacobson, A. R. (185)

1972. Water works digest - insecticide residues. Public Works 103(4): 104-105, 1 ref.

From summary:
"The two important sources of pollution are run-off from agricultural land and discharge of wastes either from industries that manufacture pesticides or from those that make use of them in their process. The main hazards of insecticide residues in water are: large numbers of aquatic invertebrates and fish may be killed, and the residues may be taken up into the tissues of these organisms. It is necessary to examine whether pesticides can be removed by water treatment processes, once water gets contaminated with them. The addition of activated carbon to the treatment system was found to decrease the amounts of insecticides in water, but the amounts of carbon required were large." HRIS No. 218984.

Kugler, B. A., Bolt, Beranek and Newman, Inc., and Galloway, W. J. Beranek and Newman, Inc. (186)

1974. Highway planning and highway noise barriers. Institute of Noise Control Engineering. Pages 479-484, 3 figs., 2 tab., 3 ref.

From summary:
"Traffic noise from highways is a major source of annoyance. Planning of new highways and the upgrading of existing installations must incorporate the parameter of noise in highway design. This paper reflects, in part, the research conducted for the Transportation Research Board under a National Cooperative Highway Research Program Project. Two fundamental aspects of highway noise are discussed: (1) assessment of the relative noise impact on the population exposed to alternate highway locations or designs and (2) control of highway noise through highway design..." Availability: Noise/News, P.O. Box 1758, Poughkeepsie, New York 12601. HRIS No. 084112.

LaBarre, N., J. B. Milue, and B. G. Oliver (187)

1973. Lead contamination of snow. Water Research-The Journal of the International Association of

Water Pollution Research, 7(8): 1215-1218, 1 table, references.

"Snow from disposal sites and along roads contained considerable lead due to the combustion of leaded gasolines by automobiles. In spite of lead concentrations up to 4330 ppm in the sample sediment, the highest concentrations in the filtrates was 0.21 ppm with the average, 0.04 ppm. Thus the dumping of snow away from water-courses instead of directly into them significantly reduces lead contamination of the waters from this source."

Lagerwerff, J. V., and A. W. Specht (188)

1970: Contamination of roadside soil and vegetation with cadmium, nickel, lead, and zinc. Environmental Science and Technology 4(7): 583-586.

"Concentrations of Cd, Ni, Pb, and Zn in roadside soil and grass samples from several locations decrease with distance from traffic. These concentrations also decrease with depth in the soil profile. The contamination has been related to the composition of gasoline, motor oil, and car tires, and to roadside deposition of the residues of these materials...Roadside distribution of Pb is traditionally ascribed to combustion of leaded gasoline by automobiles. In 1964 alone, at least 100,000 tons of Pb, or 10% of the U.S. consumption in that year, were discharged into the nation's atmosphere. The presence of Pb near highways has been related to density of traffic and to distances as far as 250 m from the road...Pb has been detected even at distances of over 100 miles from the nearest metropolitan area. The use of nickled gasoline and atmospheric abrasion of Ni-containing automobile parts, may explain the weak, yet detectable gradient of Ni at sites near dense traffic. The joint presence of Zn and Cd has been established at this laboratory in oils and motor vehicle tires...The Cd content of three lubricating oils was found to range from 0.20 to 0.26 ppm and that of three diesel oils from 0.07 to 0.10 ppm.

The Cd content of four tires of different brands we found to range from 20 to 90 ppm. This may be associated with the use of technical Zn-oxide and Zn-diethyl or dimethyl carbamate in vulcanization...No Cd could be detected ($<$ 0.01 ppm.) either in 12 brands of gasoline or in two samples of rocksalt used to deice road surfaces. The effects of wear of Cd-plated engine or chassis parts and traffic lane paints on roadside distribution of Cd have been discounted." Bibliography of 37 titles.

Lazrus, Allan L., Elizabeth Lorange, and James P. Lodge, Jr. (189)

1970. Lead and other metal ions in United States precipitation. Environmental Science and Technology 4 (1): 55-58.

"Atmospheric precipitation samples collected by a nationwide network of 32 stations throughout the United States were analyzed for lead, zinc, copper, iron, manganese, and nickel for atomic absorption. Values for each station averaged over approximately six months during 1966 and 1967 indicate human activity as the primary source of these materials in atmospheric precipitation. The concentration of lead in precipitation was found to be correlated with the amount of gasoline consumed in the area in which the sample was collected. The overall mean concentrations of the metals in precipitation are compared with analogous values in surface water supplies. The concentration of only lead is significantly high with respect to the allowable concentration in drinking water. However, the evidence indicates that lead forms insoluble materials in surface waters and is removable by sedimentation or by filtration." Bibliograpy of 14 titles.

Mason, J.W., A. M. Anderson, A. J. Englande, P. M. Smith, and A. Abdelghani (190)

1974. A study of the distribution and toxicity of MSMA applied to roadside rights-of-way. (Final Report). Departments of Civil Engineering and Environmental Health Sciences, Tulane University, 145 pages, 6 tables, 16 figures, 5 appendices.

MSMA (monosodium methanearsonate) as a grass control herbicide along Louisiana highway rights-of-way is used because of its economic advantage in the control of Johnson grass and other undesirable grasses. Concern, however, exists over the build up of residues in soil and connecting waterways. The purpose of this study was (1) to determine residue build up in soils and adjacent water bodies, (2) to determine the toxicity of MSMA applied to

Johnson grass. Results of the study indicated that more efficient and safer use of MSMA along highway rights-of-way can be affected by: (1) application should be completed by mid-morning since afternoon showers and evening dew reduce MSMA absorption and effectiveness. Application immediately after rainfall is less effective than the same application under dry conditions. (2) Exposure to cattle can be minimized if open range roads are not sprayed. (3) Care should be taken to minimize application of the herbicide to aquatic bodies which support fish populations. Arsenic residues reaching water bodies through runoff can be reduced by efforts to reduce transport of sediment.

Maurer, R. (191)

1974. The beetle and spider fauna of meadows affected by traffic pollution. Oecologia (Berlin) 14: 327-351, written in German, 6 tables, 4 figures, referencec.

"The comparative effects of heavy versus light motor traffic on the composition of two fauna, beetles and spiders, were investigated. All meadows chosen for the study were morphologically and topographically similar. Three of the meadows were adjacent to a very busy road and two to a little-used road. The fauna were examined at the edge and in the interior of each meadow and the meadows on the busy road were then compared with those on the other road.

The numbers of species and of individual specimens of Carabidae were significantly lower (Wilcoxon test $<$ 0.05) at the edges of the meadows on the busy road than at the edges of those on the little-used road. While the Staphylinini as a group showed no reduction in the number of species or individual specimens observed there was a reduction in the number of species of the Araneae group (Wilcoxon test $>$ 0.05)." (Author's abstract)

Memphis State University (192)

1971. Effects of noise on wildlife and other animals. NTID300.5 for the U.S. Environmental Protection Agency, Office of Noise Abatement and Control, U.S. Government Printing Office, 74 pages.

This report represents a literature search on the effects of noise on wildlife and other animals.

It became apparent to the authors that there is a serious lack of information concerning effects of noise on wildlife. Because of the high likelihood that noise effects on domestic or laboratory animals can provide clues regarding possible effects on wild animals, a summary of the literature concerned with the effects of noise on non-wild animals is included. The literature search here is concentrated on the period from 1950 to present, but earlier pertinent studies were reviewed. Only clearly relevant and readily obtainable reports from foreign literature are included.

Mierau, Gary W., and Blaise E. Favara (193)

1975. Lead poisoning in roadside populations of deer mice. Environmental Pollution. (Printed in Great Britain.) 8:55-64, 1 table, 2 figures, refs.

"Deer mice living adjacent to a major Colorado highway (19,800 vehicles/day flow rate) were examined to determine if current levels of lead pollution from automobile exhaust presented a hazard to this species. The level of environmental lead contamination, as measured by lead concentration in surface soil and vegetation was significantly greater 15 m from the highway than in a control site 800 m distant. Bones of roadside mice contained approximately ten times as much lead as did those from the control site. Significant differences were also found between the roadside and control populations in regard to lead accumulation in kidney, liver and brain. Lead poisoning, however, could not be demonstrated in roadside mice. The exposure level required to produce recognizable lead poisoning in captive deer mice was approximately five times greater than that encountered by the wild roadside population." (Authors' abstract)

Motto, Harry L., et al (194)

1970. Lead in soil and plants: its relationship to traffic volume and proximity to highways. Environmental Science and Technology. 4(3):231-237.

"Soils and plants sampled along heavily traveled highways (12,800-54, 700 vehicles per 24 hours) show that lead contents tend to increase with traffic volume and decrease with distance from the highway. Much of the lead was present as a removable surface contamination on the plants. The major effect of traffic was limited to the surface soil and to a narrow zone within 100 feet of the highway. Plants grown in the field contained the most lead in the aerial portion and those grown inthe greenhouse had the most lead in the roots. These studies indicate plants may obtain lead through both leaves and roots with little translocation within the plant. The fruiting and flowering parts of plants contained the smallest amounts of lead and showed little effect of changes in amounts of lead supplied...Similar relationships of lead in air, plants, and soils with traffic volume and distance from highways indicate a common source of lead, the gasoline consumed by motor vehicles." Bibliography of 19 titles.

National Academy of Sciences/National Adademy of Engineering, Environmental Studies Board, Committee on Water Quality Criteria, Geral A. Rohlich, Chairman. (195)

1973. Water quality criteria, 1972. A report of the Committee on Water Quality Criteria at the request of, and funded by, the Environmental Protection Agency, Ecological Research Series EPA-R3-73, xix +594 pages.

This comprehensive document includes reports by separate panels on: Recreation and Esthetics, Public Water Supplies, Freshwater Aquatic Life and Wildlife, Marine Aquatic Life and Wildlife, Agricultural Uses of Water, and Industrial Water Supplies, plus a Preface, a General Introduction, three Appendices, a Glossary, a table on Conversion Factors, Biographical Notes on the members of the Committee on Water Quality Criteria and the respective Panels, an Author Index, and a Subject Index.

As in most of the literature reviewed on this project, the subject index contains no entries under the headings of roads, highways, roadsides, rights-of-way, automobiles, vehicles, or traffic that would focus the reader's attention to water pollution problems stemming from highway construction or maintenance and vehicular traffic. However, used with other references describing pollution effects of road construction, road maintenance, and use by automobile vehicles, the document -- particularly in the sections dealing with recreation and aesthetics, pages 6-47; freshwater aquatic life and wildlife, pages 106-213; marine aquatic life and wildlife, pages 214-297; and the respective appendices for these sections -- summarize much of the information known on the levels of pollutants hazardous to aquatic organisms and the levels or concentrations of water pollutants under which these organisms are subject to minimal risk of deleterious effects. Included is information on heavy metals and other toxic materials known to accumulate on, and be transported from highways in runoff to receiving waters. The literature cited in the various sections of the document enables the reader to dig deeper for more details on items of particular interest, but the numerous tables in the report provide considerable detailed information on relevant research done to date.

National Research Council, Canada, (Associate Committee on Scientific Criteria for Environmental Quality, N.R.C. Canada.) (196)

1973. Lead in the Canadian environment. Publication No. BY 73-7-(ES) of the Environmental Secretariat NRCC, 116 pages, available from: Publications, NRCC/CNRC, Ottawa, Canada klAOR6, price $2.00.

This monograph contains chapters entitled:

1. Historical and background information on lead.
2. The release of lead into the Canadian environment.
3. Current lead levels in the Canadian environment.
4. Lead in vegetation.
5. Toxicity of lead to aquatic life.
6. Lead in wildlife.
7. Lead in domestic and laboratory animals.
8. Man's lead intake from all sources.
9. Lead in man.

Newton, C. D., W. W. Shepard, and M. S. Coleman (197)

1974. Street runoff as a source of lead pollution. Journal Water Pollution Control Federation, 46(5): 999-1000, 4 references.

Abstract:
"In 1972, a surface water survey conducted by the Oklahoma State Department of Health indicated excessive amounts of lead in the upper portions of the Deep Ford Branch of the North Canadian River in Oklahoma County. No point source could be located for this contamination until a recent report (1973) showed that lead from automobile emissions accumulates

on the surface of streets during dry periods and is washed into surface waters during storm run-off. Automobile emissions deposit large amounts of lead close to the source primarily on or near the roadbed. Samples of snow, ice, and water were taken from several sites along heavily traveled highways and analyzed for lead content by use of an atomic absorption spectrophotometer. Average concentration of lead in samples from road bed edges was 5.5 mg/liter (range 3.6-8.5 mg liter). Concentrations of lead decreased in samples as distance from the roadbed increased. The lowest concentration was found in the middle of an open field surrounded on three sides by heavily traveled roads. The lead level was 0.09 mg liter. (Shaffer-Firl)" WRSIC No. W75-01770

Olson, Kenneth W., and Rodney K. Skogerboe (198)

1975. Identification of soil lead compounds from automotive sources. Environmental Science and Technology 9(3): 227-230.

"Lead exhausted from automobiles occurs primarily in particulate form." Reports agree that "lead bromochloride (PbBrCl) and ammonium chloride complexes thereof comprise the major portion of the particulate lead componds in fresh auto exhaust... Several reports have indicated that there has been significant contamination of soil by lead originating from vehicular traffic...The primary lead compounds in eight different lead-contaminated soil samples have been identified through the use of the combined separation and diffraction procedures. Lead sulfate has been determined to be the principal constituent in the soils examined." Therefore the deposition of lead by fresh auto exhaust (PbBrCl) cannot account for all the lead sulfate ($PbSO_4$) present in soils. "Indirect conversions occurring during the atmospheric transport and atmospheric exposure periods or conversions occurring in the soil, groundwater system must be considered as important additional routes...Certainly the identification of lead sulfate as a primary soil form must be considered in formulating experiments dealing with lead mobility in soils, uptake of lead by plants, effects of lead on soil microbes, and related questions." Bibliography of 20 titles.

Page, A. L., T. J. Ganje, and M. S. Joshi (199)

1971. Lead quantities in plants, soil, and air near some major highways in Southern California. Hilgardia, A Journal of Agricultural Science published by the California agricultural experiment station, Vol. 41, No. 1, July, 1971. 31 pages, 31 tables, figures.

"The lead contents of 27 varieties of consumer crops and plants sampled at various distances from some major highways in southern California and in local markets were carefully determined. Amounts in and on crops grown close to these highways were shown to be influenced by (a) distance from the highway, (b) extent of plant surface exposed, (c) external plant characteristics, (d) duration of plant exposure, (e) motor vehicle traffic density, and (f) direction of prevailing winds. In soils and suspended air particulates, concentrations of lead were influenced by distance from highway and direction of prevailing winds. All results demonstrated that lead accumulations in and on plants next to these highways in southern California were caused principally by aerial deposition and not by, at least to any great extent, absorption by the plant from lead-contaminated soil." (Authors; Abstract)

Parkinson, G.S. (200)

1972. Some facts about lead in petrol. Clearway (United Kindsom) 14 (72):55-57.

Summary:
"The British standard method of classifying petrol quality uses a parameter called research octane number. By adding small amounts of lead in soluble form to petrol the octane number can be increased. Subsequently, exhaust products containing very small quantities of lead compounds are discharged into the atmosphere and in turn are deposited on soil and water. This article briefly describes investigation carried out to see whether there was any hazard from the amount of lead released into the atmosphere, particularly from car exhausts. It is considered that the present levels of lead emission do not offer a danger to health but that it is desirable they be reduced, and methods of achieving such a reduction is discussed." Transport and Road Research Lab (UK) HRIS No. 224626.

Peyton, T. O., and A. W. McIntosh (201)

1973. Distribution of heavy metals in a borrow pit.

In Proceedings of the First Annual NSF Trace Contaminants Conference August 8-10, 1973, Oak Ridge, Tenn., Publ. by U.S. Atomic Energy Commission, Office of Information Services, Technical Information Center, Oak Ridge, Tenn., March, 1974, pages 589-598, 3 figures, 3 tables, 3 references.

Abstract:
"Two systems, one of them a borrow pit and the other a small pond, lying along the Indiana Toll Road were chosen for the study of input and distribution of cadmium, lead, and zinc, in aquatic systems. The borrow pit, located in Gary, Indiana, is exposed to automotive and industrial aerial deposition, while the pond, situated near Michigan City, Indiana, receives mainly automotive inputs. Initial samples from the 0-10 cm layer of sediment indicated elevated metal levels, with maximum values of 3.3 ppm cadmium, 998 ppm zinc, and 493 ppm lead in the Gary pit and 1.40 ppm cadmium, 251 ppm zinc, and 126 ppm lead in Michigan City Pond (dry weight basis). Initial correlation coefficients between % prganic matter and heavy metal concentrations in the Gary pit sediment were high. Cadmium: lead: zinc ratios in pit sediment, while similar to ratios in emissions from a nearby metal refining industry, also reflected a lead input from automotive sources. (see also W75-05277) (Jernigan-Vanderbilt)" WRSIC No. W75-05292.

Poche, David and Barbara E. Hensley (202)

1975. An ecological assessment of a bridge demolition. Virginia Highway and Transportation Research Council (A cooperative organization sponsored jointly by the Virginia Department of Highways and Transportation and the University of Virginia), Charlottesville, Virginia, 9 pages, mimeo.

"Bridge demolition has long been known to mobilize large amounts of stream sediment in the immediate area of the structure. An ecological assessment in terms of stream macroinvertelrate samples and suspended solids measurementswas made shortly before, shortly after and eight months after a demolition of a bridge deck. No environmental damage was indicated by the study even though suspended solid levels exceeded 200 parts per million shortly after demolition. The U.S. Environmental Protection Agency's proposed limits for suspended solids appear to be too low for short-term stream disturbing events." Populations of Diptera, Trichoptera, Coleoptera, and others were found in stream surveys. Many of these organisms are indicative of excellent water quality as well as being excellent food sources for fish. Recommendations for the use of rock berms in bridge demolition and for methodology to be used for monitoring future bridge demolitions are given. Bibliography of 3 titles.

Pravoshinskiy, N. A. (203)

1968. Description of the drainage of street flushing waters. Soviet Hydrology: Selected Papers, Issue No. 2, pages 168-170, 2 tables, 9 references. Ministry of Melioration and Water Resources Management (USSR).

Abstract:
"The quality and quantity of runoff from street washing operations in Minsk were measured to study the contribution of street washing to water pollution. Data from earlier studies in Moscow and Leningrad are included for compariosn. The BOD of street cleaning runoff is 6-223 mg liter, petroleum products are up to 110 mg liter, and coliforms are nearly as abundant as in wastewater. These waters, unless they are treated, can be a major source of pollution. (KNALL-USGS)." WRSIC No. W69-08732.

Price, Peter W., Beverly J. Rathcke and David Gentry (204)

1974. Lead in terrestrial arthropods: evidence of biological concentration. Environmental Entomology 3(3): 370-372, 1 table, 1 figure.

"In areas with high lead emission from the exhaust of vehicles, insects contained averages of 10.3, 15.5, and 25.0 ppm lead (oven dry weight) for species that suck plant juices, chew plant parts, and prey on other insects respectively, indicating a biological concentration of lead from herbivore to carnivore trophic levels. In low lead emission areas insects in the same feeding categories had average lead contents of 4.7, 3.4, and 3.3 ppm respectively and showed no significant differences." (Authors' abstract)

Rameau, J. (205)

1973. Lead as an environmental pollutant. Pages 189-197 in Proc. Int. Symp. Environ. Health Aspects of Lead 1972 (Pub. 1973), held in Amsterdam (Nederland), Ocotober 2-6, 1972. Published by the Commission of the European Communities, Washington, D.C. Organized jointly by the Commission of the European Communities and the U.S. Environmental Protection Agency. 1168 pages, price $30.00.

"The report starts with a survey of how plants and soil become contaminated with lead when petrol containing tetra-alkyl lead is used.

"It is advisable not go grow leafy vegetables in direct vicinity of motorroads.

"The lead content of roadside grass in the Netherlands is not yet as high as to cause lead intoxication in cattle.

"Nevertheless it is recommendable not to feed this grass or hay as only roughage.

"Great attention has to be paid to sampling and analytic methods for lead.

"The wide discrepancies of results between different laboratories point out the further need for interlaboratory comparability studies at an international level."

Rolfe, Gary L., John Melvin Chaker, and Ben B. Ewing (206)

1972. Modeling lead pollution in a watershed-ecosystem. Journal of Environmental Systems, 2(4): 339-349.

Objectives of the study include understanding and modeling the movements and effects of heavy metals (initially lead) in the environment.

A model has been constructed which simulates the movements and predicts the accumulation points of lead in a 76-square mile watershed-ecosystem. The model contains components of both aquatic and terrestrial ecosystems and represents the ecosystem by a network of nodes and branches where the nodes represent the components of the ecosystem in a general sense and the branches indicate possible transport mechanisms between nodes.

The model provides a method for the study of pollutant transport and accumulation in ecosystems.

Rich, Saul. Connecticut Agricultural Exp. Sta. (207)

1971. Effects of trees and forests in reducing air pollution. Pages 29-33 in Proceedings of A Symposium on Trees and Forests in an Urbanizing Environment, August 18-21, 1970, University of Massachusetts. A monograph published by the Cooperative Extension Service, U.S. Department of Agriculture and County Extension Services, University of Massachusetts, 168 pages.

The authro points out that air pollutants do injure plants, the phytotoxic air pollutants of major importance being sulfur dioxide, hydrogen fluoride, and the phytochemical oxidants: ozone and peroxyacetyl nitrate. Phytotoxic pollutants enter the leaves through the stomata in order to cause injury: however, the author asks whether it might be possible that some plants have materials on their exterior that would react with and either fix or destroy the air pollutant and cited research that had been done indicating that radio-tagged SO_2 although sorbed by *Betula verrucosa*, *Fagus silvatica* and *Carpinus betula*, with somewhat less SO_2 sorbed by *Ulmus effusa*, *Salix caprea*, and *Robinia pseudoacacia*, the radioactive sulfur penetrated into the leaf tissue of only two of these species -- *Ulmus effusa* and *Fagus silvatica*. We are reminded also that not all air pollutants -- CO_2, for example, injure trees; this one, in fact, being used by trees in photosynthesis.

Sanderson, Glen C. and Richard M. Thomas (208)

1961. Incidence of lead in livers of Illinois raccoons. Journal of Wildlife Management, 25(2): 160-168.

The authors found concentrations of lead ranging from 1 to 32 micrograms per gram in livers of 100 raccoons killed in Illinois by hunters and trappers during November and December 1958, and January 1959. Only one liver was negative. Although sources of the lead were not investigated, finely divided lead from the exhaust of automobiles was suggested as one of several possible sources. No significant differences in condition factors of raccoons as related to concentration of lead in their livers was noted but adrenal weights of animals with lower levels of lead were significantly heavier than those from raccoons with higher levels of lead. "...In the absence of other obvious stresses such as injury and disease, levels of lead up to 32 mg per gram of liver caused no obvious symptoms of lead intoxication in the raccoon. Raccoons appear to be resistant to high levels of lead, but in spite of widely varying responses, lead intoxication, along with other factors, may be cause of mortality in wild raccoons."

Sartor, James D. and Gail B. Boyd (209)

1972. Water pollution aspects of street surface contaminant. A project (11034-FVJ) report prepared by the URS Research Company, under Contract No. 14-12-921 for the Office of Research and Monitoring, U.S. Environmental Protection Agency, Washington, D.C. 20460. EPA-R2-72-081, Pages xii +236. (Available, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $3.00).

Authors' abstract:

"Materials which commonly reside on street surfaces have been found to contribute substantially to urban pollution when washed into receiving waters by storm runoff. In fact, runoff from street surfaces is similar in many respects to sanitary sewage. Calculations based on a hypothetical but typical U.S. city indicated that the runoff from the first hour of a moderate-to-heavy storm would contribute considerably more pollutional load than would the same city's sanitary sewage during the same period of time.

"This study provides a basis for evaluating the significance of this source of water pollution relative to other pollution sources and provides information for communities having a broad range of sizes, geographical locales, and public works practices. Information was developed for major land-use areas within the cities (such as residential, commercial and industrial). Runoff was analyzed for the following pollutants: BOD, COD, total and volatile solids, Kjeldahl Nitrogen, Nitrates, Phosphates, and a range of pesticides and heavy metals."

This report pointed out that the major constituent of street surface contaminant material averaged on the order of 1400 lb/curb mile of street for the cities tested. It indicated that a great portion of the overall pollutional potential is associated with the fine solids fraction of the street surface contaminants and that catch basins, as they are normally used, are reasonably effective in removing coarse inorganic solids from storm runoff, such as sand and gravel, but are ineffective in removing fine solids and most organic matter. Parked and abandoned vehicles were found to be one of the serious problems in street cleaning. The authors state, page 99, "Although many small animals and a few larger ones are killed on streets and highways in the course of a year (thereby creating a concentrated source of pollution) they are generally not dealt with as a part of the street cleaning program. Rather, some organization, either within the city government or under contract to the city, is responsible for removing such bodies and ultimately disposing of them..."

They reported, page 98, the use of sodium-chloride and abrasives in the United States for the winter of 1966-67 to be 6,320,000 tons of sodium chloride, 247,000 tons of calcium chloride and 8,400,000 tons of abrasives.

With respect to heavy metals contained in the street pollutants, the authors indicated they were of special concern because of their high potential toxicity to various biological forms and showed that from the standpoint of concentration alone, zinc and lead had the heaviest loadings, chromium and nickel the lightest. They pointed out, however, page 68, that these metals may not be the worst pollutants, although they might be. Commercial land use was considered to be responsible for the heaviest loadings of zinc, copper, lead and mercury, while most of the nickel stemmed from industry and the greatest amount of chromium was from industrial sources. In consideration of their effects on aquatic organisms, they reported recommended limits for copper for salt water organisms to be 0.05 ppm and for freshwater organisms, 0.02 ppm; for lead only slightly higher than 0.05 ppm, the USPH drinking water standard; indicated that nickel was moderately toxic to aquatic organisms and can be very toxic to plants, depending on the chemical form; that mercury can be expected to be detrimental to aquatic ecosystems at concentrations as low as 0.005 ppm; and that limits of 100 ppm of chromium for fisheries and 5 ppm for irrigation water have been recommended.

They attributed, page 28, to automobiles the following contributions to street surface contaminants but were unable to quantify them: leakage of fuel, lubricants, hydraulic fluids and coolants; fine particles worn off of tires and clutch and brake linings; particulate exhaust emissions; dirt, rust, and decomposing coatings which drop off of fender linings and undercarriages; and vehicle components broken by vibration or impact (glass, plastic, metals, etc.)

Although this study focused on the contaminant materials on urban and suburban streets, the authors indicated these are common elements of freeways in most cities. And, parenthetically, one might add, many of them are common on rural highways as well.

Sehmel, G. A. (210)

1973. Particle resuspension from an asphalt road caused by car and truck traffic. Atmospheric Environment 7(3): 291-309.

"Particle resuspension caused by surface stresses from vehicular traffic on roads can produce a renewed downwind health or environmental hazard. These hazards include those due to the dose-to-man inhalation hazard of radioactive particles as well as airborn salt and lead damage on trees and vegetation near roads. Particle resuspension caused by moving-vehicular-generated surface stresses was determined by using solid ZNS tracer particles placed on a road. The fraction resuspension per vehicle pass was from 0.001 to 1 percent with the greater resuspension corresponding to increased vehicle speeds and driving directly through the deposited tracer. For constant vehicular conditions and no intervening traffic, the fraction of particles initially present which were resuspended decreased markedly with an increase in days after the tracer was placed on the road." HRIS

Shaheen, Donald G. (211)

1975. Contributions of urban roadway usage to water pollution. Office of Research and Development, U.S. Environmental Protection Agency, Environmental Protection Technology Series, EPA-600/2-75-004, pages ix-118 and 10 appendices comprising 228 pages,

From author's abstract:

"...Motor vehicular traffic is directly or indirectly responsible for deposition of substantial quantities of materials on roadways in urban areas. Significant levels of toxic heavy metals and asbestos and slowly biodegradable petroleum products and rubber are deposited directly from motor vehicles along with large quantities of particulate materials contributed indirectly by traffic. The particulates contributed indirectly by traffic are largely inorganic, but have associated with them solids and nutrients which represent a serious source of water pollutants in all metropolitan areas."

The author states that less than 5% by weight of the traffic-related deposits originate directly from motor vehicles; however, these pollutants are among the most important by virtue of their potential toxicity. He points out that much of the grease and all of the petroleum and n-paraffins result from spills or leaks of motor vehicle lubricants, antifreeze and hydraulic fluids; traffic-related lead is deposited principally through the use of leaded fuels but that some results from the wear of tires in which lead oxide is used as filler material; zinc is also used as filler in tires and at high concentrations in motor oil as a stabilizing additive; copper, nickel and chromium are wear materials from metal plating, bearings, bushings, and other moving parts within the engine, and considerable copper is deposited as a result of wear of brake linings which have copper added to increase mechanical strength and promote more rapid dissipation of heat; and that asbestos found along roads arises from wear of clutch and brake linings and traffic-related rubber from tire wear.

Considerable quantities of dust and dirt, i.e. particles smaller than 3.35 mm. were found to become airborne and settle on areas adjacent to the roadways while litter (particles larger than 3.35 mm.) was found to be more concentrated and less affected by curbs or road barriers which at a height of 15 to 20 inches tended to increase dirt and dust loadings on the roads.

The author states, pages 9 and 10, "Runoff from urban roadways induces shock effect upon receiving waters as the accumulated nutrients, toxic and oxygen demanding substances are abruptly introduced during storm events. Such events will occur several times over the course of a year and permanent changes in the downstream biota may result even though the chemical composition of the receiving water reverts to normal shortly after cessation of runoff. Chemical examinations of stream bottom samples taken from upstream and downstream of roadway runoff outfalls demonstrated that a permanent, dry weather sphere of influence exists near the roadway/receiving water interface...Zinc compounds deposited on roadways were found to be more soluble than those of lead as evidenced by the higher dissolved zinc concentrations found in the runoff samples. It is believed that this higher solubility causes zinc to be removed from roadways by stormwater runoff at a faster rate than lead compounds."

The author points out that just as roadways are efficient collectors of particulate materials, whether resulting from motor vehicles, intentional or accidental littering, various land use activities or materials representative of the local geology, they are also extremely effective in transporting them by virtue of their high runoff coefficients. He indicates that even without reduction of the amounts of materials deposited on urban roadways, it is possible to effect considerable improvements in the water quality situation by altering the kinetics of transport so that peak runoff rates are delayed or flattened out over a longer period of time in order to reduce shock loads on the receiving waters. To this end several recommendations are given including selection of roadway sites in such a manner as to minimize the roadway areas drained directly into the receiving body of water; utilization of low curbs where the road is adjacent to unpaved areas which are flat or sloping away from the street surface to facilitate deposition of the dust and dirt into grass and gravel areas and reduce the rate of deposition in receiving water; continue research on use of porous pavement to determine its applicability in areas having clay or other impervious types of soils and in colder climates; intensify and improve street cleaning operations to reduce urban roadway runoff effects; design curbs and gutters to facilitate concentration of particulate material and collection of same and investigate various approaches to detention and storage of storm runoff and separation of solids from stormwater. Comments are made, also, on elimination of specific toxic materials, vehicle design changes for containment of nonexhaust vehicular emissions, litter collection and disposal, and anti-litter campaigns. Additional studies are suggested on impacts of roadway runoff on receiving waters, on sampling procedures, contributions of urban roadway usage to asbestos exposures, and on development and standardization of analytical methodology for roadway deposits and runoff.

Shukla, S. S., and H. V. Leland - Illinois University, Urbana. (212)

1973. Heavy metals: a review of lead. Journal Water Pollution Control Federation, 45(6): 1319-1331, 118 references.

Abstract:
"This literature review on lead covers toxicity

and sources of lead pollution along with the concentrations associated with each source. (Holoman-Battelle)" WRSIC No. W73-14267

Siccama, Thomas G., and Elliot Foster (213)

1972. Lead in a Connecticut salt marsh. BioScience 22(4): 232-234.

This is a report on a preliminary investigation of the horizontal and vertical distribution of lead in a Connecticut salt marsh which is divided into three regions by a tide dike, railway embankment and wooden traprock ridge and is surrounded on the west and south by suburban housing. The authors found increasing concentrations of lead above the mud layer in the East Haven marsh and believe the major source of the lead is through runoff from the paved highway and street system of the urban complex adjacent to the marsh. The input is mainly through storm drains. Near the outfall of two of these drains, average concentrations of lead in the surface material were 198 and 179 ppm respectively, as compared to an average for the inner marsh of 107 ppm.

They state: "...Preliminary analyses of the first water to run off adjacent highways following the onset of a storm showed concentrations of between 1 and 14 ppm lead. We have made preliminary studies of lead in higher plants and animals of the East Haven marsh, and it does not seem that these organisms are accumulating unusually high concentrations of lead in their tissues, but we have no base line data with which to compare our findings."

Smith, Ralph G., Joanne Szajnar, and Laurence Hecker (214)

1970. Study of lead levels in experimental animals. Environmental Science and Technology. 4(4): 333-338.

"A large number of rodents were maintained in chambers breathing air from an intersection in central Detroit. A comparable group of animals were maintained in identical fashion, but breathed filtered air, and as a consequence were assumed to have inhaled no lead components. Tissues from animals in each of the two groups were analyzed for lead content, and although lead levels tended to be higher in the exposed group, the difference was significant only in the case of bone levels. Both rabbits and guinea pigs displayed significantly increased bone lead levels, and on the basis of the data, it was concluded that the increased levels resulted from the inhalation of approximately 2.5 ug/m^3 for a period of nearly 4 years. Estimates indicated that although the lead intake via ingestion was considerably greater than that by inhalation, the more efficient absorption of the inhaled lead accounted for the reported difference." Bibliography of 10 titles.

Smith, William H. (215)

1971. Lead contamination of roadside white pine. Forest Science 17: 195-198.

"Lead contamination of the growth of the previous year (twig plus needle samples) of eastern white pine was determined at various distances from an E-W section of an Interstate highway with a traffic density of approximately 24,000 vehicles daily. Lead contamination decreased regularly with increasing distance from the highway edge, was consistently higher on trees south of the roadway than on those to the north, and was generally greater on branches sampled from the side of the tree closest to the highway as contrasted with branches analyzed farthest from the road on individual test trees. Samples up to 15 miles distance from the highway often were contaminated with more than 100 ppm lead, much of which was presumably impacted on exterior surfaces."

Smith, William H. (216)

1973. Metal contamination of urban woody plants. Environmental Science and Technology. 7:631, 4 tables, literature cited.

"During the fall, 1970, leaf and twig tissue representing the growth of the previous growing season was collected from six woody plant species throughout the city of New Haven. Sugar maple was also sampled from remote northern New Hampshire and Vermont. These tissues were analyzed for Al, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, Na, Sn, Zn, and V by atomic absorption spectrophotometry. Co and Sn were not detected. V was present in only a few samples from two city species. All other metals were found in all New Haven woody plants and in the sugar maples from remote areas. Cd, Cu, and Mn were present in 'normal' amounts. Al, Cr, and Ni were present in 'slightly above' normal amounts. Fe, Pb, Na, and Zn were present in 'above normal' amounts. The mean Pb concentrations exceeded most Pb concentrations determined for trees in areas with geologic Pb deposits or adjacent to primary highways. Washing and analysis with an electron microprobe failed to provide conclusive evidence with regard to the specific location of the Pb on or in the tissue sampled." (Author's Abstract)

Smith, William H. (217)

1975. Lead contamination of the roadside ecosystem. 27 pages, 5 tables, 2 figures, references for presentation: Session "Effects of lead on soils, vegetation, animals, and humans," 68th Annual Meeting, Air Pollution Control Association, June 15-20, 1975, Boston, Massachusetts.

"The atmospheric, edaphic and vegetative components of the roadside ecosystem contain elevated levels of lead originating from the combustion of lead containing gasolines by motor vehicles. The size of this ecosystem may approximate 118,000 square miles in the United States. Recent evidence has greatly refined our understanding of the distribution and localization of lead in the roadside environment. This paper is a representative review of some of this recent evidence. Vehicles release approximately 80 mg of lead per km to the atmospheric compartment in the form of inorganic lead salts ranging in size from 1 to 5μ. The lead content of roadside atmospheres may be elevated 2-20 times non-roadside atmospheres. Sedimentation from the atmospheric compartment results in lead contamination of the soil and vegetative compartments. Lead in the upper 5 cm of the soil profile may be elevated 30 times non-roadside soil within a few m of a street or highway. The soil lead is largely bound by organic matter exchange sites or present as the relatively insoluble lead sulfate. The increased lead burden of plants, largely due to surface deposition, may be 5-20, 50-200, and 100-200 times baseline lead levels for unwashed agricultural crops, grass, and trees, respectively. Invariably most plant studies demonstrate a strong inverse correlation between plant lead level and sampling distance normal to the highway and a less strong, but direct, correlation between lead burden and traffic volume. While or appreciation of lead in the roadside ecosystem is good, our understanding of its chemistry and the effects on the biota are deficient. The chemistry of lead compounds associated with plants and animals of the roadside ecosystem must be established. Acute and direct impacts of lead on components of the roadside biota are not apparent. The potential for interactive effects with other stress factors and for subtle impact is considerable, however, especially in regard to plant surface and soil microbiota, foraging insects and animals, and plant leaf and root metabolism." (Author's Abstract)

Sylvester, R. O., and F. B. DeWalle (218)

1972. Character and significance of highway runoff waters -- a preliminary appraisal. Available from NTIS, Springfield, Va. 22161 as PB-220 083, Price $5.45 printed copy; $2.25 microfiche. Final contract report for Washington Department of Highways and Federal Highway Administration, 97 pages, 14 figures, 28 tables, 82 references, 3 appendices.

Abstract:
"The character and significance of highway runoff were studied in Washington. Literature was reviewed and observations were made on a limited amount of field sampling done on the runoff and particulate emissions from the State Highway 520 bridge over Portage Bay in Seattle. While highway runoff contains significant quantities of oils, heavy metals, dust and dirt, substances from vehicle wear, litter, and algal nutrients, it does not appear to be very much different in general quality from urban area runoff. Preliminary results indicate that heavy metal concentrations may be higher in highway runoff. A major portion of vehicle emissions are apparently carried off the road surface by air currents and by splashing. The large sized particulates settle close to the road surface. If they settle on a soil surface, it is likely that most of them are retained in the soil and do not appear in the right-of-way runoff. A significant portion of the oils, heavy metals and nutrients are absorbed to particulates and other solids. Deicing salts should have no significant effect on either Lake Washington or Echo Lake and bridge runoff into Lake Washington is insignificant as compared to urban area drainage to the Lake. (Knapp-USGS)" WRSIC No. W74-11775.

Ter Haar, G. (219)

1973. The sources and pathways of lead in the environment. Pages 59-76 in Proceedings of the International Symposium, Environmental Health Aspects of Lead 1972 (Pub. 1973) held in Amsterdam (Nederland), October 2-6, 1972. Published by the Commission of the European Communities, Washington, D.C. Organized jointly by the Commission of the European Communities and the U.S. Environmental Protection Agency. 1168 pages. price $30.00.

"Lead is added to the environment by the production, use, and disposition of a variety of lead-containing materials. Lead particulate is removed from the atmosphere by sedimentation, rainfall, and snowfall. Soil and sediments are the ultimate sinks for lead in the environment. The major source of lead in man is the food chain. Plants and ultimately man receive most of their lead from that naturally present in the soil. Lead in air, even near major highways, does not add measurably to the lead content of the edible portions of most crops. Leafy portions of plants near busy highways contain higher concentrations of lead. A several-fold increase in lead in soil does not measurably increase the concentration of lead in plants. The contribution of lead from automobile exhaust to our food chain is minimal and is not increasing."

Tigner, James R. (220)

1965. Effects on pheasants of certain insecticides applied under modified conditions in eastern Colorado: A thesis summary. Outdoor Facts. Game Information Leaflet No. 14, Colorado Department of Natural Resources, Division of Game, Fish and Parks. 2 pages.

This study was initiated to investigate the effects of aldrin, dieldrin, DDD, endrin, heptachlor, parathion, and toxaphene on pheasants (Phasianus colchicus L.) under field conditions. Spray concentrations in ounces per acre were: aldrin, 2 and 4; dieldrin, 3 and 6; DDD, 24; endrin 6.5 and 13; heptachlor, 4; parathion, 8; and toxaphene, 12, 24 and 48. Results of this study suggested that the concentrations of insecticides studied do not have severe deleterious effects on pheasants in Colorado.

United States Department of the Interior. (221)

1970. Mercury contamination in the natural environment. A cooperative bibliography. U.S.D.I., Office of Library Services, Washington, D.C., 32 pages.

"Environmental contamination by mercury is a current concern of many bureaus and offices of the U.S. Department of the Interior. The purpose of this bibliography is to provide access to the literature related to this subject for those people who are now beginning to work on the problem. Publications providing background and current information on the aspects of greatest concern to the Department have been selected from the large body of literature on mercury. English language material relating to fish, wildlife and water pollution have been given full coverage from the sources consulted..." From compiler's preface. Sport Fishery Abstracts No. 12159.

Vermeer, K. F., A. J. Armstrong, and D.R.M. Hatch (222)

1973. Mercury in aquatic birds at Clay Lake, Western Ontario. Journal of Wildlife Management 37(1): 58-61.

Authors' abstract:
"Total mercury levels ranging from 2 to 16 ppm in eggs did not appear to affect the hatching and fledging of herring gulls (_Larus argentatus_). Mercury levels in breast muscles of 5 American widgeons (_Mareca americana_), 16 mallards (_Anas platyrhynchos_), 17 blue-winged teals (_Anas discors_), 21 common goldeneyes (_Bucephala clangula_), 17 common mergansers (_Mergus merganser_), and 7 hooded mergansers (_Lophodytes cucullatus_) averaged 0.5, 6.1, 6.5, 7.8, and 12.3 ppm respectively at Clay Lake 4-6 weeks prior to the hunting season in 1971. Methyl mercury in five ducks ranged from 69 to 99 percent of total mercury. Crayfish (_Orconectes virilis_) muscle contained the highest mercury levels of food items found in esophagi and stomachs of ducks; the high values in breast muscles of hooded mergansers are likely related to their feeding on crayfish."

Welch, W. R. and D. L. Dick (223)

1975. Lead concentrations in tissues of roadside mice. Environmental Pollution, (Printed in Great Britain) 8:15-21, 2 tables, 1 figure, references.

"Soil samples and seven different tissues from deer mice (_Peromyscus maniculatus_) collected along a major highway were analysed for lead content. Lead concentrations in soil were related to proximity to the highway, but not to traffic volume. Accumulations of lead in mouse liver, kidney and bone, but not in brain, lung, stomach and muscle, were related to both traffic volume and nearness to highway." (Authors' abstract)

Williams, G. A., L. L. Mink, et al. (University of Idaho and Idaho Bureau of Mines and Geology) (224)

1974. Mercury and heavy metal contamination in the Jordan Creek Drainage near Silver City, Owyhee County, Idaho. Idaho Transportation Department; Division of Highways, Boise, Idaho. 20 pp.; 11 fig.; 2 tab.; 7 ref.

Summary:
"From the 1860's to the 1930's the Jordan Creek Drainage, which lies approximately 60 miles south of Boise, Idaho, was the location of a major gold and silver mining district. From the conclusions of a study by the Idaho Fish and Game Department on mercury contamination in fish, from Jordan Creek, it was found that this area was the source of mercury and other heavy metal contamination. These metals, particularly mercury, pose a potential threat to the human health and recreational resources of Owyhee and Antelope Reservoirs which lie to the west of this creek. A research team consisting of 11 undergraduates from the University of Idaho and Boise State University, conducted an extensive study on the section of Jordan Creek which lies within the Silver City mining district. With the support of a grant from the student-originated-studies program of the National Science Foundation, and the University of Idaho, the team sought to locate the source of mercury and other heavy metal contamination. The research team sampled plants, water, sediments, micro-invertebrates, fish and small terrestrial vertebrates, in an attempt to locate the source of the mercury contamination and to trace the mercury through the food chain of the wildlife dependent on the stream. The results of the study indicate that the source of the mercury contamination is the old mine and mill tailings that remain from the early day mining. The main stream of Jordan Creek is contaminated with native mercury lost during the milling methods used in the early days. During times of high runoff the stream is less contaminated than during times of low water. The main stream is less contaminated than the stagnant pools that develops near the old mills. In general, the fish contain a high mercury content that would be a hazard to humans. All wildlife directly related to the stagnant pools is contaminated. At the present time the consumption of fish from Jordan Creek in the Silver City area should be limited. The stream loses much of the contamination as it leaves the immediate vicinity of the Silver City-Delamer area." (Author)

Supplemental Note:
Presented at the 12th Annual Engineering Geology and Soils Engineering Symposium, Boise, Idaho, April 3-5, 1974, which was sponsored by the Idaho Transportation Division of Highways, University of Idaho Colleges of Engineering and Mines, and Idaho State University Departments of Geology and Engineering. HRIS No. 265536.

Williamson, P., and P. R. Evans (225)

1972. Lead: Levels in roadside invertebrates and small mammals. Bulletin of Environmental Contamination and Toxicology, 8(5): 280-288, 5 tables, 1 figure, references.

"Concentrations of lead in the bodies of roadside invertebrates were generally below 50 ppm, but reached nearly 700 ppm in woodlice (Isopoda). Lead levels in tissues of small mammals caught on roadside verges did not exceed 30 ppm, and were thus less than the levels found in many of their prey. No evidence was found of decreases in abundance of invertebrates with increasing levels of lead in soil and vegetation close to roads."

Williamson, P., and P. R. Evans (226)

1973. A preliminary study of the effects of high levels of inorganic lead on soil fauna. Pedobiologia, Bk. 13 S. pp. 16-21, 3 tables, 1 figure.

"The soil fauna of spoil heaps near disused lead mines, of roadside verges, and of plots treated with lead nitrate solutions and lead chloride powder were studied quantitatively. No (toxic) effects of inorganic lead on the distribution and abundance of different groups could be demonstrated."

4. Wildlife Mortality and Effects of Highways on Animal Behavior

Abbott, Jackson W. (227)

1958. Death on the highway. Virginia Wildlife 19(6): 16-17, 1 figure.

"Includes table, 'Wildlife traffic casualty list for one year on an 11 mile stretch of the Mt. Vernon Memorial Highway, Fairfax County, Virginia.' Gray squirrel was first on the list, cottontail second, and opossum third, among mammals. Chimney swifts and robins were the birds killed in greatest numbers". WR No. 92

Aldrich, John L. (Chairman, *ad hoc* committee, American Ornithologists' Union) (228)

1975. Report of the American Ornithologists' Union *ad hoc* committee on scientific and educational use of wild birds. Auk 92(3, Suppl.): 1A-27A

Under a section--Man-caused mortality of birds--of this report, it was stated, page 8A that "Banks (MS) estimates that the number of birds killed by flying into TV towers each year may average around 1,250,000. He estimates that mortality at picture windows may be around 3,500,000 and from traffic on highways 57,179,000."

Alkon, Philip U. (New York Conservation Department, Albany.) (229)

1965. Some effects of weather and other influences on summer roadside counts of cottontails. New York Fish and Game Journal 12 (2):180-190.

"The effect of certain weather conditions and other environmental factors on early-morning roadside counts of cottontail rabbits was studied in July each year from 1958 to 1963 on four routes consisting largely of secondary roads in Albany County. Rain, heavy fog, and winds of 8 m.p.h. or higher reduced counts significatly. Other forms of precipitation, as well as temperature and light, had less effect. Little or no relation was found between counts and barometric pressure, relative humidity, cloud cover, wetness of the road surface, or the number of predators or vehicles encountered. On one route, surveyed three times each morning, counts were consistently highest on second runs, (begun nearly one hour after sunrise.) WR No. 123

Anonymous (230)

1938. Outdoor Indiana 5(9):2.

"Warden reports show great loss of game on highways and roads, drivers first duty is to safety of himself and other drivers, but he can help save the rabbits." (DOT abstract)

Anonymous (231)

1939. Notes on destruction of wildlife by automobiles with plea for more care by drivers. March issue (3) (3) 15 pages of North Carolina Wildlife Conservation.

Anonymous (232)

1941. Motor travel a hazard to wildlife. Better Roads 11(4): 36.

"Study conducted on a section of U.S. routes 12 and 16 in Juneau County, Wisconsin." (DOT abstract)

Anonymous (233)

1947. Wildlife killed on highways. Better Roads 17(3):28.

"Statistics for 6 Pennsylvania counties 1942-46 gathered by highway caretakers, who are required to remove bodies of dead creatures from highways." (DOT abstract)

Anonymous (234)

1953. Highways take heavy deer toll. Washington State Game Bulletin. 5 (3): 8

"Figures on known losses other than those to hunters in Washington, 1952. Highway kill, 844; illegal hunting, 301; malnutrition, 126; dogs, 75; drowning, 65; fences; 22, wild predators, 15; old bullet wounds, 10. Estimated total nonhunting loss in state is at least 25,000 annually." WR No. 74.

Anonymous (235)

1975. Toads on move shut West German highway. Washington Post, April 16, 1975. (From Reuter).

This article, date-lined Munich, West Germany, April 15, indicated that police had closed an expressway in Bavaria for about eight hours that day, diverting hundreds of vehicles so thousands of toads could cross safely to their breeding grounds. This decision was made after many toads had been run over while trying to cross the busy road between Munich and Garmisch-Partenkirchen.

Baker, Keith D. (236)

1965. An observation of bird mortality on highways. Blue Jay 23 (2):79-80 illus. WR No. 130:49

Bellis, E. D. and H. B. Graves (The Pennsylvania State Univ., University Park) (237)

1971. Deer mortality on a Pennsylvania interstate highway. Journal of Wildlife Management 35(2): 232-237.

Author's abstract: "During 14 months 286 white-tailed deer (Odocoileus virginianus) were killed by vehicles on an 8-mile section of Interstate 80 in central Pennsylvania. Mortality among fawns and yearlings was not significantly different among the sexes, but among adults many more females than males were killed. Mortality was highest in the fall, high in spring, and low in summer and winter. The numbers killed per month were strongly correlated with the numbers seen grazing on the planted right-of-way. Mortality was highest in sections of highway that lay in troughs formed by steep median strips and steep right-of-way, where troughs ended by a lowering of the median strips, and through flat areas where both sides of the highway and the median strip provided good pasture." Other items of interst brought out in the discussion were: (1) most deer do not cross highways at right angles while moving to and from their feeding sites on the rights-of-way except, perhaps, where abundant food is provided on both sides of the highway; rather, many deer move along the highway, being channeled by local topography or attracted to vegetation farther down the road; (2) the suggestion that deer fences along highways in forested regions be continuous over long stretches to prevent the deer from going around the ends and being funneled along the highway by the fences; and (3) the suggestion that if the fences were constructed close to the highway rather than where the right-of-way merges with the forest some distance away, a relatively low and, less expensive, fence might suffice to keep the deer from crossing the highway since their feed would be available outside the fence. The authors suggest, further, that highway design engineers and wildlife biologists cooperate in developing ways to reduce accidents involving deer.

Bellis, E. D., H. B. Graves, B. T. Carbaugh, J. P. Vaughan (238)

1971. Behavior, ecology, and mortality of white-tailed deer along a Pennsylvania interstate highway. Research publication No. 71, The Pennsylvania State University. 96 pages, 4 tables, 22 figures, references.

In the interest of highway safety and the preservation of wildlife, the authors have been conducting a long-term study of the activity, behavior and mortality of white-tailed deer (Odocoileus virginianus) along Interstate 80, a four-lane highway traversing north Central Pennsylvania. The purpose of this report is to present results of these studies which were conducted from early 1968 to early 1970, to relate findings to previous studies, and to suggest means by which deer-vehicle collisions may be reduced.

Brockie, R. (239)

1960. Road mortality of the hedgehog (Erinaceus europaens L.) in New Zealand. Proceedings Zoological Society of London. 134 (3): 505-508, 2 figs.

"During the summer months hedgehogs accounted for 84.5% of the total mammals and birds killed on two study roads. A drop in number of animals killed from mid-June to mid-September is undoubtedly related to the period of hibernation. The abrupt rise in the number of dead animals in early spring is attributed to an increased activity following emergence from hibernation. The high mortality rate that occurs before the advent of the litters is probably a reflection of the increased activity associated with the breeding season." WR No. 107

Buchner, C. H. (240)

1957. Population studies on small mammals of southeastern Manitoba. Journal of Mammalogy 38(1): 87-97, 5 tables, 3 figs.

In connection with the study of the home range and cruising radius of small mammals such as the red-backed vole (Clethrionomys gapperi loringi, Bailey) and the field vole (Microtus pennsylvanicus drummondi, Audubon and Blackman), Buchner found that "...these species may utilize portions of their range on either side of a 'barrier' such as a roadway or a low rock out crop, but that the area of the 'barrier' itself is 'vacuum' territory in home range establishment."

Bugbee, Robert E. (241)

1945. A note on the mortality of snakes on highways in western Kansas. Transactions Kansas Academy of Science (University of Kansas, Lawrence). 47 (3):373-374, 1 table.

"Tabulation of 11 individuals along gravel and 46 along asphalt roads, (representing 7 species) in 260 miles of driving. This is a wartime record with reduced traffic. 'Such slaughter seems tragic when it is well known that most species of snakes are harmless and help to keep down the rodent and insect populations that would otherwise destroy valuable crops'". WR No. 43

Caltrans Environmental Branch, Sacramento, California (242)

Undated: Highway deer-kill district 02 regional study. Pages vi + 49, 7 tables, 11 figures.

From the authors' summary:

"Results obtained in this study indicate that (1) a computerized data file system can be employed to store and analyze explicit locational information of the highway deer-kill problem; (2) deer-kill data can be collected and summarized on a regional scale (Caltrans' District 02); (3) explicit deer-kill reporting can be used to locate particularly severe areas ("Hot Spots") within the study area; (4) California Highway Patrol reports can be used as a source of human injury and property damage information, but they account for only about 5% of the total highway deer-kill; (5) a number of site factors, including traditional deer crossings as identified by track counts, areas of high deer density (winter ranges) and specific highway design standards, were found to be directly related to deer-kill trends in the study area; (6) Maintenance Branch reporting of the highway deer-kill appears to be the best available method and this study presents justification for continuing the effort; (7) the computer file system described is operationally and economically feasible for storage, analysis and retrieval of highway deer-kill data; (8) driver warning signs and right-of-way vegetation removal were effective in reducing highway deer kill but fencing and undercrossings need further evaluation using alternate designs; (9) several western states have conducted research in the area of deer-kill mitigation producing results which are applicable in California (see LITERATURE CITED section); (10) a sufficient number of questions regarding highway deer-kill remain unanswered to warrant further study of the problem in Caltrans' District 02 and throughout California."

Carlson, LeRoy W., and Alexander T. Cringan (243)

1975. Oil shale development in northwestern Colorado. Wildlife Society Bulletin 3 (1): 7-12, 1 figure.

In commenting on the possible environmental impacts of future oil shale development in northwestern Colorado, the authors stated, page 11, "Harassment, habitat loss, interruption of movements, and wildlife-automobile collisions will result from roads in the R O S S area. New roads should be built only where necessary, and roads where heavy traffic will occur should be paved to reduce dust. Fencing areas along roads where deer-automobile collisions can be expected would reduce deer losses. Underpasses and barrier fences, placed where necessary on roadways, would reduce impacts on mule deer by helping to maintain daily and seasonal movements. Closing roads into key wildlife habitats, unnecessary for development of the oil shale industry, would lessen harassment to wildlife, and use of mass transit to reduce traffic flow would reduce harassment and collisions. Finally, regulating traffic volume and speed might further diminish hazards to wildlife."

Carbaugh, Blair, J. P. Vaughan, E.D. Bellis (244)
and H. B. Graves

1975. Distribution and activity of white-tailed deer along an interstate highway. Journal of Wildlife Management 39(3):570-581, 3 figs., 2 tabs., 12 refs.

Author's abstract: "Distribution and activity of white-tailed deer (Odocoileus virginianus) were studied on a 12.9-km sector of Interstate Highway 80 in a forested region of central Pennsylvania from May 1968 to May 1969 and on a 12.4-km agricultural section of the highway from April 1968 to May 1969. Observations of deer were made from a vehicle equipped with a spotlight for nighttime observing. Over 6,500 deer were observed and categorized as to location, behavior, sex and age. Numbers of deer seen were related to time of day, topography, vegetation, traffic, and meteorological factors. Most of the deer seen in the forested area were grazing on the highway rights-of-way; most of those seen in the agricultural area were grazing in fields and rarely were seen on the rights-of-way. Deer tended to move into our study areas at dawn. Neither traffic volume nor weather correlated strongly with numbers of deer seen; spring and fall were times of great deer abundance in both study areas, but vegetation type and topography were more important factors in the forested area than in the agricultural area. Feeding behavior of deer in both areas dominated all other activities. The impact of the highway itself on deer abundance and distribution and the relationship between deer activity and deer-automobile collisions are functions of highway location relative to deer requisites such as feeding and resting sites and to relative availability of feeding areas other than rights-of-way".

Carbyn, Ludwig N. (245)

1968. Overwintering birds observed along the Mackenzie-Great Slave Lake Highways. Arctic 21 (4):294-297.

"Only a few species of birds remain in the subarctic region around Rae and the Biological Station at Heart Lake (Northwest Territories) during winter..." Numerous ravens were seen around settlements where they were feeding on offal and garbage. Several times ravens were seen feeding on road kills along the highway.

Channing, C. H. (246)

1958. Highway casualties of birds and animals for one year period. Murrelet 39 (3):41

"List of birds and mammals found killed on about 22 miles of highway, chiefly between Clear Lake and Mt. Vernon, Washington. Total was 137. Rabbits and skunks were mammals hit most often; robins and song sparrows topped the bird list, owing to their use of roadside cover and perches." WR No. 96

Couturier, R. P. (247)

1965. Accident prone locations identification and correction. Saskatchewan Dept. of Highways. 6pp., 2 fig.

Summary:
"By thorough investigation, accident-prone locations may be identified. The type of accident, head-on collisions, with animals, alcohol usage, may be correlated with the type of vehicle, and pavement quality and the effect of icy conditions. Once these factors are established and a pattern emerges, steps toward correction of any defects may be taken." HRIS No. 219806.

Davis, William B. (248)

1940. Mortality of wildlife on a Texas highway. Journal of Wildlife Management 4 (1): 90-91, 1 table.

Based on ten months records of mammals found dead along six miles of concrete highway in Brazos County, Texas, the investigator estimated an average of nearly ten per mile per year. Extending this figure over the mileage of "fast" highways in the State would give a figure of 157,000 mammals killed annually and if mortality on unimportant roads were 40% as great, the total mortality figure for mammals in Texas would be nearly 180,000. Birds suffered less but reptiles more. Availability of cover (at a minimum in winter), population peak (fall) and overgrazing by livestock in pastures adjacent to highways were factors believed to be operative in this area with respect to seasonal mortality of wildlife.

Dickerson, L. M. (249)

1939. The problem of wildlife destruction by automobile traffic. Journal of Wildlife Management 3 (2): 104-116, 4 figs., 3 tables.

The author presented statistics and observations on roadside cover conditions associated with the presence of wild animal highway victims over a period of about three years and more than 12,000 miles of travel. He found the frequency of dead animals to be greater on highways through plains country where only grass or low herbaceous cover is found than in other parts of the country where woody cover is more common. He suggested that an investigation designed to reduce to a minimum, the death toll in each kind of highway environment be conducted, such investigation to enlist the cooperation of the wildlife manager, the landscape engineer, the horticulturist, and the highway engineer.

Evenden, Fred G. (250)

1971. Animal road kills. Atlantic Naturalist 26 (1): 36-37.

"A 16-month record of animal mortality along 1.5

miles of suburban roads in Montgomery County, Maryland, revealed a kill of 46 individuals of 12 species. This represents 30.67 animals per road mile per year and 2.875 animals per month (no mortality was recorded in January or February). The kill per month per mile of road was 1.917 animals. These figures are each minimal since observations were made only of the road and the naked shoulder. Other evidences of mortality were beyond the range of visibility, and it is probable that some animals were removed without being seen.

Calculations from the recorded data show that mammals comprise 76%, birds 22%, and reptiles 2% of the total recorded kill. Gray squirrels made up 30%, cottontails 24%, robins 13%, opossums 11%, and seven other species 21%, of the total kill. Of the mammals, gray squirrels made up 40%, cottontails 32%, opossums 14%, and three other species, 14%. Robins represented 60% of the birds killed."

Flyger, Vagn (251)

1969. The 1968 squirrel "migration" in the eastern United States. Smithsonian Institution, Center for Short-Lived Phenomena. 16 pages, 1 fig. 1 pl. 20 January, 1969. (University of Maryland)

"Reports of unusually large numbers of road-kills and increased squirrel activity in most of the eastern United States have led to conjecture that abundant food supplies in 1967 encouraged growth of a squirrel population too large for 1968 food supplies to support." WR No. 133:28

Gale, Larry R. (252)

1951. Highway mortality. Kentucky Happy Hunting Ground. 7 (6):8, 32. illus.

"Recorded highway kill of different classes of game is tabulated by district. Data were gathered by conservation officers." WR No. 73

Haas, Wilfried (253)

1964. Verluste von vogeln und saugern auf autostrassen (Mortality of birds and mammals on

the highways.) Ornithol Mitteil. 16 (12) 245-250/
In German.

"Lists are given of bird and mammal mortalities on European highways observed during 1956-1963 on more than 46,000 km of travel. Totals of 1,850 birds of 97 spp. and 832 mammals of 22 spp."
WR No. 126:3.

Harding, Reuben M. (Statistical Information Staff, Mathematical Analysis Division, U. S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D. C. 20590). (254)

1975. Letter of May 8, 1975 and tabulation of accidents involving animals by state and severity for 1973.
This information, kindly provided by Mr. Harding, indicated reported totals of 118 (human) fatalities resulting from accidents involving the striking of animals (presumably mostly deer) in or off roadways; 7,778 accidents involving injury; and 65,381 accidents resulting in property damage for the year 1973.

Haugen, Arnold O. (255)

1944. Highway mortality in southern Michigan. Journal of Mammalogy 25 (2):177-184, 3 tables.

The author reports on animals observed by 49 conservation officers while driving 994,313 miles on southern Michigan highways during all months of the year, 1941. Observations were made also in Barry County between April 1 and September 20, 1940. In Barry County, on 124 miles of state highways traveled daily except Saturdays and Sundays, 180 farm fowl, 120 cats, 12 dogs and 3 pigs were found dead in addition to 168 cottontails, 42 squirrels, and a total of 90 other wild mammals and birds. Haugen surmised that on country roads where traffic was both slower and less intense, the kill probably was less and he felt that the then war-time Federal law reducing speed limits to 35 miles an hour would cause reduction in kill of wildlife on highways. He concluded that the greatest highway mortality of cottontails, fox squirrels, muskrats, opossums, skunks and raccoons is associated with increased activity that occurs during the breeding season and periods of dispersal and that the ultimate effect of highway mortality of small game in southern Michigan, especially cottontails, is insignificant in consideration of the total population susceptible to hazards of highway traffic.

Hein, Edward N. (256)

1941. Gunless killing. Wisconsin Conservation Bulletin 6 (2) 24-26

"Number of animals, including domestic kinds killed on two highways in twelve and ten months, respectively. In both instances, rabbits furnished the greatest number of victims." WR No. 31

Hicks, Lawrence E., Daniel L. Leedy and Don H. Strode (257)

1941. September pheasant survey. Ohio Cooperative Wildlife Research Unit (Ohio State University, Columbus, Ohio) Release No. 170, 24 pp. (Mimiographed)

In connection with a roadside inventory of living birds in western Ohio, pheasants were found dead on highways at the rate of over twenty-four per one thousand miles. By walking along railways in mid-day, 573 pheasants per one thousand miles were observed.

Hodson, N. L. (258)

1959. A survey of vertebrate road mortality/1959. Bird Study 7(4);224-231, 2 figs.

"Regular counts were made in 1959 on a two-mile section of rural, arterial roadway of the number of vertebrates killed. Normal traffic averaged 101 vehicles per hour, 180 on normal weekends, and 244 on holidays. 'During the year, 288 birds of 26 species and 295 other vertebrates of 16 species were killed'. The effects of habitat, weather, and other factors are discussed." WR No. 102.

Hodson, N. L. (259)

1962. Some notes on the causes of bird road casualties. Bird Study 9 (3): 168-173, 3 tables.

One of the relatively few articles noted in which the author gives any considerable detail as to causes of bird casualties on roads. Along a 2-mile section of rural roadway in the vicinity of Corby, Northants, England he observed 644 birds of 31 species killed during 1960-61, of which 320 of the birds were house sparrows. He compared the number of dead house sparrows observed during comparable periods of time (summer and fall) with those observed along lengths of roads with bordering grainfields in 1959, tabulating an average of 5.3 per 100 yards in 1959 and 10.2 in 1962. The population of house sparrows increased as the Corby housing estates extended towards the road (recently occupied and unfinished houses were utilized for nest sites). House sparrows were found to be especially vulnerable to automotive vehicles as they flocked to the various grainfields (to feed on grain). The position of the dead birds was recorded in relation to the various types of cover on both sides of the road and analysis showed that much higher numbers of deaths occur opposite gaps and openings than along stretches of roadway with a uniform border.

The author observed that species which feed from the surface of roads, such as members of the crow family, on the remains of other animals or apparently on earthworms which frequent highway surfaces after a rain are prone to be killed. Among other reasons suggested by Mr. Hodson as to why birds become casualties of the highway are: use of "the bordering kerb-stone as 'anvils' for breaking snail shells," in the case of song thrushes; dust bathing or taking grit from roads -- game birds, finches and sparrows; low flying birds being hit as they cross the roads -- finches, sparrows, game birds, thrushes and "hirundines in particular;" pursuit of flying insects; displaying on the road during breeding season (English blackbird); young of ground-nesting species being killed as they are led across busy roads by their parents -- partridge; barn owls swooping towards a moving light, (car) during the breeding season, especially; indecision on the part of some birds when crossing roads ahead of traffic; and striking telegraph wires beside a road, then falling to the highway surface and being crushed by a passing vehicle.

Hodson, N. L. (260)

1966. A survey of road mortality in mammals (and including data for the grass snake and common frog). Journal of Zoology 148 (4):576-579.

A two mile section of roadway in England was checked during 1959,60, and 61 to determine road mortality of mammals (and grass snake and frog). The species with the highest mortalities was the common frog. "If these figures (in this article) are multipled to correspond to the thousands of similar sections of roadway which must occur throughout our country as a whole, a very large mortality is revealed." Bibliography of 2 titles.

Hubbard, John P. and Claudia L. Hubbard (261)

1969. Meadowlarks feeding on road-kills. The Wilson Bulletin 81 (1):107-108.

After three days of near blizzard-like conditions in southwestern New Mexico when the terrain was covered with 6 to 10 inches ot snow, the authors observed many birds in the only snow-free areas visible to them -- the sets of tire tracks that traversed the highway. They stated, p. 108, "Although traffic was sparse through the area, many birds had been killed or injured by automobiles and their bodies littered the highway and roadside." They had the unusual experience of seeing meadowlarks (Sturnella magna and S. neglecta) feeding on carcasses and stated: "Although the habit of feeding on road-kills is commonplace in the area among hawks (e.g. Buteo jamaicensis, B. lagopus, B. regalis, Circus cyaneus), ravens (Corvus cryptoleucus, C. corax) and the Turkey Vulture (Cathartes aura), we have not previously observed it in meadowlarks." They concluded that this was not particularly surprising, however, because procurement of normal food items was difficult.

Jackson, S. W. (262)

1945. Motor vehicles kill wildlife too! Better Roads 15(6): 40.

"Records kept by district office of Pennsylvania Dept. of Highways reveal extent of annual slaughter of animals and birds on main roads. Many domestic creatures also killed each year." (DOT abstract)

Jahn, Laurence R. (263)

1959. Highway mortality as an index of deer-population change. Journal of Wildlife Management 12 (2):187-196, 4 figs. 11 tables.

A careful analysis of records developed by wardens of the Wisconsin Conservation Department on 6,585 white-tailed deer killed by motor vehicles on Wisconsin highways from 1946 through 1955 to determine the potential usefulness of such records as population indices. Although some deer struck by vehicles may be assumed to have escaped to die without being found and other highway victims probably were not reported, this known minimum of 6,585 constituted slightly less than 1% of the deer estimated to have been taken by hunters during that period. The author concluded that the road-kill totals, as reported, cannot be used as a precise index of annual changes in deer populations but that the carcasses of road-killed deer can be used for a variety of scientific purposes. Deer crossing signs, to warn motorists of regularly used deer trails were located throughout the State at the time these records were completed. Vulnerability of adults to accidents with motor vehicles varied between months; adult males, for example, being killed in October and November (rutting season) at a rate more than twice that of the other ten months. Adult does, on the other hand, appeared to be more vulnerable in March and April when they dispersed from winter yards prior to dropping their fawns. The author hypothesized that during the late stages of pregnancy, there is an above-normal consumption of succulent green forage needed for milk production at the time fawns are born (May and June). He pointed out that preferred food is frequently available first on open road cuts, bringing the deer in close proximity to moving vehicles.

Johnson, David and James H. Enderson (264)

1972. Roadside raptor census in Colorado -- winter 1971-72. The Wilson Bulletin 84 (4):489-490. (Dept. of Biology, Colorado College, Colorado Springs).

Two sections of highway, one 150 miles long and another 54 miles long, were selected for the census because of the abundance of utility poles upon which raptors perch. Approximately 65,280 acres in the Colorado Springs-Fort Collins areas were censused in a strip one-half mile along the highways. Compared with a similar census 10 years before the authors observed 2.9 times as many raptors.

Klein, David R. (265)

1971. Reaction of reindeer to obstructions and disturbances. Science 173(3995):393-398.

"Reindeer in Scandinavia are not caribou in the American North, but the two are very similar in their behavior, both being members of the species Rangifer tarandus...Therefore, the Scandinavian experiences with reindeer, both semidomesticated and wild, should provide a basis for anticipating the problems to be encountered with caribou-and they may offer proven solutions to specific problems...

"Although roads and highways provide the Lapps access to the reindeer, they also bring tourists, sportsmen, and others into the reindeer areas. This additional traffic increases disturbances of the reindeer and requires greater effort by the herders to keep the animals in the desired areas... The usual amount of automobile traffic along highways does not appear to significantly disturb reindeer feeding or moving nearby; apparently they are somewhat habituated to it. Nevertheless, highway traffic kills a considerable number of reindeer, and, as with deaths caused by the railroad, the treatest losses occur in winter. This is because of a combination of factors, including reduced light and visibility for the motorist, slippery roads, the attraction of reindeer to roads as routes of travel, and the fact that most reindeer winter in forested areas that are transected by highways." The author also discusses the influences of railroads, hydro-electric projects, forestry, snowmobiles, and air pollution and lichens on reindeer. Bibliography of 11 titles.

Kline, Paul D. (266)

1965. Factors influencing roadside counts of cottontails. Journal of Wildlife Management. 29(4): 665-671.

Author's abstract: "Results are presented of 180 early morning cottontail (Sylvilagus floridanus) roadside surveys conducted over a single 30-mile route in east-central Iowa during a 3-year period, 1957-59. The effect of time of day, weather factors, and seasonal variation in early morning rabbit roadside activity are evaluated. Two seasonal peaks of cottontail observations occurred, one in January and February, and the other in June and July. During the winter, observations of cottontails decreased as sunrise approached. Frequency of cottontail observations during summer increased 30 minutes after sunrise and peaked between 5:30 and 6:00 a.m. Frequency of observations declined in summer with increased wind velocity and with increased nebulosity. Observations increased with greater overnight decline in temperature. Cottontails probably are attracted for a time to road surfaces in summer because these surfaces are relatively warmer and drier than adjacent terrain. Such favorable road conditions develop following sunrise when nebulosity does not obstruct insolation and wind velocity is negligible, which may help explain the peak in early morning activity apparently occurring during the summer. The peak in morning activity during August and September occurs before the roads are sufficiently warmed, and the rabbits are apparently not attracted. Wind acted as a deterrent to roadside activity of cottontails in winter, but snow depth was the dominant factor correlating with frequency of cottontails on the roads." In his discussion, the author indicated that during periods of snow, rabbits tend to be concentrated in the more favorable cover areas,"... which under Iowa conditions, often occur near roads."

Lechleitner, R. R. (267)

1958. Movements, density, and mortality in a black-tailed jack rabbit population. Journal of Wildlife Management, 22(4): 371-384.

One paragraph in this paper on the black-tailed jack rabbit (Lepus californicus) on the 6,800-acre Gray Lodge Waterfowl Management Area, Butte County, California, discusses highway mortality. "... Automobiles kill a large number of jack rabbits. During the study (18 months), over 100 carcasses were found on roads of the management area and on rural highways leading to the towns of Gridley and Live Oak. The age classes and sex ratio of these carcasses were similar to those of the study population and no differential mortality could be detected.

Leopold, Aldo (268)

1936. Game Management. Charles Scribner's Sons, (New York, London) xxi + 481 pp.

Leopold, in his treatment of highway mortality, pages 352-355 of his well known book, points out that the popular alarm over motor killing of wildlife is exaggerated and the "leakage" in wildlife productivity is relatively unimportant except for unusual circumstances such as when the application of mineral salts to highways to reduce dust may attract deer and result in heavy losses to vehicular traffic at night.

Lord, Rexford D. Jr. (269)

1959. Comparison of early morning and spotlight roadside censuses for cottontails. Journal of Wildlife Management, 23(4): 458-460.

Author's summary:
"A series of early morning and nighttime roadside censuses of cottontail rabbits was performed on a study area in central Illinois farmland over a period of 20 months. Comparison of the results of the two censuses indicates that for 8 months of the year greater numbers of rabbits are observed when the census is conducted at night. Only the summer months are better for the early morning roadside census."

MacNamara, L. G. (Compiler) (270)

1962. Survey of car-killed wildlife. New Jersey Outdoors 13 (4): 23, 1 pl.

"Between March 1, 1961 and March 1, 1962, an accurate count was kept of animals killed each month along a 20-mile stretch of U.S. 46, in New Jersey. In the survey, 476 mammals and birds were found during the year, averaging 23.8/mile or 1.9 animals/mile/month. Cottontail rabbits (173) were most frequently killed, with squirrels (86), opossums (54) and skunks (50) in descending order of abundance." As reviewed by W. T. Van Velzen, WR No. 108.

Manville, Richard H. (271)

1966. Roadside abundance of woodchucks. American Midland Naturalist 75 (2):537-538.

"Observations made on auto trips along the Taconic Parkway in New York State suggest a maximum woodchuck population of one per 46 acres along this parkway...The figures above do not approximate some reported in the literature, e.g., 1,700 animals from a 2,000-acre area near Chambersburg, Pennsylvania in two years; 12 in a 100-acre field near Guelph, Ontario; or 18 per 100 acres at Patuxent, Maryland." The above 1 per 46 acres number assumes that the observations effectively covered 100 feet on each side of the road. "Many woodchucks present in the area were probably not seen during our brief passage. Still, they did seem so well adjusted to the traffic that a passing vehicle did not disturb them." Bibliography of 3 titles.

Martinka, C. J. (272)

1967. Mortality of northern Montana pronghorns in a severe winter. Journal of Wildlife Management, 31(1): 159-164.

This study, conducted near Glasgow, Montana, in April, 1965, indicated that a minimum loss of 500 pronghorn antelopes (Antilocarpa americana) was associated with severe winter and occurred primarily on foothill grassland along the Milk River. Although malnutrition was believed to be a principal cause of death, the author reported (page 161). "...at least 300 pronghorns were killed along railroads and highways."

McClure, H. Elliott (273)

1951. An analysis of animal victims of Nebraska's highways. Journal of Wildlife Management 15 (4): 410-420.

The author counted 6,723 animals as highway victims while driving 77,000 miles on Nebraska roads during the period January, 1941 through April, 1944. More than 100 species were involved, excluding invertebrates. Losses were largest among toads, rabbits, bullsnakes, pheasants, and kangaroo rats. He felt that highway losses were fairly directed related to the experience or lack of experience of wildlife with fast-moving vehicles; to wildlife populations adjacent to roads; to the habits of each wildlife species; to the age composition and density of wildlife populations more than to amount of traffic; to the degree of road improvement and thereby to the speed of the traffic; to the interspersion of soil types; and to the density of the adjoining cover.

National Marine Fisheries Service (274)

1975. Sea turtles to be added to threatened list. U.S. Department of Commerce News (NOAA 75-99), 2 pages. This news release points out that three more species of sea turtles -- the green (Chelonia mydas), loggerhead (Caretta caretta), and Pacific ridley (Lepidochelys olivacea) -- have been pushed closer to extinction because of increased development of coastal shorelines and overuse for commercial purposes.

"...Sea turtles, which can grow to 1,500 pounds, rarely come on land except to lay eggs. Human development of coastal areas for industry and tourism has destroyed many of these nesting sites. Along some shorelines bright city and highway lights confuse hatchlings and attract them inland where they die..."

Newman, Duane E. (275)

1959. Factors influencing the winter roadside count of cottontails. Journal of Wildlife Management, 23(3): 290-294.

States that roadside counts of cottontails (Sylvilagus floridanus) as used in Iowa provide data on population fluctuations from area to area and from one year to another--information considered in setting hunting season regulations.

Observations in this study showed the largest percentage of cottontails was seen on the road in the morning while in the evening the greatest percentage seen were in adjacent fields. The author believes that the effect of certain weather conditions causing vegetation to become damp influenced the number of cottontails seen on the road during the morning. Another effect noted was related to vegetation occurring along the road, the heavier and more abundant vegetation apparently accounting for more rabbits seen along one of the study highway routes. On two 20-mile routes, each traversed 64 times from January 1 to March 20, the mean number of rabbits observed during morning counts was 5.3 and during evening counts 2.7. "...Cottontail activity decreases with increasing light conditions during morning counts and increases with decreasing light conditions during evening counts. Many weather factors influenced the number of cottontails observed, but snow was the most significant weather factor."

Nowell, Howard C. Jr. (276)

1967. Wildlife and our highway construction program. Forest notes. N.H. Conservation Magazine No. 92, p. 9-13 (New Hampshire Fish and Game Department, Concord.) WR No. 127:4

Oxley, D. J., M. B. Fenton, and G. R. Carmody (277)

1974. The effects of roads on populations of small mammals. Journal of Applied Ecology 11(1): 51-59. (Carleton University, Ottawa KIS 5B6, Canada).

Author's summary:

"(1) Trapping, observation and road mortality studies indicated that small forest mammals (e.g. Tamias striatus, Sciurus carolinensis, and Peromyscus leucopus (Rodentia) were reluctant to venture on to road surfaces where the distance between forest margins exceeded 20 m. (2) Wider roads were crossed almost exclusively by medium-sized mammals such as Marmota monax, Erethizon dorsatum (Rodentia), Procyon lotor and Mephitis mephitis (Carnivora). (3) Road mortality increased with increasing road improvement for medium-sized mammals and was highest when traffic density was high and young were emerging. (4) A four-lane divided highway may be as effective a barrier to the dispersal of small forest mammals as a body of fresh water twice as wide."

With respect to the barrier effect of highways in relation to gene flow between populations on either side of a highway, the authors stated: "If large gene pools are important to the survival of animals living under 'harsh' environmental conditions, roadways may have important effects on these populations due to fragmentation of gene pools. This is important and should be considered when roads are being planned, especially in game reserves or parks..."They commented further: "By regular mowing and or spraying, vegetation along the road verges is often kept short resulting in increased road clearance. Plants other than grasses and in particular ground-covering shrubs, would simultaneously reduce the costs of road maintenance and the road clearance. Reduced road clearance would result in more movements of forest mammals on to and across the road and also in higher road mortality. It remains to be determined if the increased mortality is more or less detrimental than the fragmentation of gene pools. In any case, the effects of roadways on the movements of animals should be considered by the planners and builders of roads and by biologists concerned with the impact of man on the environment."

Information is given on the numbers of amphibians, reptiles, birds and mammals found dead per mile along selected roads in southeastern Ontario and Quebec, including width of rights-of-way, speed limit and average daily traffic during 116 days. Observed dead, and tabulated in a table, were 150 amphibians, 228 reptiles, 217 birds and 381 mammals.

Other observations of interest: traffic volume alone does not inhibit road crossings by mammals; road surface apparently is not a critical inhibiting factor i.e. whether asphalt or gravel, but the road surface does affect volume and speed of traffic and hence influences road mortality; and light intensity, by itself apparently is not a critical factor in the daytime road crossing by gray squirrels and red squirrels.

Payne, Richard L., and Ernest E. Provost (278)

1968. The effects of some atmospheric variables on roadside activity in the cottontail rabbit. Proceedings 21st Annual Conf. S. E. Association Game and Fish Commissioners. P. 173-182. 6 figs.

"Relation of temperature, relative humidity, vapor pressure deficit and barometric pressure to numbers of _Sylvilagus floridanus_ seen during morning and evening roadside counts." WR No. 134:21.

Pojar, Thomas M., Dale F. Reed and T. C. Reseigh (279)

1972. Highway construction--motorist and deer safety. Proceedings, Western Association, State Game and Fish Commissioners Conference 52: 268-271.

The authors point out that, in addition to being hazardous to motorists and costly both financially and aesthetically, deer-vehicle accidents in Colorado result in the loss of between 5 and 10 percent of the annual legal deer harvest. They indicate that usually funds for installation of costly devices, such as 8-foot fencing, or established highways are not available since, after initial construction, the funds would have to come out of the highway maintenance budget. Also, they state, it creates a problem to install devices such as underpass that require disruption of the roadbed; hence they suggest that recommendations for installation of devices to reduce deer-vehicle accidents be included in the original highway construction proposal. State conservation agencies have this opportunity due to the Federal Highway Administration's Instructional Memorandum 21-5-63 which directed all state highway departments to include recommendations from state fish and wildlife agencies in their requests for Federal appropriations on highway construction and, also, guidelines of the Council on Environmental Quality to state highway departments and FHA that would assure that the human environment and national environmental goals are met when developing Federally financed highway improvements.

The authors determined through questionnaires obtained from 903 motorists who were involved in deer-vehicle accidents that the mean actual cost to repair 903 vehicles during 1967, 1968, and 1969 was $293. They pointed out the need for documentation on the number and exact location (to nearest tenth of a mile) of deer kills, time of year when accidents occur etc. if recommendations for construction of devices to prevent deer-vehicle accidents are to be submitted.

Puglisi, Michael J. (280)

1974. Pennsylvania conducts study of deer-vehicle collisions. Traffic Safety, April, 1974. Page 25.

States that deer-vehicle collisions have been a long neglected, and frequently underrated, highway safety problem and that approximately 130,000 accidents of this type occur annually, resulting in an estimated national property loss in excess of $34,500,000. Indicates that in Pennsylvania, deer-vehicle collisions increased 218 percent from 1960 to 1967, and 17 percent from 1967-1972, with a total of 26,435 accidents.

Author's summary:

"1) High concentrations of accidents at any one location during one year were relatively uncommon. 2) A relatively small percentage of this total number of accident locations, those which are accident sites year after year, accounted for a high percentage of the total number of collisions. 3) The estimated number of deer-vehicle collisions per mile was twice as high on divided highways as on other roads. 4) A yearly average of 58.4 percent of the deer-vehicle accidents occurred in an area where both sides of the road were fields." With respect to the last point, Puglisi observes it is well known that deer graze in roadside fields and planted highway rights-of-way and that deer will not likely stray excessive distances from woody cover.

Puglisi, M. J., J. S. Lindzey, and E. D. Bellis (281)

1974. Factors associated with highway mortality of white-tailed deer. Journal of Wildlife Management 38(4): 799-807.

Based upon Pennsylvania Game Commission reports which exclude injured deer that struggle off the highway or deer picked up by persons other than game protectors, the indicated white-tailed deer - vehicle collisions in Pennsylvania increased 218 percent from 1960 to 1967 and 5 percent from 1967 to 1971, stabilizing around 22,000 annually. The authors suggested that the reported increase was due to an increasing deer herd, an expanding highway system and a greater interest in reporting deer-vehicle collisions. The authors reported 874 deer were killed by vehicles on a recently constructed 4-lane divided highway (Pennsylvania Interstate 80) which extends 313 miles across the northern half of the State. They stated (from abstract): "The location of highway fencing was the most significant of the factors studied. Generally, high deer mortality occurred where the fence was located at the edge of a wooded area or within 25 yd (23 m) from the nearest wooded area. Low mortality also occurred where the fence was located within the woods. The effect of vegetation on deer mortality was significant only where fencing was absent." In deer-inhabitated areas where there was no highway fencing, the mean deer kill per mile was significantly high where one side of the highway was wooded and the other side a field. Deer apparently cross fences (4 to 5.5 ft.) readily when the fence is at or near the woods edge and when a good grazing area occurs on the highway side of the fence. Peak deer mortality during this study occurred in November and December but was high, also, in the spring. The high mortality during the fall was thought possibly to have been due to an increase in movement associated with the breeding season and with disturbance of deer caused by hunting activities, and the high mortality, during the spring, to an increase in grazing which occurs at this time.

Reilly, Raymond E., and Hugh E. Green (282)

1974. Deer mortality on a Michigan interstate highway. Journal of Wildlife Management, 38(1):

Author's abstract: "Yearly totals of white-tailed deer (*Odocoileus virginianus*) killed by automobiles in a northern white cedar (*Thuja occidentalis*) deer wintering area in Upper Michigan's Mackinac County were compiled for a 13 year period from 1960 through 1972 for a study area bounded by the Pine and Carp Rivers on the north and south respectively, and the Mackinac Trail and M-134 at the Pine River in the west and east respectively. Mackinac Trail, a two-lane highway (formerly US 2), intersects approximately a 5-mile stretch of this wintering area. In 1963, Interstate 75 was constructed roughly parallel to US 2 and about 0.25 mile east of it and thus also intersected the wintering area. In 1964, car kills in the study area increased by approximately 500 percent over the average of the previous four years. This car-deer kill declined slightly through 1967, and has recently fluctuated about an average which is approximately twice that of the pre-Interstate yearly mortality figure."

The highway deer mortality curve seemed to follow that expected for a newly opened highway in that there was high car-deer mortality for two or three years, then a decline to a normal annual number (after D. L. White of New Hampshire) and it was suggested, also, that those killed may have represented family groups which might have been killed before the accelerated highway mortality ceased. The authors suggest that the deer which previously yarded east of I-75 may have been killed or repelled from the area and suggest that the lower number of car kills in the study area recently may be due to a lower deer population i.e. a higher proportion of the total residual deer population may be getting killed on the expressway than in 1964 when the population was high. In any case, the authors state that proposals for construction of highways which would intersect deer yards should be evaluated in greater detail for the potentially serious detrimental effects of construction on deer movements and populations within wintering areas.

Sargeant, Alan B., and James E. Forbes (283)

1973. Mortality among birds, mammals and certain snakes on 17 miles of Minnesota roads. Loon 45 (1):

Scott, Thomas G. (284)

1938. Wildlife mortality on Iowa's highways. American Midland Naturalist 20 (3): 527-539, 5 tables.

"Observations made on improved rural roads during all months in 43 Iowa counties revealed 1,239 wildlife casualties in 2,944 miles or approximately .429 per mile. The total for the State on roads of the type inspected probably exceeded 160,000. Factors influencing mortality are discussed." WR No. 19

Schorger, A. W. (285)

1954. A study of road kills. Passenger Pigeon 16 (2):53-55, graphs.

"Summary of birds found killed on roads between Madison, Wisconsin and Freeport, Illinois; over 18 years. Kill of red-headed woodpecker paralleled decline of species; that of pheasant did not, for road kills were moderate when population was high in 1942, and high when population was low in 1947." WR No. 78

Schult, Milo J. and Karl E. Menzel (286)

1969. Some observed deer behavior in relation to an irrigation canal in Nebraska. Iowa State Journal of Science 43 (4): 335-340.

Abstract: "A subjective analysis of observations of deer behavior along the Ainsworth Canal in Nebraska showed certain noteworthy patterns. The greatest activity of deer in connection with the canal during the summer took place during the early part of the season. Deer, in the yearling age class, were the most active. Both white-tailed deer (Odocoileus virginianus) and mule deer (Odocoileus heminonus) were observed during all daylight hours. White-tailed deer accounted for 77% and 81% of the deer found trapped in the canal in 1966 and 1967, respectively. In the hunting season kill, however, they comprised only 31% of the animals bagged. This high incidence was attributed to greater movements by this species. No reason was discovered to explain exactly why deer enter the canal. Variation was present among individuals of both species of deer as far as abilities to escape from the canal were concerned. Tests of escape structures in the canal indicate they were of limited value. The best way to prevent drownings will be to exclude animals by fencing or covering the canal. Some deer were evidently unable to recognize existing earth-covered bridges as places where the canal could be crossed." WR No. 135:40

Shepard, Paul, Jr. (287)

1952. Our highways and wildlife. Nature Magazine 45 (1) 34-37, illus.

"The author discusses highways as destroyers and producers of game...He feels that with rare exceptions, highway mortality is just another cause of death and has little effect on populations, traffic-killed animals being quickly replaced, if the population is otherwise healthy. Roadsides provide habitat for many animals, especially in intensively farmed areas. 'While we are concerned with the highway toll, other aspects of highway ecology deserve more public attention. The sinister shadow of chemical poisons and flame throwers for control of vegetation and pests is being cast over the highways of the whole country. Here is the real highway danger. The threat is directed towards essential food and cover. Perhaps our efforts should be directed against the specter of chemical warfare, rather than expanded in vain wailing over the unavoidable.'" WR No. 68

Siegfried, W. R. (288)

1968. Roadside counts of raptorial birds in the Sandvels area of the Southwestern Cape. Ostrich 39 (3):195-196 (Percy FitzPatrick Inst., Capetown, South Africa) WR No 145:94

Siegler, Hilbert R. and Coleman C. Newman (289)

1944. The value and practicability of wildlife censuses along highways. Journal of Wildlife Management 8 (2): 93-99.

The authors conducted censuses of mourning doves and of dead mammals (except small rodents) along Texas highways during a two-year period, September, 1939 to September, 1941 and made a critical review of 34 articles dealing with highway wildlife censuses. They concluded that: "1. Counts of mourning doves during only two years will not reveal relative population densities from one season of the year to the next. 2. Such counts provide general impresions as to the relative abundance of doves between two major plant zones. 3. Highway mortality counts do not indicate the relative abundance, relative vulnerability to traffic, or relative mobility of one species as compared with another. 4. Such mortality counts are of little value in life history studies, but carcasses of animals dead on roads afford some kinds of information. 5. Highway mortality counts are of minor value for the study of the distribtuion of species and lateral movement, population densities, and animal behavior. 6. Because of the many variables encountered, it is generally difficult or impossible to ascertain reasons for the rise and fall of mortality of species on highways; or to discover practical remedies for decreasing such mortality. 7. Such counts are of definite value in isolated instances of large local mortality, where the cause is readily apparent and remediable. 8. Such counts, over a period of years are helpful in tracing extensions of range by some species."

Simmons, James R. (290)

1938. Feathers and fur on the turnpike. Christopher Publishing House (Boston, Mass.) 148 pp. 10 pls., 3 figs., 4 tables.

"A study of wildlife casualties on the highway, pp. 9-10, 13-93. Chiefly anecdotal account of animals and experiences with them connected with the author's 10-year study undertaken partially to salvage highway-killed wildlife for scientific purposes. Tables list the specimens noted, classified by species and, so far as practicable, as immature male, and female -- groups killed in frequency in the order given; also, in similar detail, the animals killed on 2 particular stretches of road in a year; the results tally very closely, being 8.5 and 8.0 victims per mile per year and .023 and .0219 per mile per day. At that rate, total destruction in the United States would be about six million vertebrates. The casualty curve for these roads is rather steep-sided and reaches its apex in August. In the tabulation of all animals recovered, the following were killed in greatest numbers: Robin, 375, English Sparrow, 351, Cottontail, 337, Field Sparrow, 296, and Skunk, 222. There is a partial review of contemporary studies of highway mortality, a discussion of why animals come to the road, and suggestions as to what can be done to reduce destruction. Among these are providing grit and dust areas near, but not too near, roads; refraining from throwing remains of lunches and other edible refuse on or along highways; erecting signs calling attention to deer crossings; installing escape-ways and undertaking corrective education. A chapter is devoted to cats, many of which are killed by automobiles; his remarks on their food habits are not so condemnatory as those prevalent among sportsmen." WR No. 19.

Smith, C. F. (291)

1943. Rabbit mortality along an Idaho highway. Journal of Mammalogy 24 (2): 262, 264-265, 1 table.

Smith tabulated and compared his records of rabbits found dead along highway U.S. 30 in Idaho in August, 1940, with records of other observers along the same route in 1931, 1932 and 1938. Although variations in mortality appear to parallel fluctuations in populations, he showed that occasional counts of this kind varied as much as 60% within a four-day period.

Stewart, Paul A. (292)

1971. Persistence of remains of birds killed on motor highways. The Wilson Bulletin, 83 (2): 203-204.

The fact that carcasses of animals killed by cars on highways may be consumed by other animals or smashed and essentially obliterated by continuing traffic represents one of the difficulties in evaluating the magnitude of wild animal mortality on highways. Stewart threw 50 dead house sparrows (Passer domesticus) from an automobile onto the surface of Interstate Highway 85, between Oxford and Creedmoor, North Carolina and upon returning 90 minutes later found remaining parts of only five birds and no evidence of dead birds observable from a moving car after two hours. On another occasion he threw 20 house sparrows onto a blacktop country road near Oxford and another 20 birds into the clipped vegeation along the shoulder of the same section of the highway. By the next morning all of the birds were gone from the highway surface presumably having been removed by predators but it was 16 days before all evidence of the birds on the road shoulder had disappeared. He concluded that daily travel over the same route, such as evening travel home from work, provides the best source for useful counts on traffic-killed birds.

Stoner, Dayton (293)

1941. Bird casualties on the highways. University of New York (Albany) Bull. 27 (7): 229-232.

"Mainly notes on animals seen dead along highways in four round trips from Albany, New York, to Iowa City, Iowa. Birds totalled 1,781 out of 2,975 freshly killed vertebrates. Suggestions are made as to the use of some of the victims for biological specimens." WR No. 31.

Tarburton, M.K., Eivind Ostbye, and Ivar Mysterud (294)

1972. Death on the roads. Wildlife Australia 9 (1): 8-10. (From Journal of Mammalogy 54:1) Supplement 1973. WR 150:11.

1972. Road counts as a method for description of regional distribution of lemmings, (Lemmus lemmus L,) during cyclic highs, Aquilo Ser. Zool, 13:35-39, 1 fig. (University Oslo, Oslo, Norway).

Abstract:
"Road count census is described here as a practical method in the study of regional distribution of high densities of small mammal populations. This method has proved especially useful in studies of lemmings (Lemmus lemmus) during peak years. It has also been successfully used on other non-resident Fennoscandian small mammals, for instance, the wood lemming (Myopus schisticolor). The road count method is, therefore, recommended for following the outbreaks of such species." WR No. 150:33.

Thompson, Fred A. (295)

1966. Deer on highways -- 1966 supplement. Department of Game and Fish, State Capital, Sante Fe, New Mexico, 87501. 7 pages.

Author's Abstract:

"The deer-vehicle accident record went up over nine percent in 1966. Forty-eight states reported actual or estimated numbers of deer lost due to highway accidents in which there was a loss of 119,198 deer. There were 1,249 other big game animals reported. The human fatality and casualty figure, although considered rather unreliable, indicates a decrease in fatalities and an increase in casualties. Many states were active in developing preventative measures. These states may be contacted for information about the protective measures."

In the first national survey on this subject in 1963, the deer loss was reported to be 71,073. The author indicated that the count of deer reported killed must be considered a minimum because of the deer that may die at some distance from the highway. In the state of New Mexico, the author observed that only 19 deer-vehicle accidents were reported by game and fish personnel compared with 63 accidents reported by the New Mexico State Highway Department. There is much to be desired in the data collection and reporting methods. Other big game animals reported killed in 1966 from highway accidents included 108 elk, 229 antelope, 37 bear, and 4 mountain lions. Among the methods being used or approaches being tried by the state game and fish departments to reduce the deer-vehicle collision rate were: Dutch-type reflectors, specially designed highway warning signs, highway right-of-way clearing, fencing critical areas, game passes, controlled hunting, watering units, and speed reduction.

van Gelder, J. J. (Catholic University, Toernooiveld, Xijmegen, The Netherlands) (296)

1973. A quantitative approach to the mortality resulting from traffic in a population of _Bufo bufo_ L. Oecologia 13: 93-95. Springer-Verlag 1973.

Amphibia and particularly the common toad (_Bufo bufo_ L.) are run over in great numbers by automotive vehicles when they have to cross a road during breeding season. An apparently well designed study in the Netherlands sought to establish the relationship between intensity of traffic on a particular road and the percentage of animals crossing that road which was run over. Observations were made every night from about 7 p.m. until hardly any animals were seen anymore, from February 22 through May 15, 1971. The number of cars which passed per hour when the toads were migrating averaged about 9.4. The ratio of live to dead toads observed was about the same for males and females viz. 3.4 and 3.2 respectively. By counting egg strings of the spawning females the total number of females in the population was estimated to be 280. The number of females run over before spawning was 30 and the number run over after spawning was 19 as the toads returned from the water. It was estimated that about 29 percent of the females and a like percentage of the males were run over. On this basis if the traffic volume were one car a minute rather than 10 cars per hour as many as 9 adult toads out of 10 might be killed under the conditions described.

As possible means of protecting the amphibia against traffic, the author suggested the following: (1) block the road during migration of the toad -- a method said to be used in Switzerland; (2) use traffic signs warning against crossing amphibia, however, van Gelder believes a speed of 10 km/hour would be the maximum a motorist could drive if he wanted to notice the animals and try to avoid them; and (3) help the animals across that part of the road where the toads cross it by use of barriers in conjunction with either a tunnel underneath the road or pitfalls that are to be emptied every day during the migration period. The author indicated that the latter alternative was preferred in Switzerland and would be applied there in many places.

Vaughan, Dr. Joseph Peter (297)

1970. Influence of environment on the activity and behavior of white-tailed deer (Odocoileus virginianus) along an interstate highway in an agricultural area of Pennsylvania. Ph.D.thesis, Pennsylvania State University. 106 pages. (From Dissertation Abstracts, Intern. 31(9): 1971.

"The 7.7 mile length of highway was subdivided into 202 numbered 200-foot areas, each analyzed as to major habitat types. Data on numbers of deer, area location, sex, age, behavior, distance, date and time of observation and data on weather and traffic variables were obtained. Daily and seasonal patterns of deer activities in areas on and behind the highway right-of-way were recorded. Data on deer killed in vehicle collisions in the study section were also collected. Deer kills on the highway occurred in a seasonal pattern and indicated that certain areas of the highway were more accident prone than others." WR No. 141:45.

Veckermann, E. (298)

1970. Wildverlust durch den strassenverkehr und verkehrsunfalle durch wild im lande Nordrhein-Westfalen in jagdjahr 1967/68. (Wildlife losses from highway traffic and accidents attributed to wildlife in North Rhine-Westphalia during the hunting season 1967/68). Transactions IX. International Congress of Game Biologists, p. 158-166. (In German with Russian summary). WR No. 144:15.

Vestjens, W.J.M. (299)

1973. Wildlife mortality on a road in New South Wales. Emu 73 (3): 107-112, illus. (From Biological Abstracts 57(2), 1974. WR No. 152:7.

Ward, A. Lorin (300)

1973. Elk behavior in relation to multiple uses on the Medicine Bow National Forest. Reprinted from: West Assoc. State Game Fish Comm. Proc. 53:125-141.

Author's abstract:
"Telemetry was used to monitor elk behavior in relation to multiple uses on the Medicine Bow National Forest in southern Wyoming. Elk and cattle appeared to be socially compatible where there is an adequate food supply. Traffic on Forest Service systems roads has little effect on elk activity, especially beyond 300 yards. Interstate 80 acts as a barrier to elk movement. Elk preferred to be at least 1/2 mile from people engaged in out-of-vehicle activity such as camping, picnicking, fishing and harvesting timber."

Ward, A. Lorin (301)

1975. Effects of highway construction and use on big game animal populations. Second annual report on project 3F942-41-42-13-0103-33F2-3-2582 sponsored by the Federal Highway Administration and conducted by the U.S. Forest Service. 59 pages.

The author reports on the second year of a three-year study involving the antelope (Antilocapra americana), mule deer (Odocoileus heminous) and Rocky Mountain elk (Cervus canadensis) conducted on Pole Mountain, east of Laramie, Wyoming, and a 55-mile section along I-80 west of Laramie and the adjacent north end of the Medicine Bow National Forest. This is one of the more comprehensive studies of highway-big game relationships. Tracking and monitoring animal activity using telemetry techniques provide most of the data. Among the more interesting observations stemming from this study, still in progress, are:

"Since the highway passes through the big game winter range west of Laramie it is not uncommon to count 400 elk,200 deer, and 500 antelope within one mile of I-80 over the 55 miles. From ground surveys throughout the winter and a helicopter flight in April the population of big game that wintered adjacent to, or migrated across, I-80 were at least 850 elk, 600 mule deer, and 1200 antelope during the winter of 1973-74; a yearling female deer, presumably trapped within the I-80 fence was killed by coyotes on April 5, 1974 approximately 20 feet from the highway surface; winter home range for deer is generally less in size than that for elk; traffic speed on old gravel roads in the Forest system is only about one-half that of hardtop roads; elk prefer to be at least a half mile from people engaged in out-of-vehicle activities but will tolerate people in vehicles at closer distances; antelope appear to be reluctant to use underpasses in going from one side of a road to another and fences must be maintained or they will get into the highway right-of-way through holes; 8-and-12-foot high snow fences near I-80 offer protection from climatic factors and are used by antelope for shelter and feeding sites -- the vegetation around snow fences may be of critical importance to antelope during a 'bad winter' since they cannot move to areas of lower elevation, but snow drifts permit antelope to jump over highway fences and be exposed to traffic; traffic accidents involving elk occur primarily at night; elk apparently do not use underpasses available to them; since the opening of I-80 in October 1970, 639 animals have been killed (on the 55-mile section), a mean monthly mortality of 9.4 deer, 2.9 antelope, and 0.2 elk, a total of 12.5 per month; most antelope mortality occurs in the spring when the animals can cross over the usually prohibitive right-of-way fences on snow drifts; deer have greater tolerance of human activity than elk; in the National Forest, deer did not show a preference for traveling close to stream courses; highway crossings by deer appeared to be highest through park and clearcut areas; the highest elk road crossings per mile occurred where clearcuts were adjacent to the road."

Ward, A. Lorin, J. J. Cupal, A. L. Lea, C. A. Oakley, and R. W. Weeks (302)

1973. Elk behavior in relation to cattle grazing, forest recreation, and traffic. Transactions, Thirty-eighth North American Wildlife and Natural Resources Conference, pages 327-337.

Discusses multiple use of the Pole Mountain area to the Medicine Bow National Forest near Laramie, Wyoming where 336,348 visitations by people were recorded from May to October 1971. During 1971, traffic on Interstate 80 passing through the south end of the study area had traffic averaging 8,600 units per day in July and August. Radiotelemetry was employed to assist with monitoring movements of elk in the area. Noise level readings of traffic were taken at known elk feeding sites within 1 mile of I-80. On the "A" scale noise readings on the ridge tops near the fence along the highway measured 54 to 62 decibels for cars and 58 to 70 decibels for trucks. "...The elk did not spend much time feeding in areas where noise levels were highest, but they did not show any adverse reactions to the noise when feeding...Automobile and truck traffic on I-80 highway does act as a barrier to elk movement...The major concern would be to keep roads away from elk feeding sites on open meadows and slopes and along stream courses...In planning recreation facilities in elk habitat, consideration should be made to keep elk feeding sites about a half-mile distant from people concentration areas and to provide adequate cover buffer zones."

Wilford, B. H., and J. F. Wilford (303)

1937. Skunks pay dearly for their independent attitude. Scientific American 156(2): 105.

"On three drives in regions around Washington, D. C., totaling about 600 miles, the authors counted 22 skunks. They saw no other dead animals at all." (DOT abstract)

Williams, Cecil S., and Marcus C. Nelson (304)

1939. Highway mortality of rabbits in Idaho. Journal of Mammalogy 20(3): 380-382; 1 table.

These authors made brief notes on the character of land and vegetation along sections of highway U. S. 30 in Idaho where they counted dead rabbits. Sagebrush plateaus held the greatest concentrations of rabbit carcasses per mile -- 59% of those observed -- and there seemed to be a relation between the mortality and the density of sagebrush and its undercover, the optimum environment apparently consisting of open sagebrush and scattered understory of grasses and other herbaceous plants. Fewer carcasses were found in cultivated areas and close to towns. However, in a six-mile stretch at the Thousand Springs, 433 carcasses were found. This extremely high number was thought to be correlated in some manner with the presence of the Lost River outlets as the area differed little from other sections of the area except for the Springs.

Zalunardo, Raymond A. (305)

1965. The seasonal distribution of a migratory mule deer herd. Journal of Wildlife Management, 29(2): 345-351.

This study involved the trapping, marking, release and observation of mule deer (Odocoileus hemionus) in south-central Oregon to learn about their migrations between winter and summer ranges (which are sometimes separated by highways). Of 752 marked deer, the subsequent mortality of 179 over a period from June 1960 to October 1963 was learned. Five of the 179 (2.8%) were killed by automobiles compared with 126 (70.4%) taken legally by hunters.

5. Highway Right-of-Way Vegetation Management Erosion Control and Other Purposes

a) Plantings for Erosion Control and Other Purposes.

Amein, Michael, and H. L. Chu (306)

1970. Study of erosion in roadside drainage channels in North Carolina. North Carolina State University, Raleigh, School of Engineering.

Abstract: "An extensive field study of the performance of roadside drainage channels in North Carolina against the action of erosive forces was conducted under this research. From the results of these field observations and measurements, a criteria for the design of stable roadside channels was developed. The report presents three methods of determining whether a triangular shaped roadside drainage channel will be stable if it is fully grassed, partially grassed or bare earth when the discharge to be carried, the slope of the channel bottom, the side slope of the channel, and the soil characteristics of the channel are known. (BPR)" WRSIC No. W70-09455.

American Horticultural Society (Mt. Vernon, Va.) (307)

1975. Transit planting: a manual. The Urban Mass Transportation Administration, U. S. Department of Transportation, 64 pages.

This manual, a manual for the horticultural development of public transporatation environments, was prepared for the Urban Mass Transportation Administration, U. S. Department of Transportation by the American Horticultural Society. As mentioned in the "Introduction", this manual illustrates how urban transportation facilities can be developed practically and esthetically, using plant materials designated by the Society as particularly suitable for use in specific kinds of public transportation facilities. Helpful suggestions are given for site analysis and planting procedures and plant species suggested for planting (trees, shrubs, ground cover) are listed for 10 "hardiness" zones extending from southern Canada to the southernmost United States. No specific reference is made to wildlife, but the list of plant species contains many that are known to have wildlife value.

Andresen, John W. (308)

1974. Community and urban forestry -- a selected and annotated bibliography. U. S. Department of Agriculture, Forest Service/State and Private Forestry, Southeastern Area, viii + 195 pages.

Abstract: "This bibliography contains 2,250 annotated references to literature on urban forestry. Citations are grouped within geographic provinces that include articles applicable to the National and international arena; the northeastern United States and southeastern Canada; the southeastern United States and Puerto Rico; the Plains and Rocky Mountain States, and south central Canada; and the Pacific Coast States, Alaska, British Columbia and Hawaii. Subject matter groupings within each geographic area are: 1. urban and community planning, 2. urban forestry programs, legislation, ordinances, 3. arboculture, equipment, safety programs, tree maintenance, physiology, 4. tree and woody plant materials, arboreta, arbor day, 5. ground covers, turf, composting, mulching, 6. landscape design and roadside development, 7. ecological and animal influences, beautification, watershed management, 8. protection from diseases, insects, and pollution, 9. economics, business management, arbocultural organizations, 10. audio visual aids, communications media, education.

"In addition, an introductory chapter summarizes urban forestry practices in Europe and North America. Following the annotations is a directory of urban forest practitioners and related organizations that incorporates: 1. state forestry organizations, 2. arbocultural and related agencies, 3. arboreta, and 4. state and federal assistance programs. And in closing, there is a section listing current periodicals and training aids, including: abstract journals, scientific periodicals, films and slide sets, and poster sets."

Many of the papers included in the bibliography are from horticultural type journals, proceedings of Shade Tree Conferences and the like. For the respective geographical areas, 159 publications are listed under the heading, "Landscape Design and Roadside Development" and 199 publications under the heading of "Ecological and Animal Influences, Beautification, Watershed Management." A few publications under the latter heading deal with wildlife -- use of plantings by birds, methods of attracting birds, dispersal of seeds by birds and mammals and animal damage.

Artz, John F., J. Boyd Price, et al (309)

1970. Plantings for wildlands and erosion control. Cooperative Extension Service, Max C. Fleischmann College of Agriculture, University of Nevada, Reno, pages iii +24, 3 tables, 3 appendices.

The authors' abstract states: "This is one of a series of publications relating adapted plant materials to various uses and soils in the different climatic regions of Nevada which has been developed by the Max C. Fleischmann College of Agriculture and Soil Conservation Sercice (SCS), United States Department of Agriculture with assistance from other agencies. This series includes 4 publications: "Irrigated Forages for Northern Nevada Type Climate (C105)," "Irrigated Forages for Western Nevada Type Climate (C106)," "Irrigated Forages for Southern Nevada Type Climate (C107," and "Plantings for Wildlands and Erosion Control (C108)."

"This circular differs from others in the series in that it covers the entire state. We have divided it into 5 parts - Rangeland Forage Plantings, Windbreak Plantings, Wildlife Plantings, Soil Stabilization Plantings, and an Appendix.

"These recommendations were developed to serve as a common source of information for workers in agriculture, environmental development and conservation. Adjustments to meet special situations will be necessary, particularly when working with the harsh conditions encountered on Nevada wildlands. Local agricultural and resources specialists should be called upon for advice in such situations.

"Climatic conditions and soil characteristics of the State vary to the extent that no species or variety of plant is adapted throughout. For example, the growing season varies from 248 days (32°F.) at Las Vegas to 61 days at Wells with average annual temperatures of 66° and 45°, respectively. Elevations and rain fall patterns and intensities are likewise extremely contrasting.

"Plantings should therefore be selected, not only for suitability to soils, but also to climate. These considerations govern the recommendations for each of the major uses described."

On page 11 of this publication, the authors discuss wildlife considerations for highways, recreation and rest sites.

Atchison, H. E., and G. C. Pyne - Colorado Division of Highways (310)

1972. Development of dwarf ground cover for erosion control in Colorado. Available from NTIS, Springfield, Va. 22151 as PB-213-194. Price $3.00 printed copy; $1.45 microfiche. Final report CDOH-P and RR-R and SS-72-4, 10 pages, 2 figures.

Abstract:

"Colorado's arid regions and mountainous terrain create the need for a unique ground cover along its highway system to prevent erosion, enhance the beauty of roadside areas, and reduce hazards to the

motorist. An investigation is summarized into the possibilities for the development and use of a perennial, dwarf ground cover that would grow at nearly every elevation in Colorado. Such a plant would reseed itself, require no fertilization, and require little or no mowing. Maintenance costs would be reduced to a minimum. (Woodward-USGS)" WRSIC No. W73-12071.

Beayers, J., and A. Cox (311)

1968. Erosion control study (phase 1), HPR, 736-00-35. Louisiana State University and Agriculture and Mech. College, Louisiana Department Highways, U.S. Bureau of Public Roads.

"This is a final report for a five-year study designed primarily to develop more effective methods and materials for establishing permanent vegetative cover on subsoil slope areas along Louisiana highways. The prevalence of acid soils in most of the state makes necessary the addition of an average of 1-1/2 tons of lime per acre. Basic nutrient elements must also be used to obtain a satisfactory stand of turf. Equally important is initial seedbed preparation (the authors state that this is the key to producing an effective cover on roadside slopes). Weeping lovegrass is a good erosion control species in all but the marsh areas of the state. Mowing should be minimal, as many as three mowings per year will retard vigorous growth. As a general rule-of-thumb, mowing should not be done except to control weeds and maintain sight lines." BPR. HRIS No. 233714.

Butler, B. J., and R. R. Yoerger (312)

1962. Current trends in equipment for roadside cover establishment and maintenance - Highway Research Board, Report of Committee on Roadside Development, National Academy of Sciences,National Research Council, pp. 59-91, 21 tables, 23 figures.

In this report, several observations can be made about the present situation and future trends in equipment and practices for establishing and maintaining roadside cover. With the construction of the Interstate system and expressways, more acres of roadside cover are being established and maintained. Hydraulic seeders and straw mulchers are widely accepted as the most satisfactory equipment now available for seeding slopes. Farm grains for

for temporary seedings are becoming less popular and there are indications that temporary seedings themselves are being used less each year., Highway officials are cognizant of increased maintenance costs and will increase the demand to mechanize roadside maintenance. Use of chemicals for weed control and soil sterilization is expected to expand. The public is demanding and getting better roadside appearance through improved maintenance. Expected continuation of this trend will involve (a) better roadside cover control through use of chemicals, maintenance fertilizers, and modern equipment; (b) more frequent removal of litter; (c) more roadside landscaping; and (d) more roadside parks. Roadside practices and equipment will have to be efficient to keep maintenance costs from becoming burdensome.

Cerson, E. W., Jr., and R. E. Blaser (313)

1962. Establishing sericea on highway slopes. Highway Research Board, Report of Committee on Roadside Development, National Academy of Sciences, National Research Council, pp. 3-14, 12 figures, 6 tables.

"The experiment reported here is a study of seedling competition and establishing stands of sericea (Lespedesa cuneata) as related to seeding rates and mixtures of grasses with rates of nitrogen fertilization...A suggestions for establishing sericea is to use 850 lb per acre of a 5-20-10 fertilizer and a seeding mixture of 50 lb of sericea, 1 lb of redtop, and 10 lb of Kentucky 31 fescue per acre. Seeding should be made in late winter or early spring."

Cook, David I., and David F. Van Haverbeke (University of Nebraska & U.S. Forest Service) (314)

1972. Trees and shrubs can curb noise, but with quite a few loud "ifs." Pages 28-30 in "Landscape for living." The Yearbook of Agriculture, 1972. U.S. Department of Agriculture. Available from Supertintendent of Documents, Washington, D.C. 20402. Pages xl +376.

"...Although trees and other forms of vegetation have some effect on the transmission of sound, precise information on their use as noise screens is somewhat meager." From a study made by the Forest Service and the University of Nebraska on the shelterbelts on the Nebraska plains, the potential value of vegetation as noise abaters were deemed very good. "...Findings showed that reduction of sound values in the order of 5 to 10 decibels are not unusual for wide belts of tall, dense trees. Species did not appear to differ greatly in their ability to reduce noise levels, provided the deciduous varieties were in full leaf. However, evergreens are favored for year-round noise screening...Screening for rural areas or freeways where truck traffic is heavy requires wider belts (than in urban residential areas) consisting of several rows of tall trees in dense plantings."

Davidson, W. H. (315)

1970. Planned program of tree and shrub planting enhances beauty of America's Great Plains. Highway Research News, Highway Research Board, No. 40, pp. 22-26, 1 fig., 1 tab., 7 ref.

Summary:
"Living screens of trees and shrubs can greatly enhance the natural beauty of the Great Plains while hiding unsightly views. Past experience in shelterbelt planting and research has given much useful information that can be applied to screen plantings. Many tree and shrub species used successfully in shelterbelt plantings can also serve well in screens. Because of their added aesthetic qualities, conifers should receive high priority on sites where they can be grown. The basic requirements for successful screen plantings are: (1) advance planning and diagrammiing of the planting, (2) thorough preparation of the planting site, (3) correct choice of species for the site, (4) selection of good quality nursery stock, (5) proper care of planting stock before planting, (6) proper careful planting, (7) elimination of competition by cultivation of herbicides and (8) protection from disease and insect attach by spraying, pruning, or other means when required." (Author) HRIS No. 204814.

Deakin, O. A. (316)

1958. Median design as it affects conservation of vegetation and planting for screening headlight glare and traffic guidance. Highway Research Board - Roadside Development Committee Reports. No. 613, pp. 49-54, 2 tab., 3 photos., 3 ref.

Summary:
"Acquisition of sufficient right-of-way to allow a median strip on multilane highways, while more costly than a narrow right-of-way, may ultimately pay for itself through a number of advantages of the wider median. First, the profiles can be better adjusted to existing terrain, which saves construction costs and enhances safety. Second, native vegetation can usually be preserved, which saves on replacement, seeding, and maintenance costs. Third, planting in wide medians is more effective in screening traffic noise and headlight glare. In the discussion period the author notes that neither honeysuckle nor rosa multiflora has proved a vegetation-control problem in New Jersey, but in a milder climate it very will might."
HRIS No. 205113.

Dickens, R., and H. P. Orr (317)

1969. Roadside vegetation and erosion control. Auburn University, Alabama State Highway Department, and U.S. Bureau of Public Roads.

From summary:
"In Part A, Agronomy, twenty-two different experiments concerning legume establishment, grass (including bamboo) species, seedbed preparation, fertilization needs, herbicides and related areas are described. Tests to evaluate varieties of sericea lespedeza in North, Central and South Alabama showed that Alabama Hiway, developed at Auburn University, was most adaptable. Its characteristic low-growth and fine texture are desirable for roadside purposes. Another legume, crownvetch, performed well in the Central and Northern areas. Weeping lovegrass was the most effective perennial companion crop for crownvetch. Centipede, Bahia and two varieties of Bermudagrass were best suited for Central Alabama...The Part B, Horticulture, phase of the report covers several studies to determine the adaptability and survival of various woody species along roadsides, to collect, characterize, propagate and establish native species, and to evaluate the feasibility of using herbicides in established plantings...The performance of two species of junipers was outstanding. Test planting on interstate projects showed the three most adaptable species to be Wintergreen Barberry, varieties of Flowering Crab, and Southern Waxmyrtle. A list of 14 satisfactory species includes Red Maple, Pin

Oak, Common Crapemyrtle, Smooth Sumac and Burford Chinese Holly,..A list of native species valuable for selected site conditions is given. The categories cited are dry-open areas, exposed slopes, damp sites and shady locations..." /BPR/ HRIS No. 204625.

Ehrenfeld, David W. (318)

1972. Conserving life on earth. Oxford University Press (New York), 360 pages.

Abstract:
The subject of this book is the ecology of conservation. One reference concerning highways and wildlife is made (on page 277). It is stated that "components of early successional stages grow best on the exposed soils along road shoulders; these include (in eastern U.S.) pine, yellow poplar, sweet gum, and birch. The small residents of these communities, such as rabbits and birds, may occasionally be killed by cards, but are rarely dangerous to traffic. Unusual problems such as the resistance of plant materials to salt should be considered also. A bibliography for each chapter suggested readings for chapter, and an index of 8 pages.

Gallup, Robert M. (319)

1974. Roadside slope revegetation. Past and current practice on the National Forests. U.S.D.A. Forest Service, Equipment Development Center (San Dimas, California 91773), Report #7700-8, 37 pages, 12 illustrations, 4 tables.

Abstract:
"Effective revegetation is a primary method of protecting roadside slopes from erosion. Information on current practices and equipment use was gathered from 25 National Forests and from other sources. In seedbed preparation, seeding, fertilizing, mulching, etc., a variety of methods and equipment is used, depending primarily on conditions in specific locations. A review of earlier and current literature yields suggestions for possible improvements in techniques. New equipment is needed, and suggested equipment for scarification, planting, and seeding of steep slopes is sketched." Bibliography of 25 titles, both published and unpublished.

Goss, Roy L. (320)

1970. The establishment of vegetation on nontopsoiled highway slopes in Washington. Available from NTIS as PB-196-158, $3.00 in paper copy, $.95 in microfiche. Final Report Research Project Y-1009, 29 pages, 8 figures, 6 tables, 24 references. DOT supported.

Abstract:
"Various factors of erosion control and vegetation establishment were studied over a four year period in Washington. Included were: (1) establishment of grass/legume cover without the use of topsoil, (2) species of grasses and clover and proportion of each, (3) mulching materials and (4) fertilization. Erosion control vegetation can be established on subsoils without topsoil. There were no differences found among genera and species of seed tested. Subsoils, as exposed from construction, supported good stands of grass provided adequate fertilizers were supplied and they were given proper protection (mulching) from erosion. On erodible sites on 2:1 slopes or steeper, excelsior matting or straw tacked with asphalt emulsion was superior to all other materials tested. Refertilization is important." WRSIC No. W71-05147.

Heggestad, H.E., F.S. Santamour Jr., and Leon Bernstein (321)

1972. Plants that will withstand pollution and reduce it. Pages 16-22 in "Landscape for living," the Yearbook of Agriculture, 1972. U.S. Department of Agriculture. Available from Superintendent of Documents, Washington, D.C. 20402. Pages xl - 376.

Discusses relations of various air pollutants and salt, as used in highway de-icing, to plants. Describes some of the effects of ozone, PAN (peroxyacetyl nitrate) sulfur dioxide, nitrogen dioxide, fluoride, and ethylene on plants and suggests that plants will have increasing use in detecting air pollution. States that we do not know the extent that shade trees such as elms, oaks, maples, and planes are suffering because of a polluted environment. Mentions the ginkgo and the Chinese tree-of-heaven (Ailanthus) as being pollution resistant but does not recommend ailanthus for planting except, perhaps, in the most desperate situations. States that salt concentrations in water draining off the highway can be so high that no plant adapted to northern conditions may be able to survive and suggests that installation of drains to carry away the brine solutions be considered in the design of new highways and roadside plantings.

Highway Research Board (322)

1973. Erosion control on highway construction. National Cooperative Highway Research Program Synthesis of Highway Practice #18. Highway Research Board (Washington, D.C.) 52 pages, illus.

The location, design, and construction of highways as they relate to the problem of erosion are discussed. Seeding, planting, and mulching practices, useful to design and construction personnel, are given. Also included is a chapter on supporting field practices such as berms, slope drains, sediment basins, etc. There is a list of recommended practices that have been used to minimize erosion damage. The appendix includes a selected bibliography, glossary of terms, erosion control check list, and a chart summary of erosion control practices.

Howard, William J. (323)

1936. Restoration of roadside cover by the C.C.C. Wilson Bulletin 48 (2) 101-103, 1 pl. WR No. 5.

Hunter, W. Gordon (324)

1962. Role of roadway planting design in control of drifting snow. Highway Research Board, Report of Committee on Roadside Development, National Academy of Sciences, National Research Council, pp. 23-31, 7 figures.

The author points out that the planting designer should thoroughly understand the factors that cause snow drifting and should consider them not only in designing snow control plantings, but in designing other types of plantings as well. He should determine the wind direction responsible for most drifting in the area under consideration and study the terrain to locate drift problems, supplementing these studies whenever possible with actual observations of snowfall. Recommended plant barrier height and distance from the paving to be protected are given. The author suggests further experiments with plantings of varied heights, spacing, and density in an attempt to develop a barrier that would control drifting snow in the shortest possible distance from the road and within the limits of a comparatively narrow right-of-way. The planting designs should combine snow control with other plant use where feasible.

Jurka, Harry H. (325)

1962 ? Plantings as an aid in specific problem areas. Highway Research Board, Report of Committee of Roadside Development, National Academy of Sciences, National Research Council, p.2.

"The material presented by Mr. Jurka has special interest and value in the field of noise abatement. It has been furnished to a special task committee established by the Highway Research Board to conduct a study of roadside design intended to reduce traffic noise, dust, and fumes reported on at the 42nd Annual Meeting of the Highway Research Board.
The task committee believes that traffic noise can be controlled in part through proper vehicle design and maintenance and by proper highway design. It is in the area of highway design that the planting and management of vegetation along roadsides can be effective in specific instances in dispersing and absorbing traffic noise. It is in this area that the contribution of Mr. Jurka will have significant value."

Kemmerer, H. (326)

1967. Woody and herbaceous plants for roadside ground cover. Bureau of Public Roads #IHR-66.

From summary:
"A compilation is presented of information and data regarding the establishment of woody and herbaceous ground covers along Illinois highways... A list of adaptable ground cover species with a rating guide is given to assist the designer in making suitable selections...Recommendations are made for weed control, mulching practices, erosion control methods, propagation, handling and storage, and plant cultural practices. An emulsion-form soil stabilization product, Estab (WX-889), sprayed around a planting of woody species prevented erosion for a two-month period. It did not injure the plants either in the dormant stage or when the foliage was young... A planting of _Vinca minor_ (Myrtle) sod taken from an old established bed and mulched with cracked corncobs was successfully established and effectively controlled erosion." HRIS No. 204616.

Kidd, Walter J., Jr., and Harold F. Haupt (327)

1968. Effects of seedbed treatment on grass establishment on logging roadbeds in central Idaho. U.S.D.A. Forest Service Research Paper Int-53, 9 pages, illus.

"Deep and shallow scarification treatments, before and after broadcasting seed, were studied to determine if they would be conducive to establishment of a heavier stand of grass than could be obtained by merely broadcasting seed. Mulching with wood chips and fertilizing were also tried. Results show a slight advantage for deep scarification before seeding. Three of five perennial species became well established; the other two did poorly. Crested and Intermediate Wheatgrass and Smooth Brome produced good cover; Timothy and Bulbous Bluegrass produced sparse cover. Establishment of seedlings was significantly affected by site aspect and mulch." WRSIC No. W69-05096.

Lindsay, James D. (328)

1971. Protecting and managing trees and wooded areas subjected to heavy recreational use. Pages 111-114 in proceedings of "A Symposium on Trees and Forests in an Urbanizing Environment," August 18-21, 1970, University of Massachusetts. A monograph published by the Cooperative Extension Service, U. S. Dept. of Agriculture and County Extension Service, Univ. of Mass., 168 pages.

In this paper on the special problems and solutions of heavily used recreation areas, the author states that, "In Washington, D. C., the National Park Service estimates that the loss of cultivated trees from car accidents alone amounts to $5,000 - $8,000 annually...We can and must, however, begin to protect and manage wisely our trees and shrubs."

Maryland State Highway Administration (329)

1973. Slope management standards. Bureau of Landscape Architecture, 9 pages.

A well illustrated booklet designed to facilitate maintenance of desirable vegetation on highway slopes, i.e. cut slopes 3:1 or steeper where the toe of the cut is within 30 ft. of the edge of the pavement. Black cherry

(Prunus serotina), a valuable wildlife food plant, is identified as a species to remove on uncut slopes. A. personal inquiry revealed that this was because of its susceptibility to tent caterpillar infestation.

McCully, Wayne G., and William J. Bowmer (330)
Texas Transportation Inst., College Station

1969. Erosion control on roadsides in Texas.

Abstract: "A progress report is made of a study recommending practices for vegetation establishment (seed mixtures, fertilizers, liming, soil preparation, planting dates and mulching) in various climatic and geographical regions in Texas. Tables indicating seed mixtures and planting dates for clay and sandy soil textures with a map designating geographical areas is included for reference. Illustrations depicting methods, equipment, operation and results of some experiments are included in the report. (BPR)". WRSIC No. W70-09451.

Meyer, L. D., W. H. Wischmeier, and W. H. Daniel (331)

1969. Erosion, runoff, and revegetation of denuded construction sites. Paper No. 69-704, presented at American Society of Agricultural Engineers 1969 Winter Meeting, Chicago, Illinois, Dec. 9-12, 1969. 8 pages, 4 figures, 2 tables, 24 references.

Abstract: "Erosion and runoff rates were measured for six treatments representing typical construction site conditions that result from major land reshaping. Subsequently, reestablishment of vegetation on these conditions was studied in relation to various methods of reshaping, mulching, fertilizing, and seeding. A series of simulated rainstorms totaling 5 inches was applied at an intensity of 2.5 in/hr on 35-foot subsoil plots with 12 percent slopes. The resulting erosion and runoff were very great. The only treatment that effectively controlled erosion was straw mulch, which reduced soil loss to less than 10 tons per acre. Of the five original treatments on which revegetation was studied, applied topsoil was by far the most successful treatment. Mulched subplots were greatly superior to unmulched. A layer of good soil over a denuded area plus surface mulch is the best combination of those treatments tested for

minimizing soil erosion and enhancing rapid revegetation on reshaped land. Additional benefits may be expected from minimized compaction of such areas, shallow surface tillage before seeding, use of a seed mixture containing fast-growing grasses, and application of supplemental irrigation as needed. (KNAPP-USGS)". WRSIC No. W70-10280.

Moorhead, George R. (332)

1971. Protecting urban and suburban woodlands and trees from fire. Pages 101-106 in proceedings of "A Symposium on Trees and Forests in an Urbanizing Environment," August 18-21, 1970. University of Massachusetts. A monograph published by the Cooperative Extension Service. U. S. Department of Agriculture and County Extension Services, University of Massachusetts, 168 pages.

"Within nearly all of our cities and built-up suburbs are wooded parks, rights-of-way along railroads and major roads (especially the interstates), and abandoned fields or lots where fires can start and spread in the natural fuels of grass, shrub leaves and forest floors. If the cities are located along the coast, salt- or fresh-marsh intrusions provide ample fuels for rapid spreading wildfires; and these fuels may be contiguous to some of the wooded or grass-covered areas previously mentioned." After discussing the above locations and extent of areas susceptible to wildfires, the author discusses other problems and several solutions to prevent these fires.

Noyes, John H. (333)

1971. Managing trees and woodlands to improve the aesthetics of communities. Pages 115-120 in proceedings of "A Symposium on Trees and Forest in an Urbanizing Environment," August 18-21, 1970. University of Massachusetts. A monograph published by the Cooperative Extension Service, U. S. Department of Agriculture and County Extension Service . University of Massachusetts, 168 pages.

In this paper on forest management and aesthetics, the author discusses the technique of weeding. "Species composition can be influenced in seedling and sapling stands by removing inferior, highly competitive stems in the same height class as desired trees. An excellent opportunity exists here to favor trees having special aesthetic qualities of crown form, bark, foliage and flower coloration. With variety as one of the keys to aesthetics, it is possible in the early-development period to favor individual trees or groups of individuals that are not commonplace in that particular location..."

"Potentials for aesthetic management of trees can vary greatly according to their location, as: (a) along streets, (b) in parks, (c) along roadsides, (d) in greenbelts, (e) in small suburban woodlots, (f) in large forest areas. Location also can restrict or eliminate altogether use of many trees. Toxic fumes, adverse site and other unfavorable environmental influences, including man, must be considered as highly competitive to tree survival in many areas..."Trees have value as "(a) passive recreation, as components of scenery...; (b) active recreation, such as hiking, picknicking, camping, etc.; (c) environmental benefits such as purifying air, providing shade, shielding objectionable views, tempering objectionable noise, stabilizing soil, improving water quality, regulating stream flow, providing food and shelter for wildlife; (d) commercial forest production..."

Pushkarev, Boris (334)

1962. Esthetic criteria in freeway design. Highway Research Board. Report of Committee on Roadside Development, National Academy of Sciences, National Research Council, p.47. (Abstract)

Applying the tools of formal esthetic analysis, this paper attempts to systemize the elements that make a highway beautiful within the framework of internal and external harmony of the highway.

Rhodes, Arnold D. (335)

1971. Research needs in urban-related environmental forestry. Pages 157-163 _in_ proceedings of "A Symposium on Trees and Forests in an Urbanizing Environment," August 18-21, 1970, University of Massachusetts. A monograph published by the Cooperative Extension Service, U. S. Department of Agriculture and County Extension Service, University of Massachusetts, 168 pages.

The author lists three major areas of challenging future research in the area of landscape esthetics. The subjects needing attention include:

a. "Developing a system of silviculture that takes due account of landscape esthetics.
b. Improved methods for minimizing the ugliness of dumps and borrow pits and for restoring vegetative cover to such land or for effecting its conversion to other worthwhile purposes such as the improvement of water for recreational use.
c. Improved methods for the design of highways and the esthetic management of roadsides, with particular attention to the employment of native vegetation having landscape value and which will function as a reasonably stable community requiring minimal maintenance... Much work yet remains if we are to determine what it is that people find attractive, and to learn how the countryside can be regulated so as to provide these elements of esthetic satisfaction -- through control of open space vegetation forested and otherwise, with respect to floristic composition the form of trees and stands, the development of vistas, and other special techniques." Bibliography of 32 titles.

Richardson, E. C. and E. G. Diseker (336)

1965. Establishing and maintaining roadside cover in the Piedmont Plateau of Georgia. Agronomy Journal 57:561-564, 3 fig., 1 tab., 5 ref.

Summary:
Erosion control can be secured on most steep roadbanks by establishing good vegetative cover of adapted species. Mulch aids this cover establishment and provides temporary erosion control until sufficient plant cover developes. Adequate fertilizer and lime hasten plant growth and cover. Proper mowing schedules aid seed production, plant vigor, and cover development." (Author) HRIS No. 204769.

Santamour, F. S. (337)

1971. Trees for city planting; yesterday, today, and tomorrow. Arborist's News, 36 (3): 25, 27-28.

"In order for them to play an important role in humanizing deteriorating urban environments, tomorrow's trees must be genetically improved so they can tolerate or resist the environmental stress factors that cause injury to trees in the city, impair their growth, and make them more likely hosts for damaging insect and disease pests. The development of improved shade trees requires federal, state, or university programs which, ideally, will be supported on a continuous basis for at least 30 years. Important breeding progress has been made in *Ulmus*, *Platanus*, *Magnolia*, and liquidambar, and preliminary work on *Tilia*, *Robinia*, *Liriodendron* and *Acer* shows considerable potential. Studies on air pollution tolerance will be intensified and salt tolerance studies are underway. In the next few years, some disease-resistant American elms will probably be released through some of the older projects. It will be 20 years before there is a significant number of new and improved trees on city streets." (Author) HRIS No. 204825.

Spooner, A. E. and C. L. Murdoch (338)

1970. Erosion control on highway rights-of-way in Arkansas. Available from NTIS as PB-194017. $3.00 in paper copy, $0.95 in mocrofiche. Highway Research Project No. 15 Final Report, 156 pages, 82 tables, 7 figures.

Abstract: "Materials and methods for establishment, maintenance and control of vegetation were investigated. Laboratory and field experiments indicate that a straw and/or wood cellulose fiber mulch is essential for establishment of vegetation. Prevention of erosion and maintenance of necessary moisture relationship are the principal factors. The need for adequate fertility following seeding and for maintaining nutrient levels were investigated. Original applications of 800 lbs/acre of 10-20-10 with 2 to 3 year repeat applications of 500-700 lbs/acre are recommended. Two to four tons of agricultural limestone or dicalcium silicate should be applied initially. Fall Fescue, Common Bermudagrass, Weeping Lovegrass and Bahiagrass are the most adaptable grass species for highway use in Arkansas. Effective vegetation control with 2,4D can eliminate weeds and reduce or eliminate expensive mowing operations on some areas. Greenhouse and field experiments with maleic hydrazide as a growth retardant proved effective. Johnsongrass can be effectively controlled with 2 to 3 applications of organic arsenical herbicides --DSMA (Disodium methylarsonate) MSMA (Methanerarsonic acid)--at 2 to 4 lbs/acre. A method was developed to determine the mode of action of organic arsenical herbicides on Johnsongrass." WRSIC No. W71-02051.

Turelle, Joseph W. (339)

1973. Factors involved in the use of herbaceous plants for erosion control on roadways. Pages 99-104 in Soil Erosion: Causes and Mechanisms, Prevention and Control, Special Report 135. Highway Research Board (Washington, D. C.), 141 pages.

"Roadway construction annually reshapes thousands of acres of land in the United States. High rates of soil loss and resulting sediment yields from construction sites have caused a serious erosion problem. Although an excellent job is being done to stabilize and beautify Interstate and primary highways, secondary roads remain a problem. Numerous soil materials are being exposed that commonly have physical and chemical properties, unfavorable to plant growth, thereby making roadway stabilization difficult. The basic principles for establishing vegetation are presented along with a recommendation that, where feasible, slopes steeper than 3:1 be flattened. Various planting methods and requirements for selecting plant species are discussed, emphasizing the necessity for mulching and maintaining established vegetation." Bibliography for 6 titles.

U.S.D.A. Forest Service, (Bethlahmy, Nedavia, and Walter J. Kidd, Jr.) (340)

1966. Controlling soil movement from steep road fills. USDA Forest Service Research Note Int-45, 4 pages.

Abstract:
"Eight test plots were established on the fill slope of a newly constructed road. One plot was retained as a control, while different soil-stabilizing treatments were used on each of the other plots. These consisted of various combinations of seeding, fertilizing, mulching, and surface netting. Treatments that included both straw mulch and netting effectively controlled erosion." WRSIC No. W69-05105.

Webster, Arnold H. (341)

1975. Prairie grasses, the vista-makers. Weeds, Trees and Turf, 14(2):18, Harvest Publishing Company.

Abstract:
Prairie grasses are recommended for roadside plantings and hard to mow areas. The advantages after planting are: increase in soil moisture content, increase in soil stabilization (less soil erosion), increase in roadside beauty from these colorful grasses, low-maintenance costs, and grasses act as cover and food for song birds, quail and pheasant. "Also prairie grasses crowd out unwanted weeds. Prairie grasses need about three years to become established." Two books are recommended for further information on prairie grasses. They are: Prairie Propagation Handbook, Boerner Botanical Gardens, 5879 S. 92nd Street, Hales Corners, Wisconsin 53130, price $1.25; and Grass Lands, publ. by Wide Skies Press, Polk, Nebraska 68654, text by Jim and Alice Wilson, photos by Steven C. Wilson, photos by Steven C. Wilson, price $2.35. The authors stated: "Considering current oil and related petrochemical shortages, all used for roadside maintenance programs, we'd best give the use of prairie grasses and flowers our best thought."

Weinstein, L. H. and D. C. McCune. (342)

1970. Implication of air pollution for plant life. American Philosophical Society Symposium on Atmospheric Pollution (February 16, 1970). 114(1): 18-21, 17 ref.

Summary:
"A brief history is presented of the effects of air pollution on vegetation. Although most of the attention was directed toward the effects of industrial and urban pollutants on plants, agriculture is a source as well as a victim of air pollution. The application of certain herbicides had had an impact on vegetation in surrounding areas. The effects of an air pollutant on a plant may vary both with respect to their manifestation and the circumstances of their occurrence. The best known are the visible lesions that appear on the foliage, and these take the form of chlorotic or necrotic areas that are distributed on the leaf in patterns

characteristic of the plant and the pollutant. These symptoms denote a loss of photosynthetically active tissue in the plants, and thereby indicate a potential effect on its life. Two basic approaches may be taken for the control of air pollutants that damage vegetation: (1) access of the pollutant to the plant may be restricted, and (2) the removal of the source of pollution from the receptor or vice versa, has both advantages and limitations which are discussed. The control of air pollution may prove to be as complex as its origins and effects. The means by which air pollution is controlled will involve many strategies and will depend upon the perspectives and the goals of our society." HRIS No. 204787.

White, D. B. and M. H. Smithberg (343)

1972. Turf methods and materials for Minnesota highways. Minnesota University: Dept. Hort. Science. N619; Investigation Report, 145 pp.

Summary:
"A turfgrass development program resulted in fifteen superior selections for detailed evaluation and possible introduction. Reestablishment of prairie species on minimum maintenance roadsides can be accomplished by seeding. Effectiveness of seedings may be improved by modification of present roadside maintenance practices. More research will be needed before salt and/or drought tolerant grass species can be handled as sod. Investigation into vegetation changes on roadsides indicated mowing interval was more influential than mower type in affecting species distribution and density, and that grasses should be selected for specific environments and management programs." HRIS No. 205235.

Zak, John M. and Evangel Bredakis (344)

1965. Sand dune erosion control at Provincetown, Massachusetts. Highway Research Record #93. Highway Research Board (Washington, D.C.). Pages 54-61.

"Stabilization of sand dunes is discussed, showing results of the most economical and feasible methods for the Provincetown area. Machine planting of beach grass with a spacing of 18 by 36 inches, and the use of fertilizer is an excellent method for revegetating dunes. Several species of grasses have been screened for direct seeding on dune areas. Panicum amarulum, tall fescue and weeping love grass have produced satisfactory results. The use of various mulches in grass establishment for direct seeding has been of little value."

Zak, John M. and Peter A. Kaskeski (345)

1974. Flat pea for highway slopes in Massachusetts. Transportation Research Record 506, Transportation Research Board (Washington, D.C.), pages 79-84.

Abstract:
"Flat pea (Lathyrus sylvestris L.), a perennial herbaceous legume, is an excellent plant for erosion control and a good soil stabilizer..."Lathco" (a fast-spreading flat pea) has been tested and has proved to be an excellent conservation plant for the Northeast. It has been successfully established on logging roads, utility rights-of-way, and openings created by construction in wooded areas...a solid stand of flat pea inhibits the reinvasion of forest species." Bibliography of 9 titles.

Zak, J.M., J. Troll, J.R. Havis, H.M.Yegian, (346)
P.A. Kaskeski, W.W. Hamilton, L.C. Hyde.

1972. The use of adaptable plant species for roadside cover in Massachusetts, final report. Massachusetts University, report No. 23-R5, 160 pp, figures, tables, references, 1 appendix.

"Several projects were undertaken to determine the most effective type of plant species for roadside cover on Massachusetts highways. With a view to preserving the natural growth in this climate and soil, improving roadside appearance, reducing maintenance costs, and controlling pollution, the University of Massachusetts initiated the following projects. (1) grasses, mulches, and woody perennials were used to prevent slope erosion on newly constructed highways. Direct seedings of these grasses were made in hopes that they would eventually germinate and replace the grass. (2) Experiments were conducted to establish herbaceous plant materials (legumes and grasses) as roadside cover because of their adaptability to the soil and low-cost maintenance requirements. Crownvetch was found to be effective in erosion control and to require little maintenance. (3) Small, woody plants were chosen for highway slopes because of their greater permanency and low cost. Sweet fern was found to be especially suited because of its ability to grow readily in poor soil, thereby stabilizing the roadside as well as enhancing its appearance. Experiments were conducted in transplanting root cuttings of sweet fern directly to roadside slopes. Experimenting with nursery-grown plants on roadside slopes was also done. (4) To control vegetation along guardrails, herbicides that produce soil sterility were used. The use of these chemicals in controlling growth reduces the cost of maintenance. Experiments were conducted to test the effectiveness of other growth retardants as well." (Author) HRIS No. 262999.

5. Highway Right-of-Way Vegetation Management Erosion Control and Other Purposes

b) Vegetation Control Through Use of Herbicides.

Anonymous. (347)

1968. Herbicides - A boon to highways. Carolina Highways 22 (9): 14-15,22.

Summary:
"Herbicides provide a means of keeping roadside weeds and brush under control. The broad medians can be mowed with little trouble, but guardrail areas, drainage ditches and delineators pose problems. The South Carolina Highway Dept. uses a combination of sprays and pelletized weed killers which either kill grasses outright or which control only broadleaved plants. A special truck, with hoses which can gather water from any available supply, carries 500 gallons of spray. Control of the weeds by spray is cheaper than mowing. The chemical destruction of grasses which otherwise would cause deterioration of pavements saves money on maintenance and keeps the roads in use longer." HRIS No. 204743.

Anonymous. (348)

1970. Herbicides control roadside vegetation in California. Better Roads 40(2): 24-26. 1 figure, 2 photographs.

"...the freeway system in the State serves as a laboratory for maintenance of roadside vegetation. Each of the 11 districts of the highway division has its own problems to solve...More than 30 different herbicides, and combinations of them, are used for weed control. Contact and pre-emergent herbicides, translocating sprays and soil sterilants are used to control weeds in both landscaped and non-landscaped areas. In addition to the growing use of weed-control herbicides, there has been a trend toward the use of retardants to slow the growth of ground cover, shrubs and trees." (Author) HRIS No. 218661.

Anonymous (349)

1973. Herbicide emulsions keep applicators on target. Weed, Trees, and Turf, 12(3):16, Harvest Publishing Company.

"Perhaps the biggest problem in (herbicide) application is drift." A simply designed nozzle can fit standard sprayers. Air mixes with water in the nozzle to form a foam-like substance which, when sprayed with the herbicide, keeps applications more accurately directed. Herbicide drift then becomes a small problem. Less herbicide is required and beneficial plantings can more easily not be touched by the herbicide spray.

Anonymous (350)

1975. Solving the drift problem. Weed, Trees, and Turf 14(2):16, Harvest Publishing Company.

"Tests were conducted with Lo-Drift, an Amchem product which was mixed and applied with both herbicides and insecticides." This chemical additive (Lo-Drift) helps confine spray materials to target areas, such as rights-of-way. "One of the biggest problems of roadside spraying...is hitting target areas with chemicals."

Carpenter, P. L. (351)

1972. Herbicide studies in landscape plantings. Purdue and Ind. State Highway Commission JHRP. N5; 13 pp., 5 tab.

Summary:
"Landscape planting poses several difficult

problems when considering the use of herbicides. The plantings to be covered are often irregularly shaped, and accurate determination of the area involved is difficult. Also, the areas are often small, and accurate application of small amounts of herbicides is difficult, if not impossible, with present day equipment. Further, many herbicides that can be used on woody ornaments will damage turf. Finally, many plantings contain such a wide range of plant material it is often difficult to find an effective herbicide that is labeled for all the plants. The physical problems of accurate application of herbicides to landscape plantings have been partially solved in the results of previous research reported in JHRP progress reports by Lanphear and Spangler. The present report supplements their work." (Author) HRIS No. 205203.

Coble, H.D., P.H. Harvey, and F.L. Statman (352)

1967. The utilization of plant growth control substance in the maintenance of highway rights-of-way and highway facilities, HPR, ERD-110-R, U. S. Bureau of Public Roads.

"This is the final report of an eight-year research program on the use of herbicides for the selective elimination or control of vegetation along North Carolina's roadsides. It is a presentation of a regional State-of-the-art pertinent to the use of chemicals on vegetation along highway rights-of-way. This final document includes relevant information developed since the start of the study in 1959. The three principal concepts developed in this comprehensive program are: (1) the elimination of woody plants, including difficult-to-kill species by foliar, basal, and dormant stem applications, (2) effective uses of soil-sterilant chemicals with an evaluation of leaching and lateral movement, and (3) the evaluation of growth retardant chemicals, including control of herbaceous weeds that affect appearance and mowing operations. Directions for the use of herbicides in highway operations have been recommended in a manual of maintenance practices along North Carolina's highway system. This information is also applicable to other states for similar vegetation control needs. (BPR) HRIS No. 218011.

Cornford, L.H. (353)

1967. Residual weedkillers in non-selective vegetation control. New Zealand Road Transp. & Contracting, 15(6): 57,59.

"Where long-term, continuing control of weeds is needed, the residual weed killers should be considered. They are easy to apply, inexpensive, provide positive control of seed germination for long periods and are non-toxic to men or animals. Their limitations include a tendency to leach horizontally, which may kill trees or other plantings on the roadside. A list of weed killers is appended to the article which gives the trade name, the active ingredients, and the proprietor." (Author) HRIS No. 218209.

Dickens, R. (354)

1973. Control of cogongrass (Imperata cylindrica). Auburn University, Agricultural Exp. Sta. 83 p.

"Cogongrass (Imperata cylindrica) is a weedy perennial grass native throughout the old world but introduced more recently into the western hemisphere countries including southeastern United States. Large clumps of cogongrass growing on the shoulders of highways can cause severe sight distance problems that are difficult to correct due to its aggressive growth habits. Tests conducted for three years in Alabama indicated that single applications of most postemergence herbicides gave some initial topkill of cogongrass but control lasted less than one year. Multiple applications (five applications per year) of dalapon, amitrol and paraquat gave significant reductions in cogongrass stands one year later." HRIS No. 205267.

Dickens, R. and G. A. Buchanan (355)

1971. Old weed in a new home - That's Cogongrass. Highlights of Agricultural Research. Vol. 18, No. 2, P. 4.

Summary:
"Cogongrass (Imperata cylindrica (L) Beauv.) is widely distributed in tropical and subtropical lands. More recently, it invaded the United States, and Alabama has its share. Authorities have judged

this species to be one of the world's 10 worst weed species. In January 1970 the Agricultural Experiment Station received a cogongrass study grant from the U.S. Bureau of Public Roads and the Alabama State Highway Department. Research was begun to learn reproductive habits of cogongrass and to develop methods of controlling or eradicating it from highway rights-of-way. Results show that viable seed are produced, but not in large quantities. Some promising results were obtained with herbicidal control, but at this time there are no definite conclusions about control practices." (Author) HRIS No. 205164.

Elder, J. H., C. A. Lembi, and D. J. Moore (356)

Undated. Toxicity of 2, 4-D and picloram to fresh water algae, C-36-48C, HPR-1(8). Indiana State Highway Commission, U.S. Federal Highway Administration.

"The herbicides 2, 4-D and picloram exhibit low toxicity to all fresh water and marine algal species thus far examined at rates approaching the maximum solubility of herbicides in water. Use of formulated materials (especially esters) and combinations of herbicides may increase toxicity. Yet these herbicides present a low potential hazard from normal agricultural or industrial practice." (Author) HRIS No. 218062.

Fitzgerald, Charles H. and William H. McComb (357)

1970. Damage to pine released from hardwood competition by 2,4-D. Journal of Forestry 68(3): 164-165.

"The injection by standard field methods of the amine salts of 2,4-D into hardwoods for release purposes can result in damage or the death of several species of southern pine on different soil types. Since root grafts do not occur, it is probable that the 2,4-D is translocated downward into the hardwood roots, exuded, dissolved in the soil moisture, and absorbed by the pine roots."

Fletchall, O. H. and M. R. Gebhardt (358)

Undated. Vegetation control on roadsides and similar areas. Study No. 69-2. Missouri University, Columbia, U. S. Federal Highway Administration, Missouri State Highway Commission.

"Herbicides used at a rate of 0.5 lbs/acre were found to give better control with less damage to other plants than the higher rates of 1 lb and 2 lbs per acre. Common milkweed is still being used as the test plant. Picloram, amitrole, dicamba and fenac, in addition to 2, 4-D and 2,3,6-TBA gave good results. /FHWA/" HRIS No. 218067.

Foote, L. E. and D. L. Kill (359)

1968. Canada thistle control on roadsides. HPR, State-309. Minnesota Department of Highways, U. S. Bureau of Public Roads.

"The control of Canada Thistle (Cirsium arvense, scop.) is an important facet of the vegetation maintenance program conducted by the Minnesota Highway Department. Picloram applied at 3/4 lb/acre reduced thistle stands by 80 to 100 percent as compared to a maximum of 55 percent achieved with 2, 4-D at 4 lb/acre. Where legumes constitute a significant portion of the roadside cover, picloram should not be used. The best time to apply picloram is late summer when there is the least danger of possible damage to crops in adjacent fields." /BPR/ HRIS No. 218034

Goodwin, Richard H., and William A. Niering (360)

1959. A roadside crisis: the use and abuse of herbicides. Connecticut College (New London) Connecticut. Aboretum Bulletin No. 11: 1-13.

"Herbicides are valuable in the maintenance of roadsides, but common abuse of them cause marring of the landscape and unnecessary loss of desirable vegetation. This bulletin cites examples of abuse and makes specific recommendations for proper use of herbicides along roads. The heart of the system is selective treatment of trees so as to preserve a good cover of brush and broadleaved forbs wherever possible. Techniques are described and necessary exceptions are discussed. Under the recommended procedures, ragweed and other annual weeds have little chance to compete. Also, total results are best and cheapest in the long run." WR No. 96.

Hadden, W. A. (361)

1965. Herbicides for roadsides in Louisiana. Investigation of methods for controlling weeds and brush and retarding growth chemically. Louisiana State University and Agricultural and Mechanical College, Division of Engineering Research, Bulletin No. 87, 80 pages.

Summary: "Advantages of herbicides for roadside programs to the Louisiana Department of Highways was determined. Many states report effective use of herbicides on highway right-of-ways. Proper use of herbicides have resulted in improved safety conditions, reduced maintenance crews, reduced or eliminated hand mowing or trimming, and overall roadside beautification. Crews for applying herbicides should be trained in order to get most efficient application, prevent damage to adjacent crops or ornamentals and health of those applying the herbicides. Trimming around obstructions can be eliminated by the use of herbicides. They can be applied with spray equipment now on the market with a minimum of modification. They should be applied when there is no wind, at the lowest possible pressure, in order to prevent drift to adjacent property." (Author) HRIS No. 204704

Hadden, W., D. Alexander, C. Thomas and H. Barr (362)

1964. Herbicides for roadsides in Louisiana, HPR HPS1/17, No. 61-2M, 736-00-19, Part 1-1963, Part 2-1964. Louisiana State University and Agricultural and Mechanical College.

"To determine the usefulness of herbicides in a program of vegetation management along Louisiana roadsides a considerable volume of information regarding chemical weed killers and their application was obtained from 8 State Highway Departments, Utility Companies, Industrial Organizations and parish maintenance personnel. Important and voluminous space is devoted to a review of common species of herbaceous weeds and their well-known characteristics and to photographs and explanatory notes intended to emphasize various facets related to vegetation situations and equipment..." (BPR) HRIS No. 217998

Hicas, A Pete - Manager, Industrial Herbicide Sales, Ciba-Geigy Corporation (363)

1974. The herbicide market -- highway weeds. Weed, Trees and Turf, 13(2):vv, Harvest Publishing Company.

From abstract: "It is estimated that 25% of all herbicides sold in the U. S. for non-agricultural uses are utilized in highway and roadway programs. Contact and selective herbicides are applied to more actual acres than residual or soil-active herbicides. Based on our experience in highway weed control, we estimate that per mile herbicide expenditures range from as little as $2.00 to as much as $21.00. Pramitol is used primarily for controlling hard-to-get perennial broadleaf weeds and grasses. This product in combination with Princep provides control of both deep-rooted perennials and late-germinating broadleaf weeds and grasses. A new use for Pramitol 25E is in combination with asphalt cutbacks to prevent degradation by weed breakthrough after they are applied on shoulders, on cracked asphalt surfaces, country roads, and under highway fences and guard rails. Princep is...effective in controlling shallow-rooted annual weeds. An additional asset is its safety to desirable trees, shrubs, and some ground covers. Princep is used extensively for weed control around ornamental plantings and in highway spray programs where safety to deciduous fruit and nut trees and/or citrus is an important consideration. AAtrex and Atratol (AAtrex plus Pramitol) are also used for highway weed control, especially in the Pacific Northwest."

House, W. B., L. H. Goodson, H. M. Gadberry, and K. W. Dockter (364)

1968. Assessment of ecological effects of extensive or repeated use of herbicides. Advanced Research Projects Agency, Department of Defense. xv + 371 p; 48 figures. (Available from National Technical Information Service, Springfield, Virginia).

Excerpts from abstract: "An information survey including publishers literature and personal interviews with individuals knowledgeable in the fields of herbicide usage, animal ecology and plant ecology has been conducted for the purpose of assessing the ecological consequences of extensive or repeated use of herbicides for vegetation control. The general subjects discussed in this review include (1) herbicide production, usage and trends; (2) herbicide application to crop and noncroplands, especially forests, ranges, rights-of-way, waterways, ponds, lakes and reservoirs...;(7) conclusions regarding the ecological changes are presented; and (8) some recommendations for further ecological investigations are given." WR No. 132:10.

Hull, Herbert M., Chairman (365)

1967. Herbicide handbook of the Weed Society of America. Weed Society of America ix + 293 p.

"Data on herbicides and dessicants arranged alphabetically by chemical name with an index of common names, trade names and code numbers." WR No. 132:10.

Johns, H. R. (366)

1972. Effects of herbicides on the environment. Arborists News 37(4): 81A-86A.

Summary: "This presentation puts 2,4,5-T and other beneficial herbicides back into perspective. It is shown that they are safe when used as directed, that scientific data substantiates 25 years' successful experience. Suggestions are made for continuing programs of right-of-way (R/W) maintenance on a practical, prescription basis. This will improve the cost/benefit ratio by increasing biological and decreasing chemical controls. Use of herbicides on utility R/WS improves food and cover for wildlife by promoting desirable low-growing species, provides more aesthetic R/WS compared to mechanical or hand-cutting, conserves land by controlling erosion and serving as fire breaks, and reduces R/W maintenance costs; proving herbicides are the most economical method for a large part of the United States." (Author) HRIS No. 205195.

Norris, Logan A. (367)

1971. Chemical brush control: assessing the hazard. Journal of Forestry 69(10) 715-720.

"An adequate evaluation of the hazard associated with the use of any chemical agent requires consideration of both the toxicity of the material and the potential for exposure of nontarget organisms. The hazard can be high only if both the toxicity of the chemical and the potential for exposure to a significant dose are high. The relatively large doses of 2,4-D, amitrole, 2,4, 5-T, and picloram required to produce acutely toxic responses in most nontarget organisms are not likely to occur from normal chemical brush control operations on forest lands. The short persistence, lack of biomagnification in food chains, and the rapid excretion of these herbicides by animals preclude chronic exposure and, therefore, chronic toxicity. A long history of field use and research shows our common brush control chemicals can be used with minimum hazard to the quality of our environment." Bibliography of 23 titles.

Otto, N. E. (368)

1970. Evaluation of soil-applied herbicides for vegetation control. Bureau of Reclamation/US/; Water Resources Technical Publication Research Report 22, 31 pp.

Summary:
"Twenty-seven herbicide formulations were evaluated for their ability to provide total vegetation control. Observational ratings of test plots during the initial 5-year study indicated that a triazine herbicide, a substituted urea compound, and a uracil compound were most effective in controlling all plant growth. A table and a graphic figure summarizing the results of the overall performance of each herbicide at each rate of application are included. Data obtained indicate little significant difference in herbicidal performance between aqueous and dry applications. A limited test showed that a dry application of pelleted atrazine on gravel aggregate was as effective as the aqueous treatment." (Author) HRIS No. 204808.

Rudolph, Paul O., and Richard F. Watt (369)

1956. Chemical control of brush and trees in the Lake States/a review of present knowledge. U. S. Forest Service, Lake States Forest Exp. Sta. (St. Paul, Minnesota) Station Paper No. 41, 58 pages, 3 figures.

"Much information on use of various herbicides. An appendix tells just what applications to use for control of specific woody plants. Eighty references. WR No. 88.

Ruth, Robert H., and Carl Berntsen (370)

1956. Chemical basal treatment to control red alder. U. S. Forest Service, Pacific N. W. Forest & Range Exp. Sta: (Portland, Oregon) Research Note #128, 6 pages, illus.

"Alder was readily killed by basal sprays of 2,4,5-T or foliage sprays of 2,4-D. Data are given. Of wide potential usefulness is the horseshoe-shaped spray nozzle, illustrated. It should make spraying the entire circumference of a stem quicker, simpler, and cheaper." W R No. 85.

Sargent, M. et al. (371)

Undated. The toxicity of 2,4-D and picloram herbicides to fish. Indiana State Highway Commission and the Federal Highway Admin. Report available from National Technical Information Service (Springfield, Virginia). NTIS #PB 201099.

Summary:
"Two common herbicides, picloram and tordon (4-amino-3,5,6-trichloropicolinic acid) and 2, 4-D (2-4-dichlorophenoxyacetic acid) and their salts exhibit low toxicity to fish. Certain formulated derivatives (especially esters) tend to be more toxic than acid salts as an impurity from technical picloram. Even with picloram containing impurities, adaptive and/or detoxification responses by the fish are indicated. These herbicides (picloram and 2, 4-D) seem to present a low potential hazard to fish from normal agricultural or industrial use." (Author) HRIS No. 204637.

Shipman, R. D. (372)

1971. Soil-applied herbicides in the control of temperate zone grasses, broadleaf weeds and woody plants. Pennsylvania State University, 153 pp.

"Bromacil bioassays with oats revealed a continuous loss of herbicide over an 18-month period with significant residues detected at 3 of 4 field sites. Bromacil was persistent in the highly organic surface layers of a loamy sand soil. A simplified cucumber radicle-length assay used for picloram did not prove satisfactory for residue prediction. Data from the cucumber assays indicated picloram to be very persistent in soil after an initial 6 months disappearance. Regression analyses explained bromacil and picloram residue variance on the basis of soil variables in time-stratified residue series on microclimatic variables in depth-stratified series. Of 180 species taxonomically classified, three species were dominant: poverty grass, Kentucky bluegrass, and timothy. Total vegetation control occurred with bromacil wettable powder, tandex grandular, tandex wettable powder, and picloran/diuron." (Author) HRIS No. 219018.

U.S. Department of Agriculture. (373)

1969. Suggested guide for weed control, 1969. U. S. Government Printing Office, Handbook No. 332, 70 pages.

Summary:
"Many of the most effective weed-control practices resulting from federal and state research, as well as industrial organizations, are summarized. Successful and safe use of weed-control methods depends upon strict adherence to the appropriate treatment procedures. The weed-control methods described here may be considered as a general guide. The book contains basic principles and methods of weed control, precautions for safe use of herbicides, general properties of herbicides, various uses of weed control, control of aquatic weeds, and herbicide tolerances for crops." (Author) HRIS No. 204756.

Watson, A.J., and M.G. Wiltse (Dow Chemical Co. (374)

1963. Tordon...for brush control of utility rights-of-way in the eastern United States. Down to Earth, 19 (1):11-14, illus.

"Tordon (4 ammo-3,5,6-trichloropicolinic acid) was found to be more effective for killing broad-leafed plants than 2,4,5-T when evaluated a year after treatment. Most woody plants in the eastern United States were controlled with Tordon at 0.5-1 pound/100 gallons of water. Leaf kill was not as uniform nor as rapid on some species with sprays of Tordon as with sprays of 2,4,5-T and 2,4-D. Combinations of Tordon with phenoxy compounds gave more rapid and uniform leaf kill than Tordon used alone." W R No. 110.

5. Highway Right-of-Way Vegetation Management for Erosion Control and Other Purposes

c) Vegetation Control Through Combined or Other Measures.

Aikman, J. M. and E. P. Sylwester (375)

1960. Effects of time and method treatment on tree kill and bluegrass recovery. Proceedings Iowa Academy of Science. 66:103-112, illus. (From Biol. Abstracts 35 (14), 1960.

"Box elder trees in replicated plots within four seasonal blocks were nearly uniform in age, height, and diameter. Tree cutting at three inches and at one foot was done with a chain saw; and a brush killer-fuel oil mixture, at rates of one quart of concentrate to five gallons of fuel oil and one quart to ten gallons, was applied to the stumps. Low-cut, treated stumps with tree removal gave excellent sprout control, and as a method was superior to (1) high cut stumps, (2) no tree removal, and (3) basal treatment of standing trees in the control of weeds, improvement of bluegrass growth, and utilization, sanitation, and general husbandry." --from author's abstract. W R No. 100.

Anonymous (376)

1973. Better looking roadsides. Better Roads 43(6):16-17.

"The Pennsylvania Department of transportation landscape management team has moved in seven major areas to improve operational control of its roadsides. These areas are: (1) use of crownvetch has cut mowing costs, requires little maintenance, and is valuable in erosion control; (2) use of herbicides; (3) use of a basal spray program; (4) selective mowing; (5) consideration of all landscape details in the highway planning process; (6) use of ureaform fertilizer; and (7) demonstration projects to convince the public of the value of the use of the latest tools including herbicides." HRIS No. 205265.

Anonymous (377)

1974. Vegetation control. Area Bulletin; American Railway Engineering Association; 59 East Van Buren Street, Chicago, Illinois, 60605, pp. 526-537.

"Information is provided on vegetation control, the preparation of a vegetation control program and the execution of such a program. Commonly used terminology is explained. The principal advantages and disadvantages of controlled burning, mechanical control attainable are described. The determining of the scope of work and the scheduling of work are other aspects covered. The selection of herbicides in chemical control, and the selection of equipment in burning, mechanical and chemical control are discussed. In a discussion of the execution of a control program, consideration is given to importance of progress reports, the techniques of chemical control and the precautions that must be taken." (Author) HRIS No. 260040.

Betts, C. A. (378)

1954. Brush control along National Forest roads. Highway Research Board - Roadside Development Committee Report. No. 318, pp. 37-43.

Summary:
"In 1951 and 1952 the Forest Service of the U. S. Department of Agriculture conducted tests in all regions of the continental United States and Alaska. General conclusions deriving from these tests are the following. Numerous refinements in spraying techniques have been found to apply nationwide; others, such as oil in lieu of water in dry climates, have limited application. There appears to be some advantage in regulating the concentration of sprays so that chemicals will be absorbed into the plant before leaves are killed and drop off. Spraying after cutting should be timed for when the second growth is ready. This may not be until sprouts are easily identified and well started. The extent of late kill the year after spraying, like subsequent resprouting, are unknown factors. Repetitive spraying usually pays as each successive application becomes more effective and lasting. On trails, the cost of transportation of materials and equipment has an important bearing on the feasibility of spraying. Careful planning often keeps costs from becoming prohibitive. Roadside clearing along forest roads usually involves control of young trees, as well as shrubs, vines, herbaceous ground covers, and grasses. The objective of mowing, cutting, or spraying is safety, adequate visibility for driving at legal speed, and minimum fire hazard along with preservation of natural attractiveness of the landscape." (Author) HRIS No. 205076.

Bramble, W. C. (379)

1956. A comparison of the effect of chemical brush-control techniques on plant cover. Highway Research Board - Roadside Development Committee Reports. No. 419, pp. 11-18, 4 tab., 4 ref.

Summary:
"A large scale test of common brush-control techniques was begun on a 3-mile section of a right-of-way in Central Pennsylvania in the Spring of 1953. The commonly used control techniques employed in this test were (A) a broadcast foliage spray of 2,4-D + 2,4,5-T (B), an oil-water semibasal spray of 2,4-D + 2,4,5-T (C), a summer basal spray of 2,4-D + 2,4,5-T (D), a winter basal spray of 2,4,5-T (E), and a broadcast foliage spray of ammate (F). In addition to these original treatments, one-half of each of the four replications of treatments B, C, D, and F were given a summer basal spray one year after the original spray applications. As a control for the test, one set of four replications was left unsprayed. Because of a thorough and efficient application of the spray, all techniques gave an adequate top kill that varied from 94.1 to 99.7 percent of the total number of stems. When the resurge of woody brush that followed the initial spraying was compared three growing seasons after spraying, the oil-water, the summer basal and the ammate spray techniques were the most effective in keeping woody brush under control. Certain plant species were not well controlled by specific techniques and accounted for the bulk of the resurge on the particular treatments. Although no one spray technique can be said to be the best under all conditions, the basal sprays offer the best opportunity for controlling woody brush while at the same time maintaining an attractive roadside appearance. However, where the brush is very dense, such as it often is after repeated hand cutting, a broadcast type of spray may be the most efficient treatment, with a basal follow-up used to complete the initial control program." (Author) HRIS No. 205083.

Clapham, A. J., R. C. Wakefield, R. S. Bell (380)

1969. Effect of maleic hydrazide on the growth of turf grasses. Rhode Island University; Agricultural Experimental Station. Bull. 399, 22 pp.

Summary:

"A study is reported of use of maleic hydrazide (MH) for spraying of roadside turf for the reduction of the growth of grasses, and on maintenance of maleic hydrazide treated areas. MH limited the height and dry weight of clippings of bluegrass, orchardgrass, and quackgrass in relation to its concentration in all of the experiments. The first two weeks in May proved to be the best season for MH application. Fall application of MH gave variable and often undesirable results. MH was effective in reducing growth of grasses for a period of approximately six weeks after application. The numbers of mowings for May and June were reduced about 50 percent." (Author) HRIS No. 204811.

Coffman, B., and W. Edwards (381)

1966. Roadside maintenance and its effect on highway design and construction, #EES-189. Ohio State University.

"Plots were established on median and cut and fill slope areas to determine the relationships between incidence of erosion, turf density and nitrogen, phosphorous and potassium nutrients applied in varying amounts. Moderate quantities of nitrogen and phosphorous were necessary to prevent the development of bare areas on slopes. Well organized cost/time studies and extensive observations showed that a reduced-controlled mowing program combined with appropriate equipment can result in mowing cost savings of 25 to 30 percent. On rights-of-way averaging 27 acres of roadside area per mile, the effectiveness of retardants/growth inhibitors/ is closely related to time of application. Use of vegetation control chemicals must be carefully undertaken, and proper equipment is essential particularly in areas adjacent to ornamental plants and susceptible farm crops. Karmex and simazine are effective soil sterilants. When used singly, the amounts needed for vegetation control beneath guardrails are large and costs are high. Karmex plus wk surfactant and simazine with amitrol-T are effective and reasonably safe combinations. To successfully establish plantings of woody species, it is essential that a properly prepared planting bed be provided, and that the following factors be considered: (a) proper selection of species/ecological propriety/, (b) good planting techniques, (c) maintenance during establishment period." (Author) HRIS No. 218005.

Dahms, Walter G, and George A. James (382)

1955. Brush control on forest lands with emphasis on promising methods for the Pacific Northwest (A review of selected references). U. S. Forest Service, Pacific N.W. Forest & Range Exp. Sta. (Portland, Oregon) Research Paper No. 13, iii + 81 pages.

"Valuable compilation for all concerned with brush control. The first 32 pages contain good discussion of control by all sorts of means: chemicals, machines, fire, animals, combination of treatments. Pros and cons of each are listed. A graph shows distance of drift of droplets of different sizes. Appendices tabulate effects of herbicides on brush species of N.W. and show how to make up desired concentrations of 2,4-D or 2,4,5-T. The bibliography contains 239 titles. A subject index to this bibliography is provided." W R No. 81.

Dickens, R. and H. P. Orr (383)

1969. Roadside vegetation and erosion control. Auburn University, Agricultural Experiment Station. HPR No. 44, 233 pages, 18 fig., tabs, 52 refs., 1 app.

From summary:
"Tests of grass varieties for use in highway medians in Central Alabama are discussed. Study was conducted for selecting species of trees, shrubs and vines that are adaptable for use on Alabama highways: (1) to determine the adaptability and survival of selected woody plants along roadsides in Alabama, (2) to collect, characterize, propagate and establish native species in stock blocks at Auburn University and in selected locations on the roadside, and (3) to evaluate the feasibility of using chemicals for the control of weeds around establishing highway plantings. Herbicide combinations were found to be treatments of the future for more effective weed control. To develop a versatile herbicide program, roadside maintenance men should be equipped to provide both spray and granular formulations. Timing of herbicide application is often the key to a successful herbicide program." HRIS No. 204784.

Egler, Frank E., and Stan R. Foote (384)

1975. The plight of the "rightofway" domain -- victim of vandalism. Future Media Services, Mt. Kisco, N.Y. Part I, pages xiv +294; Part II, pages iv +160.

This 2-part work is illustrated with drawings and cartoons. There is an index for each part and Part I has 10 appendices. Some literature citations are given in the text and attention is called to: "Bibliography of (79) Papers by Frank E. Egler concerning Right-of-way Vegetation Management Herbicides and Society, candidly annotated by the author..." Reference is made also, Part II, page 2, by the author to his work: "A Contribution to Comparative Human Ethology, based on One Fellow's Folly, 1947-1972. (10 p.) Connecticut Conservation Assoc., Bridgewater, Connecticut 06752, $1.00 prepaid."

In his preface to this work, William A. Niering of New London, Connecticut states: "This book documents the interactions of sound science in a social system skewed with pseudo-science and Madison Avenue techniques, promoted for the profit of a few rather than of society as a whole. The recent Nobel Prize Winner, Konrad Lorenz equates the advertising in the Western World with the indoctrination techniques of the Communist bloc. It is obviously time for our Nation to awaken to the effects of this force in molding public opinion. It has surely played a major role in corrupting sound management of the right-of-way domain. Some readers may find this volume not to their liking. However, in viewing the issues holistically, one is often exposed to more than he wants to know to be comfortable. Dr. Egler pulls no punches in attemping to interrelate the right-of-way problem to the many social institutions involved in any such complex issue."

Book I of Part I states many of the "don'ts" and principles of rights-of-way vegetation management covered in his previous articles, including some reference to wildlife. The "don'ts" include: don't clearcut the land; don't scarify (bare) the soil; don't blanket-spray the land; don't plant shrubs; don't hedge-clip brush under wires; and don't take the low bid for a contractor job! He re-emphasizes that a graded U-shaped right-of-way in cross section is far better than a flat one with only two edges and that enough is known about managing ground cover to do a better job than is being done.

Book II of Part I by Stan R. Foote deals with human ethology as related to rights-of-way vegetation management. Part II provides somewhat more documentation than is present in Part I.

Fletchall, O. H., and M. R. Gebhardt (385)

Undated. 1968 annual report vegetation control on roadsides and similar areas, No. 69-2. Missouri University, Columbia, Missouri State Highway Commission, U.S. Bureau of Public Roads.

"Four thickening agents (Norbak, Keltex, Decagin and Vistik) were combined with three herbicides (2,4-D, 2,4,5-T and 2,3,6-TBA) to develop a safer, more efficient use of herbicides to reduce the cost of controlling the vegetation on roadside areas to replace the more costly control methods now employed. Experimentation was conducted on the common milkweed. In general, the percent of injury to the milkweed was slower with the use of the thickening agent. However, the final results of percent of kill was increased with some of the thickening agents while the rate was poorer with other thickening agents." /BPR/ HRIS No. 218054.

Fletchall, O. H., and M. R. Gebhardt (386)

1972. 1971 annual report vegetation control on roadsides and similar areas. Contract No. 69-2, 100 pp. Missouri University, Columbia, Missouri.

"The discovery of highly active herbicides has permitted more effective weed control. However, chemical drift is a problem with these highly active materials, and there is a need for safer application techniques. The use of thickened sprays to reduce spray drift is being investigated. Laboratory tests have been conducted to observe the characteristics of these sprays under varying conditions. Later this spring, drift reduction will be measured in order to evaluate thickened sprays as a means of reducing spray drift. Evaluations were made of common milkweed control on roadsides from treatments applied in the summer of 1970. Maleic hydrazide was applied to tall fescue for the purpose of holding the plants back, thereby possibly reducing mowing. Soil sterilants applied in the summer of 1970 were evaluated, and another series of applications were made in the fall." (Author) HRIS.

Foote, L. E., and B. F. Himmelman. (387)

1965. Maleic hydrazide as a growth retardant. HPR, 616. Minnesota Department of Highways.

"The application of maleic hydrazide /MH/ on roadside plots in Minnesota was evaluated during a four-year period ending in 1964 to determine its usefulness as a growth retardant...On areas where the turf was neither dense nor well established, the MH retarding effect resulted in undesirable species, such as crabgrass, foxtail and ragweed becoming prominent. Turf treated with MH, but without an herbicide, generally developed a more ragged appearance than untreated areas. MH combined with an herbicide and applied in the spring provided a satisfactory turf. Maleic hydrazide applied at high rates along fence lines effectively reduced maintenance requirements. Satisfactory results are closely related to proper timing in making spring applications. In the Lake States, where the spring season is short, it would be difficult to make large scale applications of retardant at the proper stage of plant growth." /BPR/ HRIS No. 218004.

Foy, C. L., and G. E. Coats. (388)

1968. Control of plant growth along Virginia highways. HPR-1 (4), 0475. Virginia Polytechnic Institute, U.S. Bureau of Public Roads.

"This is a summary annual report concerning the effect of herbicides on weeds growing in plantings of various species of trees and shrubs. Weed control when used under nursery conditions was poor with all herbicides regardless of the date of application. Good weed control was obtained with caroson, dymid and simazine in established Japanese honeysuckle. Several growth retardants tested on Kentucky 31 fescue were not as effective as MH 30 (maleic hydrazide), or a new potassium salt formulation of MH. Field tests indicate that time of application of MH 30 is critical, spring applications are more effective than fall. Limited field and greenhouse tests using radioactively labeled herbicides indicate that dose rate, spray volume and additives employed may be critical in the control of mullein and milkweed." /BPR/ HRIS No. 218032.

Hesse, J. F., and S. S. Salac. (389)

1973. Effects of mowing on the vegetative and reproductive development of species of wild flowers, Intrm, Rpt., 38 pp. Nebraska University, Lincoln; Department of Horticulture and Forestry, Lincoln, Nebraska 68508; Neb. HPR Study 64-2.

"The response of 11 species of wild flowers to 12 mowing dates was studied. The following results were obtained: (1) all species survived the mowing treatments but plant vigor was generally reduced; (2) with the exception of shell-leaf penstemon, height was reduced by mowing and this reduction was directly correlated with the lateness of mowing. Mowed plants also showed no lodging problem and had more uniform height as compared to the unmowed plants; (3) in most cases, the number of lateral buds forced on mowed plants was significantly greater than those left unmowed. The peak number of lateral buds forced was generally noted from plants mowed 2 to 4 weeks before blooming was initiated on the unmowed plants of any one species; (4) mowing extended and delayed the blooming of all species except shell-leaf penstemon. The longest period of delay was 2 months in the case of grayhead prairie coneflower; (5) the number of flowers produced per plant was generally reduced by mowing. However, the esthetic value of the taller species was enhanced because mowing eliminated the open type of growth associated with lodging." /FHWA/ HRIS No. 265040.

Hottenstein, W. L. (390)

1963. Common sense turf management of today's highways. Highway Research Record No. 23, Hwy. Res. Board, pp. 66-69.

"The turf management techniques for highways, especially mowing and herbicide methods, are reviewed and compared. An effective roadside turf management program has been proposed. The program consists of zoning the right-of-way into mow and non-mow areas, using herbicides as a supplementary tool to mowing for eliminating weeds and encouraging desirable grasses, applying sterilants to eliminate vegetation and the need for hard mowing around posts and under guardrails, and employing equipment best suited to the character of the roadside area." (Author) HRIS No. 217971.

Huffine, W. W., L. W. Reed, and G. W. Roach. (391)

Undated. Maintenance of vegetative ground covers on Oklahoma Highways. HPR, BPR No. 63-03-3, Part II. Oklahoma State University, U.S. Bureau of Public Roads.

"In a final report for this study of ground cover maintenance along Oklahoma highways, the researchers recommend: (1) no mowing on slopes and limited mowing on those areas usually cut frequently (e.g., medians), (2) do not blade-off shoulder areas supporting a turf cover, and (3) do not borrow from the top of stablized cuts to repair fill slopes..." /BPR/ HRIS No. 218020.

Maryland State Roads Commission. (392)

1968. Mowing standards. Bureau of Landscape Architecture, 5 pages. This well illustrated (by drawings) bookler provides instructions regarding mowing and herbicide treatment of highway right-of-way vegetation in Maryland. No mention is made of timing.

McCully, W. G., and W. J. Bowmer. (393)

1971. Evaluation of soil sterilant herbicides for roadsides. Texas Transportation Institute, Texas Highway Department, and Federal Highway Administration. Interim Report, 33 pages.

Summary:
"Forty-four herbicides were used along and in various combinations as soil sterilant treatments on roadsides. Usually three rates of applications were employed, the highest rate surpassing the recommended label rate. Applications in June and August were equally effective and were superior to October treatments. Although many of the treatments, especially mixtures of herbicides, were effective soil sterilants, they have very limited use on roadsides. In every case treatments giving acceptable soil sterilization moved downslope from the point of application, and the resultant bare soil was subjected to erosion. This adverse effect could not be overcome with spray volumes up to 400 gal/A nor with asphalt emulsion as a carrier or cap over the treated area. Greater movement downslope was experienced with granular forms than with the same material applied as sprays. Higher rates of the same herbicide moved more than lower rates." /FHWA/ HRIS No. 204654.

McCully, W. G., W. J. Bowmer, and J. L. Stubbendieck. (394)

1970. Problems in establishing or maintaining vegetation on roadsides. Texas Transportation Institute. Research Report 142-1, 18 pp.

From summary:
"Tests were installed during 1968-70 to investigate the modification of roadside soil materials restricted by physical or chemical characteristics limiting plant growth, to determine the utility of plant materials for roadside use, and to develop chemical treatments for controlling unwanted vegetation...Perennial weeds growing in shoulder pavements were controlled by program sprays of fenac/dicamba combined with either prometone or bromanil. Mowing adjacent to median plantings may be facilitated by a combination contact-pre-emergence treatment." (Author) HRIS No. 205165.

Morre, D. James. (395)

1974. A minimum-cost, environmentally safe program of herbicide maintenance for Indiana roadsides. Transportation Research Record 506, Transportation Research Board (Washington, D.C., Pages 85-93.

"The program recommended and implemented for the State of Indiana involves combined herbicide and mowing treatments. Environmental and crop safety are ensured by use of nontoxic amine formulations of herbicides and late-fall and early-spring applications. Effectiveness and low cost are provided by a 3-year rotation in combination with reduced mowing."

Late-fall and early-spring herbicide applications are scheduled to avoid crops and at the dormant time for trees and shrubs. "Only nontoxic 2,4-D amine formulations are recommended. The potential hazard of pure 2,4-D to fish or algae from terrestrial runoff water (concentrations of 0.1 ppm or less) or direct or accidental contamination (3 lb./acre applied to 6 in. of water) is nil. Studies...showed that 2,4-D ester derivatives are subsequently more toxic than the parent acid; fish and phytoplankton kills result at the 3 lb/acre rate applied directly to water." The author discusses other herbicides presently under investigation to be directed at 2,4-D resistant weed species. Bibliography of 5 titles.

Morre, D. J., W. R. Eisinger, and H. W. Mussell (396)

1967. Tordon 2-4-D dimethylsulfoxide combination herbicides for use in roadside development. Purdue and Indiana State Highway Commission. JHRP No. 32, U.S. Transportation Department, U.S. Federal Highway Administration, U.S. Bureau of Public Roads. 67 pp., 33 figures, 18 tables, 80 references.

"A potent (but somewhat expensive) new herbicide providing control of a broad spectrum of plant species was selected for initial use in combination with the standard roadside herbicides 2,4-D and 2,4,5-T...It is concluded that Tordon is more toxic to plants than either of the herbicides considered. The effects induced by Tordon are more severe and persistent for a longer period of time." (Author) HRIS No. 205515.

Morre, D. J. and A. D. Werderitsh. (397)

1972. Chemical weed control. Purdue and Indiana State Highway Commission JHRP. 102 pp.

Summary:
"This study evaluates herbicides and herbicide combinations for roadside weed control and control of difficult and obnoxious weeds. Development of specific new weed control practices was concerned principally with tordon - 2,4-D combinations, which have proven to be potent herbicides for control of a wide range of broad-leaved herbaceous and woody roadside vegetation without injury to desirable species. With most perennial and biennial species, treatment in the fall when translocation of assimilates was largely to below ground parts, was found most effective in preventing regrowth. The findings point to the possibility of an eventual three-year (environmentally safe) spraying rotation in combination with one-cycle mowing which can be developed into a maximum benefit, low-cost maintenance program for Indiana roadsides with cost savings in excess of $300,000 annually." HRIS No. 205219.

Parker, Burton C. (398)

1962. Roadside maintenance practices on interstate and freeway systems. Highway Research Board, Report of Committee on Roadside Development, National Academy of Sciences, National Research Council, pp. 56-58.

The author points out that increased maintenance responsibilities with no appropriate increase in budget has caused the permanent Massachusetts' maintenance labor force to be held to a minimum. The permanent labor force is supplemented with emergency laborers and rented equipment when needed. Annual contract activities include tree removal, tree trimming, tree planting, DDT mist blower and aerial spraying for Dutch elm disease control, hydraulic soil sterilant, and custom spraying, roadside spraying and fertilization and grass mowing. The policy for tree removal and tree trimming is described. The policy requires the removal of all dead, diseased and dangerous trees in an annual program, and by removing all dead, diseased and broken branches in an annual tree trimming program, this has resulted in practically no work for tree crews during and following storm periods.

Riddle, J. R. (399)

1972. Environmental considerations in snow removal, mowing and spraying of roadsides. Ohio Highway Engineering Conference Proc., pp. 265-70.

"Damages to trees and shrubs and water contamination result from the use of salt for snow removal. The environmental effects of mowing and spraying, referred to as vegetation control, are also discussed. Recommendations are made for salt storage, and several rules to follow for a uniform weed and brush roadside management program are presented." (Author) HRIS No. 219176.

Schuster, Joseph L. (400)

1967. The relation of understory vegetation to cutting treatments and habitat factors in an east Texas pine-hardwood type. Southwestern Naturalist 12(4): 339-364. (Texas Technological College, Lubbock, Texas)

Abstract:
"The composition, frequency and occurrence and production of understory vegetation under various stands of a loblolly-shortleaf pine-hardwood forest is described. Variation in timber stand brought about differences in species composition and frequency of occurrence, with woody and forb species being favored under denser timber stands and grasses favored in stands opened by cutting. Forage production of all forage classes increased in proportion

to reduction of timber stand factors. Soil and topographic factors influenced production, but were apparently overshadowed by timber stand factors." WR 129:14.

E. EFFECTS OF ANIMALS ON PLANTINGS, VEGETATION MANAGEMENT, AND OTHER ASPECTS OF THE HIGHWAY SYSTEM: Problems of Control.

Anonymous. (401)

1937. Deer and cattle damage backslopes. Michigan Roads and Construction 34(18):4.

Hoofs of deer feeding on grass along highways has torn up sod placed to prevent erosion on steep backslopes. Maintenance workers to start experiments to find suitable vines which can be planted on backslopes in place of sod." (DOT abstract)

Anonymous. (402)

1975. Battling the budworm. Time (magazine-section on Environment), Page 80 (April 28, 1975).

The author, in discussing the problem of budworms stated: "Though the budworm infestation has been a fact of Maine's forest life for years, it grew to epidemic proportions last July, after the caterpillars became moths. In addition to Maine's native budworms, hordes more were swept southeast on prevailing winds from Canada, where 75 million acres are also infested. 'Clouds' of the insects -- one measured 64 miles long by 16 miles wide -- were tracked by the U.S. Weather Service's radar operators. When the moths landed, they clogged factory ventilators and auto radiators; their crushed bodies coated highways with a slippery, accident-causing goo; in some places, people shoveled the bugs off their porches like snow..."

Chapman, Floyd B. (403)

1939. Use of chemical sprays to increase yields of fruits utilized by wildlife. Journal of Wildlife Management 3(2): 141-143, 1 table.

Selected herbicides can be used to control vegetation in ways either to improve or to reduce the value of cover for wildlife. In this article the author points out that certain insect pests and fungus diseases, some of which attack domestic fruits also, are responsible for decreased palatability, premature abscission, decay before ripening or complete destruction of wild fruits. He suggests that in managed areas certain chemical sprays (insecticides) might be used to improve the yield and quality of certain fruits and to prolong their availability into critical periods of the year for wildlife consumption. Although he indicated excellent results with use of two applications of a lead arsenate spray on wild grape vines to control the grape berry moth, any use of insecticides to improve conditions for wildlife would require great care due to potential toxicity to the species to be benefitted.

Clougherty, J. L. (404)

1970. For the birds. Federal Highway Admin., U.S., Special Report - Use of Equipment and Methods of Maintenance, pp. 10-12.

Summary:
"About 200,000 starling roost every night on the truss members of the underside of the Fore River Bridge in Quincy, Mass., causing three main problems. The corrosive effect of their droppings makes it impossible to keep a protective coat of paint on the steel truss members; the birds harass bridge maintenance men; and the droppings, if allowed to accumulate, could present a serious health hazard. The birds were not poisoned because of the danger that pet cats and dogs would eat their bodies. Other methods were tried without success, including dropping nets from the bridge railings to prevent the birds from nesting. Unfortunately, the nets were dropped at night, trapping the birds until they fought their way out. The torn nets were removed, and the birds returned." HRIS No. 218847.

Eschmeyer, Paul H. and Van T. Harris. (405)

1974. Bibliography of research publications of the U.S. Bureau of Sport Fisheries and Wildlife, 1928-72. Resource Publication 120, U.S. Fish and Wildlife Service, Washington, D.C., v +154 pages.

The publications listed constitute, primarily, a bibliography of more than 4,500 publications that have resulted from freshwater fishery research and

and wildlife research sponsored wholly or partly by the Department of the Interior during the period 1939-72. Separate lists of publications, arranged alphabetically by author, are given for each of 17 fishery research and 6 wildlife research laboratories, stations, investigations, or centers. Many of the wildlife publications, especially those produced from the Denver Wildlife Research Center (pages 97-115) and the Patuxent Wildlife Research Center (pages 124-154), deal with methods of controlling birds and mammals, some of which may be a factor in establishing and maintaining roadside plantings of shrubs or other vegetation. Other publications listed include papers relating to vegetation control, habitat management, animal behavior, and other topics directly or indirectly concerned with highway-wildlife relations.

Garrison, George A. and A. W. Moore. (406)

1956. Relation of the Dallas pocket gopher to establishment and maintenance of range grass plantings. Journal of Range Management 9(4): 181-184, 4 figs.

"From conclusions: 'The damage caused by Dallas pocket gophers (Thomomys talpoides quadratus) to range grass plantings and the difference in vulnerability of grasses by age and species were shown by a study in eastern Oregon. Old-drill-row plants in 9 to 11 year old plantings of crested wheatgrass were not greatly affected by current gopher burrowing and feeding. Establishment of natural reproduction between drill rows of this bunchgrass, however, was definitely impaired by gopher activities.' Close spacing of drill rows is therefore advisable if pocket gophers are prevalent. 'Seedbed preparation, which destroyed all broad-leaved herbs preferred by gophers, rendered new planting sites unattractive to gophers until the new grass stand was developed enough to be a source of gopher food. When unprotected from gophers, new stands of tall oatgrass were the first to be damaged and suffered most. Wheatgrass stands were much less attractive to gophers...The practice of direct gopher control cannot be eliminated for all site conditions and gopher pressures; however, a seedbed free of broad-leaved herbs and planted to rhizomatous wheatgrasses would probably need only moderate control for the first three growing seasons and none after the fifth'." WR No. 86.

Greaves, J. H. and F. P. Rowe (Infestation Control Lab., M.A.F.F., Talworth, Surrey, United Kinddom). (407)

1969. Responses of confined rodent populations to an ultrasound generator. Journal of Wildlife Management 33 (2): 409-417.

The authors concluded that strategically placed units of the type used in this laboratory study (a Galton's whistle operated by an electrically driven air compressor and resulting in 40 ms bursts of sounds at the rate of 25 per second and at a frequency produced by the transducer varying continuously in each burst between 24 kHz and 28 kHz) "...may prevent or reduce invasion of premises with few entry points. In infested premises, it is also possible that such units could be used to divert rodents from their normal food to poisoned baits. Field trials are required to elucidate these points." They pointed out that at a distance of one foot from the transducer, the intensity of the sound above 20 kHz was about 120 db..."There were no significant harmonics..."

Hooven, Edward F. (408)

1971. Pocket gopher damage on ponderosa pine plantations in southwestern Oregon. Journal of Wildlife Management, 35(2): 346-353.

From author's abstract:
"Pocket gophers (Thomomys monticola) often make regeneration of ponderosa pine (Pinus ponderosa) difficult in Oregon, because, after logging, the pocket gophers increase in substantial numbers. Efforts to reforest with ponderosa pine can be nullified if many pocket gophers are present, and in such localities control efforts must be constant..."

In their discussion the author states, "Reforestation requires protective measures against animals as well as against adverse environmental conditions."

Hull, A. C., Jr. (409)

1971. Effect of spraying with 2,4-D upon abundance of pocket gophers in Franklin Basin, Idaho. Journal of Range Management 24(3): 230-232.

"Four 50 x 50 foot plots were sprayed with 2 lb./acre 2,4-D in 1959, 1960, 1965 and 1969 to kill fleshy-rooted, spring-growing plants and annuals. These plants are the major source of food for pocket gophers. Averaging the ten-year period, 1960-69, spraying reduced gopher mounds by 93% and winter casts by 94% when compared to the unsprayed areas." Bibliography of 10 titles.

Johnson, Donald R., and Richard M. Hansen. (410)

1969. Effects of range treatment with 2,4-D on rodent populations. Journal of Wildlife Management 33(1): 125-132.

Authors' abstract:
The treatment of perennial forb and shrub-grass ranges with 2,4-D in western Colorado usually produced an increase in grass cover and a decrease in the cover of most forbs and shrubs. Recovery time of herbicide-sensitive species varied. Dandelion reestablished dominance within 6 years following treatment. The density and litter size of the deer mouse (Peromyscus maniculatus) was little affected by the 2,4-D treatment. The density of northern pocket gophers (Thomomys talpoides) and least chipmunks (Eutamias minimus) was reduced. Montane voles (Microtus montanus) increased in abundance following treatment of a perennial forb range. With the reestablishment of forb dominance, pocket gopher and vole populations returned to pretreatment levels. Density changes of pocket gophers on treated ranges were due primarily to changes in the availability of food, those of chipmunks to both food and cover, and those of vole to cover changes."

Krefting, Laurits W., and Joseph H. Stoeckeler. (411)

1953. Effect of simulated snowshoe hare and deer damage on planted conifers in the Lake States. Journal of Wildlife Management 17(4): 487-494.

Results of this study indicated that in planting jack pine, red pine, white pine and white spruce nursery stock, the older age classes of planting stock -- especially the transplant trees -- should be used where white-tailed deer and snowshoe hare damage may occur because they can better withstand browsing. In clipping experiments to simulate hare and deer damage, white spruce was the lowest in sensitivity to clipping because it has a good scattering of internodal buds capable of developing a new leader; in contrast, the pines usually die back to the next node. Browse-tolerant plants should be selected where the animal damage problem is serious.

Kurth, W. W. (412)

1967. Muskrats and motorists: serving two masters. Public Works 98 (8): 114-115, 3 photos.

Summary:
"A small aquatic rodent, the muskrat, created a major problem in Klamath County, Oregon, by burrowing too close to road surfaces causing instant pot homes. High water levels in the marsh caused the muskrats to burrow higher and higher into the roadbed in search of dry homes. The roads caved in over the dens and areas as large as 4 x 4 posed dangerous obstacles for motorists. The marsh area was a national refuge precluding poisoning of the animals. A two-foot lift of a pit run base material was laid on the roadbed across the marsh but failures continued. Berms were constructed twenty feet wide adjacent to the road across the marsh. The berms were planned to be above the high water level and provide dry homes for the muskrat population during periods of high water. Muskrats will subdivide the new fill and, hopefully, lack reasons to continue excavations beneath the road surface." HRIS No. 218284.

Laramie, Henry A., Jr. (413)

1963. A device for control of problem beavers. Journal of Wildlife Management, 27(3): 471-476.

Beavers (Castor canadensis) sometimes build dams in areas which will result in flooding of roads; sometimes they will plug up a road culvert in connection with their dam building. This article describes the use of fiber or wood pipes with multiple small openings along the bottom portion to produce the desired water level, i.e. the pipes are placed through the beaver dam for partial drainage without the need to destroy the entire dam. A device for clearing debris from a small clogged culvert and means for preventing the beavers from rebuilding the dam in the culvert are described, also.

Mann, William F., Jr., H. J. Derr and Brooke Meanley. (414)

1955. A bird repellent for longleaf seeding. U.S. Forest Service, Southern Forest Exp. Sta. (New Orleans, La.) Southern Forest Notes No. 99, 2 pages.

"Morkit, which contains anthraguinone, is best bird repellent known for treating seed of longleaf pine. Total cost of chemical, sticker, and labor has so far averaged about 15¢ per lb. of seed. The treatment was successful in both 1953 and 1954. 3,050 to 4,500 seedlings per acre were obtained under adverse conditions after sowing about 12,500 seeds (3 lbs.) per acre. Untreated seed gave very poor results." (In direct seeding tests). WR No. 83.

Marsh, Rex E., and Walter E. Howard. (415)

1969. Evaluation of mestranol as a reproduction inhibitor of Norway rats in garbage dumps. Journal of Wildlife Management, 33 (1): 133-138.

Norway rats may sometimes infest a garbage dump such as might be found in connection with some roadside parks and recreation areas. The authors report here on the potential use of mestranol, a substance used in some human birth-control pills, as a reproductive inhibitor in rats. They stated (from abstract): "Bait treated with 0.05 percent mestranol was spread over two of the dumps on three occasions at intervals of about 30 days. A change in age structure of the rat populations in the dumps indicated that reproduction had been inhibited by the first application of mestranol. The effect on reproduction was short-lived, however, presumably because of poor bait acceptance following the initial treatment.

Meanley, Brooke, W. F. Mann, Jr., and H. J. Derr. (416)

1956. New bird repellents for longleaf seed. U.S. Forest Service, Southern Forest Exp. Sta. (New Orleans, La.)

"Morkit, a good bird repellent, has been withdrawn from the U.S. market. Fortunately, recent tests show that Arasan Seed Disinfectant and Protectant is as good or better. This compound (50% tetramethyl thiuram disulphide) gave somewhat better results in field tests than either Morkit or crude anthraguinone. The latter cannot be sold as a bird repellent until licensing negotiations are completed. Observations in all tests indicated that Arasan is an effective repellent, it is slightly irritating to eyes, nose and throat. Treated seed should be sown as soon as possible, as viability may be impaired by storage. Recommended rate of application is 1 lb. of 50% Arasan to 6 lbs. of seed." WR No. 86.

Nummi, A. A. (417)

1972. For the birds - follow-up. FHWA Special Report, pp. 76-80.

Summary: "The cleaning problem and the health and safety hazards to maintenance personnel created by bird droppings is discussed. The corrosive action of the droppings is detrimental to the paint and steel structure. The successful use of a contact poison pesticide is reviewed. The material was applied by maintenance personnel under supervision of licensed personnel. Details of the application process are given. An estimate was made of the number of birds missing from their roosting areas several weeks after application of the pesticide. Equipment used in the application procedure is described. HRIS No. 219081.

Pank, Larry F. (418)

1974. A bibliography on seed-eating mammals and birds that affect forest regeneration. U. S. Department of the Interior, Fish and Wildlife Service, Special Scientific Report -- Wildlife No. 174, 28 pp.

As noted in the introduction to this bibliography, birds and mammals that feed on tree seed can seriously delay or prevent forest generation and suitable methods to control these losses may dictate whether reforestation by artificial seeding or natural seed fall is feasible. The author points out that endrin, thiram, and 1080 have been the primary chemicals available for the protection of tree seed on the 200, 000 acres seeded annually in the United States and that the potential hazards of endrin and 1080 have resulted in renewed efforts to find alternatives.

"...References included were restricted to the following subjects:

1. Studies identifying birds and mammals that consume forest-tree seed.
2. Methods of reducing populations of seed-eating animals (e.g., toxic baits, toxic seed treatments, and habitat manipulation).
3. Methods of deterring or repelling seed-eating species (e.g., mechanical barriers, silvicultural

practices, and chemical and physical seed treatments), and
4. The effects of control measures on nontarget species and seed viability.
"Emphasis was placed on references covering the protection of conifer seed, although pertinent material on the protection of rangeland and deciduous-tree seed was included...Reference sources were restricted to journals related to forestry, mammalogy, and wildlife, and technical papers and articles published by public and private institutions concerned with forest regeneration, written in English and appearing between 1900 and 1971."

Pinnock, Dudley and D. V. Cassidy (University of California, Berkeley and California State Div. of Highways). (419)

1973. Nonchemical means of pest management in the highway landscape. Pages 155-158 in "Environmental considerations in planning, design, and construction." Highway Research Board, Div. of Engineering, Natural Research Council, National Academy of Sciences - National Academy of Engineering (Washington, D.C., price $5) Special Report 138. 161 pages.

The authors indicate that in California, although most pest outbreaks in highway landscapes can be controlled by chemical insecticides, there is a tendency to diminishing periods of control following application. Chemicals may also eliminate beneficial species of insects, some of which help keep injurious species in check. Also the pest may develop resistance to the insecticide used for control. In California, where a large proportion of the most damaging landscape pests are the caterpillars of various moths, a bacterium, (Bacillus thuringiensis) has been substituted as a first phase replacement for the chemicals previously used. This bacterium is apparently lethal only to the caterpillars and does not harm beneficial insects, fishes, birds, mammals or man. Other types of biological control are mentioned and the importance of their integration with and implementation into statewide pest control programs is stressed.

Smith, Clarence F., and Shaler E. Aldous. (420)

1947. The influence of mammals and birds in retarding artificial and natural reseeding of coniferous forests in the United States. Journal of Forestry 45 (5): 361-369, 1 table.

"'A total of 44 small mammal and 37 bird species have been found to eat seeds'...The species known to consume conifer seeds are listed in a table that includes references to the sources of information. The quantity of seeds consumed by mammals and birds is discussed and control measures are considered...Bibliography of 65 titles." WR No. 49.

Sprock, C. Merle, Walter E. Howard, and Fred C. Jacob. (421)

1967. Sound as a deterrent to rats and mice. Journal of Wildlife Management, 31(4): 729-740.

This research, done in connection with efforts to develop methods for repelling or controlling rats (Rattus norvegicus), showed that under laboratory conditions, a continuous sound at less than 120 db (decibels) at a given frequency from 4-19 kc (kilocycles per second) was ineffective. "... When the sound output was intermittent and the frequency varied an entire octave (6-12kc), and was out of phase with the off-on timer, wild rats were effectively repelled...Only under laboratory conditions can wild rodents apparently be controlled by sounds that will cause them to die from epileptiform seizures. The necessary intensities of 130 db or above are too costly and dangerous for use in the field..."

Stewart, Paul A., and Eugene H. Dustman. (422)

1955. The use of auditory stimuli for flushing ring-necked pheasants. Journal of Wildlife Management, 19(3): 403-405.

From authors' summary:
"Observations were made from a blend of the responses of incubating ring-necked pheasants to various auditory stimuli. A number of natural sounds, presumed to be of a disturbing nature, were recorded and presented to the nesting birds with the use of a tape recording machine... Freezing immobility sometimes occurred when the birds were exposed to a sound of about 60 decibels above the average background noise. There was a slightly greater sensitivity to sounds of about 800 cycles per second than to other sounds, but no indication was encountered that any auditory signal might have value for frightening ring-necked pheasants from their nests ahead of the mowing machine."

Reference was made to experiments conducted with flushing bars attached to mowers to prevent pheasants mortality: English, P. F., 1934. Game bird flushing apparatus, Michigan Dept. of Conservation, Game Division, Bulletin No. 2, 8 pages; and Warvel, H. E., 1949. Development of an upland game flushing bar, unpublished Masters Thesis, Ohio State University Library, Columbus, Ohio.

U. S. Water Resources Council (Washington, D.C.) (423)

1974. A study of mosquito prevention and control problems associated with stream modification projects. (Prepared for the Water Resources Council by the Institute of Rural Environmental Health, Department of Microbiology, College of Veterinary Medicine and Biomedical Sciences, Colorado State Univ., John R. Bagby, principal investigator). 50 pages, 65 cited references, plus general bibliography, 9 colored photos.

The authors point out that earlier stream modification projects usually had only one objective--that of flood control, but that in recent years such projects have become multipurpose with much emphasis directed toward people recognition, protection and enhancement of environmental factors. To the extent that stream modification measures reduce flooding of floodplain habitats, these projects, the authors state, are beneficial to vector control. "On the other hand, to the extent that stream channels are blocked and surface runoff impounded behind dikes and levees, or in retardation basins, these projects adversely affect vector control. The Frenchman Creek Project in Nebraska, particularly the modification done in conjunction with highway construction, is an excellent example of a stream modification project that has adversely affected vector control. The vector control problems resulted from isolation of oxbows with no provision for adequate drainage or other modifications that would have minimized mosquito problems."

Some wildlife biologists might question some of the recommended vector prevention and control measures when viewed from the standpoint of fish and wildlife production.

Vesall, David Robert Gensch and Ray Hyman (424)

1947. Beaver - timber problem in Minnesota's "Big Bog". Conservation Volunteer (Minnesota Department of Conservation, State Office Building, St. Paul) 10 (57): 45-50, 3 photos.

"The area is described; it was futilely drained for agriculture in 1915; about two decades later, control dams were installed in the ditches to reduce the fire hazard and improve the habitat for waterfowl and other wildlife. Beavers increased... Damage to timber was observed on about 19 acres for each mile of ditch; roads used for logging, patrol and fire fighting were inundated or undermined ---" WR No. 49.

Zorb, Gordon L. (425)

1957. Effectiveness of two flushing devices used in hay mowing. Journal of Wildlife Management, 21 (4): 461-462.

Discusses experiments with the "Ohio" flushing bar and with an adaptation of this bar in which the noise and blast of the unmuffled tractor motor were directed into the hay about 13 feet in front of of the cutter bar. Although there were sparse populations of pheasants and rabbits on the study sites, the tests failed to show that these devices reduced hayfield mortalities -- findings at variance with findings of other investigators.

II. OPPORTUNITIES FOR ENHANCING FISH AND WILDLIFE AND MITIGATING OR REDUCING DAMAGE TO THE RESOURCE

A. FENCING AND OTHER MEASURES FOR REDUCING HIGHWAY ANIMAL MORTALITY & ANIMAL VEHICLE ACCIDENTS

Anonymous (426)

1971. Mirrors quell deer kill. Better Roads, December, 1971, page 6.

Summary: "The Missouri Highway Department is installing mirrors along certain sections of their highways in an attempt to cut deer-vehicle accidents. Two round, three-inch mirrors mounted at 45-degree angles about four feet above the ground are installed at 75-foot intervals on both sides of the highway. Headlights from passing cars reflect against the mirrors causing light beams to flicker into the cuts, draws, and timber alongside roadways. These sharp, pencil-like light beams startle the deer and cause them to stop. Once the light beams stop flickering, the deer then cross in safety." HRIS No. 226320.

Anonymous (427)

1972. Deer mirrors in Missouri. American Highways 51(1):17

Summary: "The effectiveness and use of deer mirrors by the Missouri Highway Department are reportedly favorable. The number of deer-vehicle accidents were cut down enormously while in use. The device consists of two round three-inch mirrors mounted at 45 degree angles about four feet above the ground. These are installed on a staggered system at about 75 foot intervals on both sides of the highway depending on the terrain bordering the highway and the number of deer crossing. Headlights from passing cars reflect against the mirrors causing light to flicker sharp, pencil-like beams startling the deer and causing them to stop. Once the light beams stop flickering, the deer safely cross." HRIS No. 221668

Blair, Robert M., James A. Hays, and Louis Brunett (428)

1963. Stream-crossing structure for deer fence. Journal of Wildlife Management 27 (1):129-132, 2 figures.

Describes and illustrates by drawing and photograph installation of fences across a stream channel so as to render the fence deerproof and withstand floods.

Blaisdell, James A. and Richard L. Hubbard (429)

1956. An "outrigger" type deer fence. U. S. Forest Service, California Forest & Range Exp. Sta. (Berkeley) Forest Research Notes No. 108. 3 pages, 1 figure.

"This fence, designed by A. L. Hormay, is only 4.5 ft. above ground but has an outrigger extension that slopes from top of fence to ground 8 ft. from fence. The idea is to keep deer from getting close enough to jump fence. 'This type of construction has been used to exclude deer from study plots on three east Sierra deer winter ranges. It has given excellent results through three winters. To date, there has been no record of a deer crossing one of these fences.' Cost was between 1 and 2 dollars per linear foot. but could be reduced somewhat by economies suggested. Outriggers might be attached to standard sheep fences. It is stated that deer have been known to dig under fences. This probably does not happen often enough to justify burying the lower part of the fence." W R No. 87

Crane, Don, et al. (430)

1973. Monitor potentially critical deer-vehicle accident areas statewide. Project number W-38-R-27. Game Research Report, Colorado Division of Wildlife. Pages 163-170.

"The number and location of deer-vehicle accidents were monitored in five general areas of Colorado. Recommendations...(such as erection of 9-foot fences and attendant structures) to alleviate deer-vehicle accidents were submitted to the Division of Highways when warranted." Bibliography of 3 titles.

Garrett, Bill (431)

1955. Electric fence repels deer.

Texas Game & Fish 13 (3):9, illus.

"Single strand fence that carries continuous rather than intermittent current. This fence is placed outside field at distance equal to height of main fence of field. Directions are given for materials and installation." W R No. 80

Green, Larry, Thomas N. Woodard, Dale F. Reed and (432)
Thomas M. Pojar

1973. Effect of lighted deer crossing signs on number of deer killed by vehicles. Project Number W-38-R-27. Game Research Report, Colorado Division of Wildlife. Pages 193-195.

"Two lighted, animated deer crossing signs were installed adjacent to State Highway 82, south of Glenwood Springs, Colorado, delineating a one-mile segment of highway where deer-vehicle accidents frequently occurred. The signs were turned on and off for alternate weekly periods in 1972 and 1973 during the time when most deer-auto accidents were expected to occur. Numbers of deer crossing the highway were estimated and all deer-vehicle accidents were documented. The number of crossings per deer killed on the highway was 56.9:1 and 56.5:1 with the signs on and with the signs off respectively. There was no difference in the ratios ($P > 0.50$). Mean vehicle speeds were lower ($P < 0.05$) with the signs on but the reduction in speed was less than 3.0 mph. When three deer carcasses were placed along the highway with the signs on the mean vehicular speed dropped 6.27 mph. With the signs off the difference was 7.85 mph. There was no significant difference in the mean speeds ($P < 0.001$) when dead deer were on the highway whether the signs were on or off. Apparently motorists did see the sign but their response in the form of speed reduction and/or increased awareness was not sufficient to affect the crossings per kill ratio.

In areas where deer-vehicle accidents are especially numerous the motorist should be given some warning for public relations and liability reasons. A prototype of the lighted, animated sign cost $2,000.00 (1971 prices) and line power (110 volt) was needed. Use of conventional signs which cost $94.00 (1973 prices) each for materials, is more practical."

Halls, L. K., C. E. Boyd, D. W. Lay and P. D. Goodrum (433)

1965. Deer fence construction and costs. Journal of Wildlife Management 29 (4):885-888.

Authors' abstract: "Two 153-acre deer pens consisting of 4.4 miles of boundary fence 8½ feet high and 0.8 mile of fenced ¼-acre enclosures were constructed in 1964 at a total cost of $16,429: $6,816 for labor and right-of-way clearing and $9,613 for materials. Specifications and costs of material used in 5.2 miles of fence on the Stephen F. Austin Experimental Forest near Nacogdoches, Texas are given in detail, including extra heavy wire, etc., needed for fencing across drainages."

Jones, Milton B., and William M. Longhurst (434)

1958. Overhanging deer fences. Journal of Wildlife Management, 22(3): 325-326.

Describes tests of effectiveness, against deer, of several sloping type fences constructed at the University of California's Hopland Field Station. These were built with the knowledge that deer must be relatively close to a fence to jump over it and usually will try to go through a fence rather than jump it. The fences were constructed of two inch mesh, 20-gauge galvanized chicken wire. The first experimental fence consisted of a 2-foot vertical segment with a 6-foot 25 degree slope extension up to a height of 4 and ½ feet suspended by a second row of posts in such a way that the approaching deer go under the sloping wire before contacting the vertical fence. A variation of this fence consisted of a 4-foot vertical segment and a 4-foot horizontal overhang from the top of the fence. It was stated that this type of construction was adaptable to common mesh-wire sheep fences. A third type consisted only of the slanted portion of wire-mesh fence, the lower edge being fastened to the ground with stakes and extending upward at an angle of approximately 49 degrees. These fences work in one direction only for deer but can be built so as to turn sheep from both directions. Costs are much less than the conventional 8-foot upright deer fence.

Mapston, Raymond D., Rex S. Zobell, Kenneth B. Winter, and William D. Dooley. (435)

1970. A pass for antelope in sheep-tight fences. Journal Range Management 23 (6):457-459, 3 figs.

"Highlight: A Wyoming study has resulted in development for an inexpensive, easily installed pass structure that facilitates movement of pronghorn antelope through fences and retains livestock. Patterned after the common cattleguard, the antelope pass consists of a 5.5 x 6-foot, lightweight grill installed on timbers over a 15 inch pit with ramps on each end. Proper location and installation are essential to obtain use by antelope. Adjustment and learning through experience and association are important factors in the effectiveness of pass structures. Total cost, including installation, is less than $100.00 per unit." W R No. 140:87

McAtee, W. L. (436)

1939. The electric fence in wildlife management. Journal of Wildlife Management 3(1): 1-13, 2 pls.

"Electric fencing promises to solve outstanding difficulties of the wildlife manager, but the device needs perfecting and constantly cautious and intelligent use. Types of fences, means of electrifying them, and methods and difficulties of installation are described." W R No. 20.

McKnight, Tom L. (437)

1969. Barrier fencing for vermin control in Australia. Geographical Review 59 (3):330-347, 9 figs.

"Vermin control, vermin fencing in Australia, types of fences, effectiveness of the fences, vermin fencing today, and a summary view of the fencing program are the major topics of discussion." W R No. 135:5

Messner, Harold E., Donald R. Dietz, and E. Chester Garrett. (438)

1973. A modification of the slanting deer fence. Journal of Range Management 26 (3): 233-235.

"A slanting deer fence is designed that requires less mesh wire and shorter posts than the standard

upright deer fence. The slanting fence blends well into forest and meadow backgrounds and will withstand greater snow loads than existing slanting deer fences." Bibliography of 5 titles.

Pojar, Thomas M., R. A. Prosence, D. F. Reed, and T. N. Woodard. (439)

1975. Effectiveness of a lighted, animated deer crossing sign. Journal of Wildlife Management, 39(1): 87-91.

Authors' abstract: "Two lighted, animated deer crossing signs were installed adjacent to State Highway 82 south of Glenwood Springs, Colorado, delineating a 1.61 km (1 mile) segment of highway where deer-vehicle accidents frequently occurred. The signs were turned on and off for alternate weekly periods of 1972 and 1973 during the times when most deer-auto accidents were expected to occur. Numbers of deer crossing the highways were estimated and all deer-vehicle accidents were documented. The number of crossing per deer killed on the highway was 56.9:1 and 56.5:1 with the signs on and with the signs off, respectively. There was no difference in the ratios ($P > 0.50$). Mean vehicle speeds were lower ($P < 0.05$) with the signs on but the reduction in speed was less than 4.83 kmph (3.0 mph). There was no significant difference in the mean speeds ($P > 0.50$) when dead deer were on the highway whether the signs were on or off. Apparently motorists did see the sign but their response in the form of speed reduction and/or increased awareness was not sufficient to affect the crossings per kill ratio."

The authors reasoned that since these lighted, animated signs were not effective in reducing the number of deer-vehicle accidents, it seems unlikely that conventional deer crossing signs that have been widely used on public highways in an effort to reduce deer losses are effective either; but they state: "However, in areas where deer-vehicle accidents are especially numerous, warning signs may be useful for public relations and liability reasons. In these areas conventional signs, which cost $94 (1973 prices) each for materials, are more practical in terms of cost and maintenance than the animated sign..."

As in the case of the area discussed by Reilly and Green (1974) in Michigan, where there is heavy accident rate involving deer, the Glenwood Springs area is also a wintering area for deer.

Pojar, Thomas M., Dale F. Reed and T. C. Reseigh (440)

1972. Highway construction -- motorist and deer safety. Colorado Division of Highways and Colorado Division of Wildlife, 5 pages.

This article states that there are four points that are important to all western states in their efforts to mitigate deer-vehicle accidents. "First, the opportunity for input concerning highway construction projects is guaranteed by the National Environmental Policy Act. Second, in order to produce credible input, factual information is necessary. Third, evaluation of devices or procedures is helpful in making future recommendations. And fourth, the practice of providing for delayed construction of deer-auto protective devices is a practical approach when circumstances do not permit advance identification of problem areas."

"In Colorado it is estimated that between 5,000 and 6,000 deer-vehicle accidents occur annually... Deer-vehicle accidents result in about 1.6 million dollars of property damage to vehicles annually. In deaths of deer they result in loss of between 5 and 10 percent of the annual legal deer harvest." Procedures and devices being evaluated in Colorado, to lessen deer-vehicle accidents are, a deer underpass with adjoining 8-foot fence and a 1.1 mile 8-foot fence parallel to a 4-lane highway which has reduced the number of deer crossings by 87 percent during one season. Swarex wildlife relectors placed on both sides of the highway are also being evaluated as are animated deer crossing signs. "The number of safe crossing per deer killed increased 44 percent with the signs on compared with the number of safe crossings per kill with the signs off." Bibliography of 3 titles.

Pojar, Thomas M., Thomas N. Woodard, and Dale F. Reed (441)

1973. Effects of highway lighting on number of deer killed by vehicles. Project Number W-38-R-27. Game Research Report. Colorado Division of Wildlife. Pages 185-192.

The project objective was to "determine if highway lighting affects the rate of deer-vehicle accidents on a portion of Colorado 82." Implementation of an agreement to install luminaries was initiated February 8, 1973. "The number of deer-vehicle accidents and the number of deer counted in the Jammaron study area showed an increase in 1973 over the past two years. The number of deer-vehicle accidents (deer kill) increased linearly from January to March."

Pojar, Thomas M., Thomas N. Woodard, and Dale F. Reed (442)

1973. Deer underpass evaluation. Project W-38-R-27. Game Research Report, Colorado Division of Wildlife. Pages 177-184.

"The use of a concrete box underpass 10 feet by 10 feet and 100 feet long that permits deer to move under Interstate 70 to and from their summer range was evaluated. The structure, located 4.3 miles west of Vail, utilizes a well established deer migration trail and a natural drainage referred to as Mud Springs Gulch. According to the number of passages recorded by the electro-optical detection system and video surveillance, deer increased their use of the structure by 40 percent, from 1971 to 1972. The greatest use of the underpass occurred during June and November with maximums of 28 and 39 net passages per day respectively. An index of entrance versus exit activity indicated a behavioral reluctance on the part of deer to use the underpass....Observations, made via the video system, confirm the hypothesis that most deer spend time at the entrance before, and possibly without, passing through the structure." Bibliography of 3 titles.

Queal, Leland M. (443)

1967. Effectiveness of roadside mirrors in controlling deer-car accidents, - a progress report. Michigan Department of Conservation, Research and Development Report No. 103, 7 pages, 1 figure, 2 tables, cited references.

"The effectiveness of roadside deer mirrors was tested on highways in Calhoun and Jackson counties beginning in 1965. The Calhoun County area was a new section of highway for which no prior records are available. On the Jackson County site, the highway deer kill following installation of the mirrors decreased 26% from the previous year while the kill in the control area increased 10%. In 1966, the kill in the test area increased 135%

but decreased 23% in the control area. The number of deer killed in the test area in relation to other portions of Jackson County also tends to indicate the mirrors may have had some effect the first year, but failed to substantially reduce the deer kill for a longer period. The mirrors do not appear to be accomplishing any worthwhile reduction of the highway deer hazard. Holding deer numbers in check seems to be the only practical solution to the problem." (Author's abstract.)

Queal, Leland M. (444)

1968. Effectiveness of roadside mirrors in controlling deer-car accidents. Michigan Department of Conservation, Research and Development Report No. 137, 9 pages, 1 figure.

"In 1965, the highway deer kill following installation of the mirrors decreased 26% from the previous year, while the kill in the control areas increased 10%. The kill in 1966 increased 135% in the test area but decreased 23% in the control area. In 1967, the kill in the test area decreased 30% while increasing 88% in the control area. Changes in deer numbers and distribution patterns are thought to have more influence on these fluctuations than the presence of the mirrors". WR No. 131:65

Reed, Dale F., Thomas J. Pojar, Willial R. Heicher, Larry L. Green, J. Kris Moser, and Thomas N. Woodard. (445)

1973. An evaluation of deer-proof fence length required to prevent deer movements on or across high speed highways. Project Number W-38-R-27. Research Report, Colorado Division of Wildlife. Pages 197-202.

"Deer crossings were reduced 82% during the first March-May period after the 1.1 mile 8-foot fence on Highway 82 was installed. Annual deer kill was reduced by 61%. Deer kill was reduced by 72% and 71% after two 2.25 mile 8-foot fences were installed adjacent to Interstate 70 near Avon and Edwards, respectively. Sightings of 6 marked deer near the Vail underpass-fencing complex indicated movements parallel to the fence distances of 0.25 to 1.00 miles." Bibliography of 2 titles.

Reed, Dale F., Thomas M. Pojar, and Thomas N. Woodard (446)

1974. Mule deer responses to deer guards. Journal of Range Management. 27 (2): 111-113.

"In this investigation the effectiveness of guards 12, 18 and 24 feet long in preventing mule deer from crossing vehicle openings in fences 8 feet high was evaluated. The guards were constructed of flat mill steel rails ½ x 4 x 120 inches, and were tested under controlled tests. 16 of 18 deer successfully crossed the guard. Fifteen deer and one elk crossed guards under field conditions. Deer did not attempt wide jumps over the guards, but rather walked, trotted, or bounded across them. Use of this guard type under the condition tested is not recommended."

Reed, Dale F., Thomas M. Pojar, and Thomas N. Woodard (447)

1974. Use of one-way gates by mule deer. Journal or Wildlife Management, 38(1):9-15.

Authors' abstract: "Gates designed to allow passage of mule deer (Odocoileus hemionus hemionus) in only one direction were tested under controlled and field conditions. Two gate types had significantly ($P < 0.02$) different frequencies of use under controlled conditions. Eight gates of the type deemed most effective were installed in 8-foot (2.44-m) fences adjacent to Interstate Highway near Vail, Colorado. A total of 558 passages were recorded through these gates during 1970-72 and 96 percent of these were in the one-way direction for which the gate was designed. Based on track counts, we estimated these gates permitted about 223 deer to escape the immediate highway right-of-way."

When deer manage to go around the end of a deer fence or come in from the opposite side and become trapped or funneled next to a highway, one-way gates of the type described and illustrated in detail by drawings in this article may enable the deer to escape from the roadway. On the basis of their experiments the authors concluded that when 8-foot fencing adjacent to high-speed highways is used to reduce or prevent deer-vehicle accidents, the installation of one-way gates should be considered.

Reed, Dale F., Thomas N. Woodard, and Thomas M. Pojar (448)

1975. Behavioral response of mule deer to a highway underpass. Journal of Wildlife Management 39 (2):361-367.

Authors' abstract: "A concrete box underpass 3.05 x 3.05 m (10 feet) and 30.48 m (100 feet) long under Interstate 70 in west central Colorado was monitored for deer use during 4 years following its completion in early 1970. A seasonal mean of 345.1 - 133.0 (sd) mule deer (Odocoileus hemionus) passed through the structure when moving to or from their summer range. A video time-lapse surveillance system recorded behavioral responses during four migration periods, spring - summer and fall in 1972 and 1973. On the basis of video tape playback of 4,450 approaches and 1,739 entrances, deer displayed 3 basic overt responses: look-up, tail-up, and muzzle-to-ground. The frequency of the look-up responses was indicative of the reluctance of the animals to go through a structure of this size and character. The underpass was successful in permitting about 61 percent of the local deer population to migrate safely under the highway."

On the basis of this study supported by the Colorado Division of Wildlife, the Colorado Division of Highways and the Federal Highway Administration, the authors suggested that larger and more open underpasses would result in less reluctant deer movement. They recommended underpasses with at least 4.27-m heights and widths and minimal lengths, dirt floors and no skylights or artificial lighting. There was less reluctance to use the underpass during the fall migration than during the spring-summer migration. The two small skylights in this underpass were considered disadvantageous in that they admitted traffic noise and precipitation from the median. The precipitation froze into ice mounds in the center of the underpass and possibly discouraged passages in late December and May. The authors concluded that overt deer behavior and use of the underpass were not significantly affected by artificial illumination based on look-up and muzzle-to-ground responses.

Seamans, Roger A. (449)

1951. Electric fences for the control of deer damage.

Vermont Fish and Game Service, Montpelier, State Bulletin, Pittman-Robertson Series No. 16, 77 pages, illus.

"This detailed report is based on experience with 225 operating electric fences. Full instructions are given for installing and maintaining the type of fence found best (an outrigger arrangement), and large photographs show many of the procedures." W R No. 69

Spillett, J. Juan, Jessop B. Low, and David Sill (450)

1967. Livestock fences -- how they influence pronghorn antelope movements. Utah State University Bulletin 470. 79 pages. 36 figs.

"The effects of 22 types of livestock fences and devices on pronghorn antelope movements were tested in Wyoming from March 1953 through November 1964. Antelope readily crossed horizontal barriers such as cattle guards and simulated cattle guard devices. Dirt ramps, electric fences, and horizontal panels appeared to merit further study." W R No. 133:50

Stewart, Paul A. (451)

1973. Electrocution of birds by an electric fence. The Wilson Bulletin 85 (4):476-477, 1 fig.

The author found a dead screech owl (Otus asio) hanging, head downward, from the top of a post of an electric fence. Upon examination, he noted that the bird's left tarsus was between the wire and the post, thus grounding the fence wire on the steel post. "The wire of the fence was attached to an electric fencer lacking a 'chopper', a device providing alternate breaks in the current going to the fence wire. Also, the fence was not equipped to reduce the voltage delivered to the fence." The farm owner advised Mr. Stewart that he finds as many as 25 birds killed by his fence at one time when brown-headed cowbirds (Molothrus ater) perch on the wire and he estimated that the fence kills as many as 200 birds, of various species, in a year. Fences of the same type were still being sold as of February, 1973.

Storer, Tracy I., George H. Vansell, and Ben D. Moses (452)

1938. Protection of mountain apiaries from bears by use of electric fence. Journal of Wildlife Management 2 (4):172-178.

Describes early use of an electric fence to protect bee hives from bears in Shasta County, California. Materials are listed, instructions are given for constructing a fence, and precautions are suggested for its use.

Svoboda, Franklin J. (453)

1974. Big game - highway safety conflicts and suggested solutions. Minnesota Highway Department, Office of Environmental Services,27 pages, 1 table, 6 figures, appendix, references.

"Information has been presented documenting the fact that a conflict does exist between roadways and big game. These conflicts include direct mortality, impairment and reduction in available habitat, migration and movement pattern disruption, attraction to roadside vegetation and management complications. Access to remote areas to aid in big game herd control and rapid, efficient movement of travelers were cited as positive aspects of the road network. The negative conflicts between big game and vehicles outweighed the positive benefits.

Statistics detailing the severity of the problem are difficult to obtain and must be consolidated from various sources. The problem is national in scope with significantly serious situations occurring on the local level. It is difficult to equate losses of wildlife and habitat on an economic basis. The impact of a roadway varies from minor to serious depending upon the overall effects a roadway may have on animal movements.

Solutions to the big game-vehicle conflict are inadequate at present and more research on big game behavior in relation to highways is required. Some measures presently available include installing bridge structures, warning signs, restrictive fencing and one-way gates, modifying highway design, location and width of the right-of-way and reducing attractiveness to big game.

Highway agencies can help solve the problem by consulting with state conservation departments early in the planning stages of a new highway. Critical or problem areas may then be identified and avoided or safety measures designed into the new road. Existing roads may need some modifications to reduce the safety hazard in conflict areas. Maintenance procedures which perpetuate certain plant communities that have been designed to discourage big game use must be adopted and practiced regularly." (Author's abstract)

Tate, James, Jr. (454)

1962. Meadowlark killed by electric fence. Wilson Bulletin 74(2):184.

The bird was apparently shocked and killed when it attempted to step from the grounded brace wire to the electric wire of a "weed burner" fence--- a fence designed to burn off plants that would normally grow up around the fence and short it out. The "live" wire carried a pulsating six-volt shock, which alternated with the plant-killing (and in this instance, bird-killing) twelve-volt shock every sixth time. The "live wire" was within two inches of the brace wire.

Tierson, William C. (College of Forestry, Syracuse University.) (455)

1969. Controlling deer use of forest vegetation with electric fences. Journal of Wildlife Management, 33 (4): 922-926.

Author's abstract: "In 1961, an electric fence to control deer (*Odocoileus virginianus*) was erected around a 255-acre part of a 500-acre stand of cut-over northern hardwood forest in the Adirondack Mountains. In addition to the main fence, a 3-acre area was enclosed with an outrigger fence, as recommended by the Vermont Fish and Game Department, to test its effectiveness compared to the main fence. Observations of the outrigger fence indicated that it effectively repelled deer during early winter but was ineffective after 6 inches of snow had accumulated. High resistance to ground in dry snow was measured and the fence was modified by adding wires at ground potential. The main fence was modified in 1962 to include ground wires, and in 1963 to replace solid copper wire and copper-clad steel wire. Track counts and direct observations indicated that the electric fence effectively repelled many deer although numerous observations of deer penetrating the fence were made. Vegetative tallies indicated that deer browsing was significantly (P is less than

0.05) reduced inside the fence. Cost per acre over the study period was $22.47. The efficiency of the electric fence in controlling deer use was considered too marginal to recommend its use as a management tool, and its cost was relatively too high."

Traffic Data Systems, Inc. (456)

1969. Deer detector and counter system (Contract)--Final technical report. Traffic Data Systems, Inc. 15 pages, 2 figs.

From author's summary: "An evaluation and test are made of methods for the detection and counting of deer so that deer-vehicle accidents might be reduced. Evaluation of mechanical, magnetic, sonic, visual light and passive and active infrared, barrier or strip detection techniques were made. The result for detector techniques was generally negative." Only the electro-optical technique showed any promise.

"The problem of counting detections was successfully solved by using existing Streeter Amet portable counters. This counter has proven reliable and is reasonably priced. The feasibility of an electronic scarecrow appears to be negative since the animals are not disturbed by light or sound sources." HRIS No. 223159.

Woodard, Thomas N., Thomas M. Pojar and Dale F. Reed (457)

1973. Investigation of one-way deer structures. Project W-38-R-27. Game Research Report, Colorado Division of Wildlife. Pages 171-175.

"Gates designed to allow passage of mule deer (Odocoileus hemionus) in only one direction were tested under controlled and field conditions. Two gate types had significantly ($P < 0.02$) different frequencies of use under controlled conditions. Eight gates of type deemed most effective were installed in 8 foot fences adjacent to Interstate Highway 70 near Vail, Colorado. A total of 406 passages were recorded through these gates during 1970-71 and over 96.2 per cent of these were in the one-way direction for which the gate was designed. Based on track counts, we estimate five of these gates permitted about 145 deer to escape the immediate highway right-of-way. Two one-way fences did not meet the one-way criteria. More negative crossings occurred than positive under controlled conditions. They were rejected for field tests." These recommendations were made: "When deer-proof fencing adjacent to high-speed highways is used to reduce or prevent deer-vehicle accidents, one-way structures should be considered for installation. Deer that move around the ends of the fence, or from the side of the road not fenced, will be able to pass through a one-way gate rather than be trapped on the highway and likely killed." Bibliography of 1 title.

Woodard, Thomas N., Thomas M. Pojar and Dale F. Reed. (458)

1973. Effects of a simulated 8 foot fence angle in diverting deer from their established direction of movement. Project W-38-R-27. Game Research Report, Colorado Division of Wildlife. Pages 203-209.

"Time was measured and observations made on mule deer. (Odocoileus hemionus) response to five simulated fence angles. Of 19 deer, only 10 successfully moved through the control time zone. The mean time was 101.3 seconds. Sample sizes (n) of the angle variables (45,60,90, 120 and 135 degrees) were severely limited. Bibliography of 1 title.

Woodard, Thomas N. and Dale F. Reed (459)

1974. Economic considerations in reduction of deer-vehicle accidents. Transactions of the Central Mountain Plains Section of the Wildlife Society Conference 19:18 (Abstract) 7 pages.

"Deer-vehicle accidents are an important problem in many states. An estimated 7,000 mule deer (Odocoileus hemionus were killed on highways in Colorado during 1973, resulting in approximately $2.7 million property damage to vehicles. The Colorado Division of Highways, Federal Highway Administration, and the Colorado Division of Wildlife initiated a cooperative deer-vehicle accident study in 1968 because of a growing concern for the loss of wildlife and for motorist safety. The study has included cost: benefit ratios in evaluating the effectiveness of structures and techniques in reducing deer-vehicle accidents." Bibliography of 5 titles.

Woodard, Thomas N. and Dale F. Reed (460)

1974. Economic considerations in reduction of deer-vehicle accidents. Contribution from Federal Aid

Project W-38-R, Division of Wildlife, Colorado Department of Natural Resources (526 Pine Street, Glenwood Springs, Colorado 81601).

Results of a cooperative deer-accident study by the Colorado Division of Highways, Federal Highway Administration and Colorado Division of Wildlife are presented. Cost: benefit ratios of structures or means of reducing accidents were calculated. Deer use of a highway underpass near Vail, Colorado increased 26.0 percent annually from 1970 through 1973 following construction of the underpass. The annual mean kill of deer for the three-year period (1967-1969) preceeding installation of the underpass was 36 compared with kills of 10,14, 18, and 12 deer respectively, for the four years following construction of the underpass. Savings in vehicle repair costs for these four years amounted to an estimated $30,272 and at this rate it was calculated that the benefits of underpass construction would equal costs in another 3.5 years and would be 1:2.8 after 20 years. Projected cost: benefit ratios after 20 years for four 8-foot fences built parallel to and adjacent to highways in areas where deer did not have to cross during migrations ranged from 1:2.8 to 1:9.7. Experiments with two lighted, animated deer crossing signs did not indicate they would be cost effective. State conservation agencies have the opportunity to recommend structures to reduce deer-vehicle accidents, which according to the authors, resulted in an estimated loss of 7,000 mule deer (Odocoileus hemionus) and approximately $2.7 million property damage to vehicles in Colorado during 1973. Such recommendations are more likely to be accepted if economic feasibility is demonstrated.

B. SOIL EROSION, SEDIMENT AND POLLUTION CONTROL WITH SPECIAL REFERENCE TO WILDLIFE: Mitigation and Rehabilitation Measures.

1. Soil Erosion and Pollution Control.

Barton, James R. and Parley V. Winger (461)

1974. Stream rehabilitation concepts. Utah State Department of Highways, 44 pages, 19 figures, references.

"Altered streams generally require some means of rehabilitation in order to provide areas capable of supporting fish populations. Recent investigations have shown that rehabilitation of altered streams provides better fish habitat than would exist if no reahabilitation measures were taken. Many types of rehabilitation structures and procedures are available but many are not very effective. Generally, one type of structure that functions well in one situation may not function properly in another. Each situation is a unique condition and requires its own modifications and designs in order for the rehabilitation measures to be effective. The basic rehabilitation structures are deflectors, check dams, rocks and bank cover and are normally considered effective in mitigating some of the detrimental effects of channel alteration. Generally, permanent, solidly constructed structures are best, such as deflectors and check dams. Rocks placed in various patterns are also an effective and an economical means of rehabilitating altered channels. Banks should be stabilized to reduce erosion by planting vegetation or by installation of rip-rap. Cover can be provided by extending trees secured to the bank into or over the sides of the stream. Single, in-stream structures may provide some cover and a hole but the area of the stream influenced may be too small to warrant the time and expense needed for the installation of these structures. The length of the stream should be preserved by constructing new meanders to replace those lost due to construction." (Authors' abstract)

Boussu, Marvin F. (462)

1954. Relationship between trout populations and cover on a small stream. Journal of Wildlife Management, 18(2): 229-238.

This study of the relationship of eastern brook trout, rainbow trout, and brown trout populations to cover was conducted in Trout Creek, Gallatin County, Montana. The detrimental effects of experimental removal of brush cover overhanging the stream and the removal of undercut banks on the fish populations are quantified. It indicated that aquatic vegetation had value as cover for fish, especially smaller fish, while rooted to the stream bottom and also while free-floating or lodged in rafts against overhanging brush.

Brusven, M. A., F. J. Watts, R. Leudtke, and T. L. Kelley (463)

1974. A model design for physical and biotic rehabilitation of a silted stream. Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho. Technical Completion Report for Project A-032-IDA, x + 96 pages.

The authors observe that siltation frequently occurs downstream of gravel washing operations, placer mining, logging areas, cultivated areas, and below areas where a highway or other construction has left large expanses of unvegetated soil. They indicate that good management dictates rehabilitation of wasted streams at the earliest possible time after the sediment-producing watershed has been healed and in their study they used log drop structures, debris jam removal, channel diversion and gabion deflectors to test their usefulness in such stream rehabilitation.

Authors' abstract: "This study was conducted to develop a method for rehabilitating a silt-polluted stream and to measure the biological impact of rehabilitation on the insect community. Field work was conducted in the East Fork and main stem of Emerald Creek in Northern Idaho.

"The study invoved natural field conditions and laboratory simulation. Six control sites were selected, based on similarity of flow, substrate type and channel geometry. Sediment samples were tagged and monitored, hydraulic structures were constructed for modification, and changes in the aquatic insect community were studied in conjunction with the physical changes in the streambed.

"In-stream alterations proved to be effective for increasing sediment transport, thus improving insect and fish habitat. Other improved conditions included increased pool-riffle ratios and higher values of percent cobble.

"Due to its hydraulic cycle, Emerald Creek can flush large amounts of fine sediments per year. But until the source of pollution sediment is eliminated, excessive loading will continue."

Burns, James W. (464)

1972. Some effects of logging and associated road construction on northern California streams. Transactions, American Fisheries Society, 101 (1): 1-17, 9 figures, 9 tables.

Author's abstract: "The effects of logging and associated road construction on four California trout and salmon streams were investigated from 1966 through 1969. This study included measurements of streambed sedimentation, water quality, fish food abundance, and stream nursery capacity. Logging was found to be compatible with anadromous fish production when adequate attention was given to stream protection and channel clearance. The carrying capacities for juvenile salmonids of some stream sections were increased when high temperatures, low dissolved oxygen concentrations, and adverse sedimentation did not accompany the logging. Extensive use of bulldozers on steep slopes for road building and in stream channels during debris removal caused excessive streambed sedimentation in narrow streams. Sustained logging prolonged adverse conditions in one stream and delayed stream recovery. Other aspects of logging on anadromous fish production on the Pacific Coast are discussed."

Among the suggestions and implications mentioned for management in the interest of maintaining anadromous fish production were: some thinning when dense forest canopies along streams provided too much shade for optimum conditions for fish may be desirable but leaving a dense understory or buffering strip along streams where needed to control temperatures may be helpful elsewhere; avoiding the falling of trees into the streams when embryos and fry are in the gravel (decaying slash depletes intragravel dissolved oxygen or produces slime bacteria (Sphaerotilus) which can suffocate developing eggs and alevins; keeping timber out of the stream (removal of such timber is one of the major reasons bulldozers enter stream channels): keeping bulldozer use on steep slopes or in stream channels at a minimum; building roads away from the stream; seeding disturbed areas with grass to reduce erosion and sedimentation; and completing logging operations in the shortest period of time possible, then leaving the watershed to recover.

Cannella, A. A., and A. A. Friedman (465)

1974. Management of solid wastes incident to highway construction and maintenance. Tennessee Technological University, Department of Civil Engineering (Cookeville, Tennessee 38501). 96 pages, 5 figs., 8 tabs. refs. 3 app.

Summary: "The problem with which this report deals involves (1) the disposal of wastes resulting from highway construction with minimum offense to the environment and (2) the prevention and removal of roadside litter. Current highway waste management practices are reviewed and alternative solutions are proposed for more effective management of these wastes. The results of a survey of the current practices of the fifty states in meeting environmental legislation and litter control are reported. In addition, the report includes data regarding waste management efforts by federal and state agencies. The report is divided into the following three parts: (1) management of highway construction wastes; (2) management of highway litter; and (3) highway erosion control." HRIS No. 260478.

Carufel, L. H., J. A. Barnes, and W. D. Kesner (466)

1973. Protecting fish habitat during road development. Coordination Guidelines for fish and wildlife habitats, U. S. D. A. Forest Service (California Region) No. 7, 13 pages, illustrated by Bob Tribble.

The authors point out that in areas of commercial timber harvest, the associated road systems have had a severe impact upon stream quality. They list the major causes of damage to fish and fish habitat from road development as:

"1. Roads located too close to stream channels.
2. Siltation from road drainage and unstabilized slopes.
3. Landslides triggerd by poorly located roads.
4. Removal of vegetative cover on stream banks, resulting in higher water temperatures,

accelerated bank erosion, and dimished food supply.

5. Disturbance of the stream bed and banks at stream crossings during road construction.
6. Improperly installed culverts that inhibit or prevent fish passage."

They point out that accelerated erosion due to some of man's activities are not compatible with suitable fish environment. Increased quantities of fine sediment (clays, silts and sands) deposited in streams not only destroy spawning areas and smother eggs deposited in gravels, but reduce the amount of aquatic insect foods upon which fish depend.

This well illustrated publication provides guidelines for reducing damages to fish habitat caused by road construction. As the authors point out, however, "All of the foregoing recommendations will do little to protect the fishery habitat unless they are consistently carried out on each project. Written specifications in the contract, plus frequent followup, will help guarantee meeting the desired objectives. By applying these guidelines, it is possible to construct roads without significant damage to our fish resources."

Cook, David I. and David F. Van Haverbeke (467)

1971. Trees and shrubs for noise abatement. Pages 39-41 in proceedings of "A Symposium on Trees and Forests in an Urbanizing Environment," August 18-21, 1970, University of Massachusetts. A monograph published by the Cooperative Extension Service, U. S. Department of Agriculture and County Extension Service University of Massachusetts, 168 pages.

"Field tests during the past two years have shown a fairly wide variation in the amount that noise can be reduced by screens of trees and shrubs. Although the results have not yet been completely studied, there appear to be numerous possibilities for the use of relatively narrow bands of tree-shrub combinations around parking areas and along parkways, where passenger cars are the principal noise source... The screening effect is most pronounced when trees and shrubs are combined with other soft surfaces as an alternative to an expanse of hard-surfaced material which, otherwise, might be used to surround a recreational site or roadside development. Under these conditions, apparent loudness may be reduced 50 percent or more."

Ekey, P. W. (468)

1970. The big diaper. American Highways.(October) Pages 4 & 15; 1 fig., 3 phot.

Summary: "The Pineda Expressway, a connecting artery between two Florida primary highways, spans two rivers over a mile wide at the point of crossing. The silt content of the dredged material has resulted in substantial downstream pollution, and at one time the state pollution control board ordered work stopped. A silt barrier nicknamed, "The Big Diaper" was designed to control the problem. Difficulties encountered in early experiments with the barrier are described, together with the means devised for solving them. Silt deposits and turbidity have been controlled to within state tolerances. The barrier, which cost $2,000. to construct, obviated an additional bridge at a cost of $3.5 million." HRIS No.215375.

Foote, L. (469)

1973. Administrative "Tools" for stopping erosion, pollution. Rural and Urban Roads. 7(2):52-55. 1 photo.

From summary: "The most effective and cheapest way to limit the erosion and resultant sediment and water pollution during construction is by good contract administration...Precautions to prevent pollution of flowing and impounded waters must be checked and monitored. Plans for prevention of excessive erosion during construction must be reviewed and approved before start of operations. Pollution control, and fish and wildlife regulations must be enforced. Provisions for temporary erosion and pollution control techniques including materials and methods which could be used when required must be submitted by the contractor. Provisions must be made for payment for such measures, and the employer must reserve the right to employ assistance at the expense of the contractor if the latter fails in his erosion control efforts. The exposed erodible surface as well as the grubbing and clearing operations must be limited. In the event of conflict between specifications and pollution laws, the more restrictive requirements must be applied... If grading operations are suspended, care must be taken to prevent excessive erosion and water pollution during suspension. Special provisions must also be made for such points as payment, equipment, coordination of top soiling and finishing operations, seeding and mulching..." HRIS No. 215648

Gosselink, J. G., R. J. Reimold, J. O. Gallagher, H. L. Windom, and E. P. Odum (470)

Undated: Spoil disposal problems for highway construction through marshes: (1) Evaluation of spoil disposal techniques; (2) Revegetation techniques for spoil areas. Institute of Ecology, University of Georgia, 57 pages.

The objectives of this report are "to evaluate from a viewpoint of environmental quality past and present practices in highway construction; to recommend optimal techniques for handling spoil in future construction; and to recommend practices for reclamation and revegetation of existing and future spoil areas. In addition to undiked and diked spoil disposal, bridging of marsh areas and a recent innovation, side casting, are considered." This report includes four appendices which contain information on construction sites, ecological and economic considerations, and revegetation techniques for spoil areas. Bibliography 34 titles.

Grover, W. C., A. J. Hoiberg, T. I. Haigh, and E. Thelen - Franklin Inst. Research Labs., Philadelphia, Pa. (471)

1972. Investigation of porous pavements for urban runoff control. Copy available from GPO Sup. DOC as EP1. 16:11034 DUY 03/72, $1.25; microfiche from NTIS as PB-227 516, $1.45. Environmental Protection Agency, Water Pollution Control Research Series, March 1972. 142 pages, 19 figures, 21 tables, 37 references. EPA 11034 DUY. 14-12-924.

Abstract: "Laboratory and economic studies were undertaken to determine the feasibility of utilizing porous pavements to alleviate combined sewer overflow pollution and reduce the design parameters of storm sewer systems by allowing storm runoff to percolate back into the ground. Laboratory studies of candidate materials revealed a porous asphaltic concrete containing 5.5% asphalt by weight and aggregate graded to allow a water flow of 76 inches per hour to be the optimal porous road material. Materials testing for stability, durability, and freeze-thaw susceptibility proved this material suitable for use in road construction. Asphalt Institute specifications were used to design roads with porous asphaltic concrete surfaces and gravel bases for varying traffic densities.

Major design parameters considered were the load-bearing capacity and permeability of the subgrade, expected maxiumum precipitation and depth of frost penetration. Roads designed with porous asphaltic concrete were found to be generally more economical than conventional roads with storm sewers. The economics of porous pavement were further enhanced by the added value of benefits from combined sewer overflow pollution relief, augmentation of municipal water supplies, improved traffic safety, preservation of vegetation, relief of flash flooding and the aesthetic and directional benefits of a colored porous surface." WRSIC No. W74-05411

Hansen, Edward A. (Lake States North Central Forest Expt. Sta. (472)

1968. Stabilizing eroding stream banks in sand drift areas of the Lake States. U. S. Forest Service Research Paper, N. C. 21. Pages 1-12, illustrated, map. See also Biological Abstracts, 49 (23): Abstract No. 119184.

"Banks are stabilized to protect adjacent high-value items such as cabins and campgrounds, or to reduce reservoir or lake sedimentation rates. Also, bank stabilization is undertaken as one part of fish habitat improvement programs. Rock rip-rap is the best material for bank stabilization in most cases. It does not deteriorate with time and it blends in well with the surroundings. The upper part of the bank will revegetate naturally. However, sloping and seeding will accelerate revegetation." (Author) Sport Fishery Abstracts No. 11125

Harrison, James S. (473)

1965. Statewide fisheries investigations, evaluation of stream improvement structures. New Mexico Department of Game and Fish, Federal Aid Project F-22-R-6 work plan 2, job c-2, 10 pages, 1 table, 10 figures.

"Longevity checks were made during June of 1964 on stream improvement structures installed since 1960. Damaged and non-functional structures were noted and possible reasons for failure were noted during these checks. Test rainbow trout marked with jaw tags were recovered by electrofishing and from voluntary angler returns. Results on trout movements, growth and survival were obtained from several improved and one unimproved section of stream. In improved environments, slightly more than 41% of the test fish were recovered by electrofishing after an interval of approximately six months. The sampling period ran from November to April of 1963-64. Voluntary returns of tagged fish by anglers boosted the over-all recovery and minimum survival to slightly higher than 50% of the original test stocking. Additional stockings of tagged rainbow trout in both improved and non-improved sections of the Cimarron River are scheduled in April of 1965. Physical changes occurring since the installation of improvements were checked by depth measurements, width measurements and photographic comparisons. Normally the stream bed becomes wider and deeper just above a new structure but siltation above the structure slowly lessens the initial depth. Scouring below the structure generally increases the depth and decreases the width of the stream channel just below the improvement structures."

Hunt, Robert L. (474)

1971. Responses of a brook trout population to habitat development in Laurence Creek. Technical bulletin No. 48, Department of Natural Resources (Madison, Wisconsin), 35 pages, 15 tables, 21 figures.

Abstract: "This report has two major objectives: (1) to present completed results of an evaluation of trout habitat development previously reported on in part and (2) to present a new series of analyses that have provided additional insights into the mechanisms of trout population responses to habitat development, and at a broader level (independent of evaluating habitat improvement) to utilize these same analyses for investigating the question of why some stretches of a trout stream hold more trout than other stretches." "Habitat development was successful in Laurence Creek because it substantially increased the quantities of key environmental factors inpinging upon survival of the trout population, most notably the amounts of pool area and bank cover for trout. Development was aimed especially at supplying more of these two components and supplying them in combination. Device construction was such that much of the additional pool area was created beneath the overhanging artificial banks of the devices. Pools and bank cover as they apply to trout carrying capacity of small streams like Laurence Creek are perhaps best thought of not in terms of what each contributes to carrying capacity, but what both contribute in combination." A cost-benefit analysis of habitat development is included. Appendix of 5 pages and a bibliography of 22 titles.

Khanna, S. D. (475)

1973. Effects of highways on surface and subsurface waters. Public Works 104(11) 71-73, 123-124, 2 tab.

Summary: "This article identifies certain problems as having possible beneficial or detrimental effects on waters in the vicinity of a highway right-of-way. General solutions to the problems are suggested to minimize the detrimental effects and to maximize the beneficial ones. The problems are discussed under the following subheadings: quantity of water, water resources projects, storm drainage systems, channel relocations, flood controls and flood plains, groundwater, water recreation, community utilities, and water quality." HRIS No. 262665

Kochenderfer, James N. (476)

1970. Erosion control on logging roads in the Appalachians. USDA Forest Service Research Paper NE-158, NE, Forest Exp. Station, Upper Darby, Pa., 28 pages, illustrated.

Abstract: "Practical methods of controlling erosion on logging roads are summarized through the different stages--planning, location, drainage, maintenance, and care after logging. The material was derived from existing literature, road lore, contact with experienced land managers, and personal experience. (KOCHENDERFER-FOREST SERVICE)". WRSIC No. W70-10418

Lantz, Richard L. (477)

1971. Guidelines for stream protection in logging operations. Oregon State Game Commission, Research Division, 29 pages.

"The objective of this publication is to explain why certain logging practices in the West Coast Douglas-fir region are more desirable than others for protecting fish habitat and water quality...Streams can be protected to a large extent by (1) keeping streamside vegetation intact... and by (2) taking precautions to eliminate or minimize soil disturbance and erosion, particularly that resulting from roads."

A recommended practice for stream protection summary section is given, including advice on road location and design, construction, and maintenance. Bibliography 53 titles.

Leonard, Raymond E., (Northeastern Forest Exp. Sta.)(478)

1971. Effects of trees and forests in noise abatement. Pages 35-38 in proceedings of "A Symposium on Trees and Forests in an Urbanizing Environment," August--18-21, 1970, University of Massachusetts. A monograph published by the Cooperative Extension Service, U. S. Department of Agriculture and County Extension Services, University of Massachusetts, 168 pages.

"The unit used in acoustics to measure the intensity or pressure level of sound is the decibel (db)... a sound intensity of 0 db describes the threshold of normal human audibility. A sound of 10 db has an intensity ten times greater than a sound of 0 db. A sound of 20 db is 100 times more intense, 30 db is 1,000 times more intense and so on." The decibel intensity of normal speech is 48, while the db intensity of a busy intercity highway is 75. "Preliminary results from a recent investigation of noise reduction by shelterbelt tree planting in Nebraska indicate a sizable reduction in highway traffic noise may be obtained by 100-foot wide bands of trees and shrubs. From available literature, it appears that forest stands absorb approximately 6 to 8 db per 100 feet. Species do not seem to be as important in noise abatement as stem spacing--that is, density...Trees and shrubs may play an important role in noise abatement if they are correctly utilized. Because wave lengths of sound are large relative to the size of individual trees, fairly dense stands may be needed. The relative position of the sound source and receiver will affect the value of the forest as a sound barrier. Where the source is above the canopy... the forest may not be very effective." This type of situation "may exist where highways...are on hilltops overlooking populated areas below...Fairly dense groups of trees may serve as effective sound reducers along highways, particularly on level areas or where the sound source is at an elevation lower than the receiver."

Lund, J. W. (479)

1974. Erosion and silting problems in the Ashland watershed. Idaho Transportation Department, Division of Highways (Boise, Idaho. 8 pages, 1 fig., 8 ref.

Summary: "Soil and granitic bedrock erosion in the Ashland watershed, a granitic batholith, has produced severe silting in several reservoirs that supply domestic water to the city of Ashland, Oregon. The silting has affected the quality of the water by increasing the turbidity and also requires extensive maintenance to remove deposited material from the reservoirs. The problem has been compounded by logging and road construction initiated by the forest service in 1959. An investigation of the site to determine the general causes of the erosion and silting problem and how it could be minimized, was performed in 1972. Specific emphasis was placed on the effect of the existing roads and their contribution to the problem. Recommendations were made as to culvert installation, cross drain location, ditch construction, fill and cutbank construction and maintenance, and the geometry and surfacing of roads. For aggregate surfaced roads, insloping with a maximum cross drain spacing depending upon the roadway grade is recommended. Serration is recommended to assist in establishing vegetational growth on cutbanks. Down drain entrance protection and culvert outlet slope protection is also specified. Turbidity measurements are presently being taken of various streams in the watershed." HRIS No. 265537.

Massie, L. R. and Bubenzer, G. D. (480)

1974. Improving roadbank erosion control. Journal of Soil and Water Conservation, 29 (4): 176-178, 2 figures.

Emphasizes that erosion control along town (local) roads has not kept pace with that along county and state roads and states that a high percentage of the town roadside erosion can be attributed to inadequate maintenance and improper shaping and revegetating of the uphill and downhill slopes from the road. He excerpts information from a previous Wisconsin study of which he was one of the investigators (Briggs, W. M., J. Densmore, R. Hovind, Cy Kabat, L. Massie, and W. Steuber, 1968. Erosion on Wisconsin roadsides -- a report to Wisconsin citizens. University Extension, University of Wisconsin, Madison). Recommendations from this earlier study were to: "1. Purchase and use specialized seeding and mulching equipment. 2. Control all erosion sites reported in this survey that can be a major source of sediment for Wisconsin's surface waters within five years. 3. Consider the use of incentive funds to help reduce active erosion along town and county roads. 4. Build sediment-retention structures as a part of all new construction, and maintain them until permanent structures and vegetation achieve adequate control. 5.

Establish vegetation on all new road cuts and fills, particularly along town roads. 6. Secure wider rights-of-way where needed."

Netzer, A., P. Wilkinson, and S. Beszedits (481)

1974. Removal of trace metals from wastewater by treatment with lime and discarded automotive tires. Water Research 8(10):813-817. Pergamon Press; Maxwell House, Fairview Park; Elmsford, New York 10523

"Discarded automotive tires (DAT), a solid waste disposal problem of enormous proportions, may provide the answer to another environmental headache--the removal of trace metals from wastewaters. Experiments were designed to evaluate the feasibility of using discarded automotive tires in conjunction with lime to remove aluminum, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, and zinc from aqueous solutions. Continuous bench-scale studies showed that removals in excess of 99.5 per cent for most of the metals can be achieved by treatment with lime and DAT. Rubber is as effective as activated carbon, is cheaper and is easier to dispose of. Furthermore, the use of DAT reduces the amount of lime required which, in turn, leaves less sludge for dewatering and disposal. Therefore, the potential of DAT in the treatment of metal-bearing industrial effluents and domestic wastes contaminated with heavy metals is very high." HRIS

New York State Department of Transportation (482)

1974. Construction guidelines for temporary erosion controls. New York State Department of Transportation, Soil Mechanics and Landscape Bureaus (1220 Washington Avenue, State Campus, Albany, New York 12226. 24 pages, 7 figures.

Summary: "This manual which is presented in an effort to help project engineers fulfill their resonsibility for enforcing the department's goal of maintaining water quality, reviews the processes of erosion and sedimentation and describes the development of control measures in design. Examples of critical situations which may be encountered in transportation projects are listed and a check list for erosion and water pollution control is reviewed. Temporary erosion and sedimentation control for construction are outlined and administrative guides on the subject of sediment control are set forth. Runoff control guides were developed related to mulching and seeding cut and fill slopes, fill slope drains, cut-fill transitions and toe of fill protection. Channel protection materials, check dams in ditches and streams, sediment traps in ditches, and sediment basins are other aspects covered. Guides are presented to work in streams and lakes. These relate to temporary stream crossing, temporary stream relocations and pier construction. In a discussion of seeding and mulching, consideration is given to permanent seeding, temporary seeding, trimming, cut slopes, fill slopes, and borrow and spoil areas." HRIS No. 260095.

Packer, Paul E. (483)

1967. Criteria for designing and locating logging roads to control sediment. Forest Science, 13(1):1-18

Abstract: "A recently completed study developed criteria for the design, location and construction of logging roads in the northern Rocky Mountains to prevent damage to the water resource and to conserve soil. Results reveal which characteristics of watersheds and of secondary logging roads influence erosion of road surfaces and movement of sediment down-slope from roads. They define the manner and degree in which these characteristics affect road-surface erosion and sediment movement, and they indicate which characteristics are controllable or alterable by design, management, or choice. They also provide the quantitative criteria needed to develop road design and location requirements that should be considered in planning and executing timber harvest operations, so that soil and water resources will be protected." WRSIC No. W69-05884

Platts, William S. and Walter F. Megahan (484)

1974. Time trends in riverbed sediment composition in salmon and steelhead spawning areas: South Fork Salmon River, Idaho. U.S.D.A. Forest Service, Intermountain Forest and Range Experiment Station, 507 25th Street, Ogden, Utah 84401, 7 pages.

"The South Fork Salmon River is an important chinook salmon and steelhead trout fishery in the mountains of central Idaho. Because of increased logging, road construction, and severe floods after 1950, excessive sediment, especially fines, was deposited in the river channel, seriously damaging the major spawning areas in 1966. A study using a network of closely spaced stream channel cross-sections evaluated the riverbed surface materials by size in four major spawning areas. The size composition of materials favorable for spawning improved greatly from 1966 to 1974...The change in spawning materials resulted from a reversal of the previous high rate of sediment flow into the channel system compared to sediment flow out of the system. The reductions in watershed erosion and sediment entry into the river resulted from: (1) a moratorium on logging and road construction activities on the watershed; (2) natural watershed stabilization process; and (3) a watershed rehabilitation program. This study demonstrates that logging and road construction on high erosion hazard lands such as in the South Fork Salmon River watershed must be carefully planned and programmed over both time and space to avoid degradation of salmonid spawning areas."

In connection with spawning conditions the authors state: "Excessive fines are particularly deleterious because they can blanket over or infiltrate into spawning channel materials and cause considerable mortality to embryos, alevins, and fry still in the gravel. Excessive fines kill embryos, alevins, and fry within the channel substrate by decreasing permeability of the gravel to water (shutting off oxygen sources), concentrating metabolic wastes to toxic levels, and forming a block between the intra-gravel, fry and surface waters, which eliminates or reduces their chance for emergence."

Powell, Mel D., William C. Winter, and William P. Bodwitch - National Association of Counties Research Foundation, Washington, D. C. (485)

1970. Community action guidebook for soil erosion and sediment control. Available from the clearinghouse as PB-191 765, $3.00 in paper copy, $0.65 in microfiche. National Association of Counties Research Foundation Publication, P G1-G64, 1970. 64 pages.

Abstract: "Erosion and sediment, once thought of as rural problems, are causing extensive damage to the soil and water resources of developing communities. Sediment caused by careless development and construction has become one of the nation's most serious sources of water pollution. This guidebook is intended to help local officials to organize, plan, finance, staff, and implement comprehensive sedimentation control programs. In addition it should help local officials and administrators understand what is basically a technical problem; it will also help soil and water experts and technicians understand the administrative aspects of sedimentation control. This mutual understanding is necessary if effective control is to be achieved. The concepts and principles presented are based on a year of research, including visits to federal and state agencies and 14 visits to local sedimentation control programs across the United States. A model approach, with appropriate modifications, may be used by many local governments to control their sedimentation problems. (KNAPP-USGS)" WRSIC No. W70-06574

Sigler, C. W. (486)

1971. Pollution control - anti-pollution construction. Kentucky Highway Conference Proceedings, 22nd annual conference. University of Kentucky Bulletin 97. Page 74.

Summary: "Progress is being made in developing new programs and methods to keep air and water pollution to a minimum during highway construction. Preventive measures that should be adhered to relate to (1) controlling dust, (2) limiting burning, (3) controlling water pollution and, (4) minimizing soil erosion." HRIS No. 215514

Smith, Travis, Raymond Forsyth, and Wesley Gray (487)

1969. Performance of an asphalt treated drainage blanket in a flexible pavement section. California State Div. of Highways. Materials and Research Department Interim Report M and R No. 632618, 43 pages, 14 figures, 4 tables, 7 references.

Abstract: "The paper presents the results of a field evaluation of a two-layer highway drainage system on road 299 between Arcata and Willow Creek in the northern coastal region of California. The experimental section consisted of 400 feet utilizing a two-layer draingage blanket, the top, or drainage element, of which was stabilized with asphalt and 200 feet of normal single-layer drainage blanket to serve as a control. The section was located in a cut section with numerous springs and seeps in a high rainfall area. Both sections effectively drained all subsurface water at the site

through an unusually wet winter and spring."
WRSIC No. W70-09005

Swerdon, P. M., and R. R. Kountz (488)

1973. Sediment runoff control at highway construction sites; a guide for water quality protection. Pennsylvania State University, College of Engineering, Research Bulletin B-108, 72 pages, 72 ref.

Summary: "The effects of suspended sediment on water quality, the relationship between turbidity and suspended sediment, methods of sediment analysis, and the nature of the erosion process are summarized. A rational method, based on the universal soil loss equation, is described for predicting erosion rates at any given construction site, and therefore the need for runoff control. The utility of this method is demonstrated by applying it to a section of interstate highway I-80 in Pennsylvania, where temporary sediment runoff during highway construction necessitated installing a $1.3 million plant to treat a municipal water supply. It is shown that a system of ditches and impoundments in the construction area could have prevented the stream pollution at less cost, at the same time satisfying current state and federal regulations." HRIS No. 204491.

Thronson, R. E. - Environmental Protection Agency, Washington, D. C. (489)

1971. Control of sediments resulting from highway construction and land development. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Price $.60 EPA Office of Water Programs Report, 50 pages, 38 figures, 45 references.

Abstract: "Accelerated erosion of soils and excess deposition of sediments resulting from construction activities have caused pollution of water bodies in many parts of the country, damaged homes and drainage systems, made treatment of water supplies very costly, and adversely affected aquatic life. The technical capability of controlling these processes is available and the cost minimal. The principal problem lies in achieving effective administrative control and enforcement by concerned agencies. (EPA abstract)" WRSIC No. W72-02106

Tuz, N. (490)

1972. Temporary erosion control check dams. Highway Focus (4(3):31-34, 5 photo.

Summary: "A simple and inexpensive construction treatment for the prevention of stream pollution by soil erosion is described. The project contract which covers grading, drainage, paving and structures, was designed to meet the requirements of the temporary project water pollution control provision. The proposed method calls for temporary ditching to direct surface runoff from the construction areas to three sediment basins located at separate points outside the highway right-of-way. Two small check dams made of crushed stone were installed across the temporary diversion channel for a brook. They were located near the end of the existing stream crossing of the construction highway. The approximate bottom thickness was 5 feet and the top (spillway) about 1.5 feet. Rainfall immediately after installation caused failure of the stone check dams, which were then repaired and subsequently functioned satisfactorily. Experience with heavy rainfall, and corrective measures that may be applied are recounted. Total cost of the original dams, and remedial work, and removal of trapped sedimentation is estimated at $400.00. Photographs showing the check dams are presented." HRIS No. 215618.

U. S. Department of Agriculture, Forest Service (491)

1969. Wildlife habitat improvement handbook. FSH-2609.11 Forest Service (Washington, D. C.) 146 pages. illus.

This handbook is intended for use by field personnel. The topics discussed concerning stream improvement are: planning, direct channel improvement, streamside improvement and protection, regulating dams, maintaining water quality, controlling fish populations in streams, and fertilizing streams.

U. S. Department of Agriculture, Forest Service
California Region. (492)

Undated. Protecting fish habitat during forest road development. Coordination Guidelines for Fish and Wildlife Habitats, No. 6, 13 pages

"The major causes of damage to fish and fish habitat from road development are: (1) road located too close to stream channels; (2) siltation from road drainage and unstabilized slopes; (3) landslides triggered by poorly located roads; (4) removal of vegetative cover on stream banks, resulting in higher water temperatures, accelerated bank erosion, and diminished food supply; (5) disturbance of the stream bed and banks at stream crossings during road construction; (6) improperly installed culverts that inhibit or prevent fish passage." Guidelines are given for permanent road location and design, permanent road construction, and drainage to reduce damage to fish resources. Bibliography of 13 titles.

U. S. Department of Transportation. Federal Highway Administration (493)

Undated. Prevention, control, and abatement of water pollution resulting from soil erosion (attached region 15 report, "Erosion control with wood chips on newly graded areas"). Notice EV-33, 2 pages; Region 15 Demonstration Project No. 6, Interim Report, 15 pages.

Summary: "Woody vegetation, usually wasted during site-clearing, can be converted to wood chips for erosion control on newly graded areas. The chips are more effective than standard wood fiber mulch in preventing soil erosion. In addition, burning is made unnecessary, thus preventing air pollution from the clearing operation. The contract written for a Tennessee highway project included specifications on the use of wood chips for this purpose as part of an FHWA region 15 demonstration of their effectiveness in combatting soil erosion. The elements of the demonstration are described in detail. The topics covered are comparative costs of clearing and chipping, chip spreading, and seeding. Conclusions and recommendations are given." HRIS No. 230058.

U. S. Environmental Protection Agency (494)

1973. (October) Processes, procedures, and methods to control pollution, all resulting from construction activity. Environmental Protection Agency (Washington, D. C.), 234 pages.

Summary: "Water pollution resulting from sediment and other pollutants generated from construction activities can be prevented by the timely application of empirical structural and soil stabilization measures presently available. Processes examined include site planning, preliminary site evaluation and design, use of planning tools, and structural and vegetative design considerations relative to development of a water pollution abatement plan suited to individual construction sites. Methods examined include on-site erosion, sediment, and storm-water management control structures as well as soil stabilization practices useful for achieving control of sediment, storm-water runoff, and other pollutants resulting from construction activities." HRIS No. 215700.

Ventura, J. D. (495)

1972. Water pollution control. Highway Focus 4(2): 45-50, 1 fig., 5 photo.

Summary: "The contractor's efforts to prevent pollution of trout fishing streams with silt and sand contaminated water from a mountain tunnel boring operation are presented. In an effort to treat 160 gallons of water per minute before release into a high quality stream, the contractor used sedimentation pools built in series. Alum was added to the water to prevent coagulation and several modifications were introduced to improve effectiveness of the silt removal process. An effluent trough at the end of the pools allowed a gentle overflow and improved the clarity of the water. The pools required frequent cleaning but the addition of chemicals was not always necessary. Greater consideration for the disposition of contaminated effluent in the design phase of tunnel excavation work is urged. Provision in the plans and specifications for a treatment system and the cleaning and disposing of the silt, and also for the payment of such items is advised. The report includes a schematic diagram and photographs of the project." HRIS No. 215585

Warner, Kendall and Ivan R. Porter. (496)

1960. Experimental improvement of a bulldozed trout stream in northern Maine. Transactions of the American Fisheries' Society. 89(1): 59-63, 1 table, 5 figures, references.

"Brook-trout habitat in Big Hudson Brook was destroyed in 1950 by extensive bulldozing in preparation for pulpwood driving. Following bulldozing, the brook had no well-defined channel at low water levels, water temperatures reached the mid-seventies, and the small flow seeped through bottom rubble. Although restoration of original habitat conditions was impossible, an attempt was made, using a bulldozer, to improve trout-stream habitat that had been destroyed earlier by bulldozing. Seventy-one wing deflectors, 10 rock dams, and six spring holes were created by a single bulldozer in three working days. Evaluation of the work 2 years later showed that 63 deflectors had successfully narrowed stream flow or created pools, rock dams were largely unsuccessful, and pools created by excavation of spring areas commonly harbored trout during warm summer weather." (Authors' abstract)

Zak, John M., Joseph Troll, and Leslie C. Hyde (497)

1972. Direct seeding along highways of woody plant species under a woodchip mulch. Highway Research Record #411. Highway Research Board, Washington, D. C.) Pages 24-27.

"During highway construction, natural communities of plants are completely destroyed; the bare road banks are subjected to full exposure to the sun, fluctuations in temperature, changes in moisture conditions and erosion. Such adverse conditions make it difficult for most plants to become established, and it may take years, if left alone, before the bank becomes stabilized with vegetation. However, with the use of wood-chip mulches and the seeding of selective woody plant species, vegetation would quickly heal the scars of construction." Bibliography of 4 titles.

Zirkle, J. D. (Washington State Department of Highways) (498)

1974. State-of-the-art highway related water quality. Western Association of State Highway and Transportation Officials, AASHTO (341 National Press Building, Washington, D. C. 20004), 13 pages.

Summary: "Basic assumptions (establishment of existing quality, determination of regulatory water quality, identification of desired quality, definition of special uses, and the expenditure determined in the public interest) in any water quality program are reviewed, and the tools to improve water quality and the design features that will accomodate such tools are described. Design phase provisions must include the utilization of every opportunity to adjust the highway alignment for favorable water quality. Drainage adjustments must be made which would improve water quality for highway runoff. Settling basins or detention ponds are described which can be multipurpose units and could be temporary or permanent devices. A standard catch basin which would provide a sump below the outlet for settleable solids is another feature of drainage design. The basin is equipped with baffles to prevent short-circuiting of flow and proper establishment of the retention time. A detention time of 2 hours allows suitable settlement characteristics. The treatment plant directed basically toward biological treatment is also outlined. In the area of design treatments, slope stabilization is important to reducing erosion and water pollution. Ditch or channel stabilization may be achieved with use of matting checks or wiers formed from concrete or wood as well as gravel or rock. Stepped slope treatment, the selection of suitable plant species, the farming of right-of-way are other aspects discussed. Attention is drawn to the need for alertness to sensitive issues, the establishment of the order of work, the restriction of operating time to accomodate special biological conditions, and the use of restricted methods. Bid items for temporary measures, force account time, and the provision of adequate right-of-way are other aspects covered. The need is indicated for aggressive leadership, education, staff communication, and improved state-of-the-art studies in cost effective treatments of water pollution." HRIS No. 260818.

2. Rehabilitation of Channelized and Other Altered Streams.

Barton, J. R., E. J. Peters, D. A. White and P. V. Winger (499)

1972. Bibliography on the physical alteration of the aquatic habitat (channelization) and stream improvement. Brigham Young Univ. Publications. 30 pages (on sale from BYU Press, 205 V P B, Provo, Utah 84601 for $1.60.

Authors' abstract: "Stream channelization and dredging have destroyed many miles of pristine stream in the United States. Since water and water systems are important to the well-being and development of man, rehabilitation and preservation of water systems are a necessity. Extensive research will be needed on all aspects of habitat destruction and rehabilitation. It is hoped that this bibliography will facilitate any literature review on this subject." Sport Fishery Abstracts No. 17505.

Barton, James R., David A. White, Parley V. Winger, and Edward J. Peters. Brigham Young University. (500)

1972. The effects of highway construction on fish habitat in the Weber River, near Henefer, Utah. Ecological Impact of Water Resource Development, a technical session of the Symposium, "Water, Man, and Nature," REC-ERC 72-17, pages 17-28, 8 figs., 4 tables, 13 references.

Authors' conclusions: "The results of this study indicate that the structures built into changed channels of the Weber River have been effective in producing fish habitat that is comparable to, if not better than, the habitat of the changed sections. Deflector structures placed in the backwater area of a check dam and on the inside of a bend in the river will not be effective in producing good habitat. The decrease in the length of the river is one of the disadvantages of channelization. Where feasible, consideration should be given to maintaining the overall length of a stream. Structures made of large riprap material are often more economical and they produce good fish habitat. Invertebrates colonized the new river bottom and produced equivalent numbers and species after 6 months. Fish populations were essentially equal in changed and unchanged areas two years after the construction. More work needs to be done to establish the best combination or system of structures which will create a good habitat over a given length of river channel." Sport Fishery Abstracts. No. 15658

Barton, J. R., and P. V. Winger (501)

1973(a)A study of the channelization of the Weber River, Summit County, Utah. Brigham Young University (Provo, Utah 84601). 154 pages, 37 figs., 23 tab., ref.

Summary: "Construction of interstate 80 in Henefer Valley, Utah resulted in channelization of 1.6 miles of Weber River. In an attempt to alleviate some of the adverse effects of channelization, instream rehabilitation structures in the form of deflectors and check dams were installed in the altered sections. Because of these structures, hydrologic features in the changed portions of the River were similar to those of the unchanged areas. Holes were scoured around the structures and material was deposited below, forming riffle areas. There were as many holes and riffles in the changed sections as in the unchanged. Channelized portions of the Weber River were rapidly populated by macroinvertebrates. After six months with substantial stream flows and stabilization of the substrate, no difference in numbers, weight, or species diversity could be detected between the benthos of the changed and the unchanged sections. Fish population estimates were difficult to obtain due to the size of the River, high mobility of the fish, and low shocking efficiency especially at high discharges. However, shocking data did indicate that fish populations were essentially the same in the changed and unchanged areas as a result of the rehabilitation measures taken. Delury population estimates collected in 1972 indicate that the fish populations were similar in changed and unchanged areas and that shocking efficiency decreases as the number of holes and amount of cover increase. Rehabilitation structures did provide holes and riffles in the changed sections, nevertheless, channelization should be avoided if at all possible since other deleterious effects still occur such as loss in stream length, loss of cover, loss in streamside vegetation and loss in aesthetic value." HRIS No. 204534.

Barton, J. R., and P. V. Winger (Department Civil Engineering, Brigham Young University, Provo, Utah 84602) (502)

1973(b) Rehabilitation of a channelized river in Utah. Hydraulic Engineering and the Environment. Proceedings of the Hydraulic Specialty Conf. Bozeman, Mont., August 15-17, pages 1-10.

From authors' abstract: "Construction of Interstate 80 in Henefer Valley, Utah resulted in channelization of 1.6 miles of Weber River. In an attempt to alleviate some of the adverse effects of channelization, instream rehabilitation structures in the form of deflectors and check dams were installed in the altered sections. Because of these structures, hydrologic features in the changed portions of the river were similar to those of the unchanged areas...Channelized portions of the Weber River were rapidly populated by macroinvertebrates. After six months with substantial stream flows and stabilization of the substrate, no difference in numbers, weight, or species diversity could be detected between the benthos of the changed and the unchanged sections...DeLury population estimates collected in 1972 indicate that the fish populations were similar in the changed and unchanged areas and that shocking efficiency decreases as a number of holes and amount of cover increases. Rehabilitation structures did provide holes and riffles in the changed section, nevertheless, channelization should be avoided if at all possible since other deleterious effects still occur, such as loss in stream length, loss of cover, loss in streamside vegetation and loss in aesthetic value. Sport Fishery Abstracts No. 17459.

Funk, John L. (Missouri Department of Conservation, Columbia 65201) (503)

1973. Characteristics of channels for warm water fisheries. In Wildlife and water management: striking a balance. Soil Conservation Society of America, 7515 N.E. Ankeny Road, Ankeny, Iowa, pages 1-7.

From author's abstract: "In this first paper in an eight-paper symposium dealing with stream channelization and wetland drainage, the author attempts to explain stream ecology in terms under-

standable to a person without training in biology. The emphasis throughout is on diversity...The diversity of the fish community is due to adaptation of the individual species to the great variety of physical, chemical and biological conditions in various stream environments. Man-made channels cannot equal natural channels in diversity. Streams should be channelized only as a last resort and channels should be made as diverse as possible. Sport Fishery Abstracts No. 17509.

Grizzell, Roy A. Jr., and Richard G. Vogan (504)

1973. Characteristics of channels: managing rights-of-way for wildlife and aesthetics. Pages 27-30 in Wildlife and water management: striking a balance. Soil Conservation Society of America (7515 N. E. Ankeny Road, Ankeny, Iowa 50021)

Channel construction methods that can be beneficial for fish and wildlife are discussed. Some of these channel changes include the construction of channel loops, spoil areas, weirs, floodways, channel appurtenances, and the protection of beneficial vegetation. The management of channels for aesthetics is also considered.

Hunt, William A., and Richard J. Graham (505)

1972. Preliminary evaluation of channel changes designed to restore fish habitat. Cooperative Fisheries Unit, Montana State University. 42 pages, 11 tables.

"An evaluation of the fish habitat in two meanders constructed in the Clark Fork River west of Drummond, Montana, shows the hydraulic, topographic and fish population characteristics of these artificial meanders to be similar to those found in comparable natural sections of the river. A design procedure based on observations of meanders in stream being altered is recommended." (Authors' abstract)

Little, Arthur D. and Philadelphia Academy of Natural Sciences. (506)

1973. Report on channel modifications. 2 volumes. Prepared for the Council on Environmental Quality. Volume I, pages ii + 394, Volume II, pages ii +42 channel modification project descriptions. (U.S. Government Printing Office, Washington, D. C. 20402. Price for Volume I, $3.25, Stock No. 4111-00014; Price for Volume II, $7.75, Stock No. 4111-00015.)

This report assesses environmental, economic, financial and engineering aspects of channel modifications, and the availability and use of alternatives, as planned and carried out by the Corps of Engineers, Soil Conservation Service, Tennessee Valley Authority and Bureau of Reclamation. This assessment has drawn upon the public record and literature, observations in the field of 42 projects in 18 states, and discussions with at least 558 people in 30 public meetings throughout the nation. This report is an independent, objective and factual assessment, meant as a basis for C E Q policy considerations. Volume I describes the procedures in carrying out the assignment, summarizes findings and presents nine chapters on contractural elements of the work. Chapter 5 is entitled "Effects on Fish and Wildlife Resources, Habitat, Species Diversity and Productivity". This chapter deals specifically with the effects of stream modification on fish and wildlife. The results of the studies identified the following significant issues, which had definite effects on the biota and their habitats. They were: wetland drainage; cutting off of oxbows and meanders; clearing of flood plain hardwoods; water table levels and stream recharge; downstream effects; erosion and sedimentation; and channel maintenance.

Volume II contains field evaluation reports which describe in detail the 41 channel modification projects studied. These reports are based upon data and reports provided to the contractor by interested agencies before and after the field surveys, relevant written material supplied by other groups and interested citizens, field surveys of the project works, and discussions with interested officials and citizens.

Peters, John C. (507)

1970. Operations since 1963 under Montana's stream preservation law. Transactions of the Thirty-fifth North American Wildlife and Natural Resources Conference, pages 276-284.

Discusses operations under, and implications of a

two-year trial period law passed in 1963 and a permanent law passed in 1965 (Chapter 10, Montana Laws of 1965) providing for submission to the Montana Fish and Game Commission for review and comment and arbitration of disagreements, plans for construction and hydraulic projects affecting fishing streams.

The author states: "Before Montana had its law, the road builders listened to alternate proposals, but the final plans included only incidental considerations for the preservation of the trout stream environment. The Instructional Memorandums of the Bureau of Public Roads were not adequate because there were no provisions to settle differences. Legally, the road builders had no responsibility to consider requests aimed at stream protection. Only after passage of the Stream Preservation Law were we able to work out compromises that allowed the building of roads without the needless destruction of streams and the surrounding valley floors..."

"...The following facts based on the channel inventory were presented at the 1965 legislative committee hearings:

1. That 354 of 987 miles (36%) of channels surveyed had been altered from their natural condition.
2. There were 2,401 alterations counted, nearly three per stream mile.
3. Altered channels produced only one-fifth the number of game fish and one-seventh the weight of game fish as natural channels."

Some of the reported accomplishments under the law during the first six years include: moving of proposed road realignments to avoid encroachment on several rivers; designing and building of meanders so the channel was as long after construction as before; building and/or planning of extra bridges to preserve natural meanders; replacement of brushy floodplain vegetation removed to facilitate construction; and limiting channel excavation to those times of the year when trout are not spawning and eggs are not in the redds. Good cooperation is reported to have been developed with Federal agencies concerned and no Federal cost-sharing is allowed on channel work under the Agricultural Conservation Program unless it meets with the approval of the Montana Fish and Game Department.

"...In 1968 the Montana Legislature appropriated $100,000 to the Department for the construction of recreation lakes. Involved in this program is the utilization of highway fills to impound water. The

Fish and Game Department pays the difference in cost between a fill designed for a roadway and a fill designed for a dam embankment... Recently, we obtained a Memorandum of Understanding with the State Highway Department dealing with land isolated by road construction activities. It allows us to have the highway right-of-way personnel act in our behalf to purchase this isolated land for fish and game purposes..."

Shelton, J. M., and R. D. Pollock (508)

1966. Siltation and egg survival in incubation channels. Transactions, American Fisheries Society, 95(2): 183-187.

"Fall-chinook salmon eggs in Abernathy incubation channel suffered as much as 85% mortality when 15 to 30% of the voids in the gravel beds were filled with sediment. With one 70 foot section of the channel used as a silt-settling basin, the mortality was reduced to 10% or less. We believe that a siltation control system consisting of a flushable sand trap and settling basin constitute the most economical means of reducing the amount of sediment entering this and similar channels." (Authors, Bureau Commercial Fisheries, Columbia Fisheries Program Office, Portland, Oregon. Sport Fishery Abstracts No. 8444.

Workman, Dennis L. (509)

1974. Evaluation of stream improvements on Prickly Pear Creek, 1971-1973. Final report of projects F-9-R-19 to 22, job II, as financed by Montana State Fish and Game Commission and Montana State Highway Commission. 13 pages, 3 tables, 4 references.

This report documents the conditon of the fishery and stream channel prior to construction of Interstate Highway 15, seven miles south of Helena and describes an experimental method employed to halt bank sloughing and to enhance recovery of streamside vegetation along the man-made channel of Prickly Pear Creek. It discusses success or lack, thereof, of willow shoot plantings, rock and soil berms at the toe of steep eroding banks to stop stream bank sloughing along the relocated channel,blanket rip-rap used to protect the highway grade from stream erosion, and natural seeding in areas where good soil quality existed. After 4 to 5 years the author stated, "Fish population estimates in 1972 indicated that trout numbers returned to pre-construction (1967) levels with 79 rainbow trout (Salmo gairdneri) and 99 brown trout (Salmo trutta)per acre. The total pounds of trout (30 pounds per acre) was still below preconstruction levels (36 pounds per acre). Sucker (Catostomus catostomus and Catostomus commersoni) populations remained at a level 59 percent below the pre-construction numbers."

As one of his recommendations the author stated: "In situations where stream channels must be altered or relocated, future maintenance problems can be diminished and fish population recovery enhanced if the physical characteristics of the original channel are retained in so far as possible or transmitted to the new channel. Stream discharge and basic sediment load are not permanently changed in highway construction, therefore, it is necessary to maintain the same width, depth, meander wave length and gradient characteristics of the original channel in order to maintain stability in the river system. The final channel design should incorporate needs of fisheries, e.g. pool riffle ratios, bottom configurations or thalweg location...In inplementing this it is recommended that, if a stream must be rechanneled, the new channel be meandered so the original stream length is maintained..."

C. PLANTS AND WILDLIFE.

1. Right-of-way Vegetation Management With Specific Reference to Wildlife.

Anonymous. (510)

1940. Highway department plans for protection of state's wildlife. Ohio Public Works 13(5):10.

"To carry out program of conservation, department is planting trees, shrubs, vines and rough grasses in and around all roadside betterments." (DOT abstract)

Besadny, C. D., C. Kabat, and A. J. Rusch (511)

1968. Practical aspects of a selective brush management program on Wisconsin Roadsides. Transactions, Thirty-third North American Wildlife and Natural Resources Conference, pages 236-249.

Describes a program -- called selective brush management, "designed to increase the esthetic quality of the country road, make management of roadside rights-of-way easier, help reduce soil erosion, and provide wildlife food and cover...The program grew out of a re-evaluation of existing maintenance practices which completely eradicated native woody vegetation along rights-of-way and the concurrence that this cover should be maintained and developed for its multiple natural resource values, including the practical, biological, cultural and other related aspects."

The need for hedgerow type cover for certain forms of wildlife was brought out in a comprehensive bobwhite quail study in Wisconsin which showed that when the ratio of acres of land to miles of hedgerow cover on the study areas was changed from 250:1 to 450:1, the quail densities were reduced 50 percent; and when the ratio changed to 650:1, the quail population disappeared.

This paper provides excellent suggestions for steps that may be taken to implement a successful cooperative program (in this case it involved 19 Wisconsin public and private agencies); how to select, make and treat the roadsides and maintain the roadside vegetation; and how to carry the work through to development of a manual useful in highway rights-of-way management. Attention is given to such details as removal of trees on the south side of a road which might slow the melting of ice on the road surface; to removal of woody vegetation next to fences to prevent damage to the wire; to removal of vegetation which might interfere with water drainage; and to development of a maintenance cycle which is effective for brush management. Consideration is given to problems that might be created by disease-carrying shrubs such as buckthorn (Rhamnus cathartica), wild gooseberry (Ribes sp.) and Juniper (Juniperus sp.); to drifting snow; and to driver visability. Attention is called, also, to special types of vegetation which offer management possibilities such as remnants of native prairie vegetation found along some Wisconsin roadsides. The authors indicate that management of such vegetation consists essentially of burning -- as early in spring as possible -- on a three-or-four-year rotation, depending on the accumulation of dead plant material.

Bramble, W. C., W. R. Byrnes, and R. J. Hutnik (512)

1958. Effects of chemical brush control upon game food and cover. Pennsylvania State University. Agr. Exp. Sta. Progress Report 188. 7 pages, 6 photos, 1 graph.

"A five year study of the development of low plant cover and game usage on a transmission line right-of-way in central Pennsylvania has been made following five chemical brush control techniques. The woody brush was first brought under control by use of adequate spray volume and thorough coverage. A top kill of 94.1 per cent or higher was obtained. This was followed by a resurge of 26 to 42 woody plants over three feet in height per acre five years after spraying, sassafras excepted. When sassafras was included, the number of woody plants per acre over three feet increased to 1,224 for winter basal and to 158 for summer basal sprays. All techniques gave adequate control except for sassafras in the case of winter basal. Considerable disturbance of plant cover, both in amount and kind, followed broadcast of semi-basal techniques. Fireweed became prominent for several years after which the plant community developed toward its original composition. Blueberry, which was practically eliminated by broadcast sprays remained sparse. The selective basal techniques maintained the original plant community as a low cover. Common game species used all spray areas the first year following spraying and have either increased their use or maintained it for five years.

The development of edges and type interspersion through cutting of the right-of-way and elimination of woody brush on it has favored such species as turkey and rabbits. Deer used the sprayed areas heavily in the spring and summer, while grouse appear to prefer the wooded edges." Authors' summary. W R No.92

Bramble, W. C., W. R. Byrnes, and D. P. Worley (513)

1957. Effects of certain common brush control techniques and materials on game food and cover on a power line right-of-way. Pennsylvania State University. Agr. Exp. Sta. Progress Report 175. 4 pages, 6 photos.

Excerpts from summary: "Four years after spraying a power line right-of-way with herbicides, a comparison of five techniques indicates that by use of basal sprays, a stable ground cover can be maintained with minimum disturbance. On the other hand, broadcast spraying resulted in drastic alterations of the low plant cover which has been slowly progressing towards a more stable condition.... Summer basal spray proved to be effective on hard-to-kill mixed oak and maple brush and produced a maximum control of brush coupled with minimum disturbance of low plant cover. It also preserved several valuable wildlife shrubs that were nearly eliminated by broadcast and semi-basal sprays..." W R No. 90.

Cassal, Frank J., and Robert B. Oetting (514)

1970. Ecological consideration may favor reduced mowing. Public Works, 101(6):95-97.

"Study reveals that wildfowl move into unmowed roadside vegetation and have successful nesting seasons." (DOT abstract)

Duebbert, H. F., and H. A. Kantrud (515)

1974. Upland duck nesting related to land use and predator reduction. Journal of Wildlife Management, 38 (2): 257-265.

This study dealt primarily with effects of predation and of land use, including idled cropland planted with a grass-legume mixture under the Cropland Adjustment Program in north-central South Dakota, on upland duck nesting. Of 64 duck nests found in an area with predator reduction, 5 were in roadside cover. These nests were at a density of 100 nests per square kilometer -- considerably higher than nests found in any other cover.

With respect to cover management, the authors state: "General observations throughout the eastern Dakotas indicate that intermediate wheatgrass and tall wheatgrass (Agropyron intermedium and A. elongatum) in combination with sweet clover and alfalfa constitute highly desirable cover when established on abandoned or idled cropland. To be of maximum value for duck nesting we believe it is necessary to maintain such cover in idle status for approximately 5 or 6 years. In later years, reductions in height and density of planted vegetation combined with associated environmental changes in the habitat reduce its value as nesting cover. Thus, periodic manipulation of the cover by mechanical treatments, prescribed burning, or other methods of rejuvenation probably will be required to maintain the vegetation in a vigorous, robust form."

Egler, Frank E. (516)

1953(a) Our disregarded rights-of-way --- ten million unused wildlife acres. Transactions, 18th North American Wildlife Conference. Pages 147-157, illus.

The author estimated there are more than ten million acres in rights-of-way and roadsides east of the Mississippi River. In comparing selective basal spraying and blanket foliage spraying of vegetation with herbicides, he found the former to be just as cheap in the first conversion stages of the vegetation to trees as blanket spraying; it provides edge effects valuable to wildlife and is cheaper to maintain. Although he indicated that selective spraying required workers who know their plants in the dormant season, there are fewer tree species among the shrubs than one might think and basal spraying had been found to be a more efficient root-killer with the end result a cover that retards reforestation -- and consequently lower maintenance -- for periods of twenty-five years.

Egler, Frank E. (517)

1953(b) Vegetation management for rights-of-way and roadsides. Annual report of the Board of Regents of the Smithsonian Institution, Publication 4149, U. S. Government Printing Office, pages 299-322.

One of the definitions of this report of rights-of-way and roadsides is that they are "non-forested lands which are tending to develop into forests." This report states that "most wildlife inhabits 'edges' or 'borders' -- combinations of vegetation types, not solid forest or wide-open grasslands. To preserve these wildlife habitats, we must also preserve the roadside thickets." Specific herbicides and application methods are discussed as are the specific plant species affected. Many shrub species important to wildlife are listed. The author states that "present botanical knowledge indicates that most of the upland grasslands are easily invaded by a few species of trees, whereas the shrublands are relatively sealed against tree reinvasion."

Egler, Frank E. (518)

1957. Rights-of-way and wildlife habitat: a progress report. Transactions, Twenty-second North American Wildlife Conference, pages 133-144.

Estimates 50 million acres of land in rights-of-way of various types, including an area larger than the State of Georgia in publicly owned throughways. Points out that the first step in vegetation management on a right-of-way would be discriminate elimination, within reasonable cost limits, of the undesirable woody plants and that indiscriminate blanket spraying with herbicides often results in the root kill of desirable shrub cover before the tree roots are killed; these shrubs do not seed again, he states, whereas trees do. He states existing knowledge is entirely adequate for the revision and improvement of existing brush control program and suggests that public education, especially of land owners may be expedient to bring about needed changes in vegetation management of the rights-of-way domain.

Egler, Frank E. (Aton Forest, Norfolk Connecticut)(519)

1958. Science, industry, and the abuse of rights-of-way. Science 127 (3298):573-580, 4 photos.

"A long and convincing paper on the reasons for which 'brush control' on rights-of-way is almost universally done in harmful and uneconomical ways. Ignorance, habit, and vested interests combine to make progress slow. If qualified botanists were consulted, right-of-way could be maintained more cheaply in the long run and would provide better wildlife habitat of low fire hazard. Blanket spraying, now commonly used, has many drawbacks even to the operating companies. No one treatment is the whole answer; treatments must be adapted to the site and the vegetation." WR No. 92.

Graham, Edward H. (520)

1947. The land and wildlife. Oxford University Press, New York xiii + 232 pages, illustrated. From a section on "Roadsides" by this former Chief Biologist of the Soil Conservation Service, the following quotations appear pertinent:

"The road edge is sometimes decried by wildlife managers as a habitat, because of the disturbance by traffic. Many roadsides, however, provide desirable permanent habitats for insectivorous birds, and they offer escape cover and travel lanes to many non-game species, both bird and mammal. The modern highway demands broad, gently sloping shoulders, which are best maintained in grass for safety and control of erosion along the right-of-way. Such margins are mowed, and in themselves are of little use to most wildlife. Back of the grassed portions, however, there are often plantings of shrubs and trees, which may be of considerable value to wildlife.

Anyone who has traveled the broad highways of Texas, for example, can scarcely fail to notice the number of birds' nests in the shrubs and trees that have been planted there. This is especially notable in the prairies and other treeless sections, where woody cover is scarce. Even in the semi-arid western part of the state, Texas highways are dotted with clumps of trees and shrubs wherever, along the road, a low place indicated that enough drainage water would collect to warrant the planting of them.

"In humid areas where woody vegetation is more abundant, highway cuats and fills afford opportunities to use plant species valuable to wildlife for food and cover. As with the field border and many other sites valuable to the wildlife manager, highway sites usually consist of subsoil, or even parent material. From the standpoint of their value to wildlife, not a great deal of planting experience is at hand. Many of the plants useful on eroded sites, however, will grow on disturbed roadsides." (Pages 199-120)

"Highway revegetation. where woody plants can be used advisedly, has been pointed largely at erosion control and landscape effect. There is no reason why it cannot be modified to contribute to wildlife welfare too. Limited experience indicates that it can." (Page 121).

"A little-recognized value of revegetating our highway margins and roadsides is the effect upon aquatic environments. The control of erosion on roadsides obviously holds in place thousands upon thousands of tons of soil that would otherwise find its way into streams, rivers, ponds, lakes, and reservoirs. In many of our rural sections, as almost anyone who has been in the country during a heavy rain knows, the erosion silt moving away from road cuts, fills, and ditches is enormous. What must it be in the aggregate, therefore, when 20,000,000 acres of American land are devoted to roads and highways! Any program to control roadside erosion will contribute materially to clearer streams and waters, and consequently to better habitats for fish and other aquatic life." Page 123.

Gysel, Leslie W. (521)

1962. Vegetation and animal use of a power line right-of-way in southern Michigan. Michigan Agr. Exp. Station. Quarterly Bulletin 44 (4): 697-713, 2 figs.

From abstract: "The species composition and density of plant communities on a mile of power line right-of-way were analyzed and indications of animal use of these communities were noted. Some communities were treated with herbicides to kill trees, which would grow into the conductors. The plant species composition and density in the right-of-way were different than that of the adjacent vegetation types... All vegetation communities had a variety of dry and fleshy fruits, much browse, and generally, dense ground cover during the summer that could be used by wildlife species. Sixteen species of mammals and nineteen species of birds were trapped or observed during two summers...During the winter, white-tailed deer and rabbits were in most of the plant communities...Animal use was apparently not directly affected by the herbicide, but by the composition and density of the vegetation in the right-of-way and in the adjacent vegetation types." W.R. No. 106.

Hankla, Donald (522)

1959. Utility rights-of-way. - Wildlife lands of promise. Wildlife in North Carolina, 23 (1): 18-19, 7 photos.

"Experimental plantings of a right-of-way in Duke For. near Durham, N.C. began in 1951. They consisted of shrub lespedeza along woods edge and either fescue and ladino clover or sericea lespedeza below power lines. In the seven years, sericea provided excellent cover and some food for rabbits and quail -- and it did an excellent job of preventing tree invasion. Fescue-ladino plots provided superior wildlife habitat, for they became invaded by legumes, weeds and brambles. But they resisted tree invasion. Borders of shrub lespedeza rated high in food production, despite having no maintenance after planting. Untreated plots grew up in trees and were relatively poor wildlife habitat. 'The study indicated that if utility company rights-of-way were seeded to low growing perennials after they are cleared, long-term maintenance problems and costs would be considerably reduced and sportsmen would be greatly benefited by the creation of prime game-producing habitat'". W. R. No. 94.

Hoffman, Donald M. (523)

1973(a) Pheasant nest site selection. Special Report Number 32. Colorado Division of Wildlife. 27 pages, 22 tables, 17 figures.

From author's abstract: "The objectives of this study were to compare ring-necked pheasant (*Phasianus colchicus torquatus*) nesting use and nesting success in winter wheat (*Triticum aestivum*), alfalfa (*Medicago sativa*), crested wheatgrass (*Agropyron cristatum*), hairy vetch (Astragalus sp.). white sweet clover (Melilotus alba), alfalfa-crested wheatgrass mixture, smooth bromegrass (Bromus inermis), tall wheatgrass (Agropyron elongatum), and intermediate wheatgrass (Agropyron intermedium)... Results indicated that three cover types, alfalfa crested wheatgrass mixture, intermediate wheatgrass, and tall wheatgrass have definite possibilities for replacing weedy cover (volunteer forbs) along roadsides for pheasant nesting cover. Intermediate and tall wheatgrass are considered suitable substitutes for alfalfa and alfalfa-crested wheatgrass."

Hoffman, Donald M. (524)

1973(b) Nesting cover for pheasants. Colorado Outdoors 22 (3): 36-38. illus.

"Recommendations based upon study: roadsides and other nesting cover should not be mowed before early August nor should they be sprayed with herbicides (particularly in legume-grassland cover types.) W.R. No. 150:78.

Joselyn, G. Blair (525)

1969. Wildlife - an essential consideration determining future highway roadside maintenance policy. Reprinted from Highway Research Record, Number 280, Highway Research Board (Wash., D. C.) 14 pages, 2 tables, 1 figure.

Abstract: "Primarily because of economic considerations, many states are altering their programs of vegetation management on highway roadsides by reducing the frequency of mowing. This change in maintenance policy will result in substantial increases in acreages of nesting cover along highway roadsides for songbirds and game birds. In the Midwest, the ring-necked pheasant could be a prime beneficiary, but at the same time may cause some concern for motorist safety. This report traces the history of roadside development, and discusses newly emerging concepts of roadside vegetation management and the resulting implications for ground-nesting birds and small mammals in the Midwest." Bibliography of 80 titles.

Joselyn, G. Blair. (526)

1974. Management of roadside cover for nesting pheasants. Department of Conservation. (Springfield, Illinois). Project numbers W-66-R-8 through W-66-R-14.

In seven job completion reports covering the period from September 1, 1967 to June 30, 1974, studies concerning the management of roadside cover for nesting pheasants are discussed. The objective of these studies was "to establish and maintain grass and legume cover on roadsides in intensively farmed east-central Illinois for the purpose of creating, by predetermined design, favorable habitat for nesting pheasants and to evaluate the utilization of this habitat by nesting pheasants and pheasant broods."

The numbers of cock, hen, and juvenile pheasants observed per mile along the roadside study area remained the same or fewer than an established pheasant study area for the four years prior to maturity of the seedings. The number of pheasants observed per mile for the first three years after seeding maturity indicated a 1.5 to 2.5 times increase in pheasants observed than two other established pheasant areas. Several short bibliographies are provided.

Joselyn, G. Blair and G. I. Tate (527)

1972. Practical aspects of managing roadside cover for nesting pheasants. Journal of Wildlife Management, 36 (1): 1-11.

Author's abstract: "A study to determine the feasibility of managing roadsides for nesting ring-necked pheasants (Phasianus colchicus) in the intensively farmed cash-grain region of east - central Illinois has been underway since 1962. Data for 6 years showed that the number of pheasants hatched on roadsides was substantially increased by the seeding of a grass-legume mixture in place of old bluegrass (Poa spp.) sods and annual weeds. To evaluate cost and acceptance of such seedings as a practical tool for providing pheasant nesting cover over a large area, roadsides within, or abutting on, a 16-square mile area (equivalent to 20 square miles) were seeded to bromegrass (Bromus spp.) and alfalfa (Medicago sativa) during August and September 1968. Of the 65 farm operators residing in the management unit, (94 per cent) participated in the program. This participation included an agreement on the part of the farmers to delay mowing of their roadsides each year until July 31. Total cost of the project was calculated at $10,124, or $139 per mile for one side of the road. Amortized over a 10-year life expectancy of the seedlings, the cost per acre per year would be about $700 but could be reduced by as much as 50 percent by modifying the seeding operations. Dry weather delayed maturity of the seedings until 1970; during that year less than 10 percent of the roadsides had been mowed by July 31, as compared with 97 percent by that date in 1967."

The authors stated that the percentage of land in this Sibley study area in hay declining from 9.3 percent of the land in 1962 to only 2.6 percent in 1970, and with further decline expected, roadsides, which occupy 1.3 percent of the study area, may constitute the largest segment of potential nesting cover in the near future. They pointed out also, that in central Illinois, farmers control management practices of roadsides and that frequent mowing of roadsides by farmers beginning in June is typical. The willingness of farmers to agree to the roadside seeding and delay mowing was regarded as encouraging.

Joselyn, G. Blair, John E. Warnock, and Stanley L. Etter (528)

1968. Manipulation of roadside cover for nesting pheasants -- a preliminiary report. Journal of Wildlife Management, 32 (2):217-233.

Authors' abstract: "During the 4-year period 1963-66, densities of ring-necked pheasant (Phasianus colchicus) nests per acre established on unmowed roadside plots seeded to a grass-legume mixture (3.0 nests per acre) exceeded those on unmowed, unseeded plots (managed control plots) (2.0 per acre) and on unseeded roadside plots where mowing was not controlled (unmanaged control plots) (1.5 per acre). During each of the 4 years, seeded roadsides also had greater densities of nests per acre than any of seven other cover types on the study area, including 1.3 more per acre than unharvested hay. Rates of success for nests established on seeded plots were only slightly higher than for those established on managed and on unmanaged control plots, but higher nest densities on seeded plots resulted in significantly larger numbers of successful nests on seeded plots than on either managed control or unmanaged control plots. The hatch of pheasant nests on seeded roadsides, on a per acre basis, exceeded that in all other cover types on the study area during 3 of 4 years." This study was conducted in Ford and McLean Counties, in east-central Illinois. The author, who suggested that a minimum mowing schedule for highway rights-of-way and the seeding of selected grasses and legumes could provide cover for a variety of species such as quail, pheasants, rabbits, and some song birds, recognizes possible wildlife traffic hazards.

Kirkham, Dennis P. (529)

Undated: Establishment and maintenance of roadside cover for wildlife in central Illinois. Department of Conservation (Springfield, Illinois). Project Number W-85-D.

This report outlines the costs and time needed to permanently establish and maintain roadside cover for wildlife, especially pheasants, in central Illinois.

Latham, Roger M. (530)

1956. Rights-of-way for wildlife. Pennsylvania Game News. 27 (4): 19-23, 3 figs.

"Latham demonstrates the wildlife values of rights-of-way, especially those with grassy middle strip and increasingly tall brush toward sides. Native plants sometimes serve very well in these areas. But inferior species may dominate a site, and extensive, uniform, coverage (even by a useful species) is not desirable. Pennsylvania has 88 species under test for planting on rights-of-way. One of them, rose clover (Trifolium hirtum), seems especially promising because of its wide range of tolerance, durability, and forage value. Tests of herbicides have revealed no ill effects to wildlife when directions are followed. Selective spraying of young trees is considered a satisfactory and economical means of maintenance on rights-of-way." W.R. No. 85

Markham, K. R. (531)

Undated: A chemotaxonomic approach to the selection of oppossum resistant willows and poplars for use in soil conservation. New Zealand J. of Science, 14 (1): 179-186, 1 table, 1 photograph, 7 references.

"The level of salicin and its derivatives in the leaves of a variety of poplars and willows has been determined quantitatively. It is established that a high level of salicin (or salicin derivatives) correlates both with high relative bitterness and with unpalatability to oppossum in these plants. A semiquantitative thin-layer chromatography method for assessing relative bitterness in these plants at the nursery level is discussed." (Author) Abstract from HRIS No. 230044

Martz, Gerald F. (532)

1967. Effects of nesting cover removal on breeding puddle ducks. Journal of Wildlife Management, 31(2): 236-245.

This study was conducted in the Lower Souris National Wildlife Refuge, North Dakota in 1961 and 1962. Duck nesting and predation effects were compared on mowed and burned blocks of the area with blocks of undisturbed cover or "residual cover." In both years of the study, unmowed meadows and shorelines and roadsides had sufficient residual cover (about 12 inches tall) to conceal early nests i.e. those begun between April 28 and May 10. Nest densities were greater in areas where residual cover was untouched. Gadwalls (Anas strepera) nested readily in unmowed shoreline cover and roadsides adjacent to the mowed areas. Shorelines and roadsides produced the highest nest-success rate of the major cover types -- 43 percent.

Michaud, Howard H. (533)

1943. Treatment of highway rights-of-way for erosion control, beautification, wildlife habitat and water conservation. Proceedings 1943 Conservation Conference, Indiana Division, Izaak Walton League of America, pages 18-19

"Discussed the value properly-directed highway landscaping may have in providing cover and food for wildlife. WR No. 40.

Niering, William A., and Richard H. Goodwin (534)

1974. Creation of relatively stable shrublands with herbicides: arresting "succession" on rights-of-way and pastureland. Ecology, 55(4):784-795.

This paper deals, in part, with a description of the Connecticut Arboretum Right-of-Way Demonstration Area (established in 1953) and of shrub communities elsewhere in the Arboretum where the objective was to employ ecologically sound techniques in right-of-way vegetation management and where selective applications of herbicides were used to create shrub communities with high stability and wildlife values. "...As a result of the selective use of herbicides, more than 48 different species of shrubs and vines have been preserved along this limited section of right-of-way. In addition, four species of lowgrowing trees and over 80 species of herbaceous perennials (10 ferns, 15 grasses, sedges and rushes, and 59 forbs) add to the floristic diversity of the demonstration area..." Clones of several shrubs, once established, have high stability with virtually no tree invasion; among these are huckleberry (Gaylussacia baccata), greenbrier (Similax rotundifolia), low blueberry (Vaccinium vacillans), witchhazel (Hamamelis virginiana), speckled alder (Alnus rugosa), sheeplaurel, (Kalmia augustifolia), gray dogwood (Cornus racemosa), and nannyberry (Viburnum lentago).

Pure stands of little bluestem (Andropogon scoparius) exhibit remarkable stability also. The authors point out that in view of the stability of shrub communities and of the possibility of encouraging them through the selective removal of tree growth, the potential of creating shrub cover in vegetation management is great. They believe the selective approach in the application of herbicides, in contrast to blanket spraying, will minimize undesirable effects and maximize environmental quality while maintaining lowest costs. They indicate that this approach has application in right-of-way and wildlife habitat management, naturalistic landscaping and maintenance of habitat diversity.

Nomsen, Richard C. (535)

1969. Land use changes and the ring-necked pheasant in Iowa. Proceedings Iowa Academy of Science 76:223-225.

Excerpts from abstract: "Pheasants are farm game birds and continue to thrive in diversified farming areas. Drastic land use changes in recent years have greatly altered the pheasants' environment. The acreage of safe nesting cover has decreased to only a fraction of its former abundance... Herbicides decreased the value of potential nesting cover along roadsides and ditches. The bare field in winter offeres little resistance to blowing snow, which decreased the effectiveness of available winter cover." WR No. 139:88.

Oetting, Robert Burton. (536)

1970. Waterfowl nesting on interstate highway right-of-way in North Dakota. Ph.D thesis, N. Dakota State University. 110 pages-1970. (From Dissertation Abstracts Intern. 31(9), 1971).

"In 1969 significantly more ducks (94) chose unmowed vegetation for nest sites than mowed (62). The big ducks, mallards, pintails, and gadwalls, were especially responsive to vegetation changes. Shovelers and bluewinged teal did not respond to cessation of mowing. Ducks nesting in unmowed blocks were more successful (73%) than those nesting in mowed blocks (58%). Wildlife car kills did not increase during the year. Of 182 motorists interviewed in the study area, 82% had not noticed the unmowed right-of-way vegetation." WR No. 141:69.

Oetting, Robert B. (537)

1971. Right-of-way resources of the prairie provinces. Blue Jay 29(4), 179-183, illus.

"Rights-of-way of provincial trunk highway, roads, and railroads offer a great potential for wildlife habitat --- more than 2 million acres in the Prairie Provinces." WR No. 144:23.

Oetting, Robert B. and J. Frank Cassel. (538)

1970. Effects of I interstate right-of-way mowing on wildlife, snow buildup, and motorist opinion in North Dakota: a preliminary report. Highway Research Record #335, Highway Research Board (Washington, D. C.) pages 52-59.

"Use of interstate rights-of-way by birds and mammals warrants wildlife management attention. Ducks responded quickly to cessation of mowing when alternate miles of the right-of-way and half the interchange triangles were left unmowed. Seventy-four percent of the ducks chose unmowed nesting sites. Thirty-four percent of right-of-way waterfowl nests were not hatched by July 4 mowing. Unmowed right-of-way vegetation did not cause snow buildup on the driving surface. The majority (82 percent) of 182 motorists interviewed had not noticed the mowed-unmowed conditions of the right-of-way...No increase (in numbers and species of wildlife killed by cars) was noted during the year of alternate mowed-unmowed miles. Recommendations include delayed or curtailed mowing on Interstate right-of-way in waterfowl-producing regions. Such practices will increase nesting success and reduce highway maintenance costs." Bibliography of 25 titles.

Plummer, A. Perry (539)

1970. Plants for revegetation of roadcuts and other disturbed or eroded areas. Pages 1-8 in Range Improvement. USDA Forest Service, (Intermountain Region, Ogden Utah) 10 pages.

The objective of this cooperative research project was to determine useful vegetation on disturbed lands. "Six major purposes for establishing vegetation on such areas are:

1. Stabilize the site against erosion and reduce hazards of silt pollution in streams.
2. Prevent undesirable plants from gaining a competitive foothold.
3. Beautify the area with desirable vegetation.
4. Establish vegetation to screen unsightly backgrounds.
5. Furnish shade and food for wildlife.
6. Provide shade and pleasant environment for people."

Briefly discussed is the growth habit of shrubs, where planting stock can be obtained, selection and use of planting stock, and principles of successful revegetation.

Two tables are provided which list specific bushes, forbs and grasses recommended for use in stabilizing roadcuts and disturbed areas. Vegetal types are listed, also, in order of the adaption of the species to them. Bibliography of 11 titles.

Richter, W. C. (540)

1958. Wildlife food and cover by the mile. Pennsylvania Game News 29(5): 43-44.

The development of natural gas fields and expansion of electrification facilities has created hundreds of miles of right-of-way in north central Pennsylvania. As these areas are redeveloped as shrub areas, both food and cover will be provided for game species. The production of certain "edge" species as compared with the production of these same species in an adjacent forest, show the superior production which occurs in right-of-way edges. "Observations tend to emphasize the fact that complete release of the shrubs from the shading effect by overshadowing growth is a must if maximum production is to be maintained."

Smith, E. Ray (541)

1970. Green ribbons of hope/rights-of-way plantings hold promise of improving wildlife habitat. Forests and People 20(1): 22-23,42, illus. First Quarter 1970.

"Includes a table of planting materials benefitting deer, doves, quail, rabbit, squirrel, and turkeys."

Snyder, Warren D. (542)

1974. Seeding roadsides for pheasant nesting cover. Outdoor facts. Game information leaflet No. 99. Colorado Department of Natural Resources, Division of Wildlife. 3 pages, 2 figures.

This information leaflet suggests procedures for seeding roadsides for pheasant nesting cover in Colorado. Information on what to plant, when to plant and how to plant various permanent grasses and legumes is given. Shrub plantings are also recommended.

Tester, John R., and William H. Marshall (543)

1962. Minnesota prairie management techniques and their wildlife implications. Transactions, Twenty-seventh North American Wildlife and Natural Resources Conference, pages 267-287.

The paper reports on wildlife management aspects of four treatments -- spring burning, fall burning, grazing, and mowing -- on the flora and fauna of prairie habitat in northwestern Minnesota. An historical account of the area is given including use of the area by Indians, incidence of fire, settlement, road building, etc., and the authors state: "At the present time the agricultural operation in this area is relatively intense. Most of the tillable land is being cropped and a recently accelerated program of planned drainage along with newly-bulldozed deep highway borrow pits is rapidly eliminating the marshes and potholes. Where drainage is difficult a few tracts of native prairie remain..."

The authors suggest use of such remaining tracts of prairie for conservation purposes and point out their value for prairie chickens (_Tympanuchus cupido pinnatus_) and waterfowl. Based on their study and on the ecology of prairie chickens and breeding waterfowl the authors recommend a four-year rotation of spring burn, no treatment, graze, and no treatment to maintain the original status of prairie habitats in this ecotone between forest and grasslands.

Trautman, Carl, Robert Dahlgren and John Seubert. (544)

1959. Pheasant nesting. South Dakota Conservation Digest. 26(1) 18-21. 2 photos.

As a conservation measure the authors recommend that farmers use flushing bars on their mowers to save hen pheasants nesting in alfalfa and other cover areas, and to refrain from mowing roadsides (where pheasants often nest) until July 10. This they also recommended to highway mowing crews. After WR No. 96.

Way, J. M. (545)

1970(a) Roads and the conservation of wildlife. Institution of Highway Engineers Journal (Great Britain) 17(7):5.

"Importance of conservation of wildlife discussed and part played in this by roads, and especially road verges, is highlighted." (DOT abstract)

Way, Michael (546)

1970(b)Wildlife on the motorway. New Scientist 47 (718): 536-537.

"Ten thousand acres of motorway verge in England could develop stable plant communities, providing a valuable chain of wildlife habitat. The key is consistent management..." A botanical study completed on a motorway by the Nature Conservancy should provide data for conservationist's proposal to manage the verge for wildlife habitat.

Webb, William L. and Earl F. Patric (547)

1961. Seeding herbaceous perennials in forest areas for game food and erosion control. New York Fish and Game Journal 8 (1): 19-30.

"Forty spp. and varieties of plants were tested and 12 spp. were successfully established along recently abandoned haul roads and skid trails in the central Andirondacks. Small additions of phosphate fertilizer improved stand density, height-growth, and over-all success of legumes but had slight effect on grasses. Medium red clover and mammoth red clover were heavily utilized by deer and other game. A mixture of four grass species seeded on steep slopes prevented erosion but did not provide much game food. From abstr." WR No. 131:13.

Young, Harold E. (548)

1972. Woody fiber farming: an ecologically sound and productive use of rights-of-way. Highway Research Record #411. Highway Research Board (Washington, D. C.) Pages 15-23.

"The transportation and transmission systems in the United States are estimated to have more than 22 million acres of rights-of-way of which approximately 6 million acres are forest land. The present annual national maintenance cost for mowing, cutting, burning, and spraying is estimated to be at least $200 million, an amount that increases each year. The serious national concern about air and water pollution has already encouraged some voluntary and some legislative action to eliminate burning and spraying. In the absence of these techniques, maintenance costs are increased by a factor of five, and the future annual maintenance bill may be $1 billion, if all burning and chemical spraying are stopped. Biomass, nutrient, and pulping studies led to the complete Tree Concept in 1964. An evolution of this concept is the production and utilization of the currently non-commercial tree and shrub species, commonly called "puckerbrush", that occur on rights-of-way.

These species will produce useful paper and paperboard products in less pulping time than commercial tree species. Because "puckerbrush" is not large, 10 to 30 feet in height, and because there are many stems per acre, special harvesting equipment must be developed. Naturally occurring "puckerbrush" on rights-of-way can be harvested in 10 to 15 year cycles. Growth can be augmented by use of fertilizers and by deliberately developing genetically superior species. Thus, it should be possible to derive from the management of rights-of-way on forested land a net profit that will drastically reduce the overall right-of-way maintenance cost."
In a discussion section following the article, Alfred C. Scheer of Montana State University lists advantages and disadvantages of small-stem brush. One advantageous use of this brush which he lists is: "in wide rights-of-way, as wildlife habitat for numerous species of birds and small animals. Recent North Dakota studies have shown that managing rights-of-way as small game habitats does not create a significant accident problem." Bibliography of 18 titles.

2. Vegetation Management and Plantings for Wildlife-General

Agee, Jim (549)

1951. Habitat development plantings --- how patterns determined. Outdoor Nebraska 29(4): 17-18, illus.

"Observations on the trees and shrubs that have proved best for shelterbelt and wildlife planting in Nebraska, and how they should be arranged to provide proper game cover and control of snow drifting. The recommendations are based on study of many old plantings." WR No. 67.

Allen, Durward L. (550)

1953. Wildlife habitat in relation to the use of herbicide sprays on farms, ranches and roadsides. Proceedings 43rd Convention International Association Game, Fish and Conservation Commissioners. Pages 90-94.

"Discussion of how general use of herbicides is hurting habitat and how these chemicals can be used beneficially". (The author admonished wildlifers to get busy and develop a basis of workable techniques on which realistic recommendations can be made to those who are doing the job.) WR No. 75.

Arner, Dale H. (551)

1966. Utility line right-of-way management. Transactions, Thirty-first North American and Natural Resources Conference, pages 259-268.

Points out that although utility line right-of-way development for wildlife has been the subject of numerous papers and that techniques involving bulldozing, discing, selective basal spraying, mowing, fertilizing, seeding and prescribed burning have been described and acclaimed for their dual role in producing supplemental game food and retarding invasions of unwanted vegetation, a survey of state conservation agencies in ten southeastern states revealed that only one state appears to have made substantial gains on such dual management. He stated: "Only a fraction of the several hundred thousand acres of utility-line rights-of-way in the southern states have been cooperatively managed for dual use." He observed that prescribed burning proved to be the most economical and practical of all the maintenance techniques studied. He offered suggestions as to how to implement cooperative right-of-way maintenance programs for wildlife benefits.

Baker, Maurice F. and Neil C. Frischknecht (552)

1973. Small mammals increase on recently cleared and seeded juniper rangeland. Journal of Range Management 26(2): 101-102.

"Small mammal numbers were studied by snap trapping on six areas in Utah where juniper range had been cleared and seeded. On one area, which was trapped both before and for the first 3 years after treatment, numbers of deer mice (Peromyscus maniculatus) and pocket mice (Perognathus parvus) increased greatly in the first 2 years following treatment, then declined sharply to a level which was still above that before treatment, many more small mammals were caught in the second year. Older seedings had about the same number of small mammals as did untreated juniper. Small mammals showed a clear preference for windrowed slash. This was especially true of deer mice and long-tailed voles (Microtus longicaudus). Bibliography of 4 titles.

Baskett, Thomas S. (553)

1953. Pruning as a means of thickening multiflora rose hedges. Journal of Wildlife Management, 17(1): 87-88.

In experiments at the Ashland Wildlife Experimental Area in Boone County, Missouri, pruning or mowing of multiflora rose plants at heights of 4, 10, 14 and 30 inches lead to the conclusion that mowing vigorous young rose hedges at heights of 10-14 inches during the dormant period results in desirable thickening -- at least in a region where the rose is not subjected to repeated and severe winter injury.

Baskett, Thomas S. (554)

1955. Experimental trials of wildlife food and cover plants. University of Missouri, Agr. Exp. Sta. (Columbia) Research Bulletin 584. 24 pages, 8 figs.

From abstract: "Survival and vigor of Mo. experimental plantings after ten to thirteen growing seasons are clearly charted; the plots are described in detail. 'Multiflora rose had an average survival rate of 67%, and vigor was generally good... Other plants which showed good survival and growth over a wide variety of conditions included gray dogwood and wild plum. Tartarian honeysuckle and a variety of black raspberry showed good survival and growth in moderate or good sites... Red cedar and oriental arbor-vitae showed only moderate survival but provided dense, rather durable cover... Most of the plants which were aggressive enough to grow well under the varied and often severe conditions... tended to spread within the plantations... The sizeable number of native species, which performed at least moderately well in the wildlife trials, serves as a reminder that odd areas on the farm often contain at least part of their own planting stock...'" WR No. 83.

Bradbury, Harold M. (555)

1939. Management of apple trees in Massachusetts. Journal of Wildlife Management, 3(3):240-242. 2 pls.

Discusses introduction and spread of the common apple (Malus pumila) into North America, its use by wildlife and ways of managing -- various degrees of release, grafting with scions of Malus floribunda, and fertilizing -- for the benefit of wildlife. The author found that the apple trees should not be pruned, because it impairs persistency of the fruit, lowering its availability during the snowy season. He suggested a 50% release from surrounding vegetation and removal of competitive ground cover.

"Management of wild apple trees should be carried out only in forested or wild areas, never within 500 yards of a commercial orchard. In fact where state-owned land is situated near commercial orchards a good neighbor policy calls for removal of all wild apple trees as a pest control operation."

Bramble, W. C., and W. R. Barnes (556)

1955. Progress report on the effect of certain

brush control techniques and materials on game food and cover on a power line right-of-way. No. 11. Proceedings., 9th annual meeting, N. W. Weed Control Conference. Pages 417-427, mimeo.

Detailed vegetation analysis of effect of 2, 4-D and 2, 4, 5-T and Ammate applied by various methods and in different formulations. All were effective in immediate top-kill of tree sprouts. Effects on resprouting and composition of ground layer varied." W R No.81.

Christisen, Donald M., and Leroy J. Korschgen (557)

1955. Acorn yields and wildlife usage in Missouri. Transactions, Twentieth North American Wildlife Conference, pages 337-357.

Points out that in Missouri, acorns constitute an extremely important food for wildlife because within the State there are 15,000,000 acres of forest land, mostly of the oak-hickory type and that if only 10,000,000 acres of the forest are productive the expected yield would be 200,000,000 pounds of insect-free acorns. From a wildlife management point of view, the authors state that it is advisable to maintain a variety of oak species so that complete failures of acorn production will be unlikely, and that some oaks from the black oak group should be included inasmuch as acorns from these oaks do not germinate until spring and, therefore, are available to wildlife throughout the winter when other food supplies are scarce.

Conner, R. N., R. G. Hooper, H. S. Crawford and H. S. Mosby (558)

1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. Journal of Wildlife Management, 39(1): 144-150.

The authors point out that little information exists for many nongame species of wildlife that will permit the forest manager to coordinate wildlife and timber management practices. This study indicated that the nest cavities of the common flicker (Colaptes auratus), pileated woodpecker (Dryocopus pileatus), downy woodpecker (Dendrocopos pubescens), and hairy woodpeck (D. villosus) were all excavated

in decayed wood of trees infected by fungal heart rots. The authors found that of the four species observed, only the flicker readily used clearcut areas for nesting, their nest trees usually being in edge habitats such as woodlots and suburban areas. They indicated that all four species of woodpeckers would benefit by leaving dead snags and trees with heart rot standing during both regeneration cuts and subsequent thinnings of forest stands. They recommended the practice of leaving uncut filter strips of forest along streams and roadsides with the idea that these strips would provide suitable nest sites. It might be added, parenthetically, that an occasional dead tree in sight of a road also provides resting perches for hawks and other birds which add to the travelers' enjoyment when seen.

Cook, David B. (559)

1939. Thinning for browse. Journal of Wildlife Management, 3(3): 201-202.

In New England and New York, land formerly in agriculture was reverting to forest at the time this article was written and some of the areas were stocked with a high proportion of such species as aspen, grey birch and red maple which, when clearcut, produce an abundance of coarse sprouts of low palatability. The author tried crown-thinning on a second-growth hardwood forest well stocked with better hardwoods -- ash, red oak, sugar maple, black cherry and yellow birch -- and stated: "The effect of this winter thinning was astonishing. The additional light stimulated the growth of herbs and ferns without encouraging coarse annuals or grasses. The stumps sprouted much less vigorously than did those exposed to full sunlight." He indicated that the sprouts were much slimmer than where open-grown and that the deer preferred these "smaller and daintier shoots," nipping them back almost 100 percent and continuing to use the sprout production for three years.

Cook, David B. and Frank C. Edminster. (560)

1944. Survival and growth of shrubs planted for wildlife in New York. Journal of Wildlife Management 8(3): 185-191.

Summarizes cooperative field tests by the New York State Conservation Department and the U. S. Soil Conservation Service of three types of site treatments for planting and establishment of 13 species of hardwood trees and shrubs for wildlife. Plowing the site gave the best growth and survival. Scalping was only a little better than slit planting in undisturbed sod and the extra cost of plowing was more than offset by greater ease of planting and better growth and survival. "At the end of the third growing season, the most promising species were arrowwood. multiflora rose, early shrub lespedeza, silky dogwood, black chokeberry, and bayberry."

Cypert, Eugene (561)

1949. The effect of shading upon seed production of the trailing lespedeza. Journal of Wildlife Management, 13(1): 142.

A survey of ground cover was made in conjunction with timber type mapping on the Kentucky Woodlands National Wildlife Refuge in 1940 and 1949 to determine the effects of the degree of openness in the forest canopy on the ground cover. Samples of seeds collected from the trailing lespedeza (Lespedeza procumbens) indicated that shading inhibits seed production in this species (valuable for wildlife) to a much greater extent that it inhibits total growth of the plant.

Dambach, Charles A. (562)

1948. New lessons from old plantings. Journal of Soil and Water Conservation. 3(4): 165-168, 190, illus.

"In the summer of 1946 the author appraised the success of 33 wildlife-erosion control plantings made on Ohio farms from 1935 to 1940. Approximately 125 species of shrubs and woody vines were used in 5 types of planting sites: (1) severely eroded areas; (2) field border gullies; (3) pond areas; (4) odd areas; and (5) borders. Adaptation to site, proper handling of stock and protection from fire and grazing were the principal factors limiting success. The author gives the relative performance and site adaptation for the species he observed. The only ones that had a wide range

of site tolerance and were suitable for both erosion control and wildlife were multiflora rose, Tartarian honeysuckle, and four shrub dogwoods."
W R No.56

Davison, Verne E. (563)

1942. Bobwhite foods and conservation farming. Journal of Wildlife Management 6(2): 97-109, 1 fig., 1 table.

For bobwhites in the Southeast, Davison suggested that, in connection with conservation farming, annual lespedezas be grown in strips in the crop-rotation system; woodlands producing mast from oaks, gums, pines, hickories, and ashes be protected from grazing; and wildlife borders should be developed on the edges of fields -- *Lespedeza sericea* being suitable for the herbaceous portion, and native shrubs for the heavier cover.

Davison, Verne E. (564)

1945. Wildlife values of the lespedezas. Journal of Wildlife Management. 9(1): 1-9, 1 pl.

Two species of introduced annual lespedezas - the common, *Lespedeza striata* and the Korean, *L. stipulacea* provide food for many species of birds and mammals but when planted in field borders (roadsides) are unable to prevent the encroachment of shrubs. Sericea lespedeza (*L. cuneata*) is able to become established on poor soil and eroded areas and has cover value for wildlife. Shrub lespedezas, especially bicolor (L. *bicolor*) are useful in farm game restoration. They can be established by direct seeding or by setting out one-year plants; will live many years without reestablishment; can withstand burning, discing, cutting, or use by rabbits in winter; and are attractive, especially during August and September because of their masses of purple flowers. The author points out that shrub lespedezas do not grow well on wet lands but are suitable for borders along woodlands and roadsides.

Dickey, J. B. R. (565)

1952. The multiflora rose as a troublesome weed in pastures and on idle land. Proceedings of the 8th

Annual Northeast Wildlife Conference. Jackson's Mill, West Virginia, April 1-4, 1952. 2 pages.

In discussing wildlife plantings, the author pointed out that, before anything new is introduced, one should be very sure it will not get out of hand and prove a nuisance in the future. He cited the European barberry and its role in propagating the destructive black stem rust of small grains, as an example, and stated that the chestnut blight probably had come in on imported ornamentals. He indicated that multiflora rose, starting from nurseries where it was propagated as a stock on which to graft or bud rose varieties had become a serious pest to farmers in at least two sections of the Northeast. He suggested that it had probably been spread by birds or browsing cattle.

Dobie, John G., and William H. Marshall (566)

1954. Notes on the results of certain CCC plantings on the Paul Bunyan state forest, Minnesota. Journal of Wildlife Management, 18(4):531-533.

A report on the contributions of a Civilian Conservation Corps' game food and cover project of 1936 involving spot plantings of white spruce (*Picea glauca*) and northern white cedar (*Thuja occidentalis*). "In conclusion it must be stated that the plantings did not appear to have contributed to game cover. This was thought to be due primarily to inability of small conifers to withstand the shade of the aspen over-story or survive on dry sites and secondarily to pressure from present high deer and rabbit populations."

Edminster, Frank C. (567)

1938. Woody vegetation for fence rows. Soil Conservation. 4(4): 99-101.

"Croplands lacking year round shelter and inferior habitat for wildlife. Extensive unfavorable areas may be broken by planting fence rows with shrubs of value to wildlife. The desirable qualifications of such vegetation are catalogued under 12 headings..." WR No. 16.

Edminster, Frank C. and Richard M. May (568)

1951. Shrub plantings for soil conservation and wildlife cover in the Northeast. U. S. Department of Agriculture Circular #887. 68 pages, illus.

From abstract: "Presents the results of field tests on over 100 shrub species, and gives instructions for the care of many of them. A brief section takes up the utilization of natural growth: '... where natural stands of desired native shrubs are already present in borders, hedgerows, and odd areas, the cutting of overtopping trees may be all that is needed to make such areas as good as any that could be planted'. The bulk of the paper discusses success or lack of success, culture, and uses of many shrubs." WR No. 67.

Egler, Frank E. (569)

1952. Transmission lines as wildlife habitat. The Land 11 (2): 149-152.

"Power line rights-of-way can be extremely useful to wildlife, for they diversify the habitat and offer an enormous amount of 'edge'. They are of little value if clear-cut or blanketed with herbicide, as some are. But selective basal-bark herbicide treatment of woody plants makes possible low cost creation and maintenance of conditions that pleases both power companies and game biologists..." WR No. 71.

Forbis, Larry, et al. (570)

Undated. Wildlife and brushland management -- coordination guidelines for wildlife habitats. Number 2, U.S.D.A. Forest Service, (California Region), 19 pages.

This booklet discusses briefly what considerations of brushland management can be beneficial to wildlife. Attention is given to habitat, high-value vegetation types, and to post management considerations.

Fox, Adrian C. (571)

1935. Planting guide of trees, shrubs, vines and evergreens recommended for game bird cover and food in South Dakota and North Dakota. SCS (Huron, S. Dakota) 17 pp. 6 figs. mimeographed.

Describes cover types and lists some of plants that compose them, together with information as to whether seeds, cuttings, etc. are locally available and suggestions on methods of propagation, collection, cultivation, and fencing. WR No. 5.

Gale, Robert M., Warren F. Kelly, and John A. Lorenzana (572)

1973. Snag management. Coordination guidelines for wildlife habitats, Number 1, U.S.D.A., Forest Service California Region, 11 pages.

This illustrated booklet discusses briefly the categories of snags and their importance to fungi, insects, birds, mammals, and man.

Garrison, George A. (573)

1953. Effects of clipping on some range shrubs. Journal of Range Management 6 (5): 309-317 - illus.

"Results of various intensities of clipping current year's growth on game browse plants of eastern Oregon and Washington. Clipping was done in fall and winter. Some clipping stimulated production, but too much injured plant and reduced flowering. Good utilization levels were: antelope bitterbrush, 60-65% on good sites, 50% on poorer sites; snowbrush ceanothus, 30-40%; rubber rabbitbrush, 50%; creambush rockspirea, 50-60%; short plants of curlleaf mountain mahogany, 50-60%." WR No. 75.

Gates, J. J., E. J. Frank, and E. E. Woehler (574)

1970. Management of pheasant nesting cover on upland sites in relation to cropland diversion programs. Wisconsin Department of Natural Resources Report 48. - iii + 22 pages, illus.

"Specific suggestions are offered for the establishment and maintenance of nesting cover on diverted cropland, including plant materials and seeding rates, field size and shape, and subsequent management to promote maximum utilization by nesting birds. Broad changes in cropland diversion which would facilitate needed types of managment include (1) Emphasis on long-term instead of annual diversion contracts; (2) Incentives encouraging management diverted cropland for the purpose of pheasant nesting cover, and (3) Prohibition of cover disturbance, particularly clipping, during the major period of pheasant nesting. Most importantly, attitudes should be encouraged that publicly financed programs as expensive as cropland diversion should be multiple-purpose in scope in order to realize as many side benefits to society as possible. --From abstr. " WR No. 138:58.

Gehrken, George A. (575)

1956. Shrub lespedeza as a quail management plant in Southeastern Virginia. Journal of Wildlife Management, 20 (3): 239-242.

Discusses attempts to increase bobwhite quail populations in Virginia through the planting of bicolor lespedeza. Quail populations censused on farms having lespedeza plantings with those on farms having no such plantings showed the same trends and it was "...concluded that the plantings had no practical benefits in increasing quail populations."

Gill, John D. (576)

1957. Cutting hardwoods to help deer. Maine Department of Inland Fish and Game, Game Division Leaflet Ser. 1(3): 1-4.

"Concise recommendations for improving carrying capacity in and near yards. Cuttings as much as a mile from a (deer) yard will be used. Cuts should be repeated, and should be small and selective. Best sprouting is from smaller, dominant trees. There is little sprouting from trees of more than 16 in. DBH, or from over-topped trees. Best species, in order, are red maple, birch and hard maple. Best time to cut is November - March; the poorest time is June - August. Top of stump should be cut on slant to reduce rot. Slash should be spread rather than heaped, unless heaps are needed to protect sprouts." WR No. 90.

Gill. John D., and William M. Healy (Compilers). (577)

1974. Shrubs and vines for northeastern wildlife. USDA Forest Service General Technical Report NE-9 (Northeastern Forest Experiment Station in Cooperation with N.E. Deer Study Group and Association of N.E. Game, Fish, and Conservation Commissioners) 180 pages.

"A non-technical handbook in which 34 authors discuss management of 97 native and 3 naturalized shrubs or woody vines most important to wildlife in the Northeast --Kentucky to Maryland to Newfoundland to Ontario. Topics include range, habitat, life history, uses, propagation, and management; but not identification." Bibliography of 15 pages, a glossary of technical terms, and an index of scientific and common plant names.

Goodrum, Phil D. and Vincent H. Reid (578)

1956. Wildlife implications of hardwood and brush controls. Transactions, Twenty-first North American Wildlife Conference, Pages 127-141.

The authors point out that extensive hardwood and brush control programs through use of herbicides to rid farm, range and forest lands of so-called culls or weed species may not give due consideration to wildlife values. Various oaks, for example, in southern pine forests provide diversity and food for wildlife. In specific localities, oaks may need selective control to best serve wildlife as well as pine timber production; however, the high producing trees, i.e. those with large crowns in relation to diameter of the trunk are likely to be culled out by the pine culturist because of the space they occupy.

Goodrum, P. D., V. H. Reid, and C. E. Boyd (579)

1971. Acorn yields, characteristics, and management criteria of oaks for wildlife. Journal of Wildlife Management, 35(3): 520-531.

Over a period of from four to seven years, seven species of oak (Quercus spp.) indigenous to forests of the upper coastal plain in Louisiana and east Texas were investigated in relation to tree characteristics, acorn yields and climatological

variables. Although the amount of seed produced was related to bole diameter and size of crown, radial growth was not a reliable indicator of seed yield; some trees were inherently poor producers. Mammals and birds made ready use of acorns of all species. The authors point out that oak trees, other hardwoods, shrubs and vines should be left within the animals' range of movement and that oaks on upland pine sites, away from stream bottoms, where the oaks of larger growth form normally occur, provide food for wildlife and offer diversity in cover in an otherwise pine monoculture.

Gysel, Leslie W. and Walter Lemmien (580)

1955. The growth and wildlife use of planted shrubs and trees at the W. K. Kellogg Multiple Use Forest. Michigan State University. Quarterly Bulletin 38(1): 139-145 illus.

"Report on old wildlife plantings in Kalamazoo Co., Mich. Plants involved are Amorpha fruticosa, Caragana arborescens, Cornus ammomum, Rosa multiflora, Lonicera tatarica, Elaeagnus augustifolia, and Sorbus aucuparia. Data are given on growth habit, average production of fruit in 1953 and 1954, period of fruit retention, and on the species of birds and mammals associated with each type of planting. 'Survival and growth of the plants was generally good. Each of the plantings added to the diversity of cover in the area. The densest summer and winter cover for animals near the ground was provided by Tartarian honeysuckle and multiflora rose. The indigobush was the only planting to increase in size from seedlings and root suckers'...'From trapping records and observations there is evidence that a variety of animals, mainly small insectivores, rodents, and song birds were associated with each of the plantings. The only plant species intensively used, however, was multiflora rose which was utilized by cottontails, deer or song birds for both food and cover throughout most of the year.' About 90% of the heavy rose fruit crop of 1953 was consumed by spring." WR No.82.

Halls, L. K., and R. Alcaniz (581)

1968. Browse plants yield best in forest openings. Journal of Wildlife Management 32 (1): 185-186.

Authors' abstract: "At age 5 years, open-grown plants of seven browse species averaged 32 times more fruit and nearly 7 times more twig growth than plants beneath a sawtimber-size stand of southern pines." A table provides comparative information for the seven species in open field and beneath tree locations with respect to percentage of plants producing fruits, fruit production per plant in grams, and current twig growth per plant in centimeters. The plant species listed are: American beauty-berry (Callicarpa americana), yaupon (Ilex vomitoria), Japanese honeysuckle (Lonicera japonica), Alabama supple-jack (Berchemia scandens), strawberrybush (Euonymus americanus), flowering dogwood (Cornus florida), and yellow jessamine (Gelsemium sempervirens). This study was conducted near Nacogdoches, Texas.

Halls, Lowell K. and Thomas H. Ripley (Editors). (582)

1961. Deer browse plants of southern forests. USDA Forest Service, Southern and Southeastern Forest Experiment Stations. 78 pages, illus.

This report includes accounts of some of the more important deer browse plants of southern forests. "Plant descriptions contain information as to where species are found, normal growth habit, seasonal preferences by deer, parts taken, and tolerance to browsing. Also included are suggestions for increasing browse production." Uses of plants by other wildlife are occasionally listed. Bibliography of 6 titles.

Harshbarger, Thomas J., and Carrol J. Perkins. (583)

1971. Effect of shade on growth and seed production of partridge pea. Journal of Wildlife Management, 35 (2): 382-385.

Authors' abstract: "This study (Georgia) isolated shade as a single ecological factor and measured its influence on the growth and seed production of partridge-pea (Cassia nictitans), an annual plant whose seeds are important to quail (Colinus virgianus) and wild turkeys (Meleagris gallopavo). Plants grown under moderate shade (30 or 55 percent) produced more dry matter and seed and had greater dimensions than plants in full sun or dense shade

(92 percent). Optimum production of seed occurred under 30 percent shade. Dense shade drastically curtailed productivity. Seed germination and initiation of flowering and fruiting were not affected by shade. Results can guide modification of timber stands to enhance quail habitat."

Haugen, Arnold O. and Frank W. Fitch, Jr. (584)

1955. Seasonal availability of certain bush lespedeza and partridge pea seed as determined from ground samples. Journal of Wildlife Management, 19 (2): 297-301.

These authors report that *Lespedeza bicolor* is superior to *Lespedeza thunbergii* and *Lespedeza cyrtobotrya* and partridge peas (*Chaemaecrista fasciculata*) as a year-around dependable food supply for quail. They indicate, however, that partridge peas have the advantage of quick production and successful growth on poor soils. They recommend discing or burning at least once every two years as a maintenance practice for partridge peas.

Hooper, Robert G., Hewlette S. Crawford, and Richard F. Harlow. (585)

1973. Bird density and diversity as related to vegetation in forest recreational areas. Journal of Forestry 71(12): 766-769, 4 figs.

"Forty-nine species of birds were found nesting in 30 forest recreational areas in the southern Appalachians. The percentage of cover provided by foliage less than 12 feet high accounted for 56 percent of the variation in densities of nesting birds. The mixture of coniferous and deciduous foliage more than 12 feet high accounted for 66 percent of the variation in the diversity of birds. Clumping of understory shrubs is important to birds in open, parklike recreational areas. Recommendations for managing forest recreational areas for reasonably dense and diverse bird populations are compatible with major management goals." Bibliography of 7 titles.

Hunter, Carl (586)

1954. The value of bicolor and sericea field border plantings to quail in Arkansas. Journal of

Wildlife Management, 18 (3): 343-347.

Results of a three-year study on comparative use of 1,335 miles of lespedeza field border plantings and natural field borders by quail and other wildlife. Sericea (Lespedeza cuneata) was used at the ratio of 3.53:1 over natural borders on a year-around basis. Its chief use by quail was for roosting cover, and for feeding on insects, rather than for nesting cover. Bicolor (Lespedeza bicolor) was used slightly less than sericea. Plantings of sericea which contained also Korean or some other annual lespedeza showed much more use by quail than sericea alone. Old sericea plantings which had not been mowed had the heaviest use by rodents, but quail used these plantings very little.

Jenkins, Ben C. (587)

1956. Wild land management and chemicals. Michigan Conservationist 25 (5): 18-20, 2 photos.

"Michigan has found aerial application of herbicides useful for converting certain low-grade aspen stands into lush fields of sprouts that are fine for deer. Repeated applications are useful for converting areas to grassland and keeping them that way, which is desirable for sharptail grouse management in Michigan." WR No. 87.

Klebenow, Donald A. (588)

1970. Sage grouse versus sagebrush control in Idaho. Journal of Range Management 23 (6):396-400.

"Spraying with herbicides to control sagebrush was detrimental to nesting grouse and to sage grouse broods. Nesting ceased when one area was sprayed and another contained a nest five years after spraying. Broods were less affected. One area contained broods three years after it had been sprayed, but variation existed from one area to the next, for another that was sprayed in 1962 was not being used in 1966." Bibliography of 15 titles.

Klimstra, W. D. (589)

1951. Some factors affecting the growth and survival of multiflora rose as cover for quail in

David County, Iowa. Journal of Wildlife Management, 15 (2): 158-160.

Based on twelve one-to-two year old plantings under different conditions, the author indicated that when there was not any competition for soil moisture, shading by trees did not appear to have adverse effects on the growth of multiflora rose. Soil moisture appeared to be relatively important in top soils less than six inches deep.

Klimstra, W. D. (590)

1956. Problems in the use of multiflora rose. Illinois Academy of Science Trans. 48:66-72.

"Important paper based on study of 219 plantings 1-15 years of age in Illinois and Iowa. Eighteen percent of the plantations were serviceable, 36% were repairable, and 46% were inadequate. Nearly 70% of the farmers were dissatisfied. Responsible were poor site selection, poor early care, and over-advertising. Many plants suffered winter-kill of canes, some froze to death. Local topography is important in cold-damage. Much evidence was obtained of spreading by seeds and layering. Seedlings thrived under mowing in one pasture; it seemed unlikely that an ordinary mower could handle them after a few years. Such facts were new to farmers and angered them. Survey of literature and field data provided little evidence of value of multiflora to wildlife, except where adjacent food supply was available. Perhaps use of multiflora should be limited to areas where no other cover exists and chances for invasion of idle land are minimal. 'In those regions where agriculture is less intense and natural succession of woody vegetation and idle land relatively common, planting of multiflora rose is believed not only unwise but in general, unnecessary, for natural conditions probably offer much more for wildlife. The emphasis now being placed on multiflora in the south and southeast might well result in the establishment of another nuisance plant in those regions...The assumption that multiflora will answer all the problems created by the advent of grassland farming is unfounded'". WR No. 86.

Knierim, Philip G., Kenneth L. Carvell, and John D. Gill. (591)

1971. Browse in thinned oak and cover hardwood stands, Journal of Wildlife Management, 35(1): 163-168.

Authors' abstract: "Thinnings stimulated production of both seedling-and-sprout-origin browse in mixed oak (Quercus spp.) and cove hardwood stands. When seedling-origin browse is desired, the mixed oak type should be maintained in a high basal area condition (about 100 square feet per acre). The cove hardwood type requires a lower basal area (90-94 square feet). To stimulate sprout-origin browse in both cover types, a lower basal area should be maintained. In this study, the low basal area class for the mixed oak type was 68-70 square feet per acre, and for the cove hardwood type 90-94 feet. Most of the browse on the study area (Southern Appalachians) was rated palatable to white-tailed deer (Odocoileus virginianus). Browsing pressure was light compared to the availability of both seedling-and-sprout origin browse. A greater percentage of the seedlings than of the sprouts were browsed."

Korschgen, L. J. (Missouri Department of Conservation) (592)

1966. Foods and nutrition of ruffed grouse in Missouri. Journal of Wildlife Management, 30 (1): 86-100.

Discusses food habits of ruffed grouse (Bonasa umbrellus) wild-trapped in other states and released in Missouri in an effort to reestablish this bird in Missouri. Based on analysis of several thousands of droppings collected in all months, February 1961 to September 1964, the author estimated that approximately 15 percent, by volume, of all foods was furnished by high canopy trees, 45 percent by understory trees, shrubs, vines, and brambles, and 40 per cent by herbaceous forbs and grasses. The author suggested that preservation of productive oak trees and release-cuttings around subdominant oaks may increase acorn production; that improvement of timber stands, bulldozing small clearings, and maintaining open timber stands would encourage tick trefoils, bush clovers, fragrant sumac and native roses; and that wild grape, bittersweet, shadbush, flowering dogwood, and hazelnut fruiting quality may be measurably improved by timber stand improvement or release-cutting in the immediate vicinity of selected, large vigorous plants. He thought preservation of the hop hornbeam during forest management operations could materially improve the habitat for ruffed grouse.

Krefting, Laurits W. (593)

1941. Methods of increasing deer browse. Journal of Wildlife Management, 5 (1): 95-102.

Experiments with increasing deer browse by cutting either at ground level or at the snow line (about 3 feet high) woody plant species that sprout were conducted in Minnesota. Of the species cut -- trembling aspen (Populus tremuloides), paper birch (Betula papyrifera), mountain maple (Acer spicatum), beaked hazel (Corylus cornuta), red-osier dogwood (Cornus stolonifera), and honeysuckle (Lonicera canadensis) -- red-oiser dogwood produced the greatest amount of browse on a weight basis after cutting, while honeysuckle produced the least; mountain maple was considered the most important species treated because this shrub was abundant in deer yards and in the deer range in Northern Minnesota, the amount of browse was greatly increased by cutting and most of the browse produced still remained available 5 years after treatment; and trembling aspen and paper birch sprout growth was rapid and deer did not utilize it to any great extent. Also, with trembling aspen and paper birch, labor costs were higher -- axes were used instead of brush cutters which were used on shrubs.

Krefting, L. W., H. L. Hansen, and M. H. Stenlund (594)

1955. Use of herbicides in inducing regrowth of mountain maple for deer browse. University of Minnesota Forestry Notes No. 42, 2 pages.

"Top kill and vigorous regrowth of tall Acer spicatum was desired. Butoxy ethanol esters of 2, 4-D and 2,4,5-T were tried at concentrations of 4, 8 and 12 lbs. acid equivalent per 100 gallons diesel oil. Oil alone and scorching with propane torch were also tried. Results are reported in detail. 'In order to effectively kill back overgrown stems of mountain maple and greatly increase the amount of regrowth available for deer browse, it is recommended that 2, 4-D in the ester form be applied at breast height to the stems at a concentration of not less than 12 pounds of acid equivalent per gals.

of oil during the early bud swelling stage. This type of treatment has been found to be quickly and easily applied and the resultant browse is readily eaten by deer'." WR No. 82.

Krefting, L. W., H. L. Hansen, and M. H. Stenlund (595)

1956. Stimulating regrowth of mountain maple for deer browse by herbicides, cutting, and fire. Journal of Wildlife Management, 20(4): 434-441.

Mountain maple (Acer spicatum) is described as a staple and preferred deer browse species over much of its range in the Lake States, northeastern United States, and southern Canada west to the Prairie Provinces. To stimulate regrowth and to provide more browse, growth hormone herbicides, fire, and diesel oil were used to top-kill mountain maple that had grown out of reach of deer in northeastern Minnesota. "Applications at early bud-burst time (4, 8, and 12 pounds AHG -- acid equivalent in 100 pounds of diesel oil) showed that 2,4 - D was generally more effective than 2, 4, 5-T in inducing regrowth for breast-height treatments... Breast-height applications resulted in generally greater stimulation of regrowth as compared with basal treatments...Tests with fire (applied by a propane torch and pneumatic flame thrower) did not stimulate regrowth to any appreciable degree...Diesel oil sprays alone generally produced less regrowth than was obtained by cutting or herbicidal treatment. Cutting with an axe produced the most regrowth... and the tops could be browsed by deer. Deer browsed on both one and two-year old stems of regrowth and even some preference was shown for the herbicide-treated clumps."

Krefting, L.W., M.H. Stenlund, and R. K. Seemel. (596)

1966. Effect of simulated and natural deer browsing on mountain maple. Journal of Wildlife Management, 30 (3): 481-488.

Reports on a long term study (1952-62) of the response of mountain maple (Acer spicatum) in Minnesota to different intensities of simulated and natural browsing by white-tailed deer (Odocoileus virginianus). "...the degree of browsing had no apparent direct effect on the amount of growth the following seasons; other environmental factors were more important. Tolerance of mountain maple to browsing was high, however, since only 1 of 6 clumps had died after 100 percent of the annual growth had been clipped for 9 years. Sustained production of food within reach of deer was maintained at a level of use of about 80 percent. Since clumps are established primarily by the growth of underground stems, opportunities for management by cutting or by application of common weed killers are excellent."

LaPointe, Donald F. (597)

1958. Mourning dove production in a central Nebraska shelterbelt. Journal of Wildlife Management, 22 (4): 439-440.

The study area, a shelterbelt 102 feet wide and 553 feet long (1.3 acres), contained 557 trees and shrubs plus a plum thicket and was located three miles west of Grand Island, Nebraska. Findings from this study of mourning dove production might be indicative of the type of benefits that can be derived from extensive highway plantings in the Plains states. Ninety-eight dove nesting attempts (nests with one or more eggs or a setting dove) were noted, or approximately 75 nesting attempts per acre. The average nest height throughout the season (April 7 to September 15) was 8 feet, ranging from 4 feet to 16 feet. Although only 14 percent of the trees (not including the plum thicket) were American elms, 47 percent of the nesting occurred in this species. Ponderosa pine representing 13 percent of the trees contained 32 percent of the observed dove nests. Thirty-four doves were produced per acre of shelterbelt. Comparisons are made with other dove studies in shelterbelts in which American elm, Chinese elm, Russian olive, osage orange, mulberry, and juniper were listed as preferred trees for mourning dove nesting.

Larson, Joseph Stanley (598)

1966. Wildlife forage clearings on forest lands -- a critical appraisal and research needs. Ph. D. thesis, Virginia Polytechnic Institute, Blacksburg. 146 pages. (From Dissertation Abstracts 27(7B), 1967.

"This is a critical review of the practice of creating and maintaining agricultural clearings in forests of the United States for forest-wildlife habitat improvement. It traces the history of this practice (1935-1965), presents an inventory of its extent, critically reviews the bases for the practice, and makes specific research and management recommendations, based on the review. Published, processed and unpublished reports, correspondence and personal interviews with responsible officials, and personal inspections of clearing installation in the various states provided the data for the study." WR No. 129:13.

See also Southeast Forest Experiment Station, U. S. Forest Service Research Paper S E - 30, December 1967 for information by same author on the same subject. WR No. 129:13

Leonard, Justin W. (599)

1959. The use of herbicides in conservation. Proceedings 13th Annual Meeting N. E. Weed Control Conference: 19-25.

"Good, well-rounded discussion of subject, with examples from Michigan." WR No. 31.

Lyon, L. Jack, and Walter F. Mueggler. (600)

1968. Herbicide treatment of north Idaho browse evaluated six years later. Journal of Wildlife Management, 32 (3): 538-541.

Authors' abstract: "Five species of north Idaho browse plants that were treated in 1960 were re-examined to evaluate longterm response to herbicides. We found some lag in plant mortality of undesirable species coupled with generally poor persistence of sprouting and relatively quick recovery from crown dieback in the desirable species. Redstem ceanothus (Ceanothus sanguineus), the most desirable plant tested, was killed by all treatments."

The authors point out that these relatively long-term observations do not pinpoint any single time to spray as the one best suited for all purposes, that there is a differential response among species to spraying, and that indiscriminate herbicide application without careful consideration of treatment date, composition of the existing plant community, and ultimate result desired could easily cause an overall loss of both browse forage and cover.

McAtee, W. L. (601)

1939. Wildfowl food plants - their value, propagation and management. (United States Biological Survey) Collegiate Press, Inc., Ames, Iowa. Pages ix + 141, 17 pls. 4 figs., tables.

Discusses productivity, value and utilization of wildfowl food plants; gives an account of wild-duck food plants by families; summarizes environmental limitations on the growth of aquatic plants; gives planting suggestions; suggest methods for constructing ponds; discusses control of undesirable plants and animals; and gives vernacular names of wildfowl food plants. Bibliography of 3 pages; index.

McConnell, William P. (602)

1968. Habitat manipulation with modern herbicides. Transactions N.E. Section, Wildlife Society, 25th N. E. Fish and Wildlife Conference. Pages 11-23.

Abstract: "Forest vegetation may be economically manipulated with modern herbicides to increase wood, water, or game production. Both aerial and ground spraying techniques may be employed to control the composition of forest stands, and soil sterilants may also be used with the forest stand rather than individual trees as the target. Individual trees may be treated in various ways with many different chemicals to eliminate them from forest stands. Game managers as well as foresters should be using these modern tools to manipulate the forest to meet the specific needs of the game or the needs of hunters to pursue it. This paper describes ten years of research using chemicals to alter the forest for wood or water production or to ameliorate it for recreation, especially skiing." WR No. 131:19.

Miller, Harvey W. (603)

1971. Relationships of duck nesting success to land use in North and South Dakota. Northern Prairie Wildlife Research Center, U.S. Fish and Wildlife Service (Jamestown, North Dakota). 14 pages, 2 tabs.

"The objective of this research was to determine ways of managing habitat for nesting success in the order of 70 percent. The nesting success by land use was: idled - 44 percent; grazed - 27 percent; mowed - 29 percent; and cultivated - 14 percent. Early seral vegetation provided security from predators. The study indicated that vegetation can be established and maintained as attractive and secure nesting cover in which nesting success would be sufficient to increase duck populations." Bibliography of 26 titles.

Morton, James N. and John B. Sedam (604)

1938. Cutting operations to improve wildlife environment on forest areas in Pennsylvania. Journal of Wildlife Management, 2 (4): 206-214, 2 plates, 1 table.

Discusses various kinds of cuttings for benefiting both wildlife and trees. Release cuttings around such game-producing plants as apple, hawthorn, wild grape, dogwood, beech, etc. are described as relatively simple and inexpensive. The authors suggested that openings in forest areas, as along old roads and tram grades, and at abandoned camp sites and clearings should be maintained by removing trees to release shrubs and vines and to insure the open areas so essential to the wildlife environment. Experiments to determine the height of cuts to produce the most vigorous sprout growth indicated that stumps left 6-12 inches high produced more sprout growth and, for a longer time, than when trees were cut higher.

Mueggler, Walter F. (U.S. Forest Service, Ogden, Utah). (605)

1966. Herbicide treatment of browse on a big-game winter range in northern Idaho. Journal of Wildlife Management, 30 (1): 141-151.

From author's abstract: "2, 4-D, 2, 4, 5-T, and a mixture of these two chemicals were tested for effectiveness in lowering the live crown and increasing the basal sprouting of browse grown beyond the reach of elk and deer. Concentrations of 3/4, 1-1/2, and 3 lb. acid equivalent per acre were applied by helicopter in late June...The mixture at 3 lb per acre was most effective in killing aerial crowns...Limitations governing present use of these

herbicides for browse improvement in northern Idaho should be noted carefully. Only cautious use of spraying is proposed."

Munns, E. N. and Joseph H. Stoeckeler (606)

1946. How are the Great Plains shelterbelts? Journal of Forestry 44 (4): 237-257, 7 figs. 4 tables.

"Details of survival and growth of these plantings, so much publicized 1934-1943, are recorded. Tree survival throughout was generally good. Rodent and rabbit damage is noted and the value of the belts as havens for pheasants, doves, songbirds, and other wildlife is set forth. Greater success than at first deemed possible has been attained, but the shelterbelts need conservation and good management." WR No. 46.

Murphy, Dean A., and John H. Ehrenreich. (607)

1965. Fruit-producing trees and shrubs in Missouri's Ozark forests. Journal of Wildlife Management, 29 (3): 497-503.

Provides information on abundance and distribution of fruit-producing trees and shrubs in the Missouri Ozarks. The percentage of plants bearing fruit during the year of the survey (1961) is shown in tabular form. Six of the plant species used by squirrels were most abundant in the bottomlands but a large percentage of them were not fruiting. The authors suggested that removal of the non-commercial overstory would promote fruiting.

National Audubon Society. (608)

1974. Wildlife habitat improvement. National Audubon Society, Nature Center Planning Division (950 Third Avenue, New York, New York 10022. 96 pages, illus.

This book explains the elementary principles of wildlife management. It considers habitat improvement for different types of homesites and natural areas and for different areas of the United States. Also suggested are measures which can improve the habitat for specific birds and mammals. A summary of wildlife habitat improvements is given in list form. An appendix.

Pearce, John and Perley Spaulding (609)

1942. Plant pathology in relation to Northeastern forest wildlife cover. Journal of Wildlife Management 6 (3): 194-202, 1 table, 1 plate.

Emphasizes need for selection of hardy disease-free stock of plants for wildlife management purposes and for sanitation and care in handling. The table lists wildlife food and cover plants, the principal destructive diseases of these plants, including cause of disease, type of disease and other hosts of the parasite or causative organism, and rates the diseases as to seriousness. The authors point out that mixed stands of plants are preferable to large, pure stands since the decimation of one species by disease will not wreck the entire stand. They also cite some benefits, i.e. wildlife utilization of diseased or dead trees and stubs, fungi, etc.

Petrides, George A. (610)

1942. Relation of hedgerows in winter to wildlife in central New York. Journal of Wildlife Management 6 (4): 261-280. 2 pls., 7 tables.

Based upon a study of natural hedgerows on two farms near Ithaca, New York, the author identified and described four stages in hedgerow plant succession: herb, shrub, small-tree and tall-tree stages. He concluded that hedgerows in the shrub stage are of most value to wildlife and that for greatest efficiency in soil and wildlife conservation, contour hedges should be composed entirely of shrubs and vines, from 6 to 10 feet high, 12 to 15 feet wide and of good density near the ground. He indicated that they should be composed of plants which would provide late winter foods for wildlife and be so controlled as to insure permanency of growth form. A list of plants providing for wildlife in hedgerows of the region is included, together with a bibliography of 24 titles.

Regelin, Wayne L., Olof C. Wallmo, Julius Nagy, and Donald R. Dietz. (611)

1974. Effect of logging on forage values for deer in Colorado. Journal of Forestry 72 (5):282-285, 2 figs, Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colorado.

Abstract: "Plant species important for deer forage were collected three times in summer 1970 from clearcut and uncut strips in a lodgepole pine (Pinus contorta) - spruce-fir (Picea engelmannii-Abies lasiocarpa) forest 15 years after logging. Crude protein content, moisture content, and in vitro digestibility within a collection date did not differ statistically between clearcut and uncut strips. Crude protein and moisture content declined significantly between dates, but in vitro digestibility did not change as the plants matured. Because of greater species diversity and plant productivity, and because deer spent more time grazing in clearcut strips, they obtained over twice as much of their crude protein and digestible dry matter there." WR No. 153:32.

Riley, Charles V. (612)

1957. Reclamation of coal strip-mined lands with reference to wildlife plantings. Journal of Wildlife Management, 21 (4):402-413.

The author reports findings from studies made on wildlife aspects of 72 sites located in strip-mined areas of southeastern Ohio during the period 1947 to 1951 and from June 1954 to October 1955. Thirty-seven species of plants initially planted mostly for forestry and grazing purposes were evaluated in relation to their potentials for wildlife. Of five species of lespedeza surveyed, bicolor and serecia were the most successful and adaptable to the various sites on coal strip lands, even doing well in fairly acid soil material. Korean lespedeza did well when seeded in soil having a high percentage of calcareous materials. Yellow and white sweet clover were very successful on a wide variety of sites and soil conditions and had high seed production. Alsike clover grew well in moist ravines and depressions. Scotch broom reproduced after the second growing season and indigobush spread so rapidly in alkaline soils that it proved to be a pest in certain areas. Seven species of pine and Norway spruce growing in pure or mixed stands provided valuable winter cover and were most valuable to wildlife when used in clump plantings or narrow strips with a spacing of three to four feet. Black locust was superior to all other hardwood species planted because of its

wildlife habitat values, adaptability to various sites, its value in site preparation and modification, and rapid growth rates. "...Native plant species invaded the black locust plantations very early; and by the tenth to the fifteenth year, an extremely dense undergrowth had developed."

Robbins, P. W. (613)

1936. Propagation of trees and shrubs for game food. Agr. Expt. Sta. Quarterly Bulletin, Michigan State University, East Lansing 18 (1): 35-37, 2 tables.

Red-osier dogwood (Cornus stolonifera) cuttings survived to a satisfactory degree both when planted, unrooted in nature and in a solar frame. Red-osier considered suitable for economical increase of browse and fruit for wildlife. WR No. 3.

Rosene, Walter, Jr. (614)

1950. Spreading tendencies of multiflora rose in the Southeast. Journal of Wildlife Management 14 (3): 315-319.

Studies made in 1948-49 at the sites of three plantings of multiflora rose varying in age from 14 to 40 years indicated that seeds are carried by birds and water and that control would be necessary to keep the plant from spreading.

Rosene, Walter, Jr. (615)

1952. Care and maintenance of bicolor lespedeza. Soil Conservation 27 (7): 151-153, illus.

"50 million plants of bicolor lespedeza are produced annually in the Southeast, and the number is increasings. This paper tells how to plan the plantings, how to prepare and fertilize the site, how to plant, how to judge proper growth, how to maintain vigor in plantings, and how to rejuvenate plantings when they start to deteriorate after about three years. A considerable investment in time, fertilizer, and farm equipment seems necessary." WR No. 68.

Rosene, Walter, Jr. (616)

1955. Recommendations for the culture of Lespedeza bicolor. Journal of Wildlife Management, 19(1):84-88.

The author bases his recommendations and suggestions for the planting and maintenance of bicolor lespedeza on a study of plantings in Alabama and South Carolina. Notes were made on the history of the planting sites, soil types, the sites in relation to trees and other competing vegetation, kind and amount of fertilizer used, and the maintenance techniques that had been employed. Detailed information is provided in two tables.

Rosene, Walter, Jr. (617)

1956. An appraisal of bicolor lespedeza in quail management, Journal of Wildlife Management, 20(2): 104-110.

Discusses results of seven years of study concerning the value of Lespedeza bicolor to bobwhite quail on nine hunting preserves located in Alabama and South Carolina. He indicates that bicolor is a preferred food of the bobwhite and may be of some value in the management of this species in those parts of the Southeast where scarcity of food is a limiting factor. However, he stated: "Factors such as time and intensity of burning, amount of nesting cover available, land-use practices, and disturbances had greater effect on quail populations than the presence or absence of bicolor."

Scott, Robert F. (618)

1965. Problems of multiflora rose spread and control. Transactions, Thirtieth North American Wildlife and Natural Resources Conference, pages 360-378.

Provides information on the spread of and/or problems of controlling multiflora rose, a plant widely used in wildlife plantings; brings out some of the negative aspects of the use of this plant; and suggests that it be used only under certain circumstances, i.e. in areas where there is frequent plowing or discing or along pasture fields with dense vegetative cover.

Sharp, Ward M. (619)

1938. Food and cover plant nurseries and planting out methods for wildlife in the Great Plains. Transactions of the Third North American Wildlife Conference. Wildlife Management Institute, Wire Building, Washington, D. C. pp. 538-542.

Discusses value of tree and shrub pioneers to wildlife along watercourses in the Great Plains, and means of replacing such vegetation, which has been depleted by man and domestic animals, by establishment of temporary nurseries. Acclimated stock of the plant-species desired were used in plantings on wildlife refuges. Suggestions are given on favorable sites and on development and care of nursery type of stock, field planting methods and factors that determine success.

Spooner, Charles S. Jr., and Lee E. Yeager (620)

1942. Potential wildlife habitat on the Illinois prairie and some problems of restoration. Journal of Wildlife Management 6 (1): 44-54, 3 tables.

Includes discussion of limitations or obstacles in leasing areas such as farm woodlots, abandoned gravel pits, hedgerow and ditchbank strips, eroded fields, old orchards, and undrained prairie for wildlife habitat restoration. Landowners objected to game refuge areas along ditch banks because fencing of the ditch right-of-way prevents farming up to the bank and grazing and watering along the ditch -- common practices in the Illinois prairie region -- and drainage commissioners insisted on a guarantee that the ditch channels be kept free from debris and vegetation to ensure free flowage of water. With respect to plant species for wildlife planting, most of the farmers were opposed to Osage orange, black locust, and other large growing species -- except some wanted pines and other evergreens -- but were agreeable to the planting of small shrubs such as rose, hazelnut, and gray dogwood.

Steavenson, Hugh A. (621)

1946. Multiflora rose for farm hedges. Journal of Wildlife Management, 10 (3): 227-234.

Discusses Rosa multiflora as living fences and as wildlife food and cover. Suggests methods of planting and of propagating and handling planting stock.

Stoeckeler, J. H., R. O. Strothmann, and L. W. Krefting. (622)

1957. Effect of deer browsing on reproduction in the northern hardwood-hemlock type in northeastern Wisconsin. Journal of Wildlife Management, 2(1):75-80.

Based on observations over a period of about 8 years in which counts were made of understory seedlings within and outside of deer-proof enclosures, the authors' general conclusion was "...that a prolonged (six to eight years) period of rather low deer population is needed in second-growth hardwood-hemlock stands, to permit successful regeneration and adequate growth of the understory seedlings in northern hardwood-hemlock stands. Even though sugar maple production is known for its ability to withstand rather heavy deer browsing for many years without undue mortality, seedlings that are repeatedly browsed back become stunted and malformed, and recover rather slowly even after complete protection is established."

Tomoff, Carl S. (623)

1974. Avian species diversity in desert scrub. Ecology 55 (2): 396-403. (Department of Zoology, University of Washington, Seattle).

Author's abstract: Along a gradient of habitat complexity in desert scrub communities of the Sonoran Desert in southern Arizona, nest sites and food niches become more diverse, and breeding bird population density and species diversity increase. Birds are highly specific in their selection of plants for nest placement; densities of most species are strongly related to densities of nest plants. The MacArthur foliage - height diversity model does not yield consistently accurate predictions of breeding bird species diversities in desert scrub communities.

"A significant relationship is found between physiognomic coverage diversity and breeding bird species diversity. This index, based on a system of plant life forms, quantifies critical environmental features used by birds in habitat selection. A model that combines aspects of foliage - height diversity may provide greater accuracy and wider applicability for predicting breeding bird species diversity."

Knowledge of this model or index may be helpful in designing roadside and wildlife planting programs for desert scrub areas to favor certain bird species. Here, plant species composition is highly significant in regulating breeding bird communities -- much more so, apparently, than in a deciduous forest where a tree species may not be as important as the structural quality of the branch on which a bird nest is built.

Van Dersal, William R. (624)

1937. A border for the woods. Soil Conservation, 3(4):99-101, 7 photos.

"Shrub borders reduce undesirable effects of wind on woodlands, contribute to the natural pruning of trees, and are valuable to wildlife. Under the heads of small trees, tall shrubs, and vines, lists of fruit-bearing species are presented." WR No. 11.

U. S. Department of Agriculture, Forest Service, (California Region) (625)

1973. The hospitable oak. Coordination guidelines for wildlife habitat, Number 3, 10 pages.

"Management of oaks on a sustained-yield basis provides food and cover for wildlife, insures a continuing supply of hardwood for various forest products and contributes to a more diversified plant community."

Wildlife use of stands of oak and conifers for food (acorns, leaves, fungus, insects), for nesting and dens, (both birds and squirrels), and for cover. Recommendations for selective cutting are made. Bibliography of 8 titles.

U. S. Department of Agriculture, Forest Service, (California Region. (626)

1974. Wildlife and patchcuts. Coordination guidelines for wildlife habitats, Number 4, 15 pages.

This illustrated booklet discusses briefly "seven ways to increase variety and enhance wildlife habitat when patchcutting timber." Bibliograpy of 8 titles.

Wandell, Willet N. (627)

1948. Songbird use of wildlife habitat improvement plantings. Illinois Wildlife 3 (2):4-7, illus.

"Habitat improvement plantings in Urbana Township, Illinois in 1947, had an average of 105 pairs of songbirds per mile of cover. Mature osage orange hedge had only half as many. On an acreage basis, fence row and stream bank improvements had more than three times as many pairs of songbirds as did block plantings." WR No. 60.

Warbach, Oscar (628)

1953. Control of Japanese honeysuckle in wildlife borders. Journal of Wildlife Management, 17(3):301-304.

Author's summary: "1. Japanese honeysuckle, an exotic that can be either a pest or an asset in different localities, makes maintenance of wildlife plantings in the Southeast a difficult problem. 2. A herbicide applied during the winter and strong enough to kill dormant woody plants will stop the spread of honeysuckle from a woods edge for at least two years. 3. A low percentage 2, 4-D water spray applied to honeysuckle growing in bicolor lespedeza borders at a time when honeysuckle is starting growth and bicolor is still dormant will selectively destroy the vine without injuring the border."

Wilde, S. A. (629)

1946. Soil-fertility standards for game food plants. Journal of Wildlife Management 10(2): 77-81, 3 tables.

Emphasizes the importance of adequate soil fertility in sites selected for wildlife plantings in order to maintain the species and enable production of abundant food crops; gives information on characteristics of Wisconsin soils supporting some game food plants, standards of soil fertility for nureries rearing game food plants, and indicates site requirements for selected game food plants -- red cedar, wild crabapple, highbush cranberry, red-osier dogwood, black cherry, mountain ash and hawthorn.

Woodhouse, Charles, and Luther Partin (630)

1972. Tarheel wildlife on the farm. North Carolina Resources Commission. (Raleigh, North Carolina 27611). 17 pages.

This booklet discusses several materials which are adapted for wildlife plantings and many management techniques for improving conditions for wildlife.

Wright, Henry A. (631)

1974. Range burning. Journal of Range Management 27 (1): 5-11.

"There are many uses for prescribed burning in the management of forests, chaparral, grasslands, watersheds, and wildlife...Deer, elk, moose, bobwhite, quail, wild turkey, doves, prairie chicken, sharptails, ruffed grouse, waterfowl and many song birds are favored by fires which create variety in habitat ...Other subclimax animals that have reportedly increased following fires are cougar, wolves, coyotes, deer, mice, ground squirrels, and beavers. Climax species such as bobolinks, sparrows, caribou, martens, wolverines, tree squirrels, and grizzly bear usually decrease...Fires adversely affect population densities of animals principally by altering the habitat - not by killing...A patchy burn (about 20% unburned area) is most desirable for wildlife. This leaves adequate cover for upland and big game and a winter food supply of various nuts and acorns. Prescribed fires, in general, greatly increase the diversity of wildlife species, as well as population densities of all vegetation types.

In general, air borne particulates are the primary pollutant of fires. However, they are short lived. Hydrocarbons are another combustion product, but few, if any, appear in the combustion of wood products that are important in photo-chemical reactions. Carbon monoxide is a pollutant from fires, but it seems to oxidize quite readily and does not pose an immediate threat to people, plants or animals. Forest fires, including wildfires and prescribed burns, produce only 8% of all pollutants in the United States." Bibliography of 68 titles.

3. Some Plants and Their Use by Wildlife

Allen, Durward L. (632)

1939. Michigan cottontails in winter. Journal of Wildlife Management 3(4): 307-321.

In this two-year study of the cottontail rabbit in Kalamazoo County, Michigan, the most important woody winter food plants were dwarf and staghorn sumacs. (*Rhus copallina* and *R. typhina*). Although rabbits subsisted upon the bark of woody plants in times of deep snow, when herbaceous foods were available, very little bark was eaten. Plants receiving moderate use by rabbits for food included red oak (*Quercus borealis*), ailanthus (*Ailanthus glandulosa*), cultivated apple (*Pyrus malus*), buckthorn (*Rhamnus cathartica*), wild blackcherry (*Prunus serotina*), gray dogwood (*Cornus candidissima*), silky dogwood (*Cornus amomum*), black elder (*Sambucus canadensis*), fox grape (*Vitis vulpina*), black raspberry (*Rubus occidentalis*), and Scotch pine (*Pinus sylvestris*).

Bennett, Hugh Hammond (633)

1939. Soil conservation. McGraw Hill Book Company, Inc. New York and London xvii + 993 pp.

In this chapter entitled "Wildlife and Conservation", pages 568-595, Bennett lists plants available and used in large numbers for soil conservation and wildlife purposes under the headings of grasses, herbaceous legumes and woody plants and, in addition, lists other plant species which would seem desirable for the dual purpose of erosion control and wildlife conservation when methods of quantity production and more about their site requirements are learned.

Borell, A. E. (634)

1951. Russian olive as a wildlife food. Journal of Wildlife Management 15(1): 109-110.

Russian olive (*Elaeagnus angustifolia*) is described as a plant adaptable to a wide range of soil, moisture and climatic conditions and useful in windbreaks, for streambank protection and gully control and for planting in waste areas and for hedges and living fences. The author states that it has most of the qualities desired in a good wildlife food plant -- it grows rapidly and crop failures are practically unknown, at least in New Mexico. Its use by many species of wildlife is noted.

Christensen, Earl M. (635)

1967. Bibliography of Utah botany and wildlife conservation. Brigham Young University Science Bulletin, Ser. 9(1) i + 136 pages.

"Includes articles on botany, biotic communities, range management, forestry, recreational use of wildlands, and those aspects of zoology and wildlife management involving plant communities or habitat management. Arranged chronologically by author and with a general subject index. References through 1964 are included." WR No. 128:3

Compton, Lawrence V., and Wade H. Hamor (Soil Conservation Service (636)

1972. Some cardinal techniques for attracting birds. Pages 31-38 in "Landscape for Living", the Yearbook of Agriculture, 1972. U.S. Department of Agriculture. Available from Superintendent of Documents, Washington, D. C. 20402. Pages XL + 376.

Focuses mostly on what can be done around the home, but information -- ornamental value, adaptation to soil and sun, blooming period, height, and sources of availability -- given for 17 plant groups and species suitable for attracting birds might be helpful in roadside plantings, also. The suggested plants are autumn olive (*Elaegnus umbellata*), dogwood (*Cornus spp*), mountain ash (*Sorbus spp*), Russian olive (*Elaegnus angustifolia*), firethorn (*Pyracantha spp*), sunflower (*Helianthis spp.*), crabapple (*Malus spp.*) elderberry (*Sambucus spp.*), American cranberry-bush (*Viburnum trilobum*), cherry (*Prunus spp*), wild plum (*Prunus americana*), cotoneaster (*Cotoneaster spp*), Tartarian honeysuckle (*Lonicera tatarica*), red cedar (*Juniperus virginiana*), bittersweet (*Celastrus scandens*), holly (*Ilex spp.*), and hawthorn (*Crataegus spp.*).

Crawford, Hewlette S., Clair L. Kucera, and John H. Ehrenreich. (637)

1969. Ozark range and wildlife plants. Agricultural handbook #356. U.S.D.A., Forest Service, (Washington, D. C.) 236 pages.

This book was meant as a field manual in "identifying plants and describing their value for wildlife and livestock. Plants are arranged by genera. Distribution and site preference, characteristics, and importance are described for each species." Bibliography of 75 titles, glossary of plant identification terms, and an index of 8 pages.

Dalke, Paul D. and Palmer R. Sime (638)

1941. Food habits of cottontails. Journal of Wildlike Management. 5(2): 216-228, 2 figs., 9 tables.

Studies in New England showed two pronounced feeding periods: from three to four hours after sunrise and from sunset to one hour after"...The diet during the winter months is largely bark, twigs, buds and dried herbs. In spring the feeding habits change abruptly with the appearance of tender young shoots of herbaceous plants; herbs are largely used from that time through October.

"In the fall period of November and December comes the transition from a diet of herbaceous plants to one of woody perennials."

Dambach, Charles Arthur (639)

1948. A study of the ecology and economic value of crop field borders. Graduate School Studies, Biological Science Series No. 2 (The Ohio State University Press, Columbus) 205 pages, illus.

The author, in a three year study in southwestern Ohio, investigated the possibility that plant and animal pests, injurious to field crop production, might be fostered by field border vegetation favorable to farm game species. He describes crop field borders and discusses their relation to farm management, describes insect populations in the borders and in the litter, and describes bird and small mammal populations in relation to insect pests and as pests, themselves. He found that use of woody field border vegetation involved less risk to grain and forage crops than did the use of herbaceous vegetation.

Davis, C. A., P. E. Sawyer, J. P. Griffing, and B. D. Borden (640)

1974. Bird populations in a shrub-grassland area, southeastern New Mexico. New Mexico State University Agricultural Exp. Sta. Bulletin 619. 29 p. 1 fig. (Las Cruces, N. Mex.).

"This report describes populations and nesting habitat of birds in shrub-grassland in southeastern New Mexico from April, 1969 through mid-June, 1973. Fifty-nine species representing 11 orders and 24 families were observed. Forty-six species were adapted strictly to terrestrial habitats. Of these, 32 species were adapted specifically to habitats containing woody plants (shrubs or trees), six to grassland, and eight to a variety of habitats. In addition to the 46 terrestrial species, 13 species of wetland birds were observed. -- From summ." WR No. 154:40.

Deck, Raymond, S. (641)

1938. The hawthorne -- friend of the sportsman. Country Life and the Sportsman (Philadelphia, Pennsylvania) 74 (1) 72-73, 130-133, 5 phots.

"A popular article, embodying information on the value of Crataegus in providing food and cover, with special notes on a few species with persistent fruits." WR No. 15.

Graham, Edward H. (642)

1941. Legumes for erosion control and wildlife. U. S. Department of Agriculture. Misc. Publ. 412. ii + 153 pp., 29 pls., 3 tables.

This book discussed legumes and their use in erosion control and by wildlife. A table presenting a nutritional analysis of several species of legumes is provided and 11 of 29 plates illustrate, by drawings, 128 species. Although knowledge of wildlife utilization of legumes is inadequate, rodents, ungulates and gallinaceous birds appear to be important users of these plants. The plants are listed alphabetically by scientific name from pages 22 to 117 in which they are described, their occurrence indicated, and their habitat, outstanding characteristics and wildlife utilization noted. An appendix lists the animals known to consume the various species. There is a bibliography of 223 titles.

Grelen, Harold E. and Vinson L. Duvall. (643)

1966. Common plants of longleaf pine-bluestem range. Forest Service Research Paper SO-23. U.S.D.A., Forest Service, Southern Forest Experiment Station. 96 pages.

"This publication describes many grasses, grass-like plants, forbs, and shrubs that inhabit longleaf pine - bluestem range. Ecologists generally regard the longleaf pine-bluestem community as a fire subclimax - i.e., a successional arrestment induced by burning. The species vary widely in importance. Each species is described, its value as food for cattle and wildlife assessed, and its geographic range indicated. To aid identification of plants vegetative characters peculiar to each species and detailed botanical descriptions are given." Bibliography of 42 titles, glossary of plant identification terms and index of plant names.

Gysel, Leslie W. (644)

1971. A ten-year analysis of beechnut production and use in Michigan. Journal of Wildlife Management, 35(3): 516-519.

Author's abstract: "Beechnut (*Fagus grandiflora*) production was analyzed in three woodlots in southern Michigan. Based on a relative scale, the production of viable nuts was a failure for 2 years, low for 4 years, intermediate for 3 years, and high for 1 year. The proportion of sound nuts, collected in the seed traps was generally 10 percent or less of the total collection; the proportion of nuts utilized by animals in the trees was generally greater than 30 percent. Incomplete nuts comprised more than 20 percent of the seedtrap collections. According to the mean annual nut production for one woodlot, a single beech tree can provide the gross energy requirement for one squirrel (*Sciurus spp.*) for 13 days, assuming that 25 percent of the sound and animal used nuts are available to squirrels."

Handley, C. O. (645)

1945. Japanese honeysuckle in wildlife management. Journal of Wildlife Management 9(4): 261-264, 1 tab.

Although sometimes regarded as a pest, Japanese honeysuckle (Lonicera japonica) provides excellent wildlife cover and is used as food by wild turkey, white-tailed deer and other species, including song birds. The author states: "Wherever surrounded by permanent pasture, cropland, woodland with a closed canopy, or highway or railroad rights-of-way, it will not spread and become noxious. In such places, and there are some on most farms (in the Southeast), use of Japanese honeysuckle as food and cover for wildlife, particularly bobwhite quail, is recommended."

Hanson, William R. (646)

1960. Plants for improving bobwhite habitat in northwestern Oklahoma Oklahoma State University Publication 57 (12) Arts and Science Studies, Series No. 7. 88 pages, 20 figs.

The author stated in his summary: "Forty plant species, of more than 350 investigated, seem promising for the experimental improvement of land management and quail habitat. Native plants are more useful, in general, than introduced species. Western indigo and sensitivebriar are the most important-appearing native herbs. Hairy vetch and Austrian winterpea are the most important-appearing naturalized herbs. Matrimony vine, trifoliate orange, and winterberry euonymus are the woody plants appearing most worthy of further testing. Sand plum is the most important plant for resting and roosting cover." From WR No. 99.

Lamb, Samuel H. (647)

1971. Woody plants of New Mexico and their value to wildlife. New Mexico Department of Game and Fish Bulletin No. 14, iv+80 p., illus.

"Includes tables of ecological grouping of animals and trees by life zones, and use of woody plants by wildlife." WR No. 143:9.

Lehmann, Valgene W., and Herbert Ward (648)

1941. Some plants valuable to quail in southwestern

Texas. Journal of Wildlife Management, 5(2): 131-135, 1 fig., 2 tables.

The author states: "The most important winter foods of southwestern bob-whites are provided by panic grass (*Panicum texanum*) sorghums (*Sorghum sp*.) and doveweeds (*Croton capitatus*, *C. punctatus*, and *C. texensis*). The most prominent plant foods in 32 crops of the chestnut-bellied scaled quail were seeds of elbow bush (*Adelia angustifolia*), catclaw (*Acacia roemeriana*), amd bluebonnet (*Lupinus subcarnosus*).

"Bob-whites require woody cover, principally for resting or 'loafing' during mid-day. Clumps of woody cover 3 to 10 yards in diameter that provide concealment, freedom of movement underneath, and good visibility are ideal. Black brush, tasajillo, and wild rose often meet these requirements. The distribution of woody cover appears to approach perfection when clumps are located from 100 to 300 yards aprt."

Longenecker, George S. (649)

1960. Landscape plants that attract birds. University of Wisconsin Extension Service Circular 514. 10 pages, illus.

"The fifteen most common breeding songbirds in Wisconsin cities, and their preferred habitat are listed. Landscaping ideas and suggestions for choice of plants to attract birds are given. Included is a table which lists the food quality, fruiting season, cover characteristics, nesting quality, and habitat of more than sixty trees and shrubs." WR No. 100.

Martin, Alexander, C., Herbert S. Zim, and Arnold L. Nelson (650)

1951. American wildlife & plants. 500 pages, illus. McGraw-Hill Book Co., Inc. New York

This is a guide to wildlife food habitats -- the use of trees, shrubs, weeds and herbs by birds and mammals of the United States. Part one deals generally with the importance of plants to wildlife, farm crops and wildlife, wildlife food-habits studies, and how to interpret the data in the book. Part two describes the food of different kinds of wildlife and provides range maps of many of the wildlife species treated, and indicates the number of specimens examined, and the relative extent to which various food items are included in the diet. Part three deals with the wildlife plants of the United States -- herbaceous and woody, wild and cultivated, upland and aquatic -- that furnish food to wildlife in significant amounts. The plants are presented in family sequence. The final chapter provides a national list of plant groups ranked according to their use by wildlife as food and it provides regional lists of wildlife plants indicating the extent to which particular kinds of plants have been used by seven types of wildlife; water birds, marsh and shore birds, upland game birds, song birds, fur and game mammals, small mammals, and browsers.

Mason, Edwin A. (651)

1959. Massachusetts Audubon list of shrubs and trees for attracting birds. Published as a section without page numbers in Massachusetts Audubon 43(3), Jan.-Feb.1959. (Massachusetts Audubon Society) 155 Newberry Street, Boston, Mass. 02115.

"Lists 38 varieties of trees and shrubs that are especially useful in Massachusetts, tabulates their chief qualities and states price. All are available from nurseries or through Massachusetts Audubon Society. Sale of the stock is source of income to the Society and allied groups." WR No. 95.

McAtee, W. L. (652)

1936. Groups of plants valuable for wildlife utilization and erosion control. U. S. Department of Agriculture, Circ. 412, 11 pp., 7 pls.

"Lists the genera of plants of most value in supplying cover, browse, herbage, mast, fruit and seed for wildlife and indicates which of these groups have been recommended for use in erosion control. WR No.7.

McAtee, W. L. (653)

1941. Plants useful in upland wildlife management. U. S. Department of the Interior. Bulletin 7, 50 pp. 5 plates, tables.

"General discussion of the use of plants in wildlife management as cover makers and food producers and of management practices. The bulk of the bulletin is made up of lists of perennial plants valuable in furnishing cover, browse, herbage, mast, fruit and seed in ten regions of the U. S." WR No.31.

Miller, Harold W., Chester C. Ball, and Norman P. Knott (654)

1948. The comparative value of woody plants as food for upland game birds. State of Washington Department of Game, Biological Bulletin. No. 8, 40 pages, illus.

"A cooperative study between the Soil Conservation Service and the State of Washington Department of Game started in 1940. This was to determine the wildlife value as well as the soil conservation value of the 470 species of woody plants under test: the study took place at the Pullman nursery unit of the Soil Conservation Service, Whitman County, Washington...'During the course of the study, ninety-nine woody species produced fruit on the nursery. The fruit of thirty-five species was utilized by pheasants as food. The following groups and species were the most important: hawthorns, snowberries, wild roses, dogwoods, wild cherries, matrimony vine, Siberian peashrub, sumac and bladdersenna. Fruits of Russian olive were not preferred by pheasants. The growth habits and requirements of the various woody species shown to be of value are set forth in detail.'" WR No. 55.

Nixon, Charles M., D. Michael Worley, and Milford W. McClain. (655)

1968. Food habits of squirrels in southeast Ohio. Journal of Wildlife Management, 32(2): 294-305.

In this study, based on 833 squirrels (*Sciurus carolinensis* and *S. niger*) collected in all seasons, 1962-1966, the authors found the important foods in decreasing order of occurrence to be: hickory nuts, beechnuts, acorns, fungi, black walnuts, plant leaves, yellow buckeye nuts, tulip tree samaras, flowering dogwood drupes, ironwood nuts, and hop hornbeam nuts.

Oefinger, Simeon W. and Lowell K. Halls (656)

1974. Identifying woody plants valuable to wildlife in southern forests. Research Paper SO-92. U.S.D.A., Forest Service, Southern Forest Experiment Station. (New Orleans, Louisiana). 76 pages.

"Twigs, buds, and other key identification features are illustrated in color for 70 browse species common to pine-hardwood forests of the South. The list consists mainly of woody understory species that are eaten by wildlife, with special emphasis on those preferred by white-tailed deer." An evaluation of what kind of wildlife prefers each species is not given. A 2-page index of plant names is included.

Park, Barry C. (657)

1942. The yield and persistence of wildlife food plants. Journal of Wildlife Management 6(2): 118-121, 1 table.

The table provides information on percentage of plants of a list of woody species bearing fruit, years crop failed, volume produced, date of ripening, and persistence of fruit on the plant over a four-year period. The author points out the importance of having a variety of species of wildlife food plants to ensure a yearlong food supply and a stable environment.

Schmid, Frederick C. (658)

1958. Cedar waxwings and fox sparrows feed upon multiflora rose. The Wilson Bulletin 70 (2):194-195.

At the Patuxent Wildlife Research Refuge, Laurel, Maryland, mockingbirds have been observed to feed extensively on the hips of multiflora rose in winter. During the winter of 1955-56, when there was an abundant supply of rose hips, a large flock of cedar waxwings ate great quantities of the hips and regurgitated the seeds under their perches (52 per square foot in one sample). In late spring, fox sparrows fed on the regurgitated seed. The Editor of Wildlife Review, in reviewing this article (WR No. 93) noted: "It may be added that nearly every piece of roadside or other idle land on the Refuge that is under a wire or other bird perch has a vigorous stand of volunteer multiflora. It is reported that birds are even spreading the plant into the woods. Control of such scattered and widespread colonies is not feasible."

Sloan, Charles E. (659)

1970. Biotic and hydrologic variables in prairie potholes in North Dakota. Journal of Range Management 23 (1): 260-263.

"Prairie potholes or sloughs are depressions of glacial origin that occur north of the Missouri River in the prairie region of the United States and Canada. Potholes provide valuable wetland habitat for migratory waterfowl and are widely used for stock-water supplies. Differences in climate, geology, topography, ground-water hydrology, and land use create wide variations in pothole hydrology. Plants in and adjacent to potholes are useful indicators of water permanence, depth, and salinity - variables that are important in wetland management." Bibliography of 4 titles.

Spinner, George P. and George F. Ostrom (660)

1945. First fruiting of woody food plants in Connecticut. Journal of Wildlife Management 9(1): 79.

The value to wildlife of the first fruiting of 27 woody plant groups (mostly species) was determined for plants growing in the wild and in a Connecticut nursery. The age for first fruiting of wild plants was similar to those growing in the nursery and ranged from two years for maple-leaved viburnum to 13 years (in the wild) for pepperidge or black gum (Nyssa sylvatica). Most of the first yields were light; however, dwarf sumach, Japanese honeysuckle and coralberry produced fruit crops comparable with those on older plants of the same species.

Terres, J. Kenneth (661)

1939. Gray squirrel utilization of elm. Journal of Wildlife Management 3 (4): 358-359.

"The degree to which both elm buds and samaras are relished by gray squirrels in parts of New York and Pennsylvania during spring suggests that, seasonally, Ulmus is an important gray squirrel food in these localities." The author believes that the cutting of twigs, mostly under one-eighth inch in diameter, to secure buds can have little more than a pruning effect upon elms.

U. S. Department of Agriculture, Forest Service (662)

1973. Wildland shrubs - their biology and utilization. Page 516 in Journal of Forestry 71 (8) 516. A book review of General Technical Report INT-1, 1972, 494 pages. Intermountain Forest and Range Experiment Station, (507 25th St., Ogden, Utah 84401)

"This publication includes an overview of the world-wide pattern of shrub occurrence and usage of various shrubs by man and his animals; ways shrubs are used as food and cover for wildlife, low-maintenance landscaping, soil cover and stabilization, industrial raw materials, for medicinal products - and their relations to wildfire and fire control; evolution and diversity of arid land shrubs and possibilities for genetic improvement; shrubs in natural communities, how they respond to grazing use, role in recycling nutrients, and effects of insects, diseases and fire in community dynamics; physiological responses and characteristics of shrubs; nutritive value for livestock and wildlife; regeneration and establishment of shrubs; and the future of shrubs on arid lands."

Van Dersal, William R. (663)

1938. Native woody plants of the United States. Their erosion control and wildlife values. U. S. Department of Agriculture. Misc. Publ. 303. 362 pp., 44 pl., 3 folded maps.

"The body of this work is a list of woody plants arranged in the alphabetic order of their scientific names...Scientific names are cross-indexed in the main list and the vernacular (names), are arranged alphabetically in a terminal register. The accounts of each plant typically include a statement of range by numbers to correspond to Plant Growth Regions as defined by F. L. Mulford, notes on site preferences, growth habits, character and season of fruiting, propagation and utilization by wildlife...There is a bibliogrpahy of 649 titles. A comprehensive and useful compilation conveniently arranged and well illustrated." WR No. 16.

Van Dersal, William R. (664)

1940. Utilization of oaks by birds and mammals.

Journal of Wildlife Management 4(4): 404-428.

On the basis of data analyzed and presented by the author, he concluded that use of staple food plants, such as oaks, in plantings made to improve wildlife habitats, is worthy of more consideration than it has thus far received. He pointed out that oaks constituted the most important and the most abundant and widely distributed genus of hardwood trees in the north temperate zone, have substantial silvicultural values, and records, in 1940, showed that 186 different kinds of birds and mammals feed on oak acorns or browse. He stated, however, that of the 186 kinds of animals listed as feeding on oaks, only 53 were known to feed on oaks identified to species and indicated that more exact information is necessary to determine whether some of the 85 native oaks are of greater importance to wildlife than others.

D. Other Opportunities for Management.

Allen, Durward L., and Daniel A. Poole, et al. (665)

1973. New North American Wildlife policy. Transactions of the Thirty-eighth North American Wildlife Conference, pages 152-181.

A report of the Committee on North American Wildlife Policy.

On matters relevant to the present bibliography, the Committee stated, page 166: "Opportunities should be explored for creating or restoring water areas along rights-of-way of federal and state highway systems and on public lands generally.

Arata, Andrew A. (666)

1959. Ecology of muskrats in strip-mine ponds in southern Illinois. Journal of Wildlife Management, 23 (2): 177-186.

Although, because of acidity present in many coal strip mine ponds, these ponds may differ from those ponds created in highway construction, studies of strip mine ponds may indicate some of the fish and wildlife potentials of highway construction-created ponds. Thus, in southern Illinois, Arata found an average of 2.4 muskrat dens per 1,000 feet of pond shoreline in coal strip mine ponds. The most recent ponds (6 to 8 years old) possessed essentially

The same flora as those 20-25 years old indicating a rapid immigration of plants into these ponds. Attempts with experimental plantings to improve conditions for muskrats were largely unsuccessful.

Aus, Philip B. (667)

1969. What is happening to the wetlands? Transactions, Thirty-fourth North American Wildlife and Natural Resources Conference, pages 315-323.

In this paper the author states, page 317, "Highway construction projects modify and destroy wetlands. Improved coordination among governmental agencies help reduce the impact of road construction, but in nearly all cases there is a direct loss. Local highway officials often oppose standards which are based on national resource needs. Frequently, road construction improves or provides outlets for indirect wetland drainage." He cites the Fairdale project proposed by the Walsh County (North Dakota) Water Management Board as a good example of how wildlife values can be upheld by close cooperation and coordination of efforts -- in this case, on the part of the State Game and Fish Department, Soil Conservation Service, Fish and Wildlife Service and the Fairdale group. He suggests that wetland preservation guidelines such as those applied successfully in the Fairdale project, or satisfactory alternatives, need to be incorporated into the Watershed Protection and Flood Prevention Act. Such action, he states, would limit the use of public funds where local sponsors are interested primarily in drainage and where a satisfactory working relationship among concerned interests is lacking.

Bergstrom, K. L., University of Mass., Amherst (668)

1971. Utilization of interstate highway construction to create productive wetlands for wildlife. Massachusetts University Water Resources Research Center Report, May 1971. 72 pages, 7 figures, 2 tables, 51 references, 5 appendices.

Abstract: "The construction of interstate highways offers an opportunity to create productive wetlands with a minimum of additional expense if they are developed as an integral part of the highway. Through the use of the highway embankment as an impoundment structure and/or the careful location and development of borrow pits, numerous wetlands can be developed. Many benefits would accrue from projects

involving combined development of highways and wetlands. The wetlands would provide scenic enhancement to the highway. Rest stops adjacent to wetlands would provide recreational opportunities to travellers as well as to the local citizenry. Wetlands create much valuable habitat for a variety of mammals and birds as well as providing sources of recreation. These wetlands could be excavated to the desired morphometry while supplying fill for the highway. Highway embankments could be located so as to provide water retaining structures as needed. Planning prior to construction would give assurance that the productivity of the resultant wetlands would be improved. (see also W72-00052) (KNAPP USGS)" WRSIC No. W72-00053.

Byrd, I. B. (669)

1960. Cooperation of the Alabama State Departments of Conservation and Highways in the construction of access areas. Proceedings of the fourteenth annual conference of the Southeastern Association of Game and Fish Commissioners, pages 248-252.

Abstract: "The development of fishing access areas under a cooperative agreement between the State Conservation and State Highway Departments of Alabama appears to be a practical and economical method of supplying one of the greatest needs of the State's fishermen. Public waters are of little value to fishermen when they cannot be reached because of inadequate access."

Chamberlain, E. Burnham (670)

1974. Rare and endangered birds of the Southern National Forests. U.S.D.A., Forest Service, Southern Region (Atlanta, Georgia) 108 pages.

This report contains a survey of rare and endangered birds of the Southern National Forests. Twenty-three bird species were researched concerning their distribution, populations, habitat requirements, and their influence on the National Forests. Bibliography of 7 pages.

DeBates, Lawrence W. (671)

1967. The role of small wetland preservation in comprehensive prairie pothole region planning. Transactions, Thirty-second North American and Natural Resources Conference, pages 325-331.

Points out that efforts to acquire wetlands for wildlife under Public Law 87-383 and other legislation are quite often involved or related to township, county, state and federal road construction projects. He states that application for right-of-way permits presents an opportunity to discuss wetland preservation with engineers of the various highway departments at the same time we are protecting wildlife interests..."This procedure has prompted more cooperation with all highway organizations. Memoranda of Understanding have been signed by our agency (U.S. Fish and Wildlife Service) with state highway departments in Minnesota, North Dakota and South Dakota. These agreements are designed to insure protection of our wetland holdings adjacent to state highways."
Mention is made also of the Bureau of Public Roads Instructional Memorandum 21-5-63 which requires formal coordination between the state highway and fish and game departments to minimuze wildlife habitat losses.

Dillon, O. W., and L. D. Marriage. (672)

1973. Fish and wildlife habitat improvement in watershed projects. Pages 43-48 in Wildlife and water management: striking a balance. Soil Conservation Society of America (7515 N.E. Ankeny Road, Ankeny, Iowa 50021).

This article discusses the opportunities for fish and wildlife habitat improvements possible under the Watershed Protection and Flood Prevention Act of 1954. (Public Law 566).

Edmund, Norman W. (Edmund Scientific Company, Box 500 Edscorp. Bldg., Barrington, New Jersey) (673)

1967. Old tires: the ideal material for building fish havens. Edmund Scientific Company, 16 pages. Sport Fishery Abstracts. No. 9126.

Evans, Willis A. in collaboration with F. Beryl Johnston (674)

1972, Revised 1974. Fish migration and fish passage - a practical guide to solving fish passage problems. U.S.D.A. Forest Service - Region 5. 43 pages, 5 appendices, 3 tables, 16 figures, 5 illustrations.

"This report was prepared as a working guide for forest Biologists and Engineers who are confronted with the practical problems of providing fish passage through or over both natural and artificial structures in streams. Useful material has been selected from the various reference sources and combine to form a simplified source

of information for the California region. Perhaps the most frequently used portion of this report will be Table 4 on page 39, which serves as a quick reminder of the essential steps in providing fish passage at road crossings of streams."

Gebhards, Stacy and Jack Fischer. (675)

1972. Fish passage and culvert installations. Idaho Fish and Game Department, 12 pages, 2 figures, 4 drawings.

This publication serves the design engineer as a guide for fish passage and culvert installations in Idaho. Explanations of legal requirements, fish migration, culvert problems, culvert installation for fish passage and policy are given.

Hatcher, Robert M. (676)

1973. Floodwater retarding structures as fish and wildlife habitat. Pages 35-37 in Wildlife and water management: striking a balance. Soil Conservation Society of American (7515 N.E, Ankeny Road, Ankeny, Iowa 50021).

Discussed are the fisheries limitations and possibilities of southern watershed lakes. Lake management considerations are mentioned, as are the potentials of cage culture and waterfowl abundance of watershed lakes.

Heusmann, H. W. (677)

1970. Highway impoundments -- planning, use and control. The Massachusetts Heritage, VIII (1):1-4.

This publication discusses the engineering aspects of damming drainage ways or flooding of borrow pits to create impoundments for wildlife use. It is stated that the desired use of highway impoundments as wildlife areas may be promoted by voluntary cooperation, regulation by police powers and by acquisition. The author concludes that the creation of wetlands by highway construction offers a unique opportunity to develop scenic fish and wildlife habitat. Bibliography of 11 titles.

Heusmann, H. W. (678)

1971. Highway impoundments: a technological bonus. Massachusetts Division of Fisheries and Game (Westboro, Massachusetts)

Two types of wetlands can be created as a by-product of interstate highway construction. Water may be impounded by use of highway fill or by inundation of borrow pits. Both types of areas have value as wildlife habitat, recreational areas, reservoirs and scenic vistas. Both engineering and specific ecological aspects of impoundment construction are discussed. Bibliography of 15 titles.

Heusmann, H. W. (679)

1973. How to create wildlife habitat from highway construction. Catalyst, III (4): 17-19.

This article states that "each mile of interstate highway uses approximately 70 acres of land, most of which was previously in some form of agricultural or low intensity use which provided habitat for various forms of wildlife." It is suggested that methods needed to create new wildlife habitat are the "impoundment of water through the filling of borrow pits and from the damming of drainage ways." The creation of wetlands by highway construction, using the two above mentioned methods, "offers a unique opportunity to develop wildlife habitat." Ways to promote the use of highway impoundments as wildlife areas are discussed.

Hill, Kay R. (680)

1975. I-29 chain of lakes. Iowa Conservationist 34(6):4-6.

This popular article, illustrated with 15 color photographs, describes new fishing areas created by a chain of lakes covering approximately 260 acres along Interstate 29 in Harrison, Mills and Fremont Counties in southwest Iowa. The lakes, ranging in size from 8 to 52 acres, were formed when fill material was removed from the floor of the Missouri Valley to build the interstate roadway. Information is provided on access to the lakes -- which is described as good, although some are limited to walk-in access -- and on the types of fishing available.

Ten of the areas are presently under management by the Iowa Conservation Commission, having been transferred from the State Highway Commission in 1972.

Jahn, L. R., Chairman (681)

1969. Saskatoon wetlands seminar. Canadian Wildlife Service Report Series No. 6. 262 p., illus.

"Transactions of a seminar on small water areas in the prairie pothole region, held 20-22 February, 1967, to mark the opening of the Prairie Migratory Bird Research Center in Saskatoon, Saskatchewan. The following papers are included: "Waterfowl production habitat requirements, F. G. Cooch; Agricultural use of wetlands, R. W. Lodge; Engineering limitations on water transfers, M. N. La Rose; Legal considerations of water use, Grant C. Mitchell; Economic values of small wetlands, Ralph Hedlin; Hydrology of small water areas in the Prairie pothole region, W. S. Eisenlohr, Jr. ..." WR No. 135:7.

Kay, A. R., and R. B. Lewis (682)

1970. Passage of anadromous fish through highway drainage structures. State of California, Department of Public Works, Division of Highways, District 01 Hydraulics Section, Research Report 629110, 15 pages, plus map, 3 tables, and 6 figures.

Authors' abstract: "Highway drainage structures can be an impassable barrier to the migration of anadromous fish and thereby damage the fisheries resource of an area.

"Investigation of 40 existing drainage structures indicates that these structures can be designed so as not to be a block to migrating fish. A design procedure is presented which enables the engineer to determine if a given structure requires special consideration for fish passage."

This study, funded by the Federal Highway Administration, received assistance from members of the California Department of Fish and Game. Based on observations of the research staff as they performed the field work, they recommended: (1) some oversizing of culverts when passage facilities are warranted with the resultant effect of reducing velocities and simplifying the subsequent design of the passage devices; (2) where possible, depressing culvert grade lines below normal streambed fish entrance condition into the culvert; (3) in those installations where the total grade line cannot be depressed, giving consideration to lowering of the outlet flow lines to provide for possible streambed degradation; and (4) because, for a given culvert installation at a specific discharge, the velocity will vary inversely with the roughness coefficient or "Mannings n," selection of a higher "n" value culvert type may reduce velocities below the need for passage devices. The authors concluded that a satisfactory limiting discharge for fish passage is one that is equaled or exceeded 10% of the October through April time period.

In the practical implementation of fish passage devices biological information that may be provided by state fish and game departments or other organizations would include data on the habits and life cycle of anadromous fish, the physical capabilities of these fish for swimming past barriers and passing through culverts, and identification of streams normally used by these fish.

Lewis, R. B., and A. R. Kay (683)

1970. Passage of anadromous fish through highway drainage structures. California Division of Highways (P.O.Box 1499, Sacramento, California 95807). No. H-3-4.

Summary: "Highway drainage structures can be an impassable barrier to the migration of anadromous fish and thereby damage the fisheries resource of an area. Investigation of 40 existing drainage structures indicates that these structures can be designed so as not to be a blockage to migrating fish. A design procedure is presented which enables the engineer to determine if a given structure requires special consideration for fish passage." HRIS No. 204018.

McClellan, Thomas J. (684)

1970. Fish passage through highway culverts. Oregon State Game Commission (Portland, Oregon). 16 pages, illus.

The intent of the study discussed in this report "was to ascertain the effectiveness of installed provisions for fish passage in culverts, and to attempt to evaluate which types of installations were most effective, simplest to install, and less costly initially and in maintenance." Bibliography of 6 titles.

The bulk of the report is found in the unnumbered pages of Appendix A and Appendix B.

Metsker, Howard E. (685)

1970. Fish versus culverts. Technical Report ETR-7700-5. U.S.D.A. Forest Service, Technical Information Center (Washington, D. C. 20250). 19 pages, illus., 5 tabs., 11 figs.

This report discusses the problems culverts may present to fish and ways to correct problems by use of: outfall barriers, downstream physical features, fish passage structures, and the depth and velocity light effects. The construction of culverts is discussed in relation to unstable and stable streambeds and the swimming ability of fish. Bibliography of 12 titles.

Moulton, J. C., Univ. of Mass., Amherst (686)

1970. The fishery potential of four aquatic environments created by Interstate Route 91 construction in Massachusetts. M. S. Thesis, University of Massachusetts, 86 pages, 11 figures, 8 tables, 36 references, 8 appendices.

Abstract: "Four borrow pit ponds created as a result of Interstate Route 91 construction in Whately, Massachusetts, were studied to determine their fishery potential. Physical, biological and chemical data were collected to determine the ecological conditions in each pond. These data indicate that 91 South, 91 Swim and 91 North are capable of supporting a warm-water sport fishery. The low pH of 91 Woods is a limiting factor and no fish are present here. Age and growth studies were conducted on populations of Yellow Perch, Pumpkinseed, Bluegill and Largemouth Bass. Growth rates are compared between ponds and with other studies. Population estimates for Largemouth Bass in 91 South are included. Yellow Perch, Pumpkinseed and Bluegill stomachs were examined for food content, and terrestrial organisms comprised only a small portion of their diets. The average percentage composition, percent volume, percent frequency of occurrence and total numer of organisms in biweekly stomach samples are presented. Management recommendations are made for increasing the fishery potential of existing borrow pit ponds and guidelines are presented for future construction and management. (Legore, Washington)". WRSIC No. W72-00135.

Nowell, Howard C., Jr. (687)

1966. Wildlife and our highway construction program. Forest Notes, New Hampshire Conservation 92: 9-13.

On September 4, 1963 a cooperative program was inaugurated by the New Hampshire Department of Public Works and Highways and the Fish and Game Department. This resulted in cooperation during planning and design stages of highway construction and therefore much less fish and wildlife habitat destruction. "A previously unsuspected bonus of this cooperative program has been the opportunity actually to create new or improve existing wildlife habitat in the course of road building activities."

Under the cooperative program, when possible, rechanneling is meandered, not straightened. "Banks are properly sloped, mulched and seeded with a standard seed mixture to which has been added reed canary grass for better holding qualities...Willow cuttings have also been utilized to reduce the chances of erosion and the resultant downstream problems." Trees around streams have been left to provide shade for the streams. During the creation of new channels, boulders are left or some are placed there during construction, to provide shelter for aquatic life. Fishways and low-water (V-bottom) channels have been used to allow fish movements at all levels. Land may also be flooded to create duck habitat.

This cooperative venture between the Department of Public Works and Highways and the Fish and Game Department points out the many opportunities available in resource conservation.

Nowell, Howard C., Jr. (New Hampshire Fish and Game Department). (688)

1967. Wildlife and our highway construction program. Forest Notes, New Hampshire's Conservation Magazine No. 92, 4 pages.

Prior to enactment of NEPA and the issuance by the

Federal Highway Administration's Instructional Memorandum 21-5-63, the New Hampshire Fish and Game Department and the State Department of Public Works and Highways had already adopted a cooperative approach (September 4, 1963) designed to prevent serious damage to fish and game habitat in that State as a result of future highway construction. The author describes this arrangement, points out the need for fish and game personnel to examine practically every proposed job, preferably on the ground, and cites examples of how this approach has reduced detrimental environmental impacts of highway construction that formerly occurred such as in connection with channelization and culvert and bridge construction which had cut off the upstream movement of fish. He cites instances, also, of the creation of new or improved wildlife habitat in the course of road construction, including creation of a 30-acre duck marsh in the Alton area by incorporating stop log slots in culvert headers. Cooperation with other agencies is encouraged to take advantage of opportunities to enhance fish and wildlife.

Oregon Wildlife Commission. (689)

1975. Draft of Oregon Wildlife Commision standards for fish passage at road-stream crossings. Oregon Wildlife Commission, Portland, Oregon 97208. 38 pages.

Specific recommendations are given to avoid artificial obstructions from preventing fish stream passage. The report discusses department standards and biological considerations and provides comments regarding structures and methods to solve existing passage problems. Several illustrated attachments are included.

Peters, John C. (690)

1970. Montana highway and wildlife professions cooperate. Civil Engineering, ASCE, 40(11): 58-59.

"A Montana law gives the state Fish and Game Department power to influence highway and other construction so as to minimize adverse effects on fish and wildlife. State construction and conservation professionals are also working together to create recreation lakes by using highway fills as dams,

and to use for conservation purposes small parcels isolated by road construction? A copy of the Act is included.

Reid, Kenneth A. (691)

1955. Increasing summer streamflow. Transactions, Twentieth North American Wildlife Conference, pages 229-241.

In this paper the author stated, page 236: "The principle of utilizing road fills for impounding water by the simple installation of an elbow on the upstream end of the culvert pipe, with the addition of a vertical riser if greater depth is desired, can be used in countless places where existing roads cross small rivulets as well as in the construction of new roads. It presents a splendid opportunity to transfer the effect of a road from the debit to the credit side in our stream accounting."

Saltzman, William and R. O. Koski, Primary Contributors (692)

Undated: Fish passage through culverts. Oregon State Game Commission (Portland, Oregon). 9 pages.

"Salmon, steelhead, and other migratory fish require unobstructed access to upstream spawning areas. Road culverts may block fish passage if the drop at the outfall is too great or if they are placed at an excessive gradient. A bridge will usually cause the least disturbance to the stream and will assure fish passage. For these reasons, bridging is the recommended method for crossing a stream. When a bridge is impractical..., culverts become necessary. The most desirable culvert is a structural steel arch set in concrete footings...Less desirable, but usually satisfactory, is the pipe-arch culvert with a flattened bottom...A less desirable type of culvert for successful fish passage, but the one most commonly used, is the round corrugated pipe." The above mentioned culverts are discussed, as well as box-type culverts. Additional considerations when using cylindrical culverts are given. Several graphs concerning varying pipe size of culvert velocity curves are included.

Shearer, Leroy A., and Hans G. Uhlig (693)

1965. The use of stock-water dugouts by ducks. Journal of Wildlife Management, 29(1): 200-201.

Dugouts constructed for the purpose of livestock-watering are comparable in some respects with borrow pits developed in highway construction in that they do not provide the gentle slopes and mud flats preferred by ducks as resting areas.

The authors of this article, based on a study of 31 stock-water dugouts in South Dakota and Minnesota indicated that stock-water dugouts modified by the addition of resting sites in the form of rafts are more attractive to wild ducks than dugouts without such modifications. Ducks were found to utilize these resting rafts during the courting and breeding season.

Sheehan, Joe (694)

1971. Tortoises relocated in desert. Outdoor California 32 (6): 1.

Tortoises were moved from a 20-mile long, 1-mile wide area around State Highway 58 in the Mojave Desert, to save them from the hazards of highway traffic. "The tortoises were moved from the path of highway construction and relocated in an area on the China Lake Naval Weapons Center after weights, measurements and sexes were determined and recorded and the tortoises had been tagged." Project workers attempted to match the old habitat with the new in terms of soil, vegetation, elevation, drainage and general lay of the land. The project was initiated by a Division of Highways right-of-way engineer.

Steen, M. O. (695)

1966. Elements of successful state plans. Transactions, Thirty-first North American Wildlife and Natural Resources Conference, pages 347-354.

In discussing planning and coordination for conservation programs and opportunities for funding under the Land and Water Conservation Act, Mr. Steen stated, "...As an example of coordination where one might least expect it, in Nebraska we have what is probably the nation's outstanding example of the contribution federal and state road agencies have so far made to aesthetics and recreation.

"Interstate 80 traverses, in part, the Platte River Valley, paralleling the river proper. This valley is a mighty aquifer, with vast underground storage of Platte River waters in the uniform sand and gravel deposits that lie miles wide and very deep beneath the surface soils all along this valley. Ground water stands at the elevation of the river's flow.

"In cooperation with the Nebraska Road Department and with the blessing of the U. S. Bureau of Roads, we have developed a chain of lakes all along Interstate 80 in the Platte River Valley. In excavating fill for the roadbed some 75 crystal-clear lakes, complete with white sand beaches, were created at no added construction costs along 150 miles of this major transcontinental highway. We will landscape and develop these lakes for the use and enjoyment of the interstate travelers as well as our own citizens. Land and Water Conservation funds will contribute substantially to this development. Coordination can work wonders."

Stone, Richard B. (U.S. Department of Commerce, NOAA, Sandy Hook Sport Fish & Marine Lab., Highlands, New Jersey.) (696)

1971. Recent developments in artificial reef technology. Marine Technology Society Journal, 5(6): 33-34.

"In 1966 biologists at Sandy Hook Sport Fisheries Marine Laboratory designed a research program to study fish habitat improvement in the marine environment through beneficial use of selected, non-toxic, solid wastes as artifical reefs. Test materials included scrap metal, mostly in the form of junk car bodies, concrete culverts, scrap tires and obsolete ship hulls. Although all these materials became encrusted with invertebrates and attracted fish, most were difficult to handle or expensive to obtain. Tires are one material that was found readily available, inexpensive to assemble into units and easy to handle. After trying various arrangements, we decided to use two units which incorporated low assembly cost and ease of handling. One unit is simply a single tire with a concrete weight pushed inside the tire. One or two air holes are drilled or punched in the top of the tire to allow air to escape as the unit sinks. The other unit is a column of six to eight tires. The base tire is filled with concrete and two 4½ foot lengths of 3/8 inch reinforcing rod are inserted in holes drilled through the sidewalls on opposite sides of the tire. The rods are bent over at the top and the bottom of the column to keep the tires in place. The completed unit can be turned on its side and rolled by one man, eliminating the need for heavy equipment. There are more than 100 artificial reefs on the east coast of the United States. The construction of artificial reefs is one way sportsmen can participate in both improving the marine sport fishery and conserving our game fish resources." Sport Fishery Abstracts No. 14258.

Sullivan, Carl (697)

1958. Highway dams; water for the future. West Virginia Conservation 22 (6): 1-5,7 figures.

"The new federal highway program offers terrific opportunities for states to create many fish or wildlife impoundments. Highway fills across low areas need relatively minor changes to be acceptable dams. These changes, however, must be planned in advance and made when the fill is constructed. As the highway program is gaining force rapidly, there is no time to be lost. Conservation groups must pay the difference in construction costs, but in so doing, they get 5 to 10 times their money's worth. As of January, 1956, 45 of these projects were completed in 10 states. The impoundments varied from 1 to 1200 acres and averaged 130 acres. An av. of $23,000 per project was saved by taking advantage of highway construction. Federal highway authorities are agreeable to the plan, but in some states, special legislation is necessary -- and will have to be obtained promptly. Added construction costs often can be obtained through P.R. or D.J. funds or from local groups, and here again, early planning and action are needed." WR No. 93.

Turner, Charles H., Earl E. Ebert, and Robert R. Given (698)

1969. Man-made reef ecology. The Resources Agency, California. Department of Fish and Game, Fish Bulletin No. 146, 221 pages.

From authors' abstract: "This report discusses in detail findings and observations made during more than four years of study on three experimental multi-component man-made reefs, and one 'production' model reef, in Santa Monica Bay, California (August 1960-January 1965). The multi-component replication reefs were each constructed of 333 tons of quarry rock, one streetcar, 14 automobile bodies, and 44 concrete shelters. The 'production' model reef was 1,000 tons of quarry rock...Quarry rock was determined to be the preferred reef building material, (based upon cost and ease of handling), even though the concrete shelters attracted the largest number of fishes. Further, quarry rock disturbed the bottom sediments less than the other three materials... Fishing success on the reefs was two to three times that recorded for nearby natural reef areas...Man-made reefs can turn 'non-productive' areas of the near shore into 'productive' fishing areas. Initially, these structures attract fishes from surrounding areas. With time (about five years in our area) a natural situation is reached and the plant and animal populations exhibit fluctuations typical of reef ecosystems." Sport Fishery Abstracts No.13691.

Uhler, Frances M. (699)

1964. Bonus from waste places. Pages 643-653 in Waterfowl Tomorrow, Joseph P. Linduska, Editor, USDI Bureau of Sport Fisheries and Wildlife, U. S. Government Printing Office, Washington, D. C.

"Highways destroy wildlife habitat. They also can create breeding grounds and resting places for waterfowl. Aquatic birds make extensive use of highway ditches. In the Prairie States many species rear young in such unintentionally created habitats. Simple water control structures can be installed at the heads of secondary road culverts in many places to create small marshes and shallow ponds.

Borrow pits along the highways and fills made across swales are readymade sites for new habitats for waterfowl. It is not hard to slope their edges, add islands to give waterfowl seclusion and concealment, and erect predator-proof nesting structures to make borrow pit ponds attractive and productive.

Highway departments have helped transform such places into habitats for aquatic wildlife at the Moosehorn Wildlife Refuge in Washington County in Maine, The Thousand Acre Marsh in New Castle County in Delaware, White's Creek Impoundment in Marlboro County in South Carolina, and many other points. A study of topographic maps and aerial photographs will disclose other possibilities in every state."

U. S. Department of Commerce (700)

1975. Scrap-tire breakwaters, developed by University of Rhode Island Sea Grant Program, protect marinas and shorelines. U. S. Department of Commerce News (NOAA) 75-126.

This July 1, 1975 news release indicates that discarded tires now accumulating at a rate estimated to exceed 200 million per year can be put to beneficial use in constructing moored, floating breakwaters for protecting small boat marinas and shorelines vulnerable to erosion. As recommended for use, the discarded tire breakwater can be as large as 500 feet long and 22 feet wide, a structure that would diminish a three-foot wave to less than a foot. The Sea Grant team (Bruce Cole, University of Rhode Island, Narragansett) states that the scrap-tire breakwaters offer an added bonus to sport fishermen in that seaweed and barnacles begin growing on the tires after a few months, just as they do on artificial reefs, providing food for small fish which soon attract larger fish. It is reported, also, that experiments have shown that pollutants do not leach from the tires.

U. S. Department of the Interior (701)

1974. United States list of endangered fauna. Fish and Wildlife Service (Washington, D. C. 20240) 22 pages.

The purpose of the Endangered Species Conservation Act is "...to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions...in which the United States had pledged its support for the conservation of wild flora and fauna worldwide."

A list of endangered fauna species is shown phylogenetically by Class and Order, and alphabetically within each Order by their common names.

"A 'Where Found' column is provided for information purposes only, and does not necessarily identify the total range of the species in question."

III. ENVIRONMENTAL CONSIDERATIONS AND EVALUATIONS IN HIGHWAY PLANNING, CONSTRUCTION AND OPERATION--GENERAL

A. ENVIRONMENTAL QUALITY AND THE LAW--GUIDES FOR IMPLEMENTATION AND COMPLIANCE.

AASHTO (Operating Committee on Roadside Development (702)

1970. A guide for highway landscape and environmental design. Adopted by the American Association of State Highway Officials, 84 pages, 48 photos, 12 plates.

This Guide's purpose is that of developing quality, character and consistency in highways in general conformity with accepted landscape architectural principles and practices. It is intended to be used by persons responsible for designing, developing and maintaining the highway landscape and environment.

It is essential that the highway be considered as an element of the total environment, not apart or in conflict with it. All highway-oriented disciplines should collaborate at all stages of highway corridor selection, location and design in order to obtain the maximum beneficial potential of the highway, its roadsides and its environment.

It is essential that special attention be given to multiple use-joint development possibilities in areas over, under and adjacent to the highway, particularly in urban areas.

It is essential that there be cooperation and liaison between highway departments and other state agencies, federal, regional, county and city organizations, and private groups.

This guide contains chapters entitled: I Integration of Landscape and Environmental Design in the Complete Highway. II Landscape Elements in Highway Design. III Landscape and Geometric Design. IV Areas Requiring Special Treatment and V Multiple Use - Joint Development.

Chapters IV and V stress the need for an inventory of natural areas that occur within the highway right-of-way so they can be preserved and used properly.

Within each section of the guide, special attention is given and applicable guidelines are provided for safety, function, esthetics, multiple use - joint development and environmental compatibility in terms of highway landscape development.

Carlozzi, Carl A. et al. (703)

1971. Enhancement of ecologic and aesthetic values of water associated with interstate highways. Water Resources Research Center, University of Massachusetts at Amherst, Publication 19, pages iii + 114.

Part 1 of this report points out opportunities for creating various types of water and wetland areas valuable for fish and wildlife and recreation in the process of constructing highways through use of highway embankments as impoundment structures and the careful location and development of borrow pits. The authors observe, however, that wetlands inadvertently created are generally poor in productivity as a result of poor location, morphometry, site preparation or a combination of these factors.

Part 2 of the report deals with problems of policy; limitations in legal authorizations and funding, including use of Highway Trust Funds off the right-of-way; and coordination for accompishing potential wetland development as an important secondary result of highway construction. The authors indicate that, in practice, in Massachusetts the state highway agency, after determining a basic route for a highway, and during the detailed engineering stage, sends a letter to the State Department of Natural Resources advising the department of its plans after which the Department will make suggestions concerning the highway project's potential impact on fish and wildlife. They urge that a closer working relationship be developed among Federal, State and local agencies which will insure early input into the planning process and continuing review of design plans. Results of a questionnaire sent to officials in 105 Massachusetts towns showed a willingness to use local public funds for recreation and conservation projects related to highway construction.

Colorado Division of Wildlife in Cooperation with Colorado Division of Highways. (704)

1975. Wildlife environmental analysis: State highway 82-project area-Aspen to Carbondale. Colorado Division of Wildlife, 110 pages.

This analysis contains chapters describing potential impacts of various alternate highway alignments on big game mammals, terrestrial wildlife, aquatic wildlife, and raptors. Detrimental impacts, beneficial impacts, irreversible or irretrievable losses and threatened, rare and endangered species are addressed in each chapter. A numerical evaluation of detrimental impacts is presented in which each biologist responsible for a specific segment of the analysis gives numerical ratings to overall detrimental impacts to wildlife of various alternate alignments of Highway 82.

Council on Environmental Quality (705)

1973. Preparation of environmental impact statements: guidelines. In Federal Register 38 (147): 20549-20562.

"This directive provides guidelines to Federal departments, agencies, and establishments for preparing detailed environmental statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment as required by section 102(2)(c) of the National Environmental Policy Act (P.L. 91-190, 42 U.S.C. 4321 et. seq.)..." (From author's abstract)

Giles, Robert H., Jr., C. W. Smart, and A. Blair Jones, III (706)

Undated. POWER: a high voltage transmission corridor location system. Division of Forestry and Wildlife Sciences and Division of Environmental and Urban Systems, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061. 11 pages, 1 table.

"POWER is a man-computer interaction system which develops a decision aid for the State Corporation Commission of Virginia (SCC) faced with the legislative mandate of evaluating the environmental impact of all transmission lines of over 200 kv.

Testimony is developed for the legal staff of the Commission, consisting of written testimony, location of an optiumum route, and a graphical output and comparison of proposed alternate routes and the computer-selected route.

Information about 42 environmental, economic, esthetic, and historic factors has been recorded in 25-acre (1/9th square kilometer) cells for over 60% of the state. The system objective is to select a lowest-impact route between two designated points.

A synthetic variable is computed for each cell, reflecting total impact in terms of 12 broad resource values. Ecological interations over a 30-year line operation period are included in the computation. Probable tower construction and maintenance are included in the 'impact' of the lines. Visibility of a tower in any cell is evaluated from all roads and historic sites. Once a synthetic variable is computed for each cell on the IBM 370, a route is determined by means of a minimal path network algorithm developed by E. W. Dijkstra. The mathematical line solution is plotted on maps generated by the Harvard GRID mapping system.

The system has now been employed in two cases before the Commission. In one case the corridor located by the computer was estimated to be $5 million less expensive to the company than the proposed line and yet satisfied all environmental criteria. Testimony which demonstrates a solution with one-third the impact of the 'best' applicant's corridor is now being presented in a second case. Both corridors were over 75 miles long. The total systems development cost, including the data base, was approximately $70,000. Costs of one-run, once a project is set up, is about $100 at 1974 university rates. The system now operational, is being further improved. Other users are sought." (Author's abstract)

Jahn, Laurence R. (Wildlife Management Institute, Washington, D. C.) (707)

1974. Highway design and wildlife. A paper presented at the Interagency Seminar sponsored by the American Association of State Highways and Transportation Officials, July 8, 1974.

The author identifies and illustrates some of the problems concerned with highways with respect to wildlife -- destruction of wildlife habitat, disruption of migrations and other natural movements of wildlife, encouragement of satellite development along highways, and motor vehicle-wildlife collisions and human safety. He suggests that most of the conflicts between highway and wildlife interests can be resolved or greatly reduced and that the critical need is for increased dialogue between professionals in both fields, especially in the earliest planning stages of highway projects. He suggests, where possible, avoiding highway rights-of-way that cross or impinge upon stream flood plains, lakeshores, marshes and other wetlands; minimizing, to the extent possible, the clearing of vegetation at stream crossings and the limiting of mowing elsewhere along roadsides; suspending mowing during the peak of nesting activity in areas where roadside cover is important nesting habitat for pheasants, prairie grouse, waterfowl, and other species; and using borrow pits and other low sites for impoundments for fish and wildlife. He states that special consideration should be given to any threatened or endangered species and, because of the safety factor, any species large enough to cause vehicular damage in collisions. He recommends several ways for reducing vehicle-wildlife accidents including reduction of speed limits, installation of adequate fencing in all critical areas, and installation of adequate underpasses on big game migration routes and of reflector prism mirrors where they are known to be effective. He believes nonmigratory wildlife can be discouraged from crossing highways by maintaining good habitat along the right-of-way but that the planting of cover crops attractive to large mamals on road cuts, shoulders and median strips should be avoided.

Lash, M. (708)

1973. Environmental requirements of the Federal Aid Highway Program. Highway Research Board Special Report. Number 138, Highway Research Board (Washington, D. C.) pages 6 - 8.

"After briefly reviewing Federal legislation that bears on the highway program as related to the environment, the author lists the major aspects of the environmental guidelines called for by Section 136 (B) of the 1970 Federal Highway Act. These guidelines call on each state to prepare an action plan that outlines the organizational arrangements and procedures the state will adopt to ensure that the four following fundamental objectives are accomplished in the development of a highway project: (1) state highway departments must develop a real competence to identify and objectively study economic, social, and environmental effects of proposed highway projects. (2) an interdisciplinary approach must be used in the development of highway projects from system planning to design. (3) other agencies and the public must be involved in system planning, location planning, and design, (4) alternative solutions must be considered." HRIS No. 203816.

Leopold, Aldo (709)

1943. Wildlife in American culture. Journal of Wildlife Management 7(1):1-6.

Points out that the culture of primitive peoples is often based on wildlife; discusses how civilization has affected soil-plant-animal-man food relationships and philosophizes on impacts of technology and gadgetry. With respect to the latter he states:

"Among non-gunpowder sports, the impact of mechanization has had diverse effects. The modern field glass, camera, and aluminum bird-band have certainly not deteriorated the cultural value of ornithology. Fishing, but for motorized transport, seems less severely mechanized than hunting. On the other hand, motorized transport has nearly destroyed the sport of wilderness travel by leaving only fly-specks of wilderness to travel in.

"Fox-hunting with hounds, backwoods style, presents a dramatic instance of partial and perhaps harmless mechanized invasion. This is one of the purest of sports; it has real split-rail flavor; it has man-earth drama of the first water. The fox is deliberately left unshot, hence ethical restraint is also present. But we now follow the chase in Fords! The voice of Bugle-Anne mingles with the honk of the flivver!..."

Leopold, Luna B., Frank E. Clarke, Bruce B. Hanshaw, and James R. Balsley. (710)

1971. A procedure for evaluating environmental impact. Circular 645. U.S. Geological Survey, National Center (Reston, Virginia 22092). 12 pp., 3 figs.

It is common practice to prepare a cost-benefit analysis on any proposal for construction or development. In addition to this it is necessary to evaluate the environmental impact as put forth in the Environment Policy Act of 1969. "This circular suggests an approach to accomplish that specific requirement by providing a system for the analysis and numerical weighting of probable impacts." Bibliography of 3 titles.

Little, Arthur D., Inc. (711)

1971. Transportation and environment: synthesis for action -- impact of the National Environmental Policy Act of 1969 on the U. S. Department of Transportation. Summary Volume No. 1, 66 pages, 1 fig. and 6 tables.

From summary: "A study has undertaken to assess the effects of policy, programs, legislation, and administrative directives on the U.S. Department of Transportation with respect to environmental quality. The principal external lever on the Department is Section 102(2)(c) of the National Environmental Policy Act, which requires that a publicly scrutinized impact statement be filed with the Secretary for all proposed projects having Federal funding over a certain dollar level...(Among the recommendations of the study were)...that the quantifiable and nonquantifiable elements of environmental impact be delineated as clearly as possible and be evaluated as to their amount, effect, and value...The summary concludes with...It is noted that a variety of new legislation and programs offers DOT an opportunity to formulate a coordinated development program for federally supported elements of urban transportation systems." HRIS No. 200493.

New England Research, Inc.(Worcester, Mass.) (712)

1974. Student workbook for training course on ecological impacts of proposed highway improvements. New England Research, Inc. Contract No. DOT-FH-11-8506, v + 143 pages.

This workbook, prepared for the National Highway Institute, Federal Highway Administration, U. S. Department of Transportation for a 5-day training course on ecological impacts of proposed highway construction or improvements, has use, also, as a check list of potential impacts on aquatic and terrestrial ecosystems. It should be helpful in training personnel to prepare meaningful environmental impact statements. References listed in the workbook are mostly of a broad and comprehensive nature and appear to be generally well selected and authoritative.

Posekany, Lewis A. (Wisconsin Department of Natural Resources) (713)

1973. Biological Values - presented as a part of a 4-member panel presentation on "Action strategies and environmental values," pages 87-89 in "Environmental considerations in planning, design, and construction." Highway Research Board, Div. of Engineering, National Research Council, National Academy of Sciences - National Academy of Engineering (Washington, D.C., price $5), Special Report 138. 161 pages.

Discusses how the Wisconsin Department of Natural Resources interacts with the Department of Transportation and other agencies and organizations to prevent material damage to fish and wildlife and other environmental values in road construction. A highway liaison team of a district engineer and an experienced conservationist has resolved most problems at a local level. He indicates that over a period of 17 years the district highway engineer and his staff have learned that their counterparts in natural resources are there not to stop them but to keep things from going wrong. He states: "Something one must see to believe is a district engineer proposing a new corridor through a heavily wooded area and finding that his natural resource counterpart heartily endorses extensive cutting because an overage stand of poplar is involved. Similarly, one should see the shock the district engineer exhibits when he proposes borrow pit lakes and is asked what he is trying to produce -- boating ponds, reflecting pools, or fishing lakes? To him a lake is a lake! He is horrified to find that Wisconsin's fertile waters will not keep a reflecting pond reflecting long because a crop of aquatic plants will develop or that our harsh winters require a fishing lake to be 20 feet deep if winterkill is not to be a problem or that lakes that produce duck habitat will not necessarily produce fish. But after working with the conservationist for a number of years, the highway engineer learns either by his own experience or by advice from his predecessors that 'these' people know what they are talking about."

Roelofs, R. T. and William Jenkins (714)

1975. Environment: a bibliography on social policy and humanistic values. Project Report No. 13, Center for Water Resources Research, Desert Research Institute, University of Nevada System, Reno. ii + 136 pages.

This report, consisting of an alphabetical index of authors and items and a classification index, deals primarily with public policy relevant to environmental problems and the broader interrelations of the physical environment, social institutions, and humanistic values. Under the topical heading of Transportation, 18 references are identified by number and listed under the author index by title. Transportation is dealt with in a broad sense.

Santonas, William (715)

1968. Highway coordination project and review of existing interagency agreements. Pages 11-15 in Inter-agency Stream Disturbance Symposium Proceedings (Charleston, West Virginia) 47 pages.

"On July 1, 1968, the Game and Fish Division of the Department of Natural Resources initiated a Federal Aid project, Highway Construction Investigation, with the objective to cooperate and coordinate with the West Virginia State Road Commisssion in locating, planning, designing and construction of highways, which would appear to have effect on fish or wildlife, and to make recommendations for mitigation of losses, and/or enhancement of fish and wildlife resources." Such cooperation will present a possibility to avoid detrimental highway effects on wildlife such as: siltation blanketing spawning beds, compacting of stream gravel, taking stream gravel for highway use, and others. "In some cases the highway construction projects will present a possibility to improve upon present habitat or to create new habitat...

"There have been fish and wildlife losses on recent highway construction projects. On I-64 project in Greenbriar County, the rechanneling of Howard Creek, a quality stream, has resulted in fish losses that will be long-lasting.

On the same project, some damage to the Greenbriar River has resulted from the installation of a roadway to move fill across the river. The construction of the Scenic Highway, (FHH-1 (6)) has resulted in an extremely muddy condition to the Williams River and drastic reduction in recreation use on this resource." Proposed projects such as: th "Appalachian Corridor" 'E' (APD-483(5) through Coopers Rock State Forest has been designed to avoid damages to Coopers Rock Lake. An interchange is scheduled near the forest road to the recreation area. A large segment of the present Route 73 will be left intact...This highway should result in greater use of the (forest) area. A proposed impoundment is being considered in a rechanneled area of Middle Island Creek on the U.S. Route 50 Relocation Project (APD-282(31)) near Smithberg. This impoundment should result in mitigation for damages to Middle Island Creek. This proposed facility will be adjacent to a rest stop."

"This program between the West Virginia Department of Natural Resources and the West Virginia State Road Commission is an important milestone in providing methods of preserving and enhancing our fish and wildlife resources and at the same time providing highway access to fish, wildlife and recreation areas."

Scheidt, M.E. (716)

1967. Environmental effects of highways. American Society of Civil Engineer's Journal of Sanitary Engineering Division. 93(SA5): 17-25, Proceeding Paper 5509.

Summary: "The polluting effects of highways on the environment are generally discussed. Erosion of soil exposed during construction results in substantial sedimentation damage downstream from the construction area. Sediment loads and damages are described for localized conditions in Maryland and Virginia. Provisions for controlling the pollution effects of highway construction are being required by federal and local governments. The use of chemicals in highway maintenance and spillage in the transportation of chemicals also have damaging effects on the environment. A center for reporting of highway accidents involving spillage of hazardous commodities should be established. Roadside litter requires stronger action than presently enforced penalties." HRIS No. 204102.

Sloss, G. J. (717)

1972. Environmental aspects of transportation planning - a revision of CPL Exchange Bibliography No. 218. Council of Planning Librarians Number 353. 35 pages, 309 refs.

"This bibliography stems from a collection of backup publications for four transportation projects undertaken by environmental planning and design. Of special concern were air and noise pollution. The bibliography includes subjects pertinent to the effects of transportation systems on the environment - both human and physical. The entries are listed generally by subject. Approximately two-thirds of them have been published listing many hundreds more entries." HRIS No. 240777.

United States (718)

1972. 23 U.S.C.A. 138 (1972 Supp.)

138 provides: "It is hereby declared to be the national policy that special effort should be made to preserve the natural beauty of the countryside and public park and recreation lands, wildlife and waterfowl refuges, and historic sites. The Secretary of Transportation shall cooperate and consult with the Secretaries of the Interior, Housing and Urban Development, and Agriculture, and with the States in developing transportation plans and programs that include measures to maintain or enhance the natural beauty of the lands traversed. After the effective date of the Federal-Aid Highway Act of 1968, the Secretary shall not approve any program or project which requires the use of any publicly owned land from a public park, recreation area, or wildlife and waterfowl refuge of National, State or local significance as determined by the Federal, State or local officials having jurisdiction thereof, or any land from a historic site of National, State, or local significance as so determined by such officials unless (1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use."

U. S. Department of the Interior (Bureau of Reclamation) (719)

1974. Environmental guidebook for construction. Superintendent of Documents, U. S. Government Printing Office (Washington, D.C. 20402) 61 pages.

This guidebook is "designed to help construction people understand how their work relates to the environment."

The first part of the book 'Environmental Considerations During Construction Activities,' discusses air and water quality, and noise control. The second part of this book, 'Environment Concerns (For Supervisors),' discusses the preservation of land characteristics, surveying methods, location and control of construction facilities, roads, and signs, construction and excavation activities, refuse disposal, and impact of construction on the community. Bibliography of 17 titles.

U. S. Department of the Interior, U. S. Fish and Wildlife Service. (720)

1956. National survey of fishing and hunting/a report on the first nationwide economic survey of sport fishing and hunting in the United States, during the calendar year 1955. U. S. Fish and Wildlife Circular 44,ii + 50 pages.

One in every three households had at least one hunter or fisherman. One in five men hunted, but only one woman in 128. Nearly three billion dollars was spent on hunting and fishing. Relative to this bibliography and state-of-the-art report, hunters traveled 2,684,914,000 automobile miles and more than twice that many passenger miles. Nationwide sampling was done by Crossley S-D Surveys for the Fish and Wildlife Service.

U. S. Department of Transportation Federal Highway Administration. (721)

1972. Environmental considerations in highway design, location, construction, and operation. Federally Coordinated Program of Research and Development in Highway Transportation. Volume 3, 106 pages, tabs, refs.

Summary: "Volume III of the Federally Coordinated Program of Research and Development in Highway Transportation (FCP) contains project objectives, scope, research plans, references, and relation to other research, task flow charts, and suggested studies for 16 research tasks in four general areas: (1) engineering economic evaluation of vehicle use and traffic control; (2) socio-economic factors in highway engineering and location; (3) reduction of environmental hazards to water resources due to the highway system; and (4) pollution reduction and visual enhancement." HRIS

White House, (President's Science Advisory Committee, Environmental Pollution Panel) (722)

1965. Restoring the quality of our environment. The White House. Pages xii + 317.

Among the recommendations for action by this prestigious committee were:

"B15. We recommend that Federal agencies neither expend funds on or grant financial aid to any construction project or program which does not include effective measures for minimizing the production of dust and sediment. Temporary disturbance from highway and building construction now contributes large amounts of sediment, in some watersheds more than half the total. Much of this can be prevented.

"B16. We recommend that, especially in marshlands and coastal areas, minimizing the impairment of natural drainage patterns should be an important consideration in the building of Federally - supported highways. These areas are remarkably productive, some producing six times as much organic matter per acre as average wheat land. Nearly 60% of our total harvest of sea foods (which support 90,000 commercial fishermen) depends on these areas; unnecessary alterations can, through pollution, destroy this food supply and degrade important recreational resources."

The subpanel on "Effects of Pollutants on Living Organisms Other Than Man," David Pimentel, Chairman (Cornell University) recommended that: "In the Federal state highway program, the government should require that bridges and causeways be constructed so as not to impair natural drainage channels or access routes."

White House, President's Council on Recreation and Natural Beauty (723)

1968. From sea to shining sea--a report on the American environment, our natural heritage. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 304 pages.

Suggests that (page 19)"...as roads, factories and commercial centers spread across the landscape, the distinct forms of the land and the profuse features of plant and animal life that have always been part of man's habitat are obscured or obliterated." States that (page 201): "The principal objective of the Highway Beautification Act of 1965 is to improve the quality of the environment by preserving and enhancing the highway corridor through the reasonable control of outdoor advertising and junkyards, and to increase the safety and pleasure of the motorist by providing scenic overlooks and safety rest areas with provision for tourist information centers."

Quotes a provision of the Department of Transportation Act of 1966 which specifies that: "The Secretary (of Transportation) shall cooperate and consult with the Secretaries of the Interior, Housing and Urban Development, and Agriculture, and with the states in developing transportation plans and programs that include measures to maintain or enhance the natural beauty of the lands traversed. The Secretary shall not approve any program or project which requires the use of any land from a public park, recreation area, wildlife and waterfowl refuge, or historic site unless (1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use."

"The 1966 Federal Aid Highway Act includes similar provisions specifically aimed at the interstate and Federal aid primary and secondary highway systems."

With respect to automobile disposal and roadside litter the President's Council stated:

"...By 1966, about seven million vehicles a year were retired from the road; this rate is expected to double or triple in the next 30 years,...whether abandoned along the roads or accumulated in auto graveyards, these vehicles are particularly unsightly; if burned, they pollute the air with heavy smoke and objectionable smell. They often invite littering, harbor rodents and other pests, and create dangerous attractions for children...Rural roadsides and city highways are despoiled by thoughtless, careless motorists who toss from their cars a remarkable range of waste products. It costs the American taxpayers an estimated $100 million a year to pay for picking up highway litter. State highway agencies alone spent $25 million in 1966. Litter costs even more in indirect costs; littered countryside reduces the pleasure of recreational outings and traveling, and nails and glass puncture automobile tires..."

Examples of action being taken to remedy the situations are given.

Wolsko, Thomas D., Kenneth E. Nelson and Loren J. Habegger (724)

1974. Environmental handbook for highway systems. Argonne National Laboratory, Energy and Environmental Systems Division (9700 South Cass Ave., Argonne, Illinois 60439). A part of Environmental Impact of Transportation Systems Program conducted under subcontract number 31-109-38-2517 with the Illinois Institute for Environmental Quality. ANL/ES-30. 139 pages.

Authors' abstract: "This report provides a general background for transportation planners on the considerations that should be given to the environmental impact analysis of proposed highways. It contains a description of the major environmental effects, both direct and indirect, resulting from the construction of highway systems. In addition to the general discussion of environmental effects, a section of the report describes the considerations that should be given to impact analysis and statement preparation.

"The primary emphasis of the report, besides providing a general description of environmental impacts, is to describe quantitative analysis techniques for assessing the air and noise impacts of highways. Noncomputerized techniques are presented, along with procedures for analysis and example calculations. These models, having application to a limited number of highway designs, are simplified versions of more complex computerized models, and their capacity is intended to provide air and noise quantitative analysis capability for the experienced highway planner."

With respect to noise, the authors report on EPA studies ("Effects of noise on wildlife and other animals," December 31, 1971) that... "laboratory animals have demonstrated a complete loss of hearing after exposure to sound pressure levels of 90 dB or less, depending upon the animal." They state further, however, "Although there is no definite indication of the effects of noise on farm animals, fertility, egg laying, weight gain, and health may be adversely affected by noise exposure." There is little information available concerning the effects of noise on wildlife.

The authors point out that in the Chicago area about 20 tons of deicing chemicals per mile are deposited on major highways in the winter months. These chemicals are eventually dispersed into the soil or the groundwater near the roadway with varying effects on water quality and vegetation. To the chlorides in deicing chemicals other compounds may be added to prevent caking and erosion. The authors indicate that trout may be endangered by 400 mg/l and bass, pike and perch may be harmed by 4,000 mg/l. Among the deicing salt additives are sodium ferrocyanide which releases cyanide upon photodecomposition and forms hydrogen cyanide .2 mg/l concentrations of which were reported to be toxic to fish; hexavalent chromium which, at concentrations of 5.00 mg, could be dangerous to stock and wildlife watering and at .05 to 1.00 mg harmful to more sensitive aquatic life and to fish; and sodium hexametaphosphate which was reported to stimulate plant growth at low concentrations.

The authors point out (page 29) that although solid waste generated by ground transportation systems at first appears to be rather insignificant, parts of vehicles such as wheels, tires, and mufflers as well as an assortment of litter from passing vehicles are scattered along the rights-of-way.

They state, "Considering the more - than 100 million vehicles on the road in the United States today, approximately 200,000 cu. ft. of rubber from tires is dispersed each day into the air as particulates. The cubic feet of particulate brake lining is on the order of thousands of cubic feet per day. In Cook County alone, the State of Illinois has a maintenance crew of over 100 men who work full time cleaning the shoulders along highways. The County of Cook and City of Chicago also have men who are employed to clean the same highway right-of-ways. in 1967, 16,400 tons of debris were found along the highways in Cook County by the State of Illinois maintenance crews. This amount of debris is equivalent to the solid waste that would be generated by a city of 22,000 people."

The authors indicate that due to the lack of research, the effects of solid waste generated by ground transportation facilities are virtually unknown. They point out, however, that the oil and grease dripped on roads make highways extremely slippery shortly after a rain begins and they recognize that the runoff of oil products may contaminate nearby streams and underground water.

Recommendations are made concerning the planning, designing, locating and constructing of highways in relation to aesthetic values.

B. SOME ENVIRONMENTAL CONSIDERATIONS FOR THE PLANNING AND ROUTING OF ROADS.

Anderson, Charles R. (Maryland Department of Transportation) (725)

1973. Preservation of landscape features. Pages 95-97 in "Environmental considerations in planning, design, and construction." HIghway Research Board, Div. of Engineering, National Academy of Sciences - National Academy of Engineering (Washington, D.C., price $5), Special Report 138. 161 pages.

Anderson states: "An inventory of all natural and scenic features should be made during the early planning and location phases of highway development. If an existing highway is to be improved, the inventory should be made before design starts. The inventory should gather available data from other agencies and field check and expand those data as necessary. Field trips with natural resource personnel may also be necessary.... We must maintain continual contact with all state and local planners and natural resource agencies so that we are aware of their plans and they are aware of ours. Only through such an awareness can we see beyond the roadway right-of-way to the entire environmental picture. We should be ready to give our expertise and to receive theirs. We often hear about the use of a team of various disciplines within a highway organization to develop a highway; we now have an opportunity to be part of a team to preserve the environment."

The author pointed out the importance of woodland areas for scenic beauty, aid in highway drainage and for helping abate, screen, or reduce air, visual and noise pollutants; he indicated that every effort should be made to minimize any alteration to the natural state of streams, rivers and other surface water features and indicated that retention of natural habitat for fish and wildlife in and along such waters is extremely important; he stated that bridges and, in special cases, viaducts may be required to retain streams and stream valleys in their natural state and suggested that stream channelization and the solid paving of stream beds be minimized and, instead, vegetation, gabions, riprap and other natural or near natural liners should be used. Anderson also advocated generous acquisition of land to preserve landscape features and to create necessary buffer and transition zones between the highway and adjacent areas.

Anonymous (726)

1972. Wyoming road construction beautifies area by eliminating unsightly dumping grounds. Highway Research News No. 46 (Winter), Highway Research Board, National Research Council, National Academy of Sciences-National Academy of Engineering, pp. 28-29.

Environmental considerations influence construction from the moment plans for a new highway take shape. Cost of restoring land as nearly as possible to its original state after a road has been built is incorporated into construction contracts. Revegetating right-of-way, controlling erosion, building highways to blend in with surroundings, and working to protect and preserve wildlife and fish are automatic in constructing Wyoming highways.

Garbage dump sites were utilized at two sites in the construction of I-80. Garbage was cleared out and cinder accumulation was used as land fill. These areas were transformed into esthetically appealing ones through planning and environmental concern.

Various sections of highway throughout the nation are being built on fill comprised of garbage and other solid waste materials.

Anonymous (727)

1974. Trunk line. Engineering News Record 192(8):20.

"Engineers in Mozambique have to reroute a planned 25-mile railroad line to avoid disturbing elephants. After design of the new line was complete, they discovered that it would run along a lagoon that is a favorite haunt for pachyderms." (DOT abstract)

Anonymous (728)

1974. Ecological Paving. Engineering News Record April 11, page 41.

The country's second largest new town, Woodlands, located north of Houston, Texas, may make extensive use of porous asphalt paving. Porous paving consists of a relatively thin layer of gap graded asphalt over a deep base of permeable material that allows water to pass through the sub-grade. Major cost saving comes from eliminating curbs and drains. In addition, porous paving is less expensive than conventional "paving" and tests indicate that it will last at least as long. By permitting water to percolate directly into the soil, the porous system also reduces pollution, may prevent flooding, and can recharge the water table.

Anonymous (729)

1975. Sandhill crame gets emergency action. Outdoor News Bulletin 29(15):2. (Wildlife Management Institute, 709 Wire Building, Washington, D.C.20005).

As reported in this news bulletin of the Wildlife Management Institute, dated July 18, 1975, the first emergency action under the 1973 endangered Species Act has been taken to protect the habitat of the Mississippi sandhill crane. The U.S. Fish and Wildlife Service designated the living space of this crane as "critical habitat," which prohibits any modification or destruction of the area.

The News Bulletin states: "A Mississippi highway construction project threatens to disrupt the last remaining bit of habitat which supports the only known population of the crane. The bird is non-migratory and depends entirely on the small area. Only about 38 to 40 of the Mississippi sandhill cranes remain in the wild.

"The emergency declaration will prohibit any intrusion into the habitat for 120 days during which time consultation with other agencies and the interested public will be sought."

Barnes, R. C. Jr. (730)

1973. Erosion control structures. Pages 94-98 in Soil Erosion: Causes and Mechanisms, Prevention and Control, Special Report 135. Highway Research Board (Washington, D. C.) 141 pages.

"Erosion and excess runoff are products of many factors: soil type, plant cover, cropping practices, climatic zones, rainfall amounts and intensities, and degree and length of slope to name a few... The end product (of erosion) is sediment. It is in the construction stage that natural conditions such as topography, natural cover, soil conditions, and drainage patterns should be the goal of each design and construction engineer to control these results within reasonable limits during the construction stage and finally to permanently stabilize the area for control of erosion and runoff upon completion of the job. There are a number of basic principles for controlling runoff and erosion that have proved sound over the years for other land uses and that can prove to be just as useful for highway construction. These include such things as proper attention to soil, foundation, and topography in site selection; minimum exposure of bare areas by control of clearing and grading operations; diversion of water away from critical areas; flattening slopes; reducing slope lengths; use of temporary cover; and control of equipment access and travel ways. A number of structural measures are discussed that may be used as either temporary or permanent installations. These include such things as grassed or paved waterways, buried pipe outlets, diversion terraces, benches, various types of grade control structures, retarding structures, chutes, inlets, and debris basins." Bibliography of 1 title.

Bones, Jim (731)

1975. Riotous flora by a Texas wayside. Audubon 77 (4): 32-39.

This article, well illustrated with colored photographs, points out that fences, railroads and highways have helped to preserve a rich variety of life, including wildflowers, but the author states, page 39, "Unfortunately, injudicious roadside mowing and the increasing use of herbicides pose serious new threats to wildflower survival. As industry and urbanization continue to expand, and superhighways cover ever more of the rural countryside, the old byways that harbor fugitive life are quickly disappearing. Although it is not too late to save many of these accidental sanctuaries for those who may travel after us, time is fast running out."

Cole, LaMont C. (732)

1969. Wooded highway medians. (An editorial). BioScience 19(11):9.

This well-known ecologist observes that the median separating the lanes of limited access divided highways usually is covered with a growth of nicely manicured grass which requires considerable equipment, manpower, and money to maintain, including, he assumes, "quite a bill for fertilizers and pesticides."

He further observes that some stretches of the New York thruway west of Rochester have the median covered not by grass but by dense woody vegetation and wonders why more median strips should not be wooded. In discussing his preference for trees with others, he found only one dissenter, a man who objected to making it easier for the police to conceal their radar traps. Among the advantages, he suggested, are that trees are more pleasing to look at; head-on collisions of cars crossing the median and crashing into cars in the oncoming lane would be avoided; constant diming of lights for oncoming cars, which is necessary when the median is grass-covered, would not be required (he feels this diming and turning the lights back to high beam increases the deer-vehicle accident hazard in regions where deer cross the highway); snow drifting and effects of crosswinds on vehicles at high speeds are reduced; and woody vegetation filters out air pollutants, moderates high summer temperatures, and absorbs noise. He points out, further, that most of our important weeds are annuals that don't compete successfully in tree associations so wooded medians would not be sources of weed seeds, and that the kinds of birds for which wooded medians would provide sanctuaries can only be regarded as beneficial. He concludes his editorial with the question: "Are there other counter-indications, or have we here another example of slam-bang technology proceeding, as usual, without a thought for its total impact on the system of which it is a part?"

Frederick, Joseph C. (733)

1969. The highway roadside as an element in urban design. Highway Research Record 280. Highway Research Board,(Washington, D.C.) Pages 15-24.

One of the many concepts utilized in designing the Binghamton, New York metropolitan area, is multiple land use. A 200-acre river-front park is to be developed in the Chenango River and Interstate 81 area. "The development includes open grassed areas for active recreation, the seclusion and shade of natural and created groves, picnic areas, the inspirational aspects of created ponds and wildlife, and...sweeping views of the river...The roadside in this particular use is at an optimum level of service. It will be devoted to highway, roadside rest areas, parking, recreation, and park use, and provide erosion control, scenic overlooks, and over-bank flood protection."

The author points out that the Susquehanna River and surrounding marshlands may lie in the urban design areas. "Whenever the urban arterials and expressways are not too remote from the river's edge, these wetlands have been included in the highway roadside limits. Their acquisition preserves them for a natural ecological balance in addition to providing marginal and environmental controls." Bibliography of 15 titles.

Goode, Dewar W. (3 Mandeville, Crescent, Toorak 3142, Victoria, Australia) (734)

1971. Highways and amenity, a paper presented at the "Symposium on the relationship between engineering and biology in improving cultural landscape," V. Brno, Czechoslovakia and International Union for Conservation of Nature and Natural Resources, Morges, Switzerland. Pages 39-42.

Urges highway engineers to work with landscape architects, botanists, conservationists and ecologists to include aesthetic, recreational, and good ecologically based land use values in the designing of engineering structures. Points out that landscape of exceptional aesthetic value, such as can be found in our unspoiled natural area or national park, deserves very special care and states... "Not only do trees and shrubs contribute to the absorption of the noise, exhaust smells, carbon monoxide and smoke, they also screen unsightly structures and poor land use. Ideally indigenous species should be used. In a natural environment, bacteria, fungi, birds, and animals live in a dynamic society, the basis of which is the trees, bushes, shrubs and grasses in which they live. Not only can the aesthetic values of a highway through native forest be destroyed by a thin planting of exotics along the road verge, but the introduction of non-indigenous species will upset the natural balance, usually with a deleterious effect."

"...Very attractive rest areas can be designed into the borrow-pit and fill areas resulting from massive earthworks along highways. If raw native topsoil is stock-piled and spread over bared areas, native plants, grasses, shrubs and trees can be re-established. Too often the destruction of indigenous flora by earthworks leads to an unsightly proliferation of weeds and exotic plants. If an attempt is made to reestablish the native habitat then the traveler while resting should be able to observe bird and animal life in a natural setting."

Hay, Keith G. (735)

1960. An evaluation of Colorado's access problems. Transactions, Twenty-Fifth North American Wildlife and Natural Resources Conference, pages 364-377.

Adequate harvest of big game herds helps in preventing overpopulation, poor winter-range conditions which may result in starvation, and costly crop depredations. Although under-harvesting a trout fishery is generally considered to have little or no harmful results, some streams and lakes could sustain more fishing and thus provide additional recreation opportunity. Surveys made by the Colorado Game and Fish Department in 1957 and 1958 indicated a minimum of 236 bandholders in 28 of Colorado's 63 counties were blocking access to 1,462,720 acres of public land. Some of the State's best hunting country contained the greatest amount of blocked acreage and game-damage problems. The public at that time was also denied access to 522 miles of good trout-stream fishing and to 28 "good" fishing lakes on Federal land due to posting on private land. Similar problems existed in other western states. Several possible courses of action to mitigate the problem were suggested: "...(1) improve existing roads and provide new ones -- a responsibility of federal land-use agencies; (2) strengthen cooperation with landowners in numerous ways; (3) establish uniform regulations for identifying public land; (4) grant limited condemnation power to Conservation Departments for rights-of-way; and (5) increase and simplify lease agreements, land exchanges, and sales between landowners and the federal government."

Jackman, A. H. (736)

1973. Impact of new highways upon wilderness areas. Artic 26 (1): 68-73.

Summary: "Construction of a new highway through a wilderness area starts an irreversible series of more or less predictable events. Healing of the construction scars takes place at varying rates, but can be accelerated by careful construction practices, selection of a route which avoids the worst permafrost areas and which takes gravel and other materials from concealed sites near, but not on, the right-of-way. The greatest environmental problems are created by those who will use the highways for purposes of access and exploitation of a heretofore inaccessible wilderness. It is essential that there be a comprehensible land use plan which would allocate appropriate areas for all activities. The taps (Trans-Alaska Pipeline System) haul road might be considered an experiment designed to develop the techniques by which a first class heavy duty highway can be constructed through the subartic forest." HRIS No. 240232.

Lacate, Douglas S. (737)

1970. The role of resource inventories and landscape ecology in the highway route selection process -- a case study using the proposed relocation of New York State Route 13. Office of Regional Resources and Development, Cornell University, Ithaca, New York, vii + 198 pages.

This report suggests a method of resource and analysis -- with emphasis on the use of aerial photographs and ecological input in the early planning stages -- as a basis for highway route location. The approach is to establish where a highway should not be built, according to Lawrence S. Hamilton, Professor of Conservation, in the Foreword to this report. He indicated that public reaction to routes which would impair a scenic gorge, a valuable rainbow trout fishery, a wildflower preserve, a series of unique bogs, and high value agricultural land was predictable and sharp and suggested that regional values of this type should be identified and catalogued as a basis for a resource analysis approach to planning any kind of major development, public or private.

Maine University (738)

1973. Management of forest stands on highway right-of-ways. University of Maine/Life Sciences & Agricultural Experiment Station, 20(12): 9 pages, 8 figs.

"This paper is presented in an effort to encourage the incorporation of ecologically sound forest management into design, construction, and maintenance of

highways, and so, reduce pollution, provide an additional source of raw material, and reduce maintenance costs by the continuous sale of forest products from forest stands on the highway right-of-ways. The clearing of vegetation for major highways exposes faces on the edges to detrimental wind, light, moisture and soil temperature changes. Land fill areas cause similar changes. Thinning and pruning of forest trees by landscape architects, effects of the use of deicing salts, heavy equipment, and changes in drainage patterns caused by highway construction are reviewed. Some general forest ecology concepts are listed. Guidelines for forest management of high right-of-way are presented. Care must be exercised in road location to insure that it does not pass through a natural area of public interest. The design of each segment of a new highway to minimize changes in natural drainage is an important aspect of highway construction. The inclusion of foresters in the staffs of state highway departments and their involvement in the planning, design, construction, and maintenance of highways and the planning, supervision and usage of forest products is urged."
HRIS No. 205244.

McHarg, Ian L. (739)

1966. Ecological determinism. Pages 526-538 in "Future environments of North America-transformation of a continent (Edited by F. Fraser Darling and John P. Milton) -- a record of a conference convened by the Conservation Foundation in April, 1965, at Airlie House, Warrenton, Virginia. The Natural History Press/Garden City, New York, pages xv + 767.

Points out that 70 square miles of beautiful farmland adjacent to Baltimore were made accessible by construction of a new expressway and that "ecological determinism" suggested prohibition of development in the valleys (Green Springs and Worthington) and on bare slopes. Development should be limited to one house per three acres on wooded slopes.

McHarg, Ian L. (740)

1968. A comprehensive highway route selection method. Highway Research Record 246. Highway Research Board (Washington, D.C.) Pages 1-15.

The author points out that highways are multi-use facilities. HIghway alignment should relate to the maximum social benefit and the minimum social cost. Some of the positive social influences a highway may produce are:

"Reveal the physical and cultural identity of the region it transects.

Provide access to existing inaccessible resources.

Link scenic and recreational resources."

Some of the negative social influences listed that a highway may produce are:

"Constitute a health hazard due to stress, anxiety, lead, hydrocarbons, ozone, carcinogens, positive atmospheric ionization.

Constitute a nuisance due to noise, glare, fumes, dust, danger, ugliness.

Destroy existing resources -- scenic, historic, ground and surface water, forests, farmland, marshes, wildlife habitats, areas of recreational value, and areas of natural beauty."

McHarg, Ian L. (741)

1969. Design with nature. Paperback Edition: 1971. Doubleday/Natural History Press, Doubleday & Company, Inc., (Garden City, New York). 197 pages, illus.

The author examines nature and man's activity from an ecological point of view. A suggested criterion for interstate highway route selection is given with both the price and non-price costs and benefits listed. The author emphasizes that "the best route is the one that provides the maximum social benefit at the least social cost." This principle is discussed as it was employed in the Richmond Parkway Study, (Borough of Richmond) by the New York City Department of Parks. This book seeks to give the reader a sense of the total surrounding environment.

Middleton, John T. (Environmental Protective Agency) (742)

1973. America's highways: where are they taking the environment? Pages 3-5 in "Environmental considerations in planning, design, and construction." Highway Research Board, Div. of Engineering, National Research Council, National Academy of Sciences-National Academy of Engineering (Washington, D.C., price $5), Special Report 138, 161 pages.

Middleton states, "The Environmental Protection Agency recently conducted a study of erosion and sediment deposition resulting from highway construction and land development activities. It concluded that the cost of correcting these problems often is unjustifiably transferred to the taxpayer rather than to those benefitting from the development; that the technical capability of controlling erosion and sediment deposition is available; that the cost of effective control probably is minimal; and that the principal problem lies in achieving effective administrative control and enforcement by concerned agencies."

He stated further, "An estimated 250 square miles adjacent to freeways or highways have a noise impact affecting about 2.5 million Americans. Of the 3 billion total highway vehicle-miles traveled in 1970, better than half were within town or city limits. In addition, traffic over the 96,000 miles of major arterial roads in suburban communities exposes 7 to 14 million persons to objectionable noise levels".

After discussing various problems concerned with vehicular traffic, highways and where they are taking the environment, he asks, "However, the real question is, where should the environment take highways? Quite likely, honest and objective answers to that question will result in sweeping changes in the future development of the total transportation system."

Ottersen, Signe Ruh, compiler (743)

1967. Readings on natural beauty/a selected bibliography. U.S.D.I. Dept. Library Bibliography No. 1 iii + 94 pages.

"The references are grouped under subdivisions of these major headings: The environment setting, planning, environment pollution, urban townscape, landscape architecture and plant materials, historic preservation, rural landscape, outdoor recreation environment, transportation, and citizen action. Most of the 1100 references listed appeared after August, 1964. WR No. 128:2

Patton, David R. and B. Ira Judd (744)

1970. The role of wet meadows as wildlife habitat in the Southwest. Journal of Range Management 23 (4): 272-275.

"There are approximately 43,700 acres of wet meadows on National Forests in the Southwest. Three sites (meadow, transition, and dry forest) influence herbage production and plant composition. Average per acre production for a three-year period was 2,690 lb., and 170 lb. in the meadow, transition and surrounding dry forest sites, respectively, for two areas studied. Deer and elk spent more time in the adjacent forest edge than in the meadow, but time spent in the meadow may be more important for quality and quality of forage...The following guidelines are suggested for the protection, maintenance, or restoration of wet meadows.

1. All roads and trails should be kept out of the moist and wet sites. Preferably they should be located back into the adjacent, dry forest.
2. Sucession should be controlled by removing trees that invade the moist and wet sites.
3. Keep livestock and game numbers at a level that will improve or maintain desirable plant composition and not induce erosion from trampling.
4. Wet meadows that have been reduced to dry sites by gully erosion can be restored by remedial measures to raise the water table." Bibliography of 8 titles.

Schell, N.E.; Arizona State Air Pollution Control (745)

1971. Aspects of air pollution in Arizona. Arizona Conf. Roads & Streets Proc., Arizona Transportation and Traffic Institute, University of Arizona, pp 5-8.

"In the future, transportation and construction activities will be affected by decisions made relative to the environment in terms of location, and in terms of structural procedures for the provisions and use of these facilities. Remarks are offered here on the environmental aspects of road construction-related activity. In the clearing of rights-of-way of roads, the burning of trash and trees present a problem. Rock crushing and preparing aggregate is a source of concern to people of the locality. Asphalt mix plants and concrete batching plants contribute to air pollution problems. One of the greatest problems has to do with the use of facilities. The manner in which the desert is being used for transportation without due consideration to more than one ecological problem, is a matter of concern. Improperly surfaced roads could lead to devastation through erosion. The increasing number of automobiles in the State, could increase the problem of air pollution. The location of highways relative to cities is very important.

From an environmental standpoint it would be beneficial to bypass as much through traffic around communities as possible. The importance of environmental factors is being recognized at the federal level. The environment may be examined in terms of immediate effects at one particular point or from the standpoint of the impairments that may be created in that community, both in terms of a local situation as well as in terms of the general situation which is affected." (Author) HRIS No. 262893.

U.S. Department of the Interior, Fish and Wildlife Service (746)

1962. The value of wetlands to modern society. In Project Mar. International Union for the Conservation of Nature and Natural Resources. Publications new series 3. Pages 57-63.

From summary: "Natural wetlands have both tangible and intangible values to man. In the United States, they produce commercially valuable fur animals and support a migratory waterfowl resource that has economic, esthetic, and recreational values. They are important, too, in the production of commercially marketable fish and shellfish...Many species of plants and animals occur only in wetlands. On moral, esthetic, and scientific grounds this is ample justification for the preservation of key wetland areas as a basic obligation to man. The economic pressure to drain wetlands is increasing...construction of highways and parking areas (and others) has and still are contributing significantly to disappearance of wetlands and the natural resources they produce...The challenge of our time is to devise better methods for assessing and expressing intangible benefits that wetlands afford to people."

U. S. Department of the Interior, Fish and Wildlife Service (747)

1973. Threatened wildlife of the United States. U. S. Government Printing Office. (Washington, D. C. 20402) 289 pages.

A list of all known threatened wildlife in the United States is given. The following information is given for each species: common and scientific names, Order and Family, distinguishing characteristics, present and former distribution, status.

estimated numbers, breeding rate in the wild, reasons for decline, protective measures already taken, and measures proposed. Appendices included.

U. S. Environmental Protection Agency. (748)

1973. Processes, procedures, and methods to control pollution resulting from all construction activity. U. S. Environmental Protection Agency, Office of Air and Water Programs, Washington, D.C. 20460. EPA 430/9-73-007. xii + 234 pages. (Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $2.30).

This report prepared for EPA by Hittman Associates, Inc., Columbia, Maryland was issued in response to Section 304(3)(2)(C) of Public Law 92-500, "The Federal Water Pollution Control Act Amendments of 1972."

From the authors' summary: "Processes examined include site planning, preliminary site evaluation and design, use of planning tools, and structural and vegetative design considerations relative to the development of a water pollution abatement plan suited to individual construction sites.

"Methods examined include on-site erosion, sediment, and stormwater management control structures as well as soil stabilization practices useful for achieving control of sediment, stormwater runoff, and other pollutants resulting from construction activities. Stormwater management practices are discussed in detail.

"Information presented in this report represents the state-of-the-art in the three areas. New processes, procedures, and methods for controlling sediment and other pollutants are continually being developed from time to time to make control more effective.

"Information presented in this report indicates that water pollution resulting from sediment and other pollutants generated from construction activities can be prevented by the timely application of empirical structural and soil stabilization measures presently available.

"Non-point source pollution control plans should be drawn up adhering basically to the following steps: (1) Plan structures and vegetative measures that will protect environmentally vulnerable areas. (2) Control the speed and volume of water runoff. Detain stormwater on the construction site. Use water diversion structures to divert water away from graded areas. (3) Trap sediment on the site. (4) Stabilize exposed soils by adhering to time limits set out in the schedule for site grading, seeding, and mulching. Use stage grading, seeding, and sodding. (5) Determine the need for water pollution abatement measures on a site by site basis. (6) Outline water pollution abatement procedures for inclusion in the construction contract. Prepare a water quality control plan that will minimize stream turbidity, changes inflow, and movement of fluids, oils, wastewater, fuels, aggregate wash water, mineral salts, and pesticides into waterways. (7) Outline procedures for the management and inspection of structural and vegetative controls for graded areas, borrow pit areas, dredge spoil areas, and stockpile areas, among others, on a periodic basis for inclusion in the construction contract." Selected references and a selected bibliography are given at the end of the major sections of the report. The five appendices include a soil-erodibility nomograph; special notes relative to the Water Pollution Abatement Plan; approval and certification statements relative to the Water Pollution Abatement Plan; a joint memorandum between the U. S. Department of the Interior and the State of Nevada relative to coordination between the Bureau of Land Management and the State of Nevada Department of Highways; and a model state act for soil erosion and sediment control and examples of laws passed by the Commonwealth of Pennsylvania and the State of Michigan dealing with clean streams and soil erosion and sedimentation control.

U. S. Environmental Protection Agency (EPA Region X Water Division and Arnold, Arnold and Associates for EPA(749)

1975. Logging roads and protection of water quality. EPA 910/9-75-007. 312 pages, 16 tables, 42 figures, 128 references. This publication is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

"This report is a State-of-the-art reference of methods, procedures and practices for including water quality consideration in the planning, design, construction, reconstruction, use and maintenance of logging roads. Most of the methodology also is applicable to other forest management roads. The report is divided into two parts. The first part provides general perspective on physical features and conditions in EPA Region X which are relevant to water quality protection and logging roads. The second part outlines specific methods, procedures, criteria and alternatives for reducing the degradation of water quality. Topic coverage in this part includes road planning, design, construction and maintenance including the use of chemicals on roads. Silvicultural activities are one category of water pollution from nonpoint sources described in Public Law 92-500. Of all silvicultural activities, logging roads have been identified as the principal source of man-caused sediment." (Author's abstract).

Ward, A. Lorin (750)

1974. Effects of timber harvest on mule deer and elk. Proceedings, 18th Annual Rocky Mountain Forest Industries Conference--a meeting held jointly with the Rocky Mountain Section of the Forest Products Research Society, Cheyenne, Wyoming, March 28, 1974. 17 pages, 2 figures.

Telemetry, time-lapse photography, and fecal and track counts were used to study mule deer (_Odocoileus hemionus_) and elk (_Cervus canadensis_) behavior in relation to timber harvest on the south end of the Medicine Bow Range in southcentral Wyoming.

Fecal counts in this study indicated that both animals prefer to feed in forest openings less than 500 yards across. With respect to highways and elk the author stated: "Logging and recreation roads with moving traffic have little effect on elk activity within 300 yards once the elk become used to them. Elk cross roads in the forest mostly at night when traffic is low. Roads should be located in timber with a buffer zone of timber, at least 100 yards wide, between the road and known elk feeding sites."

Wells, R. I., Environment Development Division (FHWA) (751)

1971. The effect of highways upon the environment

Arizona Conference of Roads and Streets Proceedings; Arizona Transportation and Traffic Institute, University of Arizona, (Tucson, Arizona 85721) Pages 1-4.

"Community concern about the environmental effects of highway developments is reviewed, the opinions of professional environmentalists are discussed and steps taken to limit detrimental environmental effects are outlined. Legislation is now being enacted in some states to limit permissible noise level of each vehicle which operates on the highway. Congress is expressing interest in vehicle and construction equipment noise, and Federal legislation may be enacted. In highway location and design, the engineer must give consideration to the problems associated with highway noise. Some design-technique recommendations are proposed. Concern for soil erosion has prompted the issuance of Federal guidelines for minimizing soil erosion from highway construction. Emphasis must be placed on practical measures to eliminate soil erosion and the resultant stream or lake siltation.

"These measures must be incorporated in every highway project. Fitting the highway to the natural and cultural features should be the concern of every highway engineer. A highway must be located and designed such that it forms a tie between areas on either side of the highway. Attention is being given to location of highways along natural boundaries of ecosystems and to the continuation of established wildlife trails across highway right-of-way. Preservation and conservation of lands and historic sites is another recognized goal in highway programs." HRIS No. 262895.

Wilder, Edwin H. (Nicolet National Forest, Rhinelander, Wisconsin) (752)

1969. Walking-trail developments for winters on the Nicolet National Forest. Fournal of Wildlife Management, 33 (4) : 762-768.

Some concern has been expressed over the relative lack of access provided by superhighways for people who want to get into wildland areas. In this article the other extreme with respect to roads and trails is discussed.

Author's abstract: "Five walking-trail units (9 to 40 miles per unit) were developed on the Nicolet National Forest in northeastern Wisconsin between 1962 and 1968. Although designed primarily for ruffed grouse (Bonasa umbellus) hunters, other uses by snowmobiles, hikers, and deer hunters, emphasize multiple-use values of trail developments and the importance of their coordination with other National Forest activities. Walking-trail development included construction and maintenance of trails, forest openings and other habitat (for wildlife), parking areas, gates, foot-path markers, signs, maps, and scenic overlooks. Public response and hunting results were favorable."

C. ENVIRONMENTAL IMPACT STATEMENTS, COURT ACTIONS AND OTHER MATERIAL RELATIVE TO HIGHWAY PLANS AND CONSTRUCTION.

Alabama State Highway Department (753)

1974. Draft EIS for Randolph-Cleburne County, Alabama. Location Section, Bureau of Survey and Plans.

The project is the proposed improvement of 16.7 miles of U. S. 431. It will be a two lane facility with the purchase of right-of-way for a future four lane divided highway.

Some of the negative effects mentioned are, some erosion and water pollution and destruction of some wildlife habitat. Comments are upcoming from several agencies.

Alaska, State Department of Highways (754)

1974. Draft Environmental Impact Statement for the South Central District. Department of Highways, South Central District.

"The proposed project calls for the reconstruction and realignment of the existing 58 mile road between East Bank of the Copper River and McCarthy."

The proposed project will be used to transport copper out of the mines of the area. It is stated that, "The trees, wildlife, grasses and viable species have renewed and re-established themselves" in the area since the time of great mining and activity which decreased until the present low amount of mining activity. Common names of common wildlife species are included. More in-depth comments are included from several agencies.

Anonymous. (755)

1973. Wildlife federation asks injunction that would tie up 320 road jobs. Dixie Contractor, 48(5):26.

Anonymous. (756)

1973. NEPA vs the highway trust. Rodale's Environmental Action Bulletin, 4(33):4-5.

This article states that on the surface, NEPA sounds like it would force road builders to consider issues broader than the economic and engineering ones that formerly dominated highway planning, but a study by the Center for Science in the Public Interest found that most impact statements do not satisfy the requirements of NEPA. Yet the roads in question are still being built.

Barnes, G. D. (757)

1973. Modification of major corridor criteria. American Society of Civil Engineers, Journal of Transportation Eng. 99:31-41, 1 fig. 3 tab.

Summary: "Transportation engineers locating major transportation corridors, specifically in urban areas, must now incorporate in planning, location, and design considerations hitherto slighted--factors of esthetics, environmental and ecological controls, and concerns of existing land use surrounding the proposed corridor. They must strive to educate the public to the benefits of transportation corridors in the daily operation of the vast and complex society in which we live. They must work with sociologists, ecologists, conservationists, etc. to form a more encompassing design approach to transportation problems of today's society. Proper perspective with possible priorities of the best overall, integrated corridor design must be applied by the principal member of the transportation concept team, the transportation engineer." (ASCE) HRIS No. 242607.

Copas, Thomas L. and Herbert A. Pennock (758)

1971. Construction of embankments. National Cooperative Highway Research Program, Synthesis of highway practice number 8. Highway Research Board. (Washington, D. C.) 38 pages.

In this technical report, the authors mention that "with respect to embankment construction, environmental protection requirements are related to the disposal of waste materials and erosion control."

Burning of brush, trees, and stumps is still the disposal method used, where permitted. Where burning is prohibited, stumps and brush may be buried in the side slopes of embankments, or placed at the toe of slopes for erosion control. "In some areas, brush and stumps, as well as large rocks or boulders, must be hauled from the right-of-way for disposal... Increasingly, waste disposal pits are being purchased just as borrow pits are purchased as materials sources."

"At this time, the use of chippers is limited by the branch size of disposed trees."

"One provision of a recent FHWA memo specified that 'under no condition shall the amount of surface area of erodible earth material exposed at one time by excavation, borrow, or fill within the right-of-way exceed 750,000 sq. ft. without prior approval by the engineer."

"Mulches, temporary grass, and plastic membranes are being considered for temporary protection of side slopes..." as are open and pipe drains, berms, dikes, and sedimentation basins." Bibliography of 59 titles.

Council on Environmental Quality (759)

1970. Environmental quality - the first report of the Council on Environmental Quality. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Pages xxv + 326.

This report was reviewed and portions dealing with highway, and with automobiles as a source of pollution, etc. excerpted or quoted here.

Page 15. "The automobile freed Americans from the central city and launched the flight to the suburbs. As a consequence, thousands of acres of undeveloped land fall prey each year to the bull-dozer. More single - family, detached homes shoulder out open spaces. Many of these develop-ments are drab in design and wasteful of land. They denude the metropolitan area of trees and thus affect climate; they cause erosion, muddy rivers, and increase the cost of public services."

Page 37. "A 1969 report of the Federal Water Quality Administration estimates the average sedi-ment yield during a rainstorm at highway construction sites at about 10 times that for cultivated land, 200 times that for grass areas, and 2,000 times that for forest areas -- depending on the rainfall, land slope, and exposure of the bank..."

Page 62. "Transportation -- particularly the automobile -- is the greatest source of air pollution. It accounts for 42 percent of all pollutants by weight. It produces major portions not only of carbon monoxide but of hydrocarbons and nitrogen oxides.

Page 70. "Air pollution inflicts widespread and costly damage on plant life and buildings and materials... Today, the damage to plant life is less dramatic than in the days of unrestricted smelter operations. But the slower, chronic injury inflict-ed on agricultural, forest, and ornamental vegetation by increasing quantities and varieties of air pollu-tants has now spread to all parts of the country."

Page 109. With respect to solid waste collection and disposal problems: "The litter problem -- tires, bottles, cans, plastics, and paper thrown away ran-domly instead of into waste containers -- adds daily to collection costs and blight. Many of the nation's roads, beaches, rivers, parks, and other public areas are cluttered with refuse of thoughtless citizens. Litter collection costs average $88 per ton, more than four times as much as collecting residential refuse."

Page 117. "... Each year an estimated 1 to 2 billion glass and metal beverage containers end up as litter on highways, beaches, parks, and other public areas.

Page 118. "The Fish and Wildlife Service and the Bureau of Solid Waste Management are investigating the use of old tires as reefs and fish havens along the Atlantic coast of the United States. The ocean bottom is sandy and relatively flat for great distances. And artificial reefs constructed of tires may promote an increase in desirable species since many game fish require relief features such as reefs for protection and spawning grounds. If this concept proves practical, very large numbers of old tires could be turned into an important ecological side benefit."

Page 124. "Traffic noise in a large city may reach 90 decibels... It is widely accepted that steady exposure to about 90 decibels can cause permanent hearing loss... In general, trucks, buses, motorcycles, and rail systems are the worst offenders. With automotive vehicles at high speeds most of the noise comes from the whirl of tires, while at lower speeds motor noise dominates. At expressway speeds a single trailer truck can generate steady noise levels above 90 decibels. A line of trucks can produce noise levels of 100 decibels or more."

Page 173. "... The Department of Agriculture estimates that 2 million acres of land each year, excluding surface mining, are converted to non-agricultural use... Of that, 160,000 are covered by highways and airports."

Page 194. "Aid to states for highway construction is a major Federal outlay.... Federally assisted highway construction has been the major determinant of growth patterns and development in this country since 1956. The program has given the American people a degree of mobility never before known. But the momentum of construction and the economic importance of new road building have raised obstacles to thoughtful long-range planning for the environment..."

Council on Environmental Quality (760)

1970-1975. 102 Monitor.

The publication "102 Monitor" contains summaries of Environmental Impact Statements received by the Council on Environmental Quality. At the head of the list of Environmental Impact Statements for each agency is the name of the Agency's environmental contact who can answer questions regarding those impact statements.

Council on Environmental Quality (761)

1972: Arlington Coalition on Transportation V. Volpe, No. 71-2109 (4th Cir. April 4, 1972.) Environmental Law Reporter. Volume year II. Page 20162.

"The requirements of the National Environmental Policy Act and Section 4 (f) of the Department of Transportation Act, protecting parklands from highway construction except in unusual cases, must both be complied with for any ongoing highway project unless the project has reached such an advanced state of completion that the costs of abandoning or altering the proposed route would clearly outweigh the benefits to be gained. All doubts whether the statutes should apply must be resolved in favor of applying their requirements. Any parkland will be considered significant unless it is specifically declared not to be by the relevant local authorities."

Council on Environmental Quality (762)

1972. Daly V. Volpe, Curl Action No. 9490 (W. D. Washington, March 31, 1972). Environmental Law Reporter V. II: 20443.

A decision to change the location of I-90 in the vicinity of North Bend, Washington, had a rational basis and was not arbitrary and capricious. The provisions of 23 U.S.C. §138 on preservation of parklands do not apply to a privately-owned waterfowl refuge. Plaintiff property owners prevail on their NEPA claims, since federal courts have jurisdiction over officials of states which receive federal grants-in-aid if federal environmental protection statutes are violated. NEPA requires strict, not substantial, compliance and justifies a delay in construction. An "environmental report" that fails to ask and answer all of the pertinent questions is not acceptable under NEPA, nor is a draft environmental impact statement that is conclusory rather than analytical and fails to discuss effects of the chosen corridor on the area it traverses. An impact statement is unsatisfactory if it fails to list economically measurable costs of construction and the nature of resources lost which cannot be quantified. Perfunctory review of statements by the FHWA does not constitute the deliberation contemplated in the Act. Statements prepared after location selection do not meet the intent of Congress to provide decision-makers with sufficient information to make an environmentally sound decision. Ordered, that a new draft statement be prepared and that a new location-hearing be held.

Council on Environmental Quality (763)

1972. Arizona Wildlife Federation v. Volpe, No. Cir. 72-360 Pct. (D. Arizona. September 15, 1972.) Environmental Law Reporter V.II:20584.

"The United States Forest Service abused its administrative discretion in declaring that the 'Lakes Area' of Coconino National Forest is not a 'proclaimed recreation area' within the meaning of Section 4 (f) of the DOT Act of 1968 (49 U.S.C.A. 1653 (f)).

Although the determination of whether an area is a recreational area of national, State, or local significance is given by the statute to the Forest Service in this instance, the F.S. administered the 'Lakes Area' as a recreation area, and it is recognized in fact as an area of great significance. A preliminary injunction is issued against the construction of a highway through the area, and the Secretary of Transportation is ordered to conduct the review and funding required by Section 4 (f). Defendants' allegations regarding 53% completion of a grade and drain contract, and that this is the mid-segment of a highway of which both ends are completed, are without significance."

Council on Environmental Quality (764)

1974. Freeborn V. Bryson. No. 242 (Sup. Ct. Minn. Aug. 31, 1973.) Environmental Law Reporter. Volume year IV:20205-18.

The Supreme Court of Minnesota reverses the dismissal of an action brought under the Minnesota Environmental Rights Act to enjoin construction of a county highway across marshland, and remands the case to allow presentation of statutory defenses by the county. A prima facie case is established by evidence that the marshland is a statutorily protected natural resource which would be adversely affected by the presence of the highway. Plaintiffs have standing to sue even though they are exempted by statute from being sued themselves since their farm is family owned. The eminent domain power of the county is limited by the Act, but may be enforced by successfully asserting defenses to the statute.

Council on Environmental Quality (765)

1975. Society For The Protection of New Hampshire Forests V. Brinegar, No. 74-208 (D.N.H. August 19, 1974). Environmental Law Reporter V (6):20004-08.

"The court issues a preliminary injunction prohibiting federal officials from approving federal funds for construction of an interstate highway segment outside Franconia Notch State Park until a new environmental impact statement, which analyzses the effect of the entire interstate highway on the Park and studies alternative routes, has been prepared. The existing E I S violates N E P A in that its scope is too limited and its examination of alternate routes inadequate. The proposed segment, once constructed, would exert irresistible pressure on planners to complete the highway through the Notch, and such construction and the increased automobile traffic it would cause would irresparably harm the Park and might lead to the destruction of its most beautiful and unique features. The congressional policy is that preservation of public park lands must be accorded greater weight than the demand for highway construction."

Dane, C. W. (766)

1972. The hidden environmental costs of alternative materials available for construction. Journal of Forestry 70(12) 734-736.

"The environmental impact of four construction materials - aluminum, concrete, steel, and wood - is assessed using two different approaches: materials balance and social cost. The approach used results in different relative rankings of intensity of environmental impact. The social cost approach allows engineering cost estimates to incorporate the environmental impacts of producing alternative construction materials." Bibliography of 2 titles.

Gamble, Hays B. and Thomas B. Davinroy et al. (767)

1975. Beneficial environmental effects associated with freeway construction. Final Report of Project 20--13 prepared for National Cooperative Highway Research Program, Transportation Research Board, National Research Council. The Institute for Research on Land and Water Resources and the Pennsylvania Transportation Institute and the Institute for State University. University Park, Pennsylvania.(Report not yet released for publication). Part I - Matrix, pages iii + 13. Part II - Manual, pages x + 301.

Hall, Linda C. (768)

1968. Bibliography of freshwater wetlands/ecology and management. Wisconsin Department of Natural Resources Report No. 33 (Unpaged -- approximately 264 p.)

"Titles are arranged within seven sections: Plants and plant communities; animals and animal communities; soils, ground water, and surface water; management and artificial wetlands; values, conservation and destruction; classification, inventory and survey; general and miscellaneous. More than 3300 references are listed and key word indexed." WR 132:19.

Iowa State Highway Commission (769)

1975. Final EIS for Freeway 592, Marion and Mahaska Counties. Prepared by Environmental Section.

"The proposed project involves the construction of a segment of Freeway #592. It will require acquisition of right-of-way that will accommodate construction of four lanes."

"The most significant long-term adverse impact is the removal of agricultural land from production. The removal of trees as wildlife habitat is significant but not of major proportions. However, since wildlife habitat consists of agricultural land as well, the utilization of the landscape to obtain a smooth grade line is also a significant long-term effect." Open burning will be limited to sites at least ¼ mile from human inhabited buildings. The possibility exists of managing right-of-way for wildlife habitat. Abandoned borrow pits may be converted into habitat for wild ducks, mink, and muskrat.

Isaacson, L. and B. L. Peterson (770)

1971. Park and recreational facilities; their consideration as an environmental factor influencing the location and design of a highway. Federal Highway Administration, Environmental Policy Office.

"A framework is provided for consideration of the conflicts that may surface when highways and parks are analyzed for compatibility (environmental impact) of one upon the other. The following areas of concern are highlighted: the inventory data required for a more objective consideration of environmental impact; the generally accepted major classification of parks and their functions (present, designed or proposed); and suggested design criteria for each classification that needs to be considered. The underlying hypothesis maintains that the determination of the environmental impact of a highway upon a park, open space or other recreational value, cannot be made without adequate knowledge of the function and use of the specific area." HRIS No. 240023.

Johnson, Albert W. (771)

1973. An ecological glossary for engineers and resource managers. The Institute of Ecology. (Arthur D. Hasler, Director, 608 N. Park Street, Madison, Wisconsin 53706). 50 pages.

This booklet lists and defines technical, environmental terms.

Jones, Robert L. (772)

1975. Environment impact reports: problems and opportunities. Civil Engineering, ASCE, 45(5): 71-73.

"The author points out that designers of many projects, both private and public, must first prepare Environment Impact Reports. The intent is to prod the designer to think through both the primary and secondary impacts his project will have on the environment. Expressing dissatisfaction with some reports, government officials want to see more emphasis on analyzing secondary impacts." (Author's abstract).

Kennedy, J. B. - Oregon State Highway Div., Salem. Environmental Section. (773)

1973. Highways and environment. Pages 49-59 in: How effective are environmental impact statements. Oregon State University, Corvallis, Water Resources Research Institute Seminar WR 017.73.

Abstract: "The effects of recently required environmental impact statements in the development of programs and policies by the Oregon State Highway Division is examined. The most obvious result has been an increased workload occasioned by the preparation of the statements. To accomplish this task, a separate environmental section was created, composed of an environmental coordinator, an air quality engineer, and a highway ecologist. The large volume of statements has limited the section's activities to their preparation. Utilization of highway personnel in a regional approach may allow a speed-up in the preparation of impact statements and greater integration of environmental concerns into the planning process. The Highway Division has proposed dividing the state into five regions according to physical, sociological, and economic similarities and assigning a regional environmentalist to each. His duties would include information gathering and dissemination to the public, environmental monitoring, and creation and maintenance of a regional data center collecting physical, land use, social, economic, and transportation data over time. The readily available data would enable more comprehensive public discussion and prompt incorporation of environmental effects into the planning process. (See also W74-06107) (Schroeder-Wisconsin)" WRSIC No. W74-06114

Li, H. L. (774)

1969. Urban botany: need for a new science. BioScience, 19(10):882-883.

The author discusses some of the values of trees in urban areas, their ability to absorb CO and perhaps some other air pollutants, use as sound barriers, hazards of trees in urban areas, and problems stemming from indiscriminate and overuse of pesticides. He states that although some selection of clones from certain tree species for street planting has been made in recent years, genetics or tree breeding, specifically for urban areas, is needed.

Manheim, Marvin (775)

Undated. The impacts of highways on environmental values. Highway Research Record No. 305, Highway Research Board, Division of Engineering, National Research Council, National Academy of Sciences-National Academy of Engineering, pp. 26-27, abridgement.

This is a summary of the conclusions reached in Phase I of NCHRP research project 8-8. The objectives to be achieved and the research to be conducted are described in order to develop a practicable method for evaluating the environmental impact of highways. The major activities to be conducted include case studies, development of the evaluation technique, information display techniques, community interaction techniques, checklists, and location team strategy as first priority areas, and the development of impact prediction models and situational data as second priority areas. A field test will be conducted to assist in evaluating and refining the techniques

Minton, Sherman A., Jr. (776)

1968. The fate of amphibians and reptiles in a suburban area. Journal of Herpetology 2 (3-4): 113-116. (Indiana University Medical Center, Indianapolis).

"Abstract: Between 1949 and 1958, two species of salamanders, six species of anurans, six species of turtles and seven species of snakes were recorded from a suburban area on the edge of Indianapolis, Indiana. Most were terrestrial or semiaquatic species of broad ecological tolerance. At least 11 species bred within the area during this period. During 1963 and 1964 only two species of anurans, one species of turtle and four species of snakes were recorded, and there was no evidence of amphibian breeding. Modification of aquatic habitat appears to have been the most important factor in reducing the number of species inhabiting the area." WR No. 133:89.

Missouri State Highway Department (777)

1974. Draft Environmental Impact Statement for Route 60, Stoddard County, Missouri

The project consists of adding 2 lanes to about 13 miles of Route 60. The final 4-lane divided highway "will include three diamond interchanges, a grade separation and the outer roadways necessary to obtain full control of access."

"Clearing will have an adverse effect on some wildlife by destroying a few dens and nesting sites. Those species affected can adapt to the ample adjacent wildlife habitat. There are no species unique to the area which the strip of right-of-way would completely destroy...only common native vegetation will be destroyed and only to the extent necessary to construct a properly designed highway... Construction will temporarily pollute some drainage ditches. There are no aquatic species whose life style will be drastically changed by this temporary pollution." Letters of comments were not included in this draft of the E I S.

Noyes, John H. and Donald R. Progulske (Editors) (778)

1974. Wildlife in an urbanizing environment. Cooperative Extension Service, University of Massachusetts, U. S. Department of Agriculture, and County Extension Services cooperating. (Amherst, Massachusetts 01002)

This monograph contains research papers presented at a symposium that "was designed especially to consider the role and future of wildlife in areas of increasing urbanization and population densities directed to wildlife policy, administration, research, and management as they affect a quality environment. Consideration was given to the philosophical aspects of urban wildlife, to the public and private roles in urban wildlife management, and to a variety of examples of on-going research in and near centers of population. Attention was directed also to the regard in which people hold urban wildlife, the reactions of people to urban wildlife, the techniques for evaluating wildlife habitat, and the potentials for evolving effective educational programs which focus on urban wildlife."

Nutten, C. F. (Nebraska Department of Roads) (779)

Undated. Final environmental impact statement, Project F-300 (15) U. S. Highway 26 - Mitchell to Scottsbluff. U. S. DOT FHWA and Nebraska Department of Roads, Morrell and Scotts Bluff Counties, Nebraska.

Twelve alternate routes were considered. Considerable public opposition to any river route because of extensive wildlife population in the river bottom areas influenced the final alignment selection. Testimony presented at public hearing, and newspaper and magazine articles expressing public concern over possible extensive roadway deer kills and detrimental effects on waterfowl in the valley area was one of the primary factors for the final alignment location in the upland areas where a lower density of wildlife exists. Diversity of wildlife habitat resulting from the "edge" effect was recognized as the key to favorable ecological balance. The Department of Roads' mowing policy of mowing only 15 feet from the roads edge and seeding native and adapted grasses in the unmowed areas is cited as potentially better nesting cover for wildlife than the cover which existed prior to construction and as a buffer zone between the traveled way and adjacent land cultivated fields and residential areas. Structures bridging rivers, creeks and streams were recognized as potential hazards to fish populations. These structures were to be studied in detail during design stage to insure minimal disruption to riparian habitat and riverine ecosystems.

The impact statement indicated the highway would not produce any far reaching or irreversible changes in the general character of the region although temporary relocation impacts on local wildlife resulting from construction are unavoidable. Vehicle traffic and noise were cited as factors which may reduce the effectiveness of the habitat created by the Department of Roads' current mowing policy.

Odum, Eugene P. (780)

1971. Fundamentals of ecology. W. B. Saunders Company (Philadelphia, London, Toronto) Pages xiv + 574. (third edition).

In this well known book on fundamentals of ecology the author stated, page 449, "In metropolitan areas greenbelt vegetation and open space in general, may have as great a value in sound amelioration as in air purification. Robinette (1969) (Robinette, Gary O. 1969. The functional spectrum of plants--sound control. Grounds Maintenance, 4:42-43.) points out that plants are efficient absorbers of noise, especially noises of high frequency. A dense evergreen hedge can reduce the noise of garbage collection by 10 db (i.e. a tenfold attenuation). Border planting along highways or streets can be effective if plantings are lower towards the noise source and higher towards the hearer, thus not only absorbing but also deflecting the noise upward. A 50-foot wide band with an inner strip of dense shrubs and an outer band of trees can be quite effective (a sort of forest edge that is also good for small wildlife)."

Pointner, N., DeLeuw, Cather and Company (781)

1973. Ecological impacts of freeway construction. American Society of Civil Engineers (345 E. 47th Street, New York, New York 10017). Proceedings of the ASCE Urban Transportation Division Environment Impact Specialty Conference of May 1973. Pages 215-236, 1 tab.

Summary:
"Attention is being focused now on the ecological impacts of public works. Consideration of existing soil, air, water, flora and fauna must be given due attention before constructing a highway or the whole ecological balance of an area can be thrown off. The National Environmental Policy Act of 1969 attempts to provide this protection by requiring impact statements before construction is allowed. However some projects were already conceived and designed prior to this law and the impact statements written after the fact are merely a summary report of the design process. These cases usually end up in court. This paper discusses such a case: a section of I-70 west of Denver, Colorado planned before NEPA came into being. It gives a description of the problem, approach, findings and results of a study comparing the social economic and environmental impacts of two alternative corridors." HRIS No. 265167.

Sullivan, James B., and Paul A. Montgomery (782)

1972. (Environmental considerations) Environment 14(9), 4 tables.

The authors point out that the reponsibility for preparing complete and detailed assessments on the environmental impact of a new highway is rightly the role of government. However, citizens can make certain that those responsible for the assessment actually carry it out in adequate detail. Hopefully, public action will induce transportation planners to develop the commitment necessary to supply realistic environmental analysis. The present assessment techniques are not worthy of the United States' technical sophistication.

Teague, Richard D., editor (783)

1971. A manual of wildlife conservation. The Wildlife Society (Washington, D. C.) 206 pages.

This book deals with several topics related to wildlife conservation such as: policy and administration, people and wildlife, wildlife and fisheries management, wildlife law, wildlife and private land, wildlife research, and the techniques for developing an effective short course.

Tennessee (784)

1974. Final EIS for State Route 42, Putnam County, Tennessee. Prepared by State of Tennessee, D O T.

The projects consist of the reconstruction of State Route 42 for approximately 2.0 miles.

"The only irretrievable losses to be incurred as a result of the project is the loss of wildlife habitat and agricultural land along the project right-of-way. Post-construction seeding and mowing will allow a portion of the project right-of-way to remain as suitable habitat for small game, particularly rabbits and quail. Due to the abundance of available land in this rural region, the proposed project should have a minimal effect on the wildlife in the area...The amount of land required for the project right-of-way is approximately 80 acres. The Tennessee Game and Fish Commission concurs with the E I S."

1975. Final EIS for State Route 37, Carter County, 1975. Prepared by State of Tennessee, Department of Transportation.

The proposed project involves the improvement of State Route 37.

Approximately 115 acres of wildlife habitat will be destroyed for this project's right-of-way. Some of the right-of-way will not be used for roadway purposes. It will not be mowed, which will permit a large amount of land to remain attractive as wildlife habitat. Some habitat improvement will occur when the roadway crosses pasture and cropland not used by wildlife earlier. In this case, upland game, birds, and field mice and rats (which are a food source for certain hawks and owls of the area) will benefit.

The overstory of Indian Creek (in the project area) is mixed hardwoods and forms excellent wildlife habitat. The creek contains a large red breast sunfish population. Its riffles produce snails and algae. "Where in-stream construction will take place, sediment basins, ponds and traps will be constructed to trap and store sediments to protect the stream channel below the construction areas from excessive siltation."

It is noted that the project will provide a better chance for people of the area to visit the recreational facilities of Cherokee National Forest. Some advice from the Tennessee Wildlife Resources Commission was included in the environmental impact statement.

U. S. Army Corps of Engineers District, New Orleans, La. (786)

1972. Bayou Plaquemine waterways and (closed) lock as affected by proposed relocation of Louisiana State Highway Route 1 in Plaquemine, Iberville Parish (draft environmental impact statement)

Available from the National Technical Information Service as PB-207 772-D, $3.00 in paper copy, $.95 in microfiche. February 1972. 125 pages, 5 figures, 1 map, 1 photo, 1 table.

Abstract: "This project consists of filling a section of Bayou Plaquemine with granular material

from the unused Plaquemine Lock to a point 200 feet west of the Texas and Pacific Railway bridge, Plaquemine, Louisiana. The purpose of the project is to create a suitable roadbed which will accommodate the relocation of Louisiana Highway 1 and provide an improved ingress route to the city of Plaquemine, Louisiana. A little used portion of Plaquemine Bayou will be eliminated as an existing and potentially more serious maintenance, noxious aquatic plant control and mosquito control problem. There will be a loss of seven acres of public land which has the potential of becoming a water recreation area and of approximately 1,500 feet of marginally navigable waterway. Existing structures must be removed and established businesses relocated. An officially unlisted area of some historical significance will be eliminated. Alternatives considered included different routing sites, which were all fiscally impossible and no project. Included are comments from interested agencies and the public. Also included are petitions from citizens opposing the location of the highway." WRSIC No. W73-00731.

United States Coast Guard (787)

1971. New Jersey, State Route 152, fixed high level highway bridge, New Jersey Intracoastal Waterway, Atlantic City, Environmental Impact Statement, 6 pages.

"The proposed bridge will replace an old bridge considered unsafe for axle loading of more than 3 tons. It will provide a safe highway crossing of the waterway, improve traffic flow and increase the capacity of the highway for heavy vehicles. The new bridge will enhance aesthetic values of the vicinity and reduce noise. The new bridge will have a possible adverse effect on the waterbird rookery located immediately adjacent to the bridge site on the north side, by causing the birds to vacate the area, alter their reproductive behavior patterns, and reduce the species population." HRIS No. 261061.

U. S. Department of the Interior, Washington, D. C. (788)

1969. Environmental impact of the Big Cypress Swamp Jetport. U. S. Department of the Interior Report, 153 pages, 19 figures, 4 tables.

Abstract:

"Development of the proposed Big Cypress Swamp Jetport, Florida and attendant facilities will lead to land drainage and development for agriculture, industry, housing, transportation, and services in the swamp which will destroy the south Florida ecosystem and Everglades National Park. Construction of each training strip will destroy about 400 acres of natural habitat. No significant problems are expected from the limited sewage, industrial wastes or pesticides in the training phase. Air pollutants from engine exhausts will be substantial. There will be frequent high level noise intrusion on the wilderness character of the northern part of Everglades National Park and even more on the Big Cypress and Conservation Area No. 3. A severe bird strike problem may develop within the airport boundaries. With sufficient culverts provided through runways, ramps, roads, and other facilities, interference with overland flow will be negligible. The combination of bird strikes, pest insect problems and incidence of small animals on runways will probably lead to drainage of at least part of the jetport property. Construction and imminent operation of the first training strip have elevated surrounding land prices and sales. Economic and social pressures for further development within and without the port property will mount rapidly. Land development and drainage will be accompanied by increased nutrients in the water, will alter the hydroperiod, and will promote eutrophication. (LANG-USGS)" WRSIC No. W70-08596.

U. S. Department of Transportation, Federal Highway Administration, Florida Division. (789)

1972. The multi-laning of State Road 50...(Draft) National Technical Information Service, 135 pages.

From summary: "The report describes the proposal for the project which involves the multi-laning of a 7.2 mile segment of state road 50. The proposed improvement will have both adverse and beneficial effects on the environment in this area. Among the most significant of the adverse effects expected will be to the water quality of the lakes adjacent to the project that will receive stormwater discharges. Recommendations to minimize these potentially harmful effects are presented in this statement..." Other harmful effects and beneficial effects are also discussed. HRIS No. 203691.

U. S. Department of Transportation (790)

1974. Draft environment impact statements for Divide-Anlauf section of Pacific Highway I-5, Douglas and Lane Counties, Oregon.

"This project consists of the reconstruction of about seven miles of I-5 to bring it to current Interstate standards." Also included is the reconstruction of an interchange, and the construction of a frontage road.

A wildlife inventory of birds, mammals, reptiles and amphibians, and fish appears in the statement. Common names are listed; numbers are not given. Most of the environmental impact is said to occur on fish. "Both temporary and permanent effects will result from the removal of streamside vegetation, channel changes, and pipe installations on Pass Creek. Increased turbidity will reduce production of food for fish, and spawning may be impeded. Permanent changes in the streambed, including loss of vegetation and spawning gravels will mean a reduction in fish habitat...Also, two beaver dams... will be destroyed in the channel modification."

Road kills of deer have been and may continue to be, a problem on this section of the highway. "The increased width of the roadway, with the addition of a concrete median barrier, may increase the number of deer killed." If the roadkill becomes unacceptably high, it is said that "remedial measures will be taken."

U. S. Department of Transportation, Federal Highway Administration (791)

1975. Final EIS for State Highway #35, Brazoria County. Prepared by Texas Division.

"The proposed project consists of constructing a four-lane divided expressway without control of access on new location for a distance of 6.9 miles with future interchanges at each terminus and major thoroughfares."

"The sedimentation, together with noise and vibration also caused by pile driving, would tend to temporarily remove from the immediate vicinities of the bridges most fish species. These commonly include, among others, catfish, carp, buffalo, perch, gar, drum, white perch and eel... no significant adverse effects are anticipated to result in the long-term which would be caused by the proposed bridges." Animals of the region include the raccoon, opossum, mink, skunk, squirrel, quail, prairie chicken, duck, geese, wolf, fox, deer. The road will destroy wildlife habitat, but the habitat is not unique to the surrounding lands. "Nevertheless, the possibility is acknowledged that the remaining range, pasture, and wooded areas in Brazoria County may already be 'saturated' with respect to one or more species removed from the affected acreage."

U. S. Department of Transportation (792)

1975. Final EIS for New Hampshire Route 175, Woodstock, New Hampshire. Prepared by the Federal Highway Adm.

"The project involves the relocation of 1.2 miles of New Hampshire Route #175. The project's construction will destroy open field and old habitats... "Microecosystems will be destroyed or disrupted, but there should be no disruption of ecosystems of any larger scale." A river flows in the project area. If siltation is held to a minimum, river insects, bottom-dwelling organisms and fish won't have serious disruptions occur in the ecosystem of the river. Sediment control devices, which might be used, are listed. It is mentioned that the threat of salt run-off is no greater in the proposed project than before the road relocation. Plant and animal species of the area are listed.

Walcott, Charles F. (793)

1974. Changes in bird life in Cambridge, Massachusetts from 1860 to 1964. Auk 91 (1):151-160 (R.F.D. #1, Petersborough, New Hampshire 03458).

Discusses changes in bird life on two originally similar 6-acre tracts in the Cambridge, Massachusetts area over the period 1860 to 1964. Effects of urbanization -- including city streets and plantings -- are noted and effects of two exotic species, house sparrow and starling, and use of insecticides on the native bird species are discussed. "Implicit in urbanization is replacement of natural habitat with housing development, a process that taxes the adaptive powers of native species of birds by depriving them of their accustomed habitat... In the course of the study, the bird life of the residential area changed from 26 nesting species, mostly summer residents, and a few transients, to 9 nesting species composed of a majority of permanent residents and outnumbered by transient species."

Western States Landscape Associates (794)

1972. Roadside development, evaluation of research. National Cooperative Highway Research Program Report #137. Highway Research Board (Washington, D. C.) 78 pages.

An evaluation of research done and research needed is given. The categories used in the roadside development evaluation are:

1. highway location and design,
2. roadside space,
3. resource conservation,
4. motorist services,
5. erosion control,
6. planting,
7. roadside maintenance,
8. organization and administration.

Appendices of literature evaluation, field interview results, and additional roadside development research needs or ideas.

TE 662
.A3
no.FHWA-RD
76-5
BORROW
A MARSAN
~~TRACOR~~

DOT LIBRARY
00054321

FHWA
R&D