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Volume III

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Final Report

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16. Abstract

This manual, Volume III in a four-volume series of reports relating to water quality impacts of highway maintenance practices, is designed to aid State highway officials, planners, and local officials in the preparation of environmental impact statements, environmental assessments, and similar environmental documentation where required by Federal and State environmental legislation. Relevant environmental legislation is briefly discussed. Each of the six maintenance practices considered to be the most significant is fully described in terms of its potential for causing water quality impacts. Detailed methods are provided for predicting and assessing whether impacts from each of the six practices may be significant.

The volumes in this series are:

Volume I - "Highway Maintenance Impacts to Water Quality - Executive Summary" (FHWA/RD-85/057)

Volume II - "Investigations of Impacts of Selected Highway Maintenance Practices on Water Quality" (FHWA/RD-85/058)

Volume III - "A Reference Manual for Assessing Water Quality Impacts from Highway Maintenance Practices" (FHWA/RD-85/059)

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INTRODUCTION

PURPOSE

This reference manual is a resource document designed to help State highway officials, planners, and local officials consider the impacts of highway maintenance practice on water quality when preparing environmental impact statements, environmental assessments, and similar environmental documentation required by Federal and State environmental legislation. Highway maintenance practices considered in this manual include the activities listed in Table 1. One major category of maintenance practices, the use of deicing chemicals for snow and ice removal from highways, is not included here.

Relevant environmental legislation is briefly discussed in this manual, including the requirements of the legislation with respect to highway maintenance activities. This manual also identifies the criteria used to determine the potential of each maintenance practice to impact water quality and impacts associated with each criterion.

Maintenance practices are classified into three types, those which can have a probable impact (Type I), those which can have possible impact (Type II), or those which have no probable impact (Type III). The rest of the manual focuses on Type I practices. Because each of these practices can meet more than one of the impact criteria, each Type I practice is fully described in terms of its potential for causing water quality impacts, although, for any specific case, the actual impacts may vary because of site-specific or case-specific considerations.

Detailed methods are provided to assess water quality impacts from Type I maintenance practices. Assessment requires site-specific information and possibly field measurements; therefore, a generic quantitative assessment of the water quality impacts from each Type I maintenance practice cannot be made. However, the tools necessary to quantitatively estimate impacts from each maintenance practice at a specific location are presented to aid the environmental professional responsible for assessing expected impacts and preparing required environmental documentation. These methods center on a habitat evaluation assessment which involves evaluating

Table 1. Highway maintenance objectives and practices.

Maintenance objective	Maintenance practice
Rideability Maintenance	• Pothole patching
	• Surface repairs
	• Full depth repairs
	• Filling and sealing joints and cracks
	• Surface treatments
	• Pavement jacking
	• Planing pavements (bituminous and concrete)
	• Blading unpaved surfaces
Roadside Maintenance	• Blading and restoring unpaved berms and/or shoulders
	• Repairing curbs, gutters, and paved ditches
	• Repairing slopes, slips and slides
	• Controlling and disposing of roadside litter
Vegetation Maintenance	• Mowing
	• Chemical vegetation control
	• Planting or care of shrubs, plants and trees
	• Seeding, sodding, and fertilizing
Drainage Maintenance	• Cleaning ditches, channels, and drainage structures
	• Repairing drainage structures
Structural Maintenance	• Bridge surface cleaning
	• Bridge painting
	• Bridge deck repair
	• Bridge joint repair
	• Substructure repair
	• Superstructure repair
Safety Maintenance	• Cleaning pavement
	• Guardrail repair
	• Snow plowing
	• Application of abrasives
	• Crash attenuator repair
	• Snow fence installation and removal
	• Highway lighting
Comfort Area Maintenance	• Care of rest areas
Sign Maintenance	• Flat sheet, side-mounted, and overhead sign repair and replacement
Traffic Control Device Maintenance	• Pavement marking
Equipment Maintenance	• Washing and cleaning equipment
Storage and Handling Materials	• Bulk storage of non-fuel materials
	• Bulk storage of motor fuels
	• Disposal of used lubricating oils

the resource value of the water body of concern prior to performance of the maintenance practice, evaluating the resource value of the water body after the performance of the maintenance practice, and determining if the difference in resource value is significant. Several different assessment methods, each specific to a particular maintenance activity or type of pollution expected (e.g., bridge painting, herbicide applications, sediment loading, nutrient loading), are presented for use in determining the resource value of the water body after performance of the maintenance practice. These specific methods provide the quantitative estimates of "before" and "after" pollutant loadings or concentrations that are inputs for the habitat evaluations.

RELATED DOCUMENTS

This manual is part of a four-volume series of reports relating to water quality impacts of highway maintenance practices:

- Volume I: "Highway Maintenance Impacts to Water Quality - Executive Summary" (Report No. FHWA/RD-85/057). This report provides a concise summary of the major findings and conclusions of this project.

- Volume II: "Investigations of Impacts of Selected Highway Maintenance Practices on Water Quality" (Report No. FHWA/RD-85/058). This report presents the results of field research undertaken to improve the state of knowledge concerning highway maintenance impacts to water quality from two highway maintenance practices, herbicide application and road surface treatment (seal-coating).

- Volume III: "A Reference Manual for Assessing Water Quality Impacts from Highway Maintenance Practices" (Report No. FHWA/RD-85/059). This manual provides full descriptions of the potential water quality impacts of most maintenance practices. Methods are detailed for determining if impacts are likely to be significant for a specific maintenance project or program.

- Volume IV: "Guidelines Manual for Minimizing Water Quality Impacts from Highway Maintenance Practices" (Report No. FHWA/RD-85/060). Manual provides guidance for minimizing water quality impacts for any maintenance activity which may adversely affect water quality.

INFORMATION SOURCES

Information sources utilized in the preparation of this document were obtained primarily through intensive computerized and manual literature searches of published literature on highway maintenance practices and related water quality impacts. Computer data bases that were searched included:

- TRIS (Transportation Research Information Service)
- NTIS (National Technical Information Service)
- COMPENDEX (Engineering Index, Inc.)
- ENVIROLINE (Environment Information Center)
- SWRA (Water Resources Scientific Information Center)

Information compiled from the open literature was supplemented with FHWA National Environmental Policy Act (NEPA) compliance guidance published in the Code of Federal Regulations (23 CFR 771) and information provided by the Federal Highway Administration (FHWA) Office of Environmental Policy. Researchers who are actively involved in studies involving highway maintenance practices and their potential water quality impacts were contacted to determine the status of their current research and the availability of any unpublished reports or data. A number of county engineers and experts in State highway agencies were interviewed for their insight into determining the relationship between highway maintenance practices and water quality impacts. The States contacted were chosen on the basis of their topography and climate being representative of the range of conditions likely to be encountered in the United States, and whether there was any on-going research in the areas of highway maintenance and/or environmental impacts. Highway agencies interviewed include:

- Ohio Department of Transportation
  - Lake County, Ohio
  - Washington County, Ohio
  - Wyandot County, Ohio

- Florida Department of Transportation

- Missouri Highway and Transportation Department

- Texas Department of Highways and Public Transportation

- California Department of Transportation

STATUTORY AND REGULATORY BASIS FOR PREPARATION OF ENVIRONMENTAL DOCUMENTS COVERING HIGHWAY MAINTENANCE ACTIVITIES

This manual is not intended to present FHWA or State agency policies and procedures for the preparation and review of environmental impact statements (EISs), environmental assessments (EAs), or similar documents that may be required under the National Environmental Policy Act (NEPA) or analogous State statutes. For Council on Environmental Quality (CEQ) requirements, the reader is referred to 40 CFR 1500-1508. However, consideration of Federal and State laws is necessary to determine under what circumstances the preparation of environmental documents on maintenance activities on Federal-aid highways may be required.

Under FHWA regulations, three classes of actions determine the level of environmental documentation required in the NEPA process. Class I actions, those that may significantly affect the environment, require the preparation of an EIS. Examples of Class I actions are:

- Any new controlled access freeway.
- Any highway project of four or more lanes on a new location.
- Any project whose construction involves large amounts of demolition, displacement of a large number of people or businesses, or substantial disruptions to local traffic patterns.

Class II actions (categorical exclusions), those that do not individually or cumulatively have a significant effect on the environment, do not require an EIS or an EA. Highway maintenance activities are Class II actions (except for special cases involving maintenance of bridges to barrier islands, and bridges on or eligible for the National Register). Additionally, the FHWA Administrator may require appropriate environmental studies for any action if extraordinary circumstances warrant, e.g. (23 CFR 771.117(c)):

- Significant impacts on the environment
- Substantial controversy on environmental grounds
- Significant impacts on properties protected by Section 4(f) of the Department of Transportation Act and other environmental legislation

- Inconsistencies with any Federal, State, or local environmental law

Class III actions, in which the environmental effects of the proposed action are not clearly established, are all those actions not classified as a Class I or Class II. All Class III actions require the preparation of an EA (23 CFR 771.115(c)). The EA is then used to make a Finding Of No Significant Impact (FONSI) (23 CFR 771.121) or determine when an EIS is required. Figure 1 briefly outlines the NEPA requirements as they pertain to FHWA actions.

States and local governments do not receive Federal monies for routine maintenance activities. The 4-R funding, however, provides funds for major maintenance activities such as reconstruction or rehabilitation. These major maintenance activities are considered Federal actions and may be subject to NEPA regulations. As noted above, FHWA rules for complying with NEPA categorically exclude virtually all routine maintenance activities, thereby generally eliminating any Federal requirement for environmental assessments or EISs concerning maintenance activities in and of themselves. However, an EIS or an EA prepared for a new construction activity must evaluate post-construction water quality impacts from highway operations and maintenance (Dickerson, 1973). A highway official preparing such environmental documentation may determine that future highway maintenance may cause significant impacts to water resources. In this event, these impacts must be evaluated to satisfy NEPA requirements. Other Federal environmental statutes, regulations, and executive orders may define requirements that trigger the need for a NEPA document or some other sort of environmental document. These laws are listed in Table 2.

In addition to complying with NEPA, State highway agencies may also have to consider environmental requirements of individual State Environmental Policy Acts (SEPA). Various SEPAs may require evaluation of water quality impacts from highway maintenance. At this time (dating since June 8, 1984), 15 States have comprehensive statutory requirements, 5 States have comprehensive executive or administrative orders, and 7 States have special or limited EIS requirements (BNA, 1984) (see Table 3). Although the individual SEPAs may vary in their jurisdiction over State, county, and local projects, the environmental documents required by most are similar to those required by NEPA in that they must address adverse environmental effects of the proposed action and possible alternative actions. In most cases, State requirements will be satisfied by the preparation of a NEPA-required EIS or EA (Rodgers, 1977). For details of State requirements the responsible highway agency official should contact the State agency which administers the SEPA.

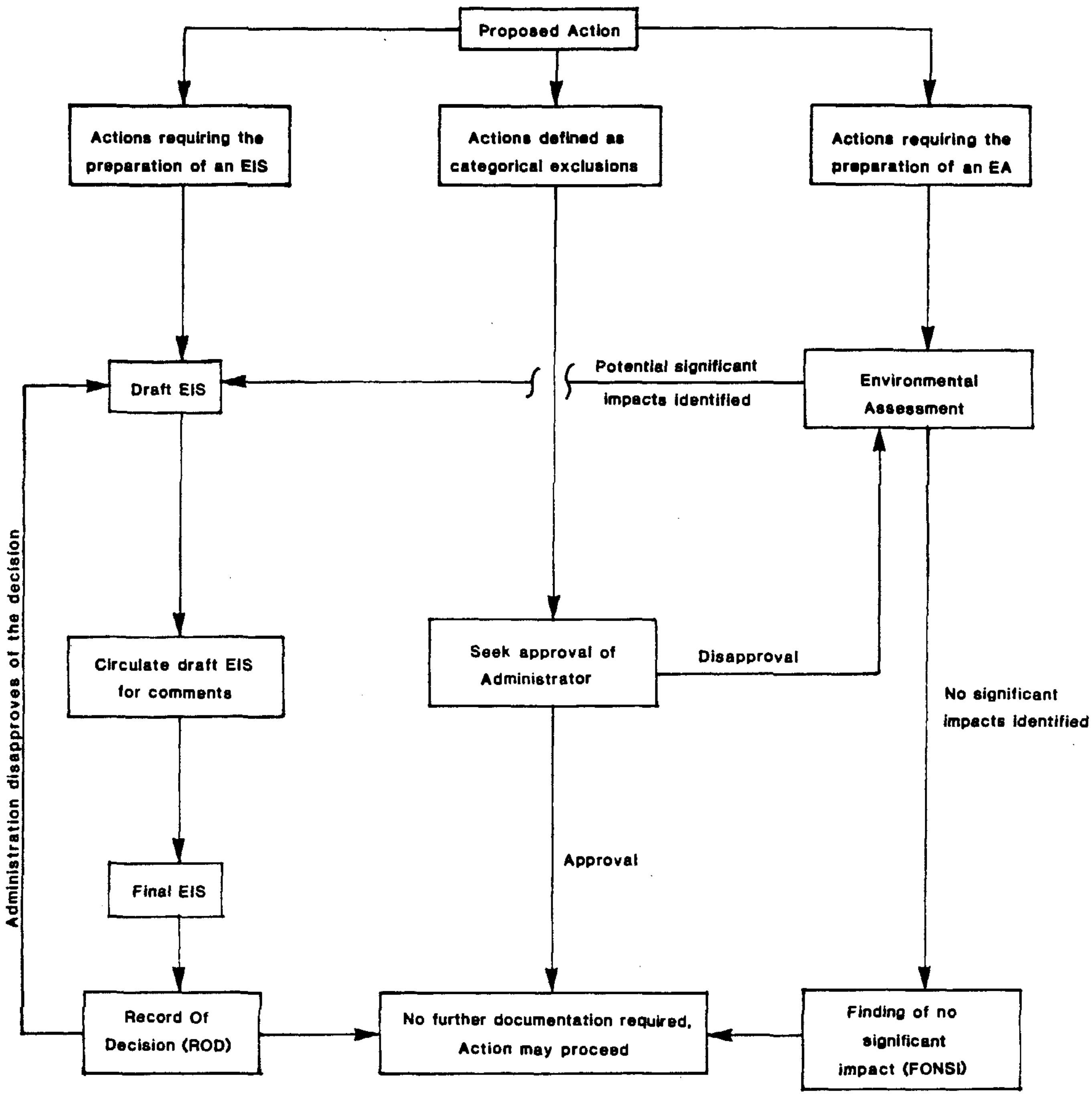


Figure 1. The NEPA process as it applies to FHWA actions.

Table 2. NEPA-related Federal environmental legislation to be considered in preparing environmental assessments and environmental impact statements related to highway projects.

Related statutes and orders	Citation
Section 4(f) of the Department of Transportation Act of 1966	23 U.S.C. 138; 49 U.S.C. 1653(f)
Archaeological and Historic Preservation Act	16 U.S.C. 461; 23 U.S.C. 305
Section 106 of the National Historic Preservation Act of 1966	16 U.S.C. 470(f)
Section 2 of the Fish and Wildlife Coordination Act	16 U.S.C. 662
Sections 303 and 307 of Coastal Zone Management Act of 1972	16 U.S.C. 1452, 1456
Section 7 of the Endangered Species Act of 1973	16 U.S.C. 1536
Clean Water Act of 1977	33 U.S.C. 1251, et seq.
Safe Drinking Water Act	42 U.S.C. 300(f) et seq.
Environmental Quality Improvement Act of 1970	42 U.S.C. 4371 et seq.
Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970	42 U.S.C. 4601 et seq.
Noise Control Act of 1972	42 U.S.C. 4901 et seq.
Clean Air Act	42 U.S.C. 7401 et seq.
Title VI of the Civil Rights Act of 1964	42 U.S.C. 200d-d4
Protection and Enhancement of Environmental Quality	Executive Order 11514; Executive Order 11991
Protection and Enhancement of the Cultural Environment	Executive Order 11543; DOT Order 5650.1
Floodplain Management	Executive Order 11988; DOT Order 5650.2
Protection of Wetlands	Executive Order 11990; DOT Order 5660.1A

Source: Code of Federal Regulations Chapter 23, Paragraph 771.103 (23 CFR 771.103).

Table 3. States with environmental impact statement requirements.

States with Comprehensive Statutory Requirements:

State/Code	Source	State contact agency
Alabama (E)	Coastal Area Management Rules	Coastal Area Board
Arizona (S)	Game and Fish Commission Policy of July 2, 1971	Game and Fish Commission
California (C)	Environmental Quality Act of 1970	The Resources Agency
Connecticut (C)	Environmental Policy Act of 1973	Department of Environmental Protection
Delaware (S)	(a) Coastal Zone Act	Office of Management, Budget and Planning
	(b) Wetlands Law of 1973	Department of Natural Resources
Georgia (S)	Law 1972-179-State Tollway Policy	Department of Transportation
Hawaii (C)	Governor's Executive Order of August 21, 1974	Office of Environmental Quality Control
Indiana (C)	Public Law 98, Section 1-301(c)	Environmental Management Board
Maryland (C)	Environmental Policy Act of 1973	Department of Natural Resources
Massachusetts (C)	Chapter 781, Acts of 1972; Annals of Ch. 30 Section 61-62	Executive Office of Environmental Affairs
Michigan (E)	Executive Directive 1971-10	Environmental Review Board
Minnesota (C)	Environmental Policy Act of 1973	Environmental Quality Council
Mississippi (S)	Title 49, Ch. 27 - Rules of Marine Resources Council	Marine Resources Council
Montana (C)	Environmental Policy Act of 1971	Environmental Quality Council
Nebraska (S)	State Environmental Action Plan	Office of Planning and Programming
Nevada (S)	Ch. 311, Laws of 1971	Department of Human Resources
New Jersey (E)	Executive Order No. 53 (October 15, 1973)	Department of Environmental Protection
New Jersey (S)	(a) Coastal Area Facility Review Act	Office of Coastal Zone Management, NJDEP
	(b) Wetlands Act of 1970	Office of Wetlands Management, NJDEP
New York (C)	State Environmental Quality Review Act	Department of Environmental Conservation
North Carolina (C)	Environmental Policy Act of 1971	Department of Natural and Economic Resources
Puerto Rico (C)	Environmental Policy Act	Environmental Quality Board
South Dakota (C)	Environmental Policy Act of 1971	Department of Environmental Protection
Texas (E)	Policy for the Environment	Governor's Budget and Planning Office
Utah (E)	Executive Order, August 27, 1974	Assistant Attorney General's Office
Virginia (C)	Environmental Policy Act of 1973	Council on the Environment
Washington (C)	State Environmental Policy Act of 1971	State Department of Ecology
Wisconsin (C)	Environmental Policy Act of 1971	Office of State Planning and Energy

Source: BNA, 1984.

KEY TO CODE:

(C) = State has comprehensive statutory requirement.

(E) = State has comprehensive executive or administrative orders.

(S) = State has comprehensive special or limited EIS requirements.

POTENTIAL WATER QUALITY IMPACTS OF HIGHWAY MAINTENANCE ACTIVITIES

INTRODUCTION

Not all maintenance activities have the potential for creating adverse water quality impacts. The maintenance practices examined (Table 1) were reduced to practices likely to impact water quality and are appropriate for analysis in EAs and EISs. The basis for narrowing the list of maintenance practices is explained in this section. The narrowing process involved developing a set of criteria of impact potential and determining how closely each maintenance practice meets each of the criteria. The potential water quality impacts of each of the practices is described in detail in this section along with the rationale for these determinations. These are general impact potentials. The probable impacts of specific maintenance projects or activities are to be determined using methods in the Assessment Methods section of this manual.

DETERMINING HIGHWAY MAINTENANCE PRACTICES WITH PROBABLE WATER QUALITY IMPACTS

Criteria for Determining Potential Impacts and Related Considerations

Determining whether or not a highway maintenance practice may have an impact on the aquatic environment requires evaluating several factors. These factors, in order of importance, are discussed below.

(1) The first is the proximity of the maintenance activity to a water body. A maintenance activity which takes place in or immediately adjacent to a water body, ditch, or drainage channel is more likely to have an impact on the aquatic environment than one which takes place in a site removed from the water body. By their very nature, some practices are more likely to take place in or near water or drainage structures than others.

(2) The second factor to consider in evaluating the potential effects of a given maintenance practice is the nature of the materials used or generated by the activity. The following criteria were used in determining the possible impacts to water quality from various maintenance practices:

- Exposing or moving soil or sediments. (This includes activities that result in accidental or incidental removal of vegetative cover.)

- The use or disposal of toxic chemicals or materials with toxic components, especially if such components are leachable.

- The use or disposal of materials containing plant nutrients (e.g., phosphate, nitrate, ammonium salts).

- The disposal of decomposable organic materials (e.g., grass cuttings, weeds, brush, sewage).

- The use or disposal of other materials that could change the turbidity, pH, or suspended or dissolved solids content of a receiving body of water.

(3) The third factor considered in evaluating the potential impact of a highway maintenance practice is the quantity of materials used and the frequency of the activity.

(4) The fourth factor considered in evaluating the potential impact of a highway maintenance practice is the frequency of the activity.

<u>Basis for the Criteria of Probable Impact</u>

The basis for the criteria developed to evaluate the potential for water quality impacts described above is explained below.

<u>Exposing/Moving Soils</u> - Any activity which involves exposing or moving of soils, either directly or indirectly through accidental or incidental removal of vegetative cover, can result in increased erosion of the soils. This may result in an increased sediment load to the receiving waters as the exposed soils are displaced and transported to the receiving water via overland runoff (Swerdon and Kountz, 1973). Sediment, the end product of erosion, is by volume the greatest single pollutant of surface waters and may also be the principal carrier of other pollutants such as nutrients or toxics (Stewart et al., 1975). Additionally, any in-stream disruption of sediments (as may occur with substructure repair, channel, or ditch cleaning) may have an adverse water quality impact. As with erosion, the major pollutant by mass or volume is sediment; however, the resuspension or redissolution of toxics or nutrients associated with these sediments may be far more damaging to aquatic life or other beneficial uses of the surrounding waters (Bhutani et al., 1975).

Increased sediment loads may be harmful to the aquatic environment in several ways: (1) increased siltation may smother benthic organisms or sufficiently alter the habitat so as to affect fish and shellfish feeding and reproduction, and aquatic plant growth; (2) sediment abrasion can damage fish gills and injure other forms of aquatic life upon which fish depend for food; (3) increased turbidity may decrease light penetration sufficiently to affect photosynthesis by aquatic plants; (4) suspended sediments may alter water chemistry by the adsorption and/or absorption of nutrients and toxic chemicals; and (5) sediments may destroy the attractive appearance of waters and diminish their recreational value (Swerdon and Kountz, 1973).

Specifically, sediment loads can adversely affect fish in various ways, indirectly and directly. For instance, the aquatic primary producers (including both rooted and floating plants and algae) are affected (Farnworth et al., 1979) by decreased light penetration and destruction of photosynthetic organisms by abrasion, scour and burial, reducing production. Also, changes in sediment type or composition may change species composition or relative abundances. Since many fish, and many organisms fed upon by fish, depend on the aquatic plants and algae (primary producers) for food, any modification in the species composition or abundance of this community will have indirect but possibly far-reaching effects on the aquatic community as a whole (Hynes, 1970).

Another effect of increased sediment loads on the fish populations of a water body would be an alteration in the macroinvertebrate populations. The macroinvertebrates (e.g., insects, crustaceans, worms, mollusks) comprise the major food source for many desirable sport fish species (Muncy et al., 1979). Increased sediment loads can adversely affect macroinvertebrates in five ways (Farnworth et al., 1979):

- Increase in the migration and downstream drift of macroinvertebrate populations as they seek to avoid the local adverse conditions.
- Increase in mortality rates due to physiological effects, burial, and physical destruction through abrasion.
- Reduced reproductive rate due to physiological effects, alteration of suitable substrates, and destruction of early life stages.
- Modification of growth rates by decreasing food availability and modifying existing habitats.
- Habitat destruction.

In addition to these food-chain effects, suspended solids may be directly harmful to fish. They may act directly on fish swimming in the water by either killing them or reducing their growth rate, resistance to disease, etc. (Muncy et al., 1979). Impairment of the gills, which function not only in respiration but also in the excretion of nitrogen and chloride wastes, may have broad metabolic effects (Swerdon and Kountz, 1973). Increased sediment loads may decrease fish reproductive rates either directly, by increasing egg and fry mortality, or indirectly by altering adult reproductive behavior or reducing desirable breeding habitats (Muncy et al., 1979). Finally, fish growth and production may be modified by a loss or alteration of habitat (Farnworth et al., 1979), reduction in the abundance of available food, and behavioral changes resulting in a modification of natural movements and migrations (Muncy et al., 1979). For these reasons, many fish species may avoid turbid streams or lakes. Fish which are intolerant of turbid systems (see Table 4) include many of the desirable sport fish. Fish tolerant of turbid conditions are rough fish, such as carp, gizzard shad, drums, and chubs.

As the preceding discussion shows, sediments may have many adverse impacts on water quality, all of which may ultimately alter the habitat and make it unsuitable for the desired uses (e.g., commercial and sport fishing, recreation, water supplies). Although several thousand ppm suspended solids may not kill fish during several hours or days of exposure, temporary high concentrations should be prevented in waters where good fisheries are to be maintained (EIFAC, 1965). The U.S. Environmental Protection Agency (1972) recommends the following maximum long-term concentrations of suspended solids not be exceeded in order to protect aquatic communities at various levels:

High level of protection	25 mg/L
Moderate protection	80 mg/L
Low level of protection	400 mg/L
Very low level of protection	>400 mg/L

All of the above impacts resulting from an increased sediment load to a receiving water body are functions of the sediments themselves. As previously mentioned, the materials associated with the sediments (e.g., nutrients, toxic chemicals) may be more damaging than the actual sediments (Bhutani et al., 1975; Stewart et al., 1975). Some of the effects of these materials are discussed below.

Use/Disposal of Toxic Materials - Any maintenance practice which involves the use or disposal of toxic materials may potentially have acute or chronic toxic effects on the

Table 4. Warmwater fishes which are tolerant or intolerant of suspended solids (turbidity) and sediments in the water column.

Species which are intolerant of turbid systems:

Acipenser fulvescens - Lake sturgeon
Ambloplites rupestris - Rock bass
Amia calva - Bowfin
Ammocrypta asprella - Crystal darter
Ammocrypta clara - Western sand darter
Ammocrypta pellucida - Eastern sand darter
Carpiodes velifer - Highfin carpsucker
Clinostomus elongatus - Redside dace
Culaea inconstans - Brook stickleback
Cycleptus elongatus - Blue sucker
Erimyzon oblongus - Creek chubsucker
Erimyzon sucetta - Lake chubsucker
Esox lucius - Northern pike
Esox masquinongy - Muskellunge
Etheostoma blennioides - Greenside darter
Etheostoma exile - Iowa darter
Etheostoma tippecanoe - Tippecanoe darter
Etheostoma zonale - Banded darter
Exoglossum laurae - Tonguetied minnow
Exoglossum maxillingua - Cutlips minnow
Fundulus notatus - Blackstripe topminnow
Hiodon tergisus - Mooneye
Hybopsis amblops - Bigeye chub
Hybopsis dissimilus - Streamline chub
Hybopsis x-punctatus - Gravel chub
Hypentelium nigricans - Northern hog sucker
Ichthyomyzon castaneus - Chestnut lamprey
Ictalurus furcatus - Blue catfish
Labidesthes sicculus - Brook silverside
Lagochila lacera - Harelip sucker
Lepistosteus platostomus - Shortnose gar
Lepomis gibbosus - Pumpkinseed
Lepomis megalotis - Longear sunfish
Micropterus dolomieui - Smallmouth bass
Micropterus salmoides - Largemouth bass
Minytrema melanops - Spotted sucker
Maxostoma carinatum - River redhorse
Maxostoma duquesni - Black redhorse
Maxostoma valenciennesi - Greater redhorse
Nocomis biguttatus - Horneyhead chub
Nocomis micropogon - River chub
Notropis amnis - Pallid shiner
Notropis boops - Bigeye shiner
Notropis cornutus - Common shiner
Notropis emiliae - Pugnose minnow
Notropis heterodon - Blacknose shiner
Notropis heterolepis - Blacknose shiner
Notropis hudsonius - Spottail shiner
Notropis rubellus - Rosyface shiner
Notropis stramineaus - Sand shiner
Notropis texanus - Weed shiner
Notropis topeka - Topeka shiner
Notropis volucellus - Mimic shiner
Noturus flavus - Stonecat
Noturus furiosus - Carolina madtom
Noturus gyrinus - Tadpole madtom
Noturus miurus - Brindled madtom
Noturus trautmani - Scioto madtom
Perca flavescens - Yellow perch
Percina caprodes - Log perch
Percina copelandi - Channel darter
Percina evides - Gilt darter
Percina maculata - Blackside darter
Percina phoxocephala - Slenderhead darter
Percopsis omiscomaycus - Trout-perch
Polydon spathula - Paddlefish
Pylodictis olivaris - Flathead catfish

Species which are tolerant of turbid systems:

Aphredoderus sayanus - Pirate perch
Aplodinotus grunniens - Freshwater drum
Carassius auratus - Goldfish
Catostomus commersoni - White sucker
Conesius plumbeus - Lake chub
Cyprinus carpio[*] - Common carp
Dorosoma cepedianum[*] - Gizzard shad
Ericymba buccata[*] - Silverjaw minnow
Etheostoma gracile - Slough darter
Etheostoma microperca - Least darter
Etheostoma nigrum - Johnny darter
Etheostoma spectabile - Orangethroat darter
Hiodon alosoides - Goldeye
Hybopsis gelida - Sturgeon chub
Hybopsis gracilis - Flathead chub
Ictalurus catus - White catfish
Ictalurus melas[*] - Black bullhead
Ictiobus cyprinellus - Bigmouth buffalo
Lepomis cyanellus - Green sunfish
Lepomis humilis - Orange-spotted sunfish
Lepomis microlophus - Redear sunfish
Micropterus punctulatus - Spotted bass
Micropterus treculi - Guadalupe bass
Moxostoma erythrurum - Golden redhorse
Notropis dorsalis[*] - Bigmouth shiner
Notropis intrensis[*] - Red shiner
Orthodon microlepidotus - Sacramento blackfish
Phenacobins mirabilis - Suckermouth minnow
Phoxinusa oreas - Mountain redbelly dace
Pimephales promelas[*] - Fathead minnow
Pimephales vigilax - Bullhead minnow
Plagopterus argentissimus - Woundfin
Pomoxis annularis - White crappie
Pomoxis nigromaculatus - Black crappie
Scaphirhynchus albus - Pallid sturgeon
Semotilus atromaculatus[*] - Creek chub
Stizostedion canadense - Sauger

Source: Muncy et al., 1979.

[*] Species may exhibit a preference for turbid systems.

aquatic environment. Toxic materials of potential concern that are used in highway maintenance practices include herbicides, insecticides, asphalts, and heavy metals (e.g., copper) contained in these materials. These substances may enter the water directly through spillage or drift, or may be carried into the surface and groundwaters via overland runoff or leaching.

Toxic effects at any level of the aquatic food chain can have deleterious effects on the entire system. Toxic effects to the primary producers may have a detrimental effect on the oxygen balance of the stream or lake, as well as reducing their availability as a food source; and if the macroinvertebrate population is affected, its availability as an important fish food source could be drastically reduced (Muncy et al., 1979). Some toxic pollutants bioconcentrate in fish or shellfish tissues or may biomagnify across the food chain. Combinations of pollutants may display either additive, synergistic, or antagonistic toxicity effects (Welch, 1980). For these reasons, toxic chemicals can also pose a threat to human health through contamination of drinking water supplies and food fish and shellfish.

It is beyond the scope of this manual to identify or discuss the available toxicity data for all potential toxic pollutants derived from highway maintenance practices. However, because of their particular relevance to the maintenance practice of chemical vegetation control and lack of ready availability elsewhere, pesticide toxicity, bioaccumulation, and other environmental fate data are presented in Appendix A. These data are for herbicides and insecticides known to be used in highway maintenance.

<u>Use/Disposal of Plant Nutrients</u> - An increase in the nutrient load to a stream or lake, as might result from the use or disposal of materials containing plant nutrients (e.g., phosphates, nitrates, ammonium salts), may result in accelerated eutrophication of the water body. Eutrophication is a natural aging process whereby lakes or stream basins gradually fill in, blooms of undesirable algae appear, and a reduction in oxygen levels may occur resulting in a shift in fish species and, in severe cases, fish kills (Farnworth et al., 1979). While eutrophication is a natural process, human activities are often responsible for accelerating it to unnatural rates.

The plant nutrients of concern are most often found in fertilizers. Runoff waters may transport the fertilizers (associated with sediments) into the receiving water body, causing an increase in primary productivity. As the primary productivity booms, an increasing number of organisms (plant and algae cells) die and sink to the bottom of the lake or stream pool. This leads to an increase in decomposition which may rapidly deplete the oxygen levels in the bottom waters of the lake. This oxygen depletion will reduce populations of bottom-dwelling fish. Additionally, the resulting oxygen depletion may increase the release of nutrients, metals, and toxic chemicals which may be bound to the sediments (Wetzel, 1975).

Therefore, although nutrient inputs will not directly affect the higher organisms in an aquatic system, they will set off a chain of events which may change the character of the lake or stream (Farnworth et al., 1979). The final results of increased eutrophication are almost all unpleasant. The water becomes turbid due to increased algal production. The algal species shift from green to blue-green algae. The latter tend to be slimy, malodorous, and toxic. This shift to an undesirable food source (blue-green algae) may have an adverse effect throughout the food chain as each successive level is affected by the reduced availability of its primary food source. Finally, the water declines in suitability for industrial and municipal water supplies and becomes generally less attractive for recreational purposes (Hynes, 1974).

<u>Disposal of Decomposable Organic Material</u> - Any activity which involves the disposal of decomposable organic materials (e.g., grass cuttings, weeds, brush, sewage, sewage sludge) may alter the oxygen balance of the receiving waters. Wet material such as grass cuttings or sewage is of much greater concern than woody trash because of its more rapid rate of decomposition.

The oxygen consumed by the decomposition process may lower the oxygen levels sufficiently in the water to have an adverse effect on the indigenous aquatic life. Depressed dissolved oxygen levels may have direct and adverse effects on the reproduction, growth, and production of indigenous fishes (EPA, 1972). Furthermore, the efficiency of oxygen uptake by aquatic animals is reduced and consequently reduces their ability to adapt to other sources of stress in their environment.

There is also evidence that reduced dissolved oxygen levels increase the toxicity of some pollutants (Welch, 1980). Additionally, if the oxygen depletion results in anaerobic bottom waters in a lake or pond, nutrients and toxic pollutants may be released from the sediments (Wetzel, 1975). The potential release of nutrients from the sediments and nutrients generated from the decay of the organic materials may contribute to increased eutrophication of the receiving water body.

Use/Disposal of Materials That Change pH, Turbidity, or Suspended or Dissolved Solids - Maintenance practices which involve the use or disposal of materials which could alter the pH content of a receiving body of water may have varied potential water quality impacts. Alterations in turbidity and solids content would have impacts similar to those associated with increased sediment loads.

An alteration in pH (acidity or alkalinity) may increase the desorption of materials adsorbed to the sediments. The resulting resolubilization of metals, other toxic materials, and nutrients may have negative impacts on the aquatic environment in terms of increased toxicity and eutrophication (Farnworth et al., 1979). Alteration of the pH may increase the toxicity of some chemicals (Welch, 1980). A change in the pH may also have a direct effect on fish survival, so that in extreme cases of drastic changes or sensitive species, a gradual decline may accelerate and the fishery may be extinguished (Welch, 1980).

Ranking Maintenance Practices on the Basis of Potential Water Quality Impacts

Maintenance practices common to most States were ranked according to their projected potential impacts to water quality. This was done by considering the proximity of the practice to a water body, the nature of materials used and information contained in the open literature, maintenance manuals from several States, and interviews with State and county maintenance personnel. However, it was not possible to assess the actual quantity of materials used or the frequency of the activity since, in most cases, this factor will depend on individual site characteristics. The four steps of the ranking method are:

(1) Each practice was evaluated in terms of its proximity to a water body, ditch, or drainage channel. Research has indicated that grassy vegetation is a very effective filter for trapping sediments and other pollutants in surface flow, so the distance of surface flow over grassy areas has to be considered. According to Wang et al. (1982), 197 ft (60 m) of surface flow through grassy vegetation is sufficient to remove pollutants found in highway stormwater runoff. Thus, proximity values (PV) were assigned as follows:

- If the practice takes place in or over a body of water, then PV = 3.

- If the practice takes place within 200 ft (61 m) of a waterbody, then PV = 2.

- If the practice takes place further than 200 ft (61 m) from a waterbody, then PV = 1.

(2) Each practice was evaluated in terms of the five criteria. Based on how well each criterion describes a practice a criterion value (CV) of zero (0) to three (3) was assigned. If the criterion was not applicable, then CV = 0. If the criterion described the practice very well (e.g., chemical vegetation control and criterion for toxic materials), then CV = 3. In evaluating the toxicity criterion, if a chemical or material is being used specifically for its toxic properties (e.g., herbicides, insecticides) then the CV was doubled because it represents a potentially greater threat to aquatic life.

(3) For each practice, the criterion values were summed and the total multiplied by the proximity value to yield the impact value (IV).

$$(CV_1 + CV_2 + \ldots + CV_5) \times PV = IV$$

(4) Based on the impact value, the maintenance practice was placed in one of the following types:

Type I: Probable Impact, IV >10.

Type II: Possible Impact, $5 \leq IV \leq 10$.

Type III: No Probable Impact, IV <5.

This ranking method is subjective both in design and in the assignment of criterion and proximity values. The impact value is not intended to be an absolute assessment of the potential impact of a maintenance practice. The method has its greatest utility in providing a starting point for evaluating maintenance practices. By ranking the practices according to their impact value, it is possible to immediately eliminate from future consideration maintenance practices which probably have little or no impact on water quality. Figure 2 illustrates an application of this ranking method to the maintenance practices listed in Table 1. Table 5 lists the results of this ranking by grouping the maintenance practices as Type I, II, or III. Each maintenance practice is identified and the rationale for considering it to be probably, possibly, or probably not having an impact to water quality are briefly identified. Potential water quality impacts from each of the Type I maintenance activities will be discussed in detail later.

Maintenance Activities / Activity Involves:	Exposing or moving soils or sediments (including accidental or incidental removal of vegetation)	Use or disposal of toxic chemicals or material with toxic components, especially if leachable	Use or disposal of materials containing plant nutrients	Disposal of decomposable organic material (e.g., grass cuttings, weeds, brush, etc.)	Use or disposal of material that could change the pH, turbidity, or solids content	Water involvement factor	IV Score
Rideability Maintenance:							
Pothole patching		1			2	1	3
Surface repairs		1			2	1	3
Full depth repairs		3			2	1	5
Sealing joints and cracks		1			1	1	2
Surface treatments		* 6				1	6
Planing pavements					3	1	3
Blading unpaved surfaces	3				1	1	4
Pavement jacking	3				1	1	4
Roadside Maintenance:							
Blading unpaved berms/shoulders	3				3	1	6
Repairing curbs and gutters		1			2	2	6
Repairing slopes, slips and slides	3		2		2	2	14
Controlling roadside litter	1					1	1
Vegetation Maintenance:							
Mowing			1	3		2	8
Chemical vegetation control	1	* 6				2	14
Planting and care of shrubs and trees	2	* 2	2	1	1	1	8
Seeding, sodding, and fertilizing	3		3	1	1	1	8
Drainage Maintenance:							
Cleaning ditches, channels, and drainage structures	3		2	2	1	3	24
Repairing drainage structures	3	1			2	3	18
Structural Maintenance:							
Bridge surface cleaning		2			1	3	9
Bridge painting		2			2	3	12
Bridge deck repair		2			2	2	8
Bridge joint repair		1			1	2	4
Substructure repair	3	1			2	3	18
Superstructure repair		1			1	2	4
Safety Maintenance:							
Cleaning pavements		1		1	2	1	4
Guardrail painting	1					1	1
Snow plowing	2				1	1	3
Application of abrasives					3	2	6
Crash attenuator repair		1			1	1	2
Snow fence installation and removal	1					1	1
Highway lighting	1					1	1
Comfort Area Maintenance:							
Care of rest areas		* 4	1	1		1	6
Sign Maintenance:							
All sign repair and replacement	1					1	1
Traffic Control Device Maintenance:							
Pavement marking		2				1	2
Equipment Maintenance:							
Washing and cleaning equipment		* 6			1	1	7
Storage and Handling of Bulk Materials:							
Bulk storage of nonfuel materials		1	1	1	1	1	4
Bulk storage of motor fuels		3			2	1	5
Disposal of used lubricating oils		3			2	1	5

* *Toxicity factor (x2)*

Figure 2. Impact value (IV) method for assessing impacts to water quality from highway maintenance practices.

Table 5. Classification of highway maintenance practices based on impact value (IV) scores.

IV score	Maintenance practice	Significance rationale
Type I - Maintenance practices which can have a probable impact		
24	Cleaning ditches, channels, and drainage structures	Potential increase in sediment load through erosion of newly exposed soils or resuspension of deposited solids; deposits may be high in metals content; increased nutrient loads with use of fertilizers.
18	Substructure repair	Potential increase in sediment load through bank erosion and in-stream sediment disturbance.
14	Chemical vegetation control	Potential toxicity to aquatic life from residual runoff and accidential or incidental direct application to receiving waters.
14	Repairing slopes, slips, and slides	Potential increase in erosion due to disturbance of vegetative cover; increased nutrient load from fertilizer use.
12	Bridge painting	Possible introduction of blasting abrasives and paint chips or cleaners; overspray may be toxic.
Type II - Maintenance practices which can have a possible impact		
9	Bridge surface cleaning	Potential resuspension of pollutants deposited on the roadway from sweeping or flushing (e.g., heavy metals, chlorides, etc.); increased solids load to stream.
8	Bridge deck repair	Use of asphalts and epoxies may pose toxic threat to aquatic life; surface removal debris may enter the stream.
8	Mowing	Decay of grass clippings reaching receiving waters may lead to dissolved oxygen depletion.
8	Planting and care of shrubs and trees	Minor potential for erosion; use of plant nutrients and insecticides may impact receiving waters.
8	Seeding, sodding, and fertilizing	Potential increase in suspended solids and nutrient loads to stream.
7	Washing and cleaning equipment	Solvents used may be toxic to aquatic life; improper disposal of wash-water may cause impact.
6	Blading and restoring unpaved shoulders and/or berms	Exposing soils may lead to increased solids load to streams; use of soil sterilants pose threat of toxic effects to aquatic life.

Table 5. Classification of highway maintenance practices based on impact value (IV) scores. (Continued)

IV score	Maintenance practice	Significance rationale
6	Repairing curbs and gutters	Use of mortar presents potential for increased turbidity.
6	Application of abrasives to road surfaces	Abrasives washed into receiving stream may increase turbidity and be detrimental to aquatic life.
6	Care of rest areas	Potential toxicity due to use of herbicides and insecticides; potential for nutrient loads; improper disposal of sewage may cause impact.
6	Surface treatments	Runoff from freshly applied cut-backs and improper use of solvents present potential toxicity to aquatic life.
5	Disposal of used oils	Improper disposal presents potential toxicity to aquatic life.
5	Full depth repairs	Suspended solids from cutting and cleaning pavement.
5	Bulk storage of motor fuels	The toxicity of the fuels and the possibility of undetected leaks from underground tanks create the possi- bility of an impact.
Type III - Maintenance practices which have no probable impact		
4	Blading unpaved surfaces	Moving and exposing of soils may lead to increased solids load to receiving stream.
4	Pavement jacking	Potential change in pH due to lime usage, but limited occurrence of this activity makes impacts unlikely.
4	Bridge joint repair	Potential change in water chemistry from use of lime/cement, but small amounts of materials required makes impacts unlikely.
4	Superstructure repair	Potential toxicity from paints or solvents possible but impacts are not likely due to relatively small scale of projects.
4	Cleaning pavements	Resuspension of operation-generated toxics. Maintenance practice of cleaning pavement does not generate any new pollutants and cannot be considered to impact water quality.
4	Bulk storage of nonfuel materials	No impacts likely.

Table 5. Classification of highway maintenance practices based on impact value (IV) scores. (Continued)

IV score	Maintenance practice	Significance rationale
3	Pothole patching	No impacts likely.
3	Surface repairs	Slight potential for suspended solids loads from cutting and cleaning pavement.
3	Planing pavements	Increase in suspended solids if the slurry is improperly disposed of. Best management practices will eliminate any significant impacts.
3	Snow plowing	Disturbance of roadside vegetation may lead to increased erosion but not of significant magnitude.
2	Filling and sealing joints and cracks	No impacts likely.
2	Crash attenuator repair	Sand or calcium chloride used in attenuators may reach stream if released by collision, but repairing such structures and removal of debris should eliminate any potential impacts.
2	Pavement marking	Solvents may be toxic; paints contain toxic metals but not likely to reach streams due to rapid drying time.
1	Guardrail painting	No impacts likely.
1	Snow fence installation	No impacts likely.
1	Highway lighting maintenance	No impacts likely.
1	Highway signing maintenance	No impacts likely.

HIGHWAY MAINTENANCE PRACTICES WHICH CAN HAVE A PROBABLE IMPACT (TYPE I)

A highway maintenance practice may, of course, meet one or more criteria, and each such criteria to varying degrees. To more completely understand the potential water quality impacts, it is necessary to examine each maintenance practice individually and assess the possible impacts to water quality. Figure 3 summarizes the potential general water quality impacts possible from each maintenance practice.

Most of the information regarding the potential water resources impacts of these highway maintenance impacts was obtained from case studies involving specific maintenance practices, information contained in the literature, interviews with State maintenance personnel, field studies conducted in conjunction with this research project, and general knowledge of how each activity is accomplished. The discussion will attempt to identify which of the potential impacts associated with each criterion are applicable to a given maintenance practice. This descriptive approach is designed to assist the interested official in identifying which assessment methods described in the following chapter are appropriate. An actual assessment of the magnitude and significance of the expected impacts is necessarily site-specific and therefore cannot be presented in this manual.

Cleaning Ditches, Channels, and Drainage Structures

Ditches - Drainage ditches are constructed to direct highway and right-of-way runoff flow to the nearest channel. The flow in ditches is intermittent in character, occurring primarily after storm events. The properly designed ditch will allow adequate drainage to prevent ponding of water on the pavement or standing pools to develop in the ditch. Occasionally ditches are cleaned and reshaped to remove accumulated debris and restore the ditch to its original cross section and design capacity. This activity is accomplished using hand methods or equipment such as a backhoe, graders, and excavators. The cleaning and reshaping of ditches will result in approximately 4 to 5 ft^2 (0.4 to 0.5 m^2) of newly exposed soils per foot of ditch.

The most significant impacts to water resources from ditch cleaning and reshaping are related to erosion. The

KEY: □ Nonsignificant ■ Significant **Maintenance Activities** / **Potential Impacts:**	Sedimentation	Turbidity	Toxicity	Eutrophication	Oxygen Depletion	pH Changes
Rideability Maintenance:						
Pothole patching			□			
Surface repairs			□			
Full depth repairs	□	□	□			
Sealing joints and cracks			□			
Surface treatments		□	□			
Planing pavements	□	□				□
Blading unpaved surfaces	□	□				
Pavement jacking		□				
Roadside Maintenance:						
Blading unpaved berms/shoulders	□	□				
Repairing curbs and gutters		□	□			□
Repairing slopes, slips and slides	■	■		□	□	
Controlling roadside litter						
Vegetation Maintenance:						
Mowing		□			□	
Chemical vegetation control			■			□
Planting and care of shrubs and trees	□	□	□		□	
Seeding, sodding, and fertilizing	□	□		□		
Drainage Maintenance:						
Cleaning ditches, channels, and drainage structures	■	■	□	□	□	
Repairing drainage structures	■	■	□			
Structural Maintenance:						
Bridge surface cleaning	□					
Bridge painting	■	□	□			
Bridge deck repair	□	□	□			
Bridge joint repair	□					
Substructure repair	■	■	□			
Superstructure repair			□			
Safety Maintenance:						
Cleaning pavements	□	□	□			
Guardrail painting			□			
Snow plowing	□	□				
Application of abrasives	□	□				
Crash attenuator repair						
Snow fence installation and removal	□					
Highway lighting						
Comfort Area Maintenance:						
Care of rest areas			□	□		
Sign Maintenance:						
All sign repair and replacement						
Traffic Control Device Maintenance:						
Pavement marking			□			
Equipment Maintenance:						
Washing and cleaning equipment		□	□			
Storage and Handling of Bulk Materials:						
Bulk storage of nonfuel materials			□			
Bulk storage of motor fuels			□			
Disposal of used lubricating oils			□			

Figure 3. Potential types of water quality impacts from highway maintenance practices.

major pollutant will be sediments with nutrient and toxic chemical pollution also possible. Nutrients can be of particular concern if the bare soils are seeded, fertilized, or mulched as part of the maintenance practice.

The existence of pollutants in runoff waters is well-documented (Gupta, Agnew, and Kobriger, 1981). These pollutants (metals, nutrients, oils and grease, suspended solids, etc.) are transported from the highway surface via runoff waters to drainage structures, roadside ditches, and receiving waters. The migration and accumulation of these pollutants (metals especially) in roadside soils and vegetation is also well documented (Chow, 1970; Lagerwerff and Specht, 1970; Laxen and Harrison, 1977; Howard, 1981; Kobriger, 1984). It is not unreasonable to assume that a portion of these pollutants may become incorporated into roadside drainage ditches (Laxen and Harrison, 1977), and that any excavation of these sediments increases the possibility of resuspension and resolubilization of these toxic pollutants. However, with proper disposal of deposited sediments, impacts from the above pollutants are probably minimized.

Measures to mitigate water resources impacts would include establishing grassy vegetation in the ditch to reduce erosion and promote removal of the pollutants (Wang et al., 1982)), and adding riprap or mulches on the ditch slopes to reduce erosion. One possible strategy to reduce erosion and promote grassy vegetation in a ditch is to clean only a portion of a ditch each year and to employ aggressive seeding practices to promote regrowth if scraped bare (Horner and Mar, 1982).

Channels - Cleaning and reshaping stream channels involves the removal of vegetation debris and sediments and regrading the channel to its proper grade and cross section. More extensive channelization (channel realignment and dredging) around bridges and culverts may become necessary if the stream is undercutting or weakening the substructure or roadbed. If this channelization work is extensive, a 404 Permit will be required from the U.S. Army Corps of Engineers (47 FR 31794-31834). Additionally, many State resource agencies also require permits for construction or maintenance activities within stream channels.

By definition and design, channel cleaning and reshaping takes place in a body of water. This fact increases the likelihood, and possibly the magnitude, of potential impacts occurring as a result of the maintenance practice. The environmental effects of channel cleaning will depend on the type and amount of change in the stream habitat caused by the maintenance activity. If the channel maintenance includes extensive channelization, often involving widening, straightening, or shortening a natural stream channel, the following effects may be expected (Patrick, 1973):

(1) Removes the natural diverse substrate that allow the development of diverse benthic communities.

(2) Increases the sediment load which in turn decreases light penetration and primary production.

(3) Creates a shifting bedload that is hazardous to benthic organisms.

(4) Simplifies the current pattern and eliminates the habitat diversity.

(5) Reduces the stability of the banks and may lead to cave-ins of trees and overhanging vegetation whose shade reduces high stream temperatures during the summer months.

In addition to these actual physical effects of channelization, several pollutants of concern may be generated, most significantly sediment. Depending on the amount of organic matter (trees, roots, shrubs, etc.) in the channel or on its banks, decomposition products of this material may also be present (Bhutani et al., 1975). If herbicides are used to control vegetation in channels, a threat of toxicity to indigenous aquatic organisms is created. Finally, bank stabilization employing mulches, seed and fertilizers, sod or riprap may be incorporated into the channel reshaping process in an attempt to reduce subsequent bank erosion due to the increased velocity of the channelized stream (Stern and Stern, 1980), leading to a temporary increase in the nutrient load to the stream.

All of the potential impacts mentioned above (sedimentation, turbidity, toxicity, nutrient enrichment, etc.) will affect the aquatic biota. The magnitude and significance of these impacts to the receiving waters will depend on the duration and extent of the channel work required and the resource value of the habitat affected.

Mitigation measures include avoidance or reduction of actual in-stream work whenever possible; limited use of herbicides; best management practices; and use of slow-release fertilizers, such as ureaform fertilizers in bank stabilization, if fertilizers are required. Additionally, best management erosion control practices in the watershed itself may reduce the need for or the frequency of channel cleaning.

Drainage Structures - The generic term "drainage structure," which includes any structure (other than a ditch) designed specifically to convey water away from the road surface to a receiving channel or water body, may refer to culverts, storm sewers, catch basins, drop inlets, manholes, scupper drains, etc. Cleaning these structures involves removal of sediments and debris that have collected. The method of removal will vary greatly depending on the type of structure and degree of blockage. Culverts are usually cleaned with hand tools and the removed deposits spread on the surrounding earth. Catch basins, storm sewers, scupper drains, etc., are either flushed out with water or the deposits are removed by hand (shovels) or by vacuum ("vactor jet"). Repairing drainage structures ranges from minor repairs to gratings or other surface features to complete replacement requiring extensive excavation and subsequent full depth road repairs.

The potential water quality impacts associated with these maintenance practices are as varied as the drainage structures themselves. Drainage structures are, by definition, in or closely associated with waterways. Thus, there is a potential impact to water resources due to the proximity to receiving waters. The major pollutants associated with cleaning drainage structures are the resuspended sediments. These sediments may have very high concentrations of metals associated with them resulting from operations (Wilber and Hunter, 1979; Howell, 1978). If the sediments removed from drainage structures are not properly disposed of, the metals adsorbed to the sediments may resolubilize and pose a toxic threat to indigenous aquatic organisms.

Repairing drainage structures may require major excavation and construction. The exposed soils are subject to increased erosion resulting in an increased sediment load to the receiving water. Likewise, any in-stream work associated with the repairs would result in disturbance of the substrate and resuspension of solids and nutrients and toxic chemicals potentially associated with these sediments.

Mitigation measures would involve standard erosion preventative measures such as stabilization of slopes using mulches or riprap or seeding, diversion of flow, and construction of bulkheads. In addition, best management practices to prevent the introduction of toxic materials into the receiving water should lessen the impacts to water quality. Proper disposal of sediments and debris cleaned out of drainage structures should aid in mitigating the water quality impacts from this maintenance practice.

Bridge Painting

Bridge painting involves two basic steps: (1) cleaning the surface by sandblasting or washing to remove oil and grease, dirt, rust, loose paint, etc.; and (2) application of the prime and finish coats of paint using hand tools (brushes, rollers, gloves) or spray applicators.

Any bridge painting project that takes place over a water body has the potential to impact water quality. Perhaps the aspect of bridge painting with the most impact is the cleaning of the structure prior to repainting. The most common cleaning method is sandblasting. The sandblasting activity has the potential to introduce large amounts of abrasive blasting material, rust, and paint chips into the stream below. The metals present in debris (e.g., lead, iron, chromium, and aluminum) are known to have toxic effects on aquatic communities at high dissolved concentrations. The effect of the undissolved portion is unknown (Nakao et al., 1977). Preliminary analyses indicate that the metals associated with this debris are not very soluble. Long-term tests (3-year exposures) did not show any significant increase in the dissolved metals content of water overlying the blasting residue (Parks and Winters, 1982), which suggests no long-term (chronic) toxicity effects to the aquatic ecosystem. Investigations by the North Carolina Division of Environmental Management (1983) showed no correlation between sediment concentrations of aluminum, zinc, and lead and those found in benthic macroinvertebrates following sandblasting. These findings suggest that bridge sandblasting activities do not detrimentally impact aquatic communities.

In addition to toxic effects, the large amounts of abrasives entering the water are of concern. The Middle River Bridge project in California (Nakao et al., 1977) generated over 300 tons (272 kkg) of blasting material. A sediment input of this magnitude may, depending on the size of the stream, have major detrimental effects on the aquatic organisms (plants and animals). Smothering of the benthos, abrasive damage to gills and other respiratory structures, reduction of primary productivity, and alteration of benthic habitats are all potential detrimental effects (discussed previously) of the increased sediment load. The significance of these impacts will depend upon the original quality of the habitat including the type of substrate present (e.g., sandy, gravelly, silty, rocky).

Cleaners used in bridge cleaning have been shown to be highly toxic to aquatic life (Jeffrey Gidley, California Department of Transportation, personal communication). Thus, spent cleaners entering nearby streams present the possibility of causing impacts. Of course, the likelihood of an impact is also a function of the volume of receiving water available for dilution.

During the painting phase, overspray of paint and spillage of paint solvents may contribute to in-stream toxic effects, particularly if the operation is carried out haphazardly. Paint overspray may collect on the surface of the receiving waters, probably creating more of an aesthetic problem than a water quality problem. No studies of the toxicity of this paint accumulation to aquatic organisms have been conducted. Lead-pigmented (generally oil-based) paints do not dry in the air as rapidly as do zinc-pigmented (generally water-based) paints. Overspray from the lead paints will consequently result in a scum of paint on the surface of the water which may mix more readily with the water column. Overspray from the zinc paints dries rapidly in the air before it settles on the surface of the water. This dried overspray is readily removed from the water surface with skimmers or collected with tarps or netting for subsequent removal and disposal.

Mitigation measures include nets and shrouding systems to catch the sand-blasting debris. However, these are only about 50 percent efficient. Floating straw or boom-type collectors may be used to confine the overspray settling on the water surface. Use of cleaners should be avoided if the bridge is located in the immediate vicinity of a stream. Use of paints with pigments other than lead will reduce the potential toxicity threat to aquatic organisms.

<u>Substructure Repair</u>

Repair of bridge substructures (e.g., abutments, piers, wing walls, support piling) can be a major operation with resultant disruptions of the aquatic environment. Heavy equipment used include air compressors, concrete mixers, dump trucks, cranes, etc. Materials required include aggregates, cement, epoxy, reinforcing steel, timber, and structural steel. Repair of underwater piers may require the construction of cofferdams.

The integral involvement of in-stream work with substructure repair make this a maintenance practice of major concern. The major pollutant, as with channel cleaning, is resuspended sediment, with other bottom materials redissolved or resuspended to some degree (Bhutani et al., 1975). In addition to the disturbance of in-stream sediments, the heavy equipment moving in and out of the stream bed will break down the banks of the waterway. This may lead to increased bank erosion and result in increased sediment loads. Due to the size of most substructure repair projects and the necessity for in-stream work, this maintenance practice may have major, although short-term, impacts on the aquatic environment.

Possible mitigation measures would include the use of sediment traps, retention basins (in large-scale projects warranting them), or floating siltation fences with filter fabric downstream of the activity to attempt to localize the impact, and erosion control practices, such as riprap, mulches, or sod, on the affected slopes. Cofferdams are also a possible mitigation measure for in-stream work. Additional mitigation of impacts may be achieved during installation of cofferdams by pumping water into retaining basins or onto grassed slopes, not into the stream.

Chemical Vegetation Control

Chemical vegetation control includes the use of herbicides, growth retardants, and soil sterilants as a viable alternative to mowing and hand trimming of vegetation.

Herbicide classifications include the selective herbicides which control the undesirable vegetation without seriously injuring the desirable plants. Nonselective herbicides will essentially kill all vegetation and act as soil sterilants. Herbicides also vary in their mode-of-action and their persistence. Some herbicides are contact poisons which kill or affect only the parts of the plant covered by the chemical. These provide short-term, nonselective, postemergent control which will not kill the entire plant (i.e., foliage may die but roots remain viable). The other mode-of-action is represented by the systemic herbicides. They are translocated from the leaves downward (foliar systemic) or from the roots upward (root systemic). Systemic or translocated herbicides perform best when the plants are actively growing. Finally, herbicides are classified as being either residual or nonresidual herbicides. Residuals remain active in the soil for a period of time and generally are root systemic herbicides. Nonresiduals are generally contact or foliar systemic herbicides which break down rapidly and completely in the soil.

In addition to the many different chemicals available, there are also many formulations of the same chemical available for use. All these variables must be considered when choosing the right product for the job. The formulation used may affect the amount of the chemical which may be lost to surface and groundwaters via runoff (Wauchope, 1978). The formulations include (Florida Department of Transportation, n.d.):

<u>Dry Formulations</u>:	Soluble powders (SP) - totally dissolve in water. Wettable powders (WP) - form a suspension in water. Granular (G) - pellets applied in a dry state.
<u>Liquid Formulations</u>:	Emulsifiable concentrates (EC) - mixed with water or a petroleum solvent to form an emulsion. Solutions (S) - liquids which dissolve in water. Flowables (F) - liquids which remain in suspension in water.

Table 6 lists the pesticides used by States responding to a survey of chemical vegetation management. This list represents the universe of pesticides (herbicides and insecticides) considered in this study. Appendix A includes an index-type listing of the common names used in this manual and the many synonyms currently in use for these pesticides. Although insecticides, by definition, are not used in the chemical control of vegetation, they are used by many States to control insect pests along the roadways. For this reason, insecticides were included in the compilation of pesticide toxicity and fate data.

The impact of a herbicide on the aquatic environment is dependent upon several factors including: (1) time of application; (2) rate of application; (3) method of application; (4) toxicity; (5) movement of the herbicide through the ecosystem; (6) persistence of the herbicide in the environment; and (7) bioconcentrations (Voorhees, 1982). The first three factors are functions of best management practices. By using the recommended rates of application and following all label instructions regarding application methods and cautions, the impact to the aquatic environment should be minimized. The final four factors are functions of the particular herbicide chosen and will vary greatly. The highway maintenance personnel can again minimize water quality impacts from herbicide application and maximize vegetation control efficiency by being aware of the merits and inherent dangers associated with each individual herbicide.

Table 6. Pesticides used by State highway maintenance departments in the United States.

Common name	Percent of States using compound[a]	General purpose uses[b]
Insecticides:		
Acephate	2	Insecticide with contact and systemic activity
Carbaryl	9	Insecticide which acts as a stomach and contact poison
Diazinon	2	Insecticide-acaricide which acts as a stomach and contact poison
Dicofol	2	Contact acaricide
Dimethoate	2	Insecticide with contact, residual, and systemic activity
Malathion	2	Insecticide-acaricide
Methoxychlor	5	Insecticide with long residual activity
Tetradifon	2	Acaricide acting on all mites except adults
Herbicides:		
2,4-D esters and amines	65	Postemergent, selective, translocated herbicide
Aminotriazole	21	Postemergent, nonselective, translocated herbicide
Ammate	7	Postemergent, nonselective, contact, and translocated herbicide
Asulam	7	Postemergent, selective, translocated herbicide
Atrazine	9	Preemergent and early postemergent, selective, herbicide
Bromacil	37	Pre and postemergent, nonselective, herbicide and sterilant
Bromoxynil	2	Postemergent, selective, contact herbicide
Cacodylic acid	2	Postemergent, nonselective, contact herbicide
Chloflurenol	2	Growth regulator for suppression of plant growth
Dalapon	26	Pre and postemergent, selective, contact and translocated, herbicide
Dicamba	23	Pre and postemergent, selective, translocated herbicide
Dichlobenil	12	Preemergent, selective, primarily aquatic herbicide
Dinoseb	5	Pre and postemergent, selective herbicide
Diquat	5	Postemergent, nonselective, contact aquatic herbicide and plant dessicant
Diuron	30	Pre and postemergent, nonselective, contact herbicide and soil sterilant
DSMA	2	Postemergent, selective, contact herbicide
Fenac	2	Preemergent, selective, translocated herbicide and soil sterilant
Fenavar	5	Temporary, nonselective soil herbicide
Fosamine	42	Postemergent, growth-regulator and contact herbicide
Glyphosate	56	Postemergent, broad spectrum, translocated herbicide
Hexazinone	23	Postemergent, nonselective, contact herbicide

Table 6. Pesticides used by State highway maintenance departments in the United States. (Continued)

Common name	Percent of States using compound[a]	General purpose uses[b]
Maleic hydrazide	16	Growth inhibitor/regulator and herbicide
Mefluidide	9	Postemergence herbicide and growth regulator
MSMA	21	Postemergent, selective, contact herbicide
Napropamide	5	Preemergent, selective, incorporated herbicide
Oryzalin	14	Preemergent, selective, nonincorporated herbicide
Oxadiazon	5	Preemergent, selective, contact herbicide
Paraquat	5	Postemergent, nonselective, contact herbicide
Picloram	40	Postemergent, selective, translocated herbicide
Pramitol (Prometone)	19	Preemergent, nonselective, soil herbicide
Pronamide	2	Preemergent and early post-emergent, selective herbicide
Simazine	30	Preemergent, selective, non-contact herbicide
Tebuthiuron	23	Pre and postemergent, nonselective herbicide and sterilant
Terbutryn	2	Preemergent, selective, translocated herbicide
Trifluralin	2	Preemergent, selective, incorporated herbicide
Ureabor	7	Nonselective soil herbicide, sterilant

[a] Source: Voorhees, 1982.

[b] Source: Thomson, 1981a; Thomson, 1981b; Thomson, 1982.

The toxicity of pesticides (herbicides and insecticides) varies widely. Acute toxicity to aquatic organisms is usually expressed as a measure of the median lethal concentration (called the LC_{50}) that is lethal to 50 percent of the test organisms over a specified period of time (e.g., 24, 48, or 96 hours). The LC_{50}s provide a general measure of toxicity within a taxon (i.e., fish) although it may vary from species to species (Voorhees, 1982). Another measure of toxicity is expressed as an EC_{50}, which represents the concentration at which 50 percent of the test organisms over a specified period of time (usually 48 hours) exhibit a particular effect such as immobilization. This measure is useful for organisms, such as mollusks and insects, in which death sometimes is not easily distinguished from inactivity. Generally speaking, insecticides are more toxic than herbicides to aquatic organisms (Wauchope, 1978). Table 7 lists the lowest reported acute toxicity for fish (LC_{50}) and invertebrates (EC_{50}). These lowest reported values give a worst-case indication of the toxicity of each pesticide in relation to others used in roadside maintenance. Appendix A provides a summary of the acute toxicity values available for the pesticides listed in Tables 6 and 7.

The movement of the herbicide through the ecosystem provides some indication of availability to the aquatic environment. The transport of herbicides in runoff waters to receiving waters is the primary mechanism for contaminating these receiving waters with herbicides. (The exception to this is the direct application of herbicides to water surfaces to control aquatic weeds. This is usually done to prevent massive weed growths in channels or ditches which may inhibit proper drainage of runoff waters.) The amount of herbicide lost via runoff waters is determined, in part, by the formulation of the pesticide applied. The wettable powders show the highest long-term losses (2 to 5 percent of application) of any formulation, and this loss may be up to 3 times higher if a large runoff-producing event occurs within 2 weeks of application (Wauchope, 1978). The water insoluble formulations, such as the emulsifiable concentrates, show the next worst long-term losses (typically 1 percent). Water soluble formulations show losses of 0.5 percent or less unless a major runoff-producing event occurs within 2 weeks of application (Wauchope, 1978). The amount of these losses associated with either the sediment or the water phase of runoff varies widely dependent upon the solubility of the pesticide. Generally, although the concentrations may be two to three orders of magnitude higher in sediments than in the associated water, most pesticides are lost mainly in the water phase, simply because sediment is usually such a small fraction, by weight or by volume, of runoff from vegetated areas (Wauchope, 1978).

Table 7. Lowest reported acute toxicities for fish (96-h LC50) and invertebrates (48-h EC50) for insecticides and herbicides used in roadside vegetation control.[a]

Common name	Lowest reported LC50 (ppm)	Lowest reported EC50 (ppm)
Insecticides:		
Methoxychlor	0.0017	0.0008
Diazinon	0.020	0.0008
Malathion	0.027	0.001
Dicofol	0.053	--
Carbaryl	0.069	0.006
Tetradifon	0.88	--
Dimethoate	7.50	--
Acephate	25.5	--
Herbicides:		
Trifluralin	0.009	0.56
2,4-D-ester	0.24	0.40
2,4-D-amine	0.30	0.15
Atrazine	0.36	--
Simazine	0.396	1.10
Terbutryn	0.82	--
Oxadiazon	0.83	--
Diuron	1.4	1.4
Picloram	1.4	--
2,4-D-acid salt	2.0	--
Glyphosate	2.3	3.0
Pramital	2.94	--
Oryzalin	3.14	--
Dichlobenil	5.7	5.8
Fenac	6.08	4.5
Chloflurenal	6.73	--
Diquat	9.96	--
MSMA	12.2	--
DSMA	12.2	--
Paraquat	13.0	3.7
Cacodylic acid	17	--
Dicamba	28	>100
Aminotriazole	40.5	--
Bromoxynil	40.5	--
Bromacil	56.7	--
Dalapon	75.9	11.0
Ureabor	>100	--
Hexazinone	>100	--
Ammate	825	--

[a] The lower the LC_{50} or EC_{50}, the more toxic the pesticide.

Most pesticides in use today have a persistence time of less than 1 year (Hileman, 1982). Persistence time is defined as the time necessary for the soil concentrations to decline to 10 percent of the initial application value. The half-life of the pesticide is generally 0.3 times the persistence time (Wauchope, 1978). The more persistent a pesticide, the greater the chance it will affect nontarget organisms. Two of the more persistent pesticides in use today are atrazine and picloram, with persistence times of 2 to 3 years (Hileman, 1982).

Some toxic chemicals may bioconcentrate in nontarget organisms, accumulating in the tissues of the organisms to concentrations many times higher than the levels found in surrounding waters, and increase the potential toxicity to consumers of these organisms. The bioaccumulation data available on pesticides is scarce. Preliminary data suggests that, while some insecticides may bioaccumulate to relatively high levels, most herbicides do not (Ghassemi et al., 1981).

The water quality impacts from pesticide applications are both direct and indirect. Direct effects include toxicity to aquatic organisms and contamination of drinking waters. Runoff waters containing herbicides may cause a die-off of aquatic vegetation in receiving waters. This may result in an oxygen depletion as the vegetation decomposes and may alter the species composition of the aquatic habitat as food sources, breeding areas, and shelter are removed from the aquatic habitat. There is very little information available on the toxicity of herbicides to aquatic plants.

Another complicating factor is that many States use herbicides in combinations for more effective vegetation control. All toxicity data available are for single compounds, yet the mixture of several chemicals may cause more serious additive or synergistic toxic effects to the aquatic organisms.

Indirect effects to water quality may include a change in the pH of the water (Voorhees, 1982), as well as a change in the dissolved oxygen balance. When use of a herbicide results in the complete elimination of one species, another, less desirable, species may emerge to take its place. Additionally, over a period of time, the target species may develop a resistance to the herbicide necessitating a switch to a different, possibly more toxic, replacement.

Many of the above potential water quality impacts are based on the use of pesticides in agriculture and do not necessarily reflect potential impacts from highway maintenance usage. As part of this research project, field studies were conducted to determine whether two commonly used herbicides, 2,4-D and picloram, (1) are detectable in stormwater runoff from highway rights-of-way following proper application to control broadleaf weeds, and (2) if found, whether the concentrations are toxic to aquatic life. Volume II of this report series, "Investigations of Impacts of Selected Highway Maintenance Practices on Water Quality," (Report No. FHWA/RD-85/058) presents the detailed methods and results of this investigation. The results indicate that the two herbicides are present in runoff several weeks after application, but well below toxic levels for aquatic life. Moreover, dilution of runoff with receiving stream flows would further reduce herbicide concentrations, making aquatic life impacts highly unlikely.

Mitigation measures include alternative application techniques, choice of less toxic and/or less resistant pesticides, and careful attention to the label directions (best management practices). The companion Volume IV, "Guidelines Manual for Minimizing Water Quality Impacts from Highway Maintenance Practices," (Report No. FHWA/RD-85/060) describes mitigation measures such as alternative application techniques and herbicide selection in more detail. In addition, biocontrol techniques, using insect species, may be feasible under some situations to control specific weeds.

Repairing Slopes, Slips, and Slides

These practices have similar potential water quality impacts. The maintenance objective is to restore the integrity of a roadside slope. Slope repair is usually minor, requiring only the filling of gullies or sloughs with topsoil and the reestablishment of vegetation. Slope repair may also require cutting an interceptor ditch to eliminate erosion gullies. It is often necessary to drive stakes or pickets down into the existing slope to help retain new material. Slip-and-slide repair constitutes a major repair of a large-scale dislocation of earth on either side of the roadway. A slip or slide is usually serious enough to threaten the structural integrity of the roadway. Slip-and-slide repair can involve driving of piling, placing retaining walls, and using rock fills to stabilize the slope. Removal and replacement of the entire soil mass may be necessary to locate and reroute the water source causing soil slippages. Repair also involves replacing the dislocated soil mass and reestablishing vegetation. All of these activities may require the use of heavy earthmoving equipment, soil, rock, seed, mulches, emulsions, and fertilizers.

The primary water quality impact is soil erosion resulting in increased sediment load to the receiving water. Slips and slides probably pose a greater threat to water quality because they usually occur in valleys near streams. In any event, water quality may well have been impacted prior to the onset of repair work due to the exposure of soils as a result of natural phenomenon. However, the repair is likely to increase the sediment load to the water in the short term because it is necessary to add soil and, in severe cases, to excavate large areas of the slopes increasing the potential for erosion. The reestablishment of vegetation may increase the amount of nutrients entering the stream, especially if fertilizers are used.

This repair activity is carried out to restore the structural integrity of the roadway and eliminate the erosion resulting from the original damage. The best mitigation measures are probably the maintenance practices themselves. However, during the repair phase when the greatest amount of disturbance is taking place, it may be necessary to install interceptor ditches, retention basins, sediment traps, and silt fences, to reduce sediment entering the waterways. A conscientious effort to promptly establish vegetation or riprap bare slopes when the repair is complete will reduce subsequent erosion, thus protecting the water quality and the integrity of the repaired slope.

ASSESSMENT METHODS

Assessing the magnitude of the expected water quality impacts from a particular highway maintenance activity is dependent on (1) where the maintenance activity occurs and (2) how the maintenance objective is accomplished (e.g., extent, duration, materials, equipment, procedures). Assessing the significance of the expected water quality impacts is dependent on the magnitude of the impact and the resource value of the receiving water body.

The resource value of a body of water is based on several factors: the ability of the habitat to support fish and wildlife populations, the desirability of the populations it supports (e.g., sport fish vs. rough fish), and the suitability of the water body for specific human uses such as recreation, navigation, source of drinking water, etc. A water body which supports a desirable mix of fish species, serves as a prime recreational resource, and provides drinking water to a municipality will have a significant resource value. A water body which is degraded to the point that it supports only rough fish and is suitable for navigation or industrial water supplies will have a lower value. Assessing the significance of water quality impacts from maintenance impacts to waters with high resource values will be biologically, economically, and socially more important.

The assessment of highway maintenance-generated water quality impacts centers on the determination of the habitat resource value through a specific habitat evaluation assessment. To more accurately assess habitat response to impacts may require one or more assessment methods of specific activities (bridge painting assessment, herbicide assessment, nutrient loading assessment, and sediment loading assessment methods). These four specific methods can be used in appropriate combination to define the magnitude of the expected water quality impacts from specific activities. Figure 4 illustrates the general scheme of this assessment procedure.

The expected impacts from some maintenance activities are not easily quantifiable (no specific method is available). In these cases, exercising best professional judgment is required. By comparing the maintenance activities to the criteria used for determining probable water quality impact, the potential impacts to water resources can be

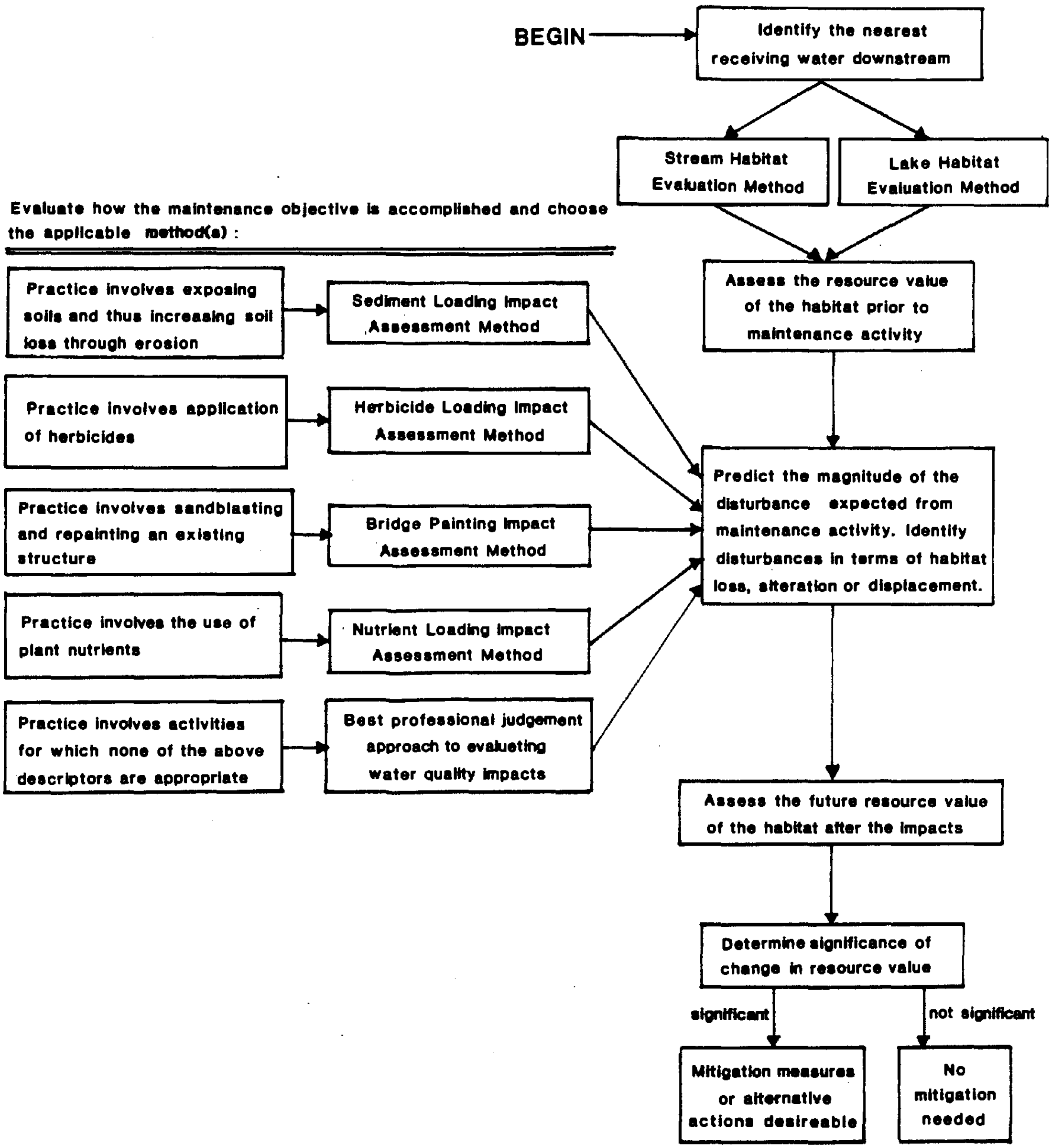


Figure 4. General impact assessment method for evaluating potential impacts to water quality from highway maintenance practices.

identified. Comparing these potential impacts to the key variables for the habitat in question allows the interested official to estimate the change in resource value. This decision-making process is carried out with a specific site and a specific maintenance activity in mind. The final estimation of the magnitude of the expected impacts will be based on best professional judgment, rather than on absolute quantities or concentrations of pollutants.

The remainder of this section will be comprised of the habitat evaluation assessment method followed by the four specific methods available for defining the magnitude of impacts from specific activities. For each assessment method, sample calculations are presented to enhance one's understanding of the procedure. In addition, calculation worksheets for each method are provided to permit highway agency personnel to perform impact assessments based on situation-specific data.

HABITAT EVALUATION ASSESSMENT METHOD

Introduction

The habitat evaluation assessment has three basic goals:

(1) Assess the resource value of the undisturbed habitat of the nearest receiving water downstream of the expected impact.

(2) Predict what effects the disturbance expected from the maintenance practice might have on the habitat in terms of habitat loss, alteration, or displacement.

(3) Assess the value of the disturbed habitat and determine if the difference in resource values constitutes a significant impact.

The method presented is based on the principles set forth in the Habitat Evaluation System (HES) as adapted by the U.S. Army Corps of Engineers (COE, 1980) from the Fish and Wildlife Service Habitat Evaluation Procedure (HEP) (Raleigh, 1978). The HES operates on three basic assumptions: (1) the presence or absence, and abundance and diversity, of animal populations in a habitat or community is determined by basic biotic and abiotic factors that can be quantified; (2) if the necessary habitat requirements for a species are present, then a viable population will be, or could be, supported by that habitat; and (3) general habitat characteristics can be used to indicate the quality of a habitat and its ability to support fish and wildlife populations.

The HES method determines the quality of a habitat type using functional curves relating habitat quality to quantitative biotic and abiotic characteristics of the habitat. The habitat size and quality are combined to assess project impacts. The general HES method, which is applied to each specific habitat type, is as follows:

Step 1. Determine habitat type or land use areas.

Step 2. Derive habitat quality index (HQI) scores for each habitat type or land use category. Key variables (Table 8) are converted into a HQI score using a specific functional curve (see Appendix B, Figures 9 to 22, pages 118 to 131). Each HQI score is assigned a weight factor which reflects the relative importance of that key variable to habitat quality. The weighted HQI scores are summed and divided by 100 to yield an aggregate HQI score for the habitat type.

Table 8. Aquatic ecosystem key variable weights for streams.

Variables	Weights[a]
1. Fish Species Association	30
2. Sinuosity Index	20
3. Total Dissolved Solids	20
4. Turbidity	10
5. Chemical Type	10
6. Benthic Diversity	10[b]

Source: COE, 1980.

[a] Weights for stream variables may be reassigned based on knowledge of local area and other considerations.

[b] If sufficient information on benthic populations is not available to derive a diversity index, this variable may be eliminated and the other variable weights reassigned based on knowledge of the local area. One simple reassignment would be to distribute the diversity weight (10) over the remaining five in proportion to their relative weight (i.e., 34, 22, 22, 11, 11).

Step 3. The area of a given habitat type is multiplied by the aggregate HQI to obtain a Habitat Unit Value (HUV) for the habitat.

Step 4. An HUV is projected for the future, taking into account the impacts expected from the maintenance practice in question. The four specific assessment methods are used in evaluating the future HUVs. Projected HUVs are based on estimated changes in habitat type due to such influences as channel dredging, sediment loading, addition of toxic materials, etc.

Step 5. The HUV is used to assess impacts from the maintenance practice (HUV after practice - HUV before practice = impact)

Step 6. The significance of the impact on the resource value of the habitat is evaluated and possible mitigation requirements examined.

Conducting an HES evaluation for streams and lakes requires obtaining data on basic chemical, physical, and biological features of the receiving water bodies for key variables. The key variables used in aquatic evaluations for streams and lakes are covered below. The presentation for each is designed to relate habitat characteristics to habitat quality and aesthetic and recreational uses.

Stream Habitat Evaluation Method

If the nearest downstream receiving water is a stream, then this method is appropriate. (If the receiving water is a lake, then the lake habitat evaluation method should be used.) This method consists of the six steps outlined above. If applicable, one or more of the four specific methods will be incorporated in Step 4 to determine the overall impact of the maintenance activity on the resource value of the receiving stream.

Step 1. Calculate the area of the receiving water body expected to be impacted by the maintenance practice in question. Calculate the surface area from the point of entry of runoff water or pollutants from the maintenance activity downstream to the first major tributary (tributary of equal or higher stream order (Hynes, 1970)). Calculate the area using a planimeter and USGS topographic maps, COE navigation charts, or aerial photographs.

Step 2. Derive the HQI for the receiving water body using the key variables and weights in Table 8.

2a. Fish Species Association - The fish species composition of a stream is an indicator of the overall quality of the stream habitat. A stream dominated by rough fish such as carp or gar is considered to be of lower quality than a stream with a well-balanced mix of sport and commercial fish (COE, 1980). Sources for local fisheries information include:

- Regional Fish and Wildlife Service (FWS)
- State natural resources department
- BIOSTORET (computerized database accessible through regional or State EPA)
- Local fisheries experts such as universities
- Fish distribution information (i.e., Lee et al., 1980)
- Field sampling

(i) Analyze the available fish data to determine the species association typical of the stream. Classify the stream fish association into one of the five species associations described in Table 9. A stream characterized by the first species association would have a higher resource value because of the greater abundance of desirable fish species. Conversely, a stream characterized by the fifth species association (rough fish) would have a lower resource value due to the undesirable fish species.

Table 9. Fish species associations for habitat evaluation of a stream.[a]

Species association	Description
1. Smallmouth/rock bass	The dominant large fish of the stream community are generally hog suckers and redhorses. The most abundant centrarchids in terms of biomass are usually the longeared sunfish, rock bass, and smallmouth bass. Largemouth bass and bluegill may also be present if large quiet pool habitats occur, but are few in number. Catfishes are typically represented by the yellow bullhead and various species of madtoms. Numerous species of minnows and darters comprise the assemblage of small fishes.
2. Spotted/rock bass	This association is typically found in somewhat more turbid and warmer lowland and hill streams than the smallmouth bass association. Characteristic large fishes include blue and channel catfish, spotted and redhorse suckers, buffalo fishes, and river carp sucker; gizzard shad may also be present. Dominant sunfishes include spotted bass, longear sunfish, spotted sunfish, rock bass, and black and white crappie.
3. Largemouth bass/bluegill	This association is found in more sluggish alluvial streams with relatively high silt load and high summer temperatures. Gizzard shad, longnose and shortnose gar, river carp sucker, freshwater drum, buffalo fishes, channel, blue and flathead catfishes are the most abundant large fishes. Dominant sunfishes include white bass, largemouth bass and bluegill (found mainly in pools, floodplain lakes, and channel habitats having low current velocity), black and white crappie, and longear sunfish. Numerous species of shiners and minnows are among the common small fishes.
4. White crappie/warmouth	This association is characteristic of sluggish, turbid, and silt-laden streams in lowland regions. Large fishes that are most abundant include gizzard shad, buffalo fishes, carp, freshwater drum, channel catfish, and bullheads. Warmouth, white crappie, orangespotted sunfish, and bluegill are the dominant sunfishes. Largemouth bass and spotted bass are absent or occur in very small numbers, i.e., about one percent or less of total numbers.
5. Rough fish	This association is typical of highly degraded streams characterized by one or more polluted conditions including heavy silt loads, comparatively large concentrations of biocides and other toxic chemicals, sewage, and industrial wastes. Carp, bowfin, gar, and bullheads are common dominant fish species. Few or no sunfishes are present.

Source: COE, 1980.

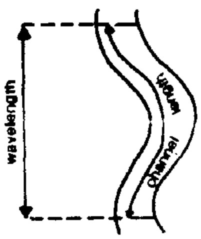
[a] These fish associations may be changed dependent upon local conditions. Consult the regional FWS or DNR for information on species associations characteristics of a given area.

(ii) Obtain the appropriate HQI score from the functional curve for fish species associations (see Figure 9, Appendix B, page 118).

(iii) Multiply the HQI by the weight factor in Table 8 to obtain the weighted HQI.

2b. <u>Sinuosity Index</u> - The sinuosity index (SI) is an indicator of habitat diversity. It is associated with stream gradient, width, velocity, and points of erosion and deposition (Hynes, 1970). The more sinuous a stream, the more aquatic habitat there is available per unit length.

(i) Derive an SI for the length of stream expected to be impacted using a USGS topographic map, COE navigation charts, or aerial photographs. A cartometer is useful for measuring the channel and wavelengths.



$$SI = \frac{\text{length of natural stream channel}}{\text{average wavelength of the meanders}} \qquad (1)$$

(ii) Obtain the appropriate HQI score from the functional curve for stream sinuosity (see Figure 10, Appendix B, page 119).

(iii) Multiply the HQI by the weight factor in Table 8 to obtain the weighted HQI.

2c. <u>Total Dissolved Solids (TDS)</u> - In freshwater systems TDS consist of the dissolved inorganic salts (including nutrients) and small amounts of organic matter. Generally, TDS are proportional to the productivity of a water body (Hynes, 1970).

(i) Obtain average yearly TDS data from agencies monitoring local water quality. Sources include local environmental agencies with access to STORET, and USGS-published maps giving average TDS values for a watershed (COE, 1980). If available, STORET data or other actual sampling data are preferable to published maps in determining TDS because they take into account upstream sources of TDS. USGS-published maps give TDS values based solely on the geomorphology of the watershed (COE, 1980).

(ii) Obtain the appropriate HQI score from the functional curve for TDS (see Figure 11, Appendix B, page 120).

(iii) Multiply HQI by the weight factor in Table 8 to obtain the weighted HQI.

2d. Turbidity - Excessive turbidity and suspended solids concentrations may result in reduced light penetration, increased nutrient concentrations, depressed dissolved oxygen, and numerous other physical and chemical responses. Major changes in the turbidity of a water body will generally result in alteration of the aquatic community. Data on stream turbidity can be obtained from USGS, EPA (STORET), and State water quality monitoring agencies (COE, 1980).

If field turbidity determinations are necessary, measurements should be taken at several points along the stream. These data should be averaged to obtain a final turbidity value for the stream.

(i) Calculate final turbidity value for the stream.

(ii) Obtain the appropriate HQI score from the functional curve for turbidity (see Figure 12, Appendix B, page 121).

(iii) Multiply the HQI by the weight factor in Table 8 to obtain the weighted HQI.

2e. Chemical Type - The different chemical types of U.S. waters are attributable to the the geologic make-up of the drainage basin. Rainwater (1962) divided U.S. waters into four chemical types dependent on the dominant cation:anion species of the dissolved solids: Type 1, calcium-magnesium, carbonate-bicarbonate; Type 2, calcium-magnesium, sulfate-chloride; Type 3, sodium-potassium, carbonate-bicarbonate; and Type 4, sodium-potassium, sulfate-chloride. Type 1 waters are generally more productive than other chemical types (Reid and Wood, 1976). Therefore, the general chemical type of a stream may be used as the factor in evaluating potential productivity of the habitat (COE, 1980).

Chemical type data are available from USGS, EPA, and State water-quality monitoring agencies. If chemical type data are not available locally, consult Rainwater (1962) for data on watersheds throughout the country. Chemical type can also be determined through a field-sampling program.

(i) Determine chemical type of stream (Type 1, 2, 3, or 4).

(ii) Convert chemical type to HQI using appropriate functional curve (see Figure 13, Appendix B, page 122).

(iii) Multiply HQI by the appropriate weight factor in Table 8 to obtain weighted HQI.

2f. Benthic Diversity - Diversity is a function of species evenness and richness. The most common diversity index is the Shannon-Weaver Diversity Index ($\bar{d}$). The index value is an indicator of the quality and diversity of the available habitat. Data on benthic populations is best obtained through a field survey. If sufficient benthic populations data are not available to calculate the diversity index, and field sampling is not a viable alternative, then this key variable may be eliminated and the remaining variable weights reassigned.

(i) Calculate the Shannon-Weaver diversity index for the stream. For the best results, $\bar{d}$ values should be averaged over all sampling stations in the affected area.

$$\bar{d} = - \sum_{i}^{i=1} P_i \log_2 P_i \qquad (2)$$

where P_i = proportion of the ith species in the sample.

The Shannon-Weaver index is used because it is a widely accepted diversity index. Identification of organisms to species is not necessary; identifications to higher taxonomic levels (e.g., Orders) or simple groupings by gross morphology will yield acceptable $\bar{d}$ values for purposes of this assessment method, provided all receiving waters being evaluated are compared at the same taxonomic levels.

(ii) Obtain an HQI score from the functional curve for benthic diversity (see Figure 14, Appendix B, page 123).

(iii) Multiply the HQI by the appropriate weight factor in Table 8 to obtain weighted HQI.

2g. Aggregation of the Habitat Quality Indices - Sum the weighted HQI values for Step 2 and divide by 100 to obtain the aggregate HQI for the stream.

Step 3. Multiply the area of receiving water body (Step 1) by the aggregate HQI (Step 2) to yield the undisturbed Habitat Unit Value (HUV) for the habitat.

Step 4. If a specific method (i.e., bridge, herbicide, sediment, nutrient) is applicable, evaluate the impacts expected. Compare the increased loading or concentrations to existing conditions.

Determine which key variables will be affected and, if possible, to what degree. Recalculate the HUV using the new HQI values for the affected key variables.

If expected impacts from some maintenance practices cannot be quantified because no specific method is given, exercise best professional judgment in assessing expected impacts. Compare the expected impacts to the key variables for the habitat type in question, determine which variables are likely to be changed and in which direction. Examine the functional curve for each key variable, and determine what effect the expected change will have on the HQI and subsequently on the final HUV.

Step 5. Assess the impacts from the maintenance practice by subtracting the original HUV (Step 3) from the impacted HUV (Step 4).

$$HUV_{after\ m.p.} - HUV_{before\ m.p.} = \text{potential impact} \qquad (3)$$

Step 6. Evaluate the significance of the impact. This final determination of significance will be dependent on the original HUV of the stream. This determination must take into consideration the resource value of the stream to humans and its importance to the ecosystem (watershed). In some cases, a slight decrease in HUV may be sufficient to make the habitat undesirable for preferred fish species associations. On the other hand, a stream with a fairly low HUV originally may not suffer any adverse effects from the same maintenance impacts. The determination of significance must take place on a case-by-case basis taking many factors into account.

Sample Calculations - Stream Habitat Evaluation Method

Step 1. Receiving water area = 0.3 acres.

Step 2. Derivation of aggregate HQI.

	Variable	HQI	Weight Factor	Weighted HQI
Step 2a.	Fish species association = largemouth bass/bluegill	0.62	30	18.6
Step 2b.	Sinuosity index (SI)			
	$SI = \frac{1{,}295 \text{ ft stream length}}{810 \text{ ft wave length}}$			
	SI = 1.6	0.12	20	2.4
Step 2c.	Total dissolved solids (TDS) = 95 ppm	0.86	20	17.2
Step 2d.	Turbidity = 120 JTU	0.55	10	5.5
Step 2e.	Chemical type = 2	0.6	10	6
Step 2f.	Benthic diversity Shannon-Weaver diversity index = 2.6	0.79	10	7.9

Step 2g. Aggregate HQI = $\frac{18.6 + 2.4 + 17.2 + 5.5 + 6 + 7.9}{100}$

= 0.58

Step 3. HUV derivation

HUV = 0.3 acres x 0.58 aggregate HQI

$HUV_{before\ m.p.}$ = 0.17

Step 4. $HUV_{after\ m.p.}$ = 0.22

Step 5. $\text{Potential impact}_{after\ m.p.}$ = 0.22

${}_{after\ m.p.}$ − 0.17 ${}_{before\ m.p.}$ = 0.05

Calculation Worksheet - Stream Habitat Evaluation Method

Step 1. Receiving water area = ________ acres.

Step 2. Derivation of aggregate HQI.

Variable	HQI	Weight Factor	Weighted HQI
Step 2a. Fish species association = ________________________	_____	30	_________
Step 2b. Sinuosity index (SI)			
$SI = \frac{\_\_\_\_\_ \text{ ft stream length}}{\_\_\_\_\_ \text{ ft wave length}}$			
SI = _____	_____	20	_________
Step 2c. Total dissolved solids (TDS) = _____ ppm	_____	20	_________
Step 2d. Turbidity = _____ JTU	_____	10	_________
Step 2e. Chemical type = _____	_____	10	_________
Step 2f. Benthic diversity Shannon-Weaver diversity index = _____	_____	10	_________

Step 2g. Aggregate HQI = $\frac{\_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_}{100}$

= _____

Step 3. HUV derivation

HUV = _____ acres x _____ aggregate HQI

$HUV_{before\ m.p.}$ = _____

Step 4. $HUV_{after\ m.p.}$ = _____

Step 5. Potential impact$_{after\ m.p.}$ = _____

$_{after\ m.p.}$ − _____ $_{before\ m.p.}$ = _____

Lake Habitat Evaluation Method

If the nearest downstream receiving water is a lake or pond, this method is appropriate. It would also be appropriate to use both the lake and stream habitat evaluation methods if the pollutants from the maintenance activity first enter a stream and then move directly to a pond or lake without confluence with a stream of equal or higher order. The method again has six steps. If applicable, one or more specific methods (i.e., bridge painting, herbicides) will be incorporated in Step 4 to determine the overall impact of the maintenance activity on the resource value of the lake or pond.

Step 1. Calculate the area of the receiving water body using a planimeter and USGS topographic maps or aerial photographs. Use the entire surface area of the lake or pond.

Step 2. Derive the HQI for the lake using the key variables and weights in Table 10.

Table 10. Aquatic ecosystem key variable weights for lakes.

	Variables	Weights[a]
1.	Total Dissolved Solids	30
2.	Spring Flooding Index	20
3.	Mean Depth	15
4.	Turbidity	15
5.	Chemical Type	15
6.	Shoreline Development Index	5
7.	Total Fish Standing Crop	a
8.	Sport Fish Standing Crop	a

Source: COE, 1980.

[a] If fish data are available, weights may be reassigned or the fish data may be used solely to determine habitat quality.

2a. Total Dissolved Solids (TDS) - In freshwater systems TDS consists of the dissolved inorganic salts (including nutrients) and small amounts of organic matter. Generally, TDS are proportional to the productivity of a water body (Hynes, 1970).

(i) Obtain value for TDS from agencies monitoring local water quality (EPA, DNR, USGS, COE, etc.).

(ii) Determine the HQI from the functional curve in Figure 15 (Appendix B, page 124).

(iii) Multiply the HQI by the weight factor in Table 10 to obtain the weighted HQI.

2b. Spring Flooding Index - Flooding above the normal shoreline in lakes is important in that it provides spawning and nursery areas for lake fish populations. Spring flooding expands the shallow water habitat of the lake during the critical reproductive season and eliminates the limiting factors of space, predation, and available food (COE, 1980).

(i) Calculate the flooding index (FI):

$$FI = A \times D \quad \text{where, } A = \text{flooded area as a percent of normal lake area (acres)}, \quad D = \text{duration of flooding (days)} \tag{4}$$

Data on flooded areas may be available from area water resources agencies or lake associations. If this information is not available, approximate acreages may be derived using topographic maps of the area. Water surface elevation for the flood period (from gage readings) can be plotted on topographic maps and contoured. Compute the surface area between the lake shore and the flooding contour using a planimeter (COE, 1980). If water surface elevation information is not available, estimate the floodplain area by examining the distribution of floodplain plant species (contact the local DNR) or hydrosoil types on soil maps (contact local SCS). These distributions will approximate the boundaries of flooded areas and allow the area of inundation to be calculated.

(ii) Obtain the HQI from the functional curve for spring flooding in Figure 16 (Appendix B, page 125).

(iii) Multiply the HQI by the weight factor in Table 10 to obtain the weighted HQI.

2c. Mean Depth - The mean water depth of lakes is generally related to the quality of the habitat for fish populations, recreational uses, and basic ecological characteristics. Very shallow lakes may be subject to nuisance growths of aquatic plants, are typically low in sport fish populations, and are of limited recreational value (COE, 1980).

Mean water depth should be calculated for the average water level elevation.

(i) Determine mean depth for the lake in question. This value is usually available from USGS, COE, EPA, or other local authorities. Depth information may also be available from hydrograph surveys, topographic maps, and navigation charts. It can also be measured by sounding line or electronic depth meter if fieldwork is appropriate.

(ii) Compare the mean depth to the functional curve in Figure 17 (Appendix B, page 126) to obtain HQI.

(iii) Multiply the HQI by the weighting factor in Table 10 to yield weighted HQI.

2d. Turbidity - Excessive turbidity and suspended solids concentrations may result in reduced light penetration, increased nutrient concentrations, depressed dissolved oxygen, and numerous other physical and chemical responses. Major changes in the turbidity of a water body will generally result in alteration of the aquatic community. Data on stream turbidity can be obtained from USGS, EPA (STORET), and State water quality monitoring agencies (COE, 1980).

If field turbidity determinations are necessary, measurements should be taken at several points along the stream. These data should be averaged to obtain a final turbidity value for the stream.

(i) Obtain turbidity values from EPA (STORET), USGS, COE, or through field sampling program.

(ii) Determine HQI by comparing turbidity value to functional curve in Figure 18 (Appendix B, page 127).

(iii) Multiply HQI by the weighting factor in Table 10 to yield weighted HQI.

2e. Chemical Type - The different chemical types of U.S. waters are attributable to the geologic make-up of the drainage basin. Rainwater (1962) divided U.S. waters into four chemical types dependent on the dominant cation:anion species of the dissolved solids: Type 1, calcium-magnesium, carbonate-bicarbonate; Type 2, calcium-magnesium, sulfate-chloride; Type 3, sodium-potassium, carbonate-bicarbonate; and Type 4, sodium-potassium, sulfate-chloride. Type 1 waters are generally more productive than other chemical types (Reid and Wood, 1976). Therefore, the general chemical type of a stream may be used as the factor in evaluating potential productivity of the habitat (COE, 1980).

Chemical type data are available from USGS, EPA, and state water-quality monitoring agencies. If chemical type data is not available locally, consult Rainwater (1962) for data on watersheds throughout the country. Chemical type can also be determined through a field-sampling program.

(i) Obtain chemical type value from local water quality agencies (EPA, USGS, COE, etc.).

(ii) Determine HQI by comparing type value to functional curve in Figure 19 (Appendix B, page 128).

(iii) Multiply HQI by the weighting factor in Table 10 to yield weighted HQI.

2f. <u>Shoreline Development Index</u> - The shoreline development index (SDI) is a function of the degree of irregularity of the shoreline and is associated with the amount of shallow, littoral habitat available. Littoral areas are valuable habitat for fish spawning, nursery, and feeding activities.

The SDI is the ratio of actual shoreline length of the lake perimeter to the circumference of a circle with the same area as the lake.

(i) Calculate the SDI for the lake in question using topographic maps or aerial photographs. Use a cartometer to measure the perimeter of the shoreline.

$$SDI = \frac{S}{3.5449 \sqrt{A}} \quad (5)$$

where S = actual length or perimeter of shoreline (ft or m)

A = actual surface area of lake (ft^2 or m^2) (from Step 1)

(ii) Estimate a HQI score from the SDI functional curve in Figure 20 (Appendix B, page 129).

(iii) Multiply the HQI score by the weighting factor in Table 10 to obtain weighted HQI.

2g. Aggregation of Habitat Quality Indices - Sum the weighted HQI scores from Step 2 and divide by 100 to obtain the aggregate HQI for the lake. (If fish standing crop data are available from local conservation agencies then use the fish data alone, or reassign variable weights in Table 10 to include standing crop data, to determine HQI [Figures 21 and 22, Appendix B, pages 130, 131]. If this information is not readily available, it is considered too costly to obtain for the purpose of a preliminary assessment.)

Step 3. Multiply the area of the lake (Step 1) by the aggregate HQI (Step 2) to yield the habitat unit value (HUV) for the habitat.

Step 4. Estimate expected effects to key variables from maintenance activities. If a specific method is applicable, evaluate the impacts expected using the appropriate method. If expected impacts from some maintenance practices cannot be quantified because no specific method is given, exercise best professional judgment in assessing expected impacts. Recalculate the HUV (Step 3) using the revised key variable values.

Step 5. Assess the impacts from the maintenance practices by subtracting the original HUV (Step 3) from the revised HUV (Step 4). The difference is the change in habitat value expected from the maintenance practice.

Step 6. Evaluate the significance of the impact in terms of the change in HUV and human uses. A lake with a high resource value (high HUV) might warrant greater mitigation measures than one of low resource value (low HUV).

Sample Calculations - Lake Habitat Evaluation Method

Step 1. Lake or pond area = 22 acres = 958,320 ft^2

Step 2. Derivation of aggregate HQI

	Variable	HQI	Weight Factor	Weighted HQI
Step 2a.	Total dissolved solids (TDS) = 35 ppm	0.32	30	9.6
Step 2b.	Spring flooding index (FI) A = 4 acres D = 26 days FI = 4 acres x 26 days FI = 104	0.14	20	2.8
Step 2c.	Mean depth = 6 ft	0.6	15	9
Step 2d.	Turbidity = 50 JTU	1.0	15	15
Step 2e.	Chemical type = 2	0.6	15	9
Step 2f.	Shoreline development index (SDI) S = 2,462 ft A = 958,320 ft^2 $SDI = \frac{2{,}462 \text{ ft}}{3.5449 \sqrt{958{,}320 \text{ ft}^2}}$ SDI = 0.71	0.08	5	0.4

Step 2g. Aggregate HQI = $\frac{9.6 + 2.8 + 9 + 15 + 9 + 0.4}{100}$

= 0.45

Step 3. HUV derivation

HUV = 22 acres x 0.45 aggregate HQI

$HUV_{before\ m.p.}$ = 9.9

Step 4. $HUV_{after\ m.p.} = \underline{0.61}$

Step 5. Potential impact = $\underline{0.61}_{after\ m.p.} - \underline{0.45}_{before\ m.p.} = \underline{0.16}$

Calculation Worksheet - Lake Habitat Evaluation Method

Step 1. Lake or pond area = ______ acres = _________ ft^2

Step 2. Derivation of aggregate HQI

	Variable	HQI	Weight Factor	Weighted HQI
Step 2a.	Total dissolved solids (TDS) = ______ ppm	_____	30	_________
Step 2b.	Spring flooding index (FI) A = _____ acres D = _____ days FI = _____ acres x _____ days FI = _____	_____	20	_________
Step 2c.	Mean depth = _____ ft	_____	15	_________
Step 2d.	Turbidity = _____ JTU	_____	15	_________
Step 2e.	Chemical type = ______	_____	15	_________
Step 2f.	Shoreline development index (SDI) S = __________ ft A = __________ ft^2 SDI = (_______________ ft) / (3.5449 √(__________ ft^2)) SDI = ______	_____	5	_________

Step 2g. Aggregate HQI = (_____+_____+_____+_____+_____+_____) / 100

= _____

Step 3. HUV derivation

HUV = _____ acres x _____ aggregate HQI

$HUV_{before\ m.p.}$ = _____

Step 4. HUV $_{after\ m.p.}$ = ______

Step 5. Potential impact = ______ $_{after\ m.p.}$ −

______ $_{before\ m.p.}$ = ______

SPECIFIC METHODS

Introduction

Each of the four following specific methods presents a worst case analysis. This approach is used because if no impacts are found using entirely worst-case assumptions, then no impacts will occur under more realistic conditions.

Bridge Painting Impact Assessment Method

The method presented below is designed to estimate the effects of blasting materials and abrasives entering a stream during a bridge painting project. For a worst-case analysis, the method assumes that 100 percent of the blasting material will fall into the water body.

Step 1. Estimate the quantity of blasting material required to clean the bridge surface to base metal. This may be made either by (1) multiplying the area to be treated by a typical abrasive application rate, or (2) using data obtained from previous projects of similar scope.

Step 2. Using the sediment loading impact assessment method from this manual, estimate other solids loads from the watershed during the blasting period. (Use 'cover' and 'erosion index' variable values appropriate for the months in question and multiply estimated annual load by the fraction of the year during which the blasting activity is taking place.)

Step 3. Calculate the percent increase in sediment load due to the bridge blasting activity.

Step 4. Evaluate the resource value of the undisturbed habitat using the habitat evaluation assessment method. Based on the undisturbed habitat value, determine the significance of the sediment load to the stream from the blasting activity. If a significant change in habitat value is expected, then consider the maintenance practice impact to be significant.

Sample Calculations - Bridge Painting Impact Assessment Method

Step 1. Quantity of blasting material = 36 tons.

Step 2. Watershed solids load based on sediment loading impact assessment method presented in this manual

Annual solids load from watershed = 1,000,000 lbs

Load for duration of blasting operation =

$$1{,}000{,}000 \text{ lb solids/yr} \times \frac{60 \text{ day duration}}{365 \text{ days/yr}} \times \frac{1 \text{ ton}}{2{,}000 \text{ lb}} = 82 \text{ ton/ } 60 \text{ - day period}$$

Step 3. Percent increase of sediment load

Quantity of blasting material	=	36	tons
Watershed solids load	=	82	tons
Total sediment load	=	118	tons
Percent increase	=	44	

Calculation Worksheet - Bridge Painting Impact Assessment Method

Step 1. Quantity of blasting material = ______ tons.

Step 2. Watershed solids load based on sediment loading impact assessment method presented in this manual

Annual solids load from watershed = __________ lbs

Load for duration of blasting operation =

$$\_\_\_\_\_\_\_\_\_\_\_\_ \text{ lb solids/yr} \times \frac{\_\_\_ \text{ day duration}}{365 \text{ days/yr}} \times$$

$$\frac{1 \text{ ton}}{2{,}000 \text{ lb}} = \_\_\_\_\_\_\_\_ \text{ ton/}\_\_\_\_\_\_ \text{ - day period}$$

Step 3. Percent increase of sediment load

Quantity of blasting material = ________ tons
Watershed solids load = ________ tons
Total sediment load = ________ tons
Percent increase = ________

Herbicide Applications Impact Assessment Method

The method presented below is designed for a herbicide application program of considerable size, not just one application site or spot treatments.

A. Loading estimation

Step 1. Area estimates.

a. In consultation with maintenance personnel and design engineers determine the probable targets of herbicide application (areas around guardrails, grassy slopes, etc.).

b. Estimate area (A) (acres) of each application target within drainage basin.

Step 2. In consultation with maintenance personnel, determine probable herbicide compounds and formulations to be used (e.g., 2,4-D amine solution).

Step 3. Determine application rate for each compound (from maintenance records or manufacturer's labels).

Step 4. Multiply application rate (R) by target area (A) to obtain quantity of herbicide applied (L_A).

$$R \times A = L_A \text{ (kg/application)} \quad (6)$$

Step 5. Multiply loading/application (L_A) by expected number of applications (from maintenance records or manufacturer's labels) to obtain yearly loading (L_Y) in kg/yr.

Step 6. From Table 11 estimate the percent of the herbicide lost via runoff for each compound and formulation. These values represent runoff losses (water and sediment portions) expected from agricultural fields and are greater than those expected from a vegetated highway right-of-way. Thus, they represent a worst-case analysis.

Step 7. Multiply percent loss by yearly loading (L_Y) to obtain loading to receiving waters (L_w).

$$L_Y \times \text{percent loss in runoff} = L_w \text{ (kg/yr)} \quad (7)$$

Table 11. Seasonal runoff losses of pesticides.

Compound	Formulation	Percentage of amount applied lost via runoff: Mean	Range
Atrazine	Powder dispersed in water	3.19	0.19-15.9
Carbaryl	Granules	0.15	--
2,4-D (amine salt)	Solution	0.21	0.04-0.33
2,4-D (ester)	Emulsion	0.50	0.007-1.0
Diuron	Liquid dispersed in water	0.06	0.03-0.10
Ferrac (salt)	Solution	1.45	0-2.9
Methoxychlor	Emulsion	0.005	--
MSMA	Solution	1.20	0.1-2.0
Paraquat	Solution	6.91	0.91-22.0
Picloram (salt)	Pellets	4.50	--
Picloram (salt)	Solution	0.010	0.002-0.007
Simazine	Powder dispersed in water	3.5	--
Trifluralin	Emulsion	0.22	0-0.76
	Average losses for specific formulations		
--	Wettable powders	2 (slopes ≤10%)	
--	Wettable powders	5 (slopes >10%)	
--	Water insoluble (emulsions)	1	
--	Water soluble (solutions)	0.5	

Source: Wauchope, 1978.

B. Runoff concentration estimation

Step 1. Estimate total (mean) annual runoff from target area using the following equation (derived from the Rational Method as described in Searcy, 1973):

$$\bar{V} = \frac{(\bar{p})(c)(A)(k)}{12\ \text{in/ft}} \tag{8}$$

where $\bar{V}$ = average annual runoff volume (L/yr)

$\bar{p}$ = mean annual precipitation (in/yr)

A = target area (acres)

c = runoff co-efficient (from Table 12)

k = constant (1.23×10^6) to convert $\frac{acre \cdot ft}{yr}$ to L/yr

Estimate annual average runoff concentration of herbicides:

$$C_R = \frac{Lw}{(V)\ 1 \times 10^6} \tag{9}$$

where C_R = runoff concentration in mg/L

Step 2. Compare estimated annual average runoff concentrations for each herbicide to the lowest available 96-h LC_{50} (Table 13). Concentration in runoff should not exceed 0.1 x 96-h LC_{50} for non-persistent, noncumulative herbicides, or 0.05 x 96-h LC_{50} for persistent or cumulative herbicides (U.S. EPA, 1972). If the runoff concentration does not exceed these limits, then it is reasonable to conclude that there is no significant impact. If the runoff concentration does exceed these then estimate in-stream concentrations.

C. In-stream concentration estimation

Step 1. Obtain average instantaneous stream flow (F_S, cfs) from USGS gaging data or from the National Water Data Exchange (NAWDEX) data base.

Step 2. Estimate instantaneous runoff flow rate in cfs:

$$\frac{(V\ L/yr)(0.035\ ft^3/L)}{(hr/yr\ precipitation)(3{,}600\ sec/hr)} = F_R,\ cfs \tag{10}$$

(Hours of precipitation per year can be obtained from the local weather bureau.)

Step 3. Estimate average in-stream concentration (assume no background concentration).

$$\frac{F_R \times C_R}{F_R + F_S} = C_I\ mg/L \tag{11}$$

Step 4. Compare in-stream concentrations to 96-h LC_{50} data as described in Step B-2. If an apparent impact is still found then mitigation measures (alternative herbicide, alternative application technique, etc.) may be warranted. Evaluate the significance of the impact in terms of the habitat resource value as determined in the habitat evaluation assessment method.

Table 12. Values of runoff coefficients (C) for use in the runoff volume estimation.

Type of surface	Runoff coefficient (C)[a]
Rural Areas	
Concrete or sheet asphalt pavement	0.8-0.9
Asphalt macadam pavement	0.6-0.8
Gravel roadways or shoulders	0.4-0.6
Bare earth	0.2-0.9
Steep grassed areas (2:1)	0.5-0.7
Turf meadows	0.1-0.4
Forested areas	0.1-0.3
Cultivated fields	0.2-0.4
Urban Areas	
Flat residential, with about 30 percent of area impervious	0.40
Flat residential, with about 60 percent of area impervious	0.55
Moderately steep residential, with about 50 percent of area impervious	0.65
Moderately steep built up area, with about 70 percent of area impervious	0.80
Flat commercial, with about 90 percent of area impervious	0.80

Source: Searcy, 1973.

[a] For flat slopes or permeable soil, use the lower values. For steep slopes or impermeable soil, use the higher values.

Table 13. Lowest reported acute toxicities for fish (96-h LC50) and invertebrates (48-h EC50) for insecticides and herbicides used in roadside vegetation control.[a]

Common name	Lowest reported LC50 (ppm)	Lowest reported EC50 (ppm)
Insecticides:		
Methoxychlor	0.0017	0.0008
Diazinon	0.020	0.0008
Malathion	0.027	0.001
Dicofol	0.053	--
Carbaryl	0.069	0.006
Tetradifon	0.88	--
Dimethoate	7.50	--
Acephate	25.5	--
Herbicides:		
Trifluralin	0.009	0.56
2,4-D-ester	0.24	0.40
2,4-D-amine	0.30	0.15
Atrazine	0.36	--
Simazine	0.396	1.10
Terbutryn	0.82	--
Oxadiazon	0.83	--
Diuron	1.4	1.4
Picloram	1.4	--
2,4-D-acid salt	2.0	--
Glyphosate	2.3	3.0
Pramital	2.94	--
Oryzalin	3.14	--
Dichlobenil	5.7	5.8
Fenac	6.08	4.5
Chloflurenal	6.73	--
Diquat	9.96	--
MSMA	12.2	--
DSMA	12.2	--
Paraquat	13.0	3.7
Cacodylic acid	17	--
Dicamba	28	>100
Aminotriazole	40.5	--
Bromoxynil	40.5	--
Bromacil	56.7	--
Dalapon	75.9	11.0
Ureabor	>100	--
Hexazinone	>100	--
Ammate	825	--

[a] The lower the LC_{50} or EC_{50}, the more toxic the pesticide.

Sample Calculations - Herbicide Applications Impact Assessment Method

A. Loading estimation

Step 1. Area estimates

a. Target area type = grassy slope

b. Target area = 6.7 acres

Step 2. Herbicide = 2,4-D amine salt

Step 3. Application rate (R) = 5 lb/acre x 0.45 lbs/kg = 2.25 kg/acre

Step 4. 2.25 kg/acre x 6.7 acres = 15 kg/application

Step 5. 15 kg/application x 2 applications = 30 kg/yr

Step 6. Percent lost via runoff = 0.21

Step 7. 30 kg/yr x 0.21 percent lost = 6.30 kg/yr

B. Runoff concentration estimation

Average annual runoff volume

$\bar{P}$ = 24 in/yr

A = 6.7 acres

C = 0.5

$K = 1.23 \times 10^{6}$

$$\bar{V} = \frac{(24 \text{ in/yr})(0.5)(6.7 \text{ acres})(1.23 \times 10^{6})}{12 \text{ in/ft}}$$

$\bar{V}$ = 8,241,000 L/yr

Average annual runoff concentration

$$C_R = \frac{6.3 \text{ kg/yr}}{(8{,}241{,}000 \text{ L/yr})(1 \times 10^{6} \text{ mg/L})}$$

$C_R = 7.6 \times 10^{-13}$ mg/L

Comparison of runoff concentration with toxicity data

$$\frac{7.6 \times 10^{-13} \text{ mg/L}}{0.1 \times 0.30 \text{ mg/L}} = 2.55 \times 10^{-11}$$

C. In-stream concentration

Step 1. Average instantaneous stream flow

F_S = 120 cfs

Step 2. Instantaneous runoff flow

$$F_R = \frac{(8{,}241{,}000 \text{ L/yr})(0.035 \text{ ft}^3\text{/L})}{(181 \text{ hr/yr})(3{,}600 \text{ sec/hr})}$$

F_R = 0.44 cfs

Step 3. Average in-stream concentration

$$\frac{0.44 \text{ cfs} \times 7.6 \times 10^{13} \text{ mg/L}}{0.44 \text{ cfs} + 120 \text{ cfs}} = 2.78 \times 10^{-15} \text{ mg/L}$$

Step 4. Comparison of in-stream concentration with toxicity data

$$\frac{2.78 \times 10^{-13} \text{ mg/L}}{0.1 \times 0.30 \text{ mg/L}} = 9.27 \times 10^{-12}$$

Calculation Worksheet - Herbicide Applications Impact Assessment Method

A. Loading estimation

Step 1. Area estimates

a. Target area type = ____________________

b. Target area = _____ acres

Step 2. Herbicide = ____________________________

Step 3. Application rate (R) = _____ lb/acre x 0.45 lbs/kg = _____ kg/acre

Step 4. _____ kg/acre x _____ acres = _____ kg/application

Step 5. _____ kg/application x _____ applications = _____ kg/yr

Step 6. Percent lost via runoff = _____

Step 7. _____ kg/yr x _____ percent lost = _____ kg/yr

B. Runoff concentration estimation

Average annual runoff volume

$\bar{P}$ = _____ in/yr

A = _____ acres

C = _____

$K = 1.23 \times 10^6$

$$\bar{V} = \frac{(\_\_\_\_\_ \text{ in/yr})(\_\_\_\_\_)(\_\_\_\_\_ \text{ acres})(1.23 \times 10^6)}{12 \text{ in/ft}}$$

$\bar{V}$ = __________ L/yr

Average annual runoff concentration

$$C_R = \frac{\_\_\_\_\_\_\_\_\_\_\_\_ \text{kg/yr}}{(\_\_\_\_\_\_\_\_\_ \text{ L/yr})(1 \times 10^6 \text{ mg/L})}$$

C_R = __________ mg/L

Comparison of runoff concentration with toxicity data

$$\frac{\rule{3cm}{0.4pt}\ \text{mg/L}}{\rule{1cm}{0.4pt}\ \times\ \rule{1cm}{0.4pt}\ \text{mg/L}} = \rule{2cm}{0.4pt}$$

C. In-stream concentration

Step 1. Average instantaneous stream flow

F_S = __________ cfs

Step 2. Instantaneous runoff flow

$$F_R = \frac{(\rule{2cm}{0.4pt}\ \text{L/yr})(0.035\ \text{ft}^3\text{/L})}{(\rule{2cm}{0.4pt}\ \text{hr/yr})(3{,}600\ \text{sec/hr})}$$

F_R = __________ cfs

Step 3. Average in-stream concentration

$$\frac{\rule{1cm}{0.4pt}\ \text{cfs} \times \rule{2cm}{0.4pt}\ \text{mg/L}}{\rule{1cm}{0.4pt}\ \text{cfs} + \rule{1cm}{0.4pt}\ \text{cfs}} = \rule{3cm}{0.4pt}\ \text{mg/L}$$

Step 4. Comparison of in-stream concentration with toxicity data

$$\frac{\rule{3cm}{0.4pt}\ \text{mg/L}}{\rule{1.5cm}{0.4pt}\ \times\ \rule{1cm}{0.4pt}\ \text{mg/L}} = \rule{2.5cm}{0.4pt}$$

Sediment Loading Impact Assessment Method

Any maintenance activity which involves exposing soils, which will be subject to erosion via overland runoff, may be evaluated using this method. Representative maintenance practices include ditch cleaning and reshaping, repair of slopes, slips, and slides. This method is also suitable for evaluating the impacts of pollutants such as nutrients and metals associated with these eroded soils.

This method is based on an adaptation of the Universal Soil Loss Equation (USLE) (McElroy et al., 1976). The assessment involves a comparison of the sediment and related nutrient load emanating from the maintenance area to that from the remainder of the drainage area. For the purpose of this assessment the drainage area will be defined as the drainage area upstream of the first receiving water potentially impacted by runoff from the maintenance area (Figure 5).

A. Area calculations

Step 1. Outline the drainage area on a USGS topographic map.

Step 2. Using a planimeter, measure the area (acres) of each land use subarea (A_i) in the watershed (e.g., woodland, grassland, urban areas).

Step 3. Using design plans, estimate the area which will be disturbed by the maintenance practice in question.

B. Sediment loading calculations

Step 1. Sediment loading function (McElroy et al., 1976):

$$ys = \sum_{i=1}^{n} [A_i \cdot K \cdot L \cdot S \cdot C \cdot P \cdot S_{d_i})] \qquad (12)$$

where
- ys = sediment load of area under consideration (lbs/acre)
- n = number of subareas in the area
- A_i = acreage of subarea i (Step A-2)
- R = rainfall factor, usually expressed in units of rainfall-erosivity index; EI: (ft ton/acre•in)(maximum 30-minute intensity, in/hr)(10^{-2})
- K = soil-erodibility factor, commonly expressed in ton/acre/EI unit
- L = the slope-length factor, dimensionless ratio

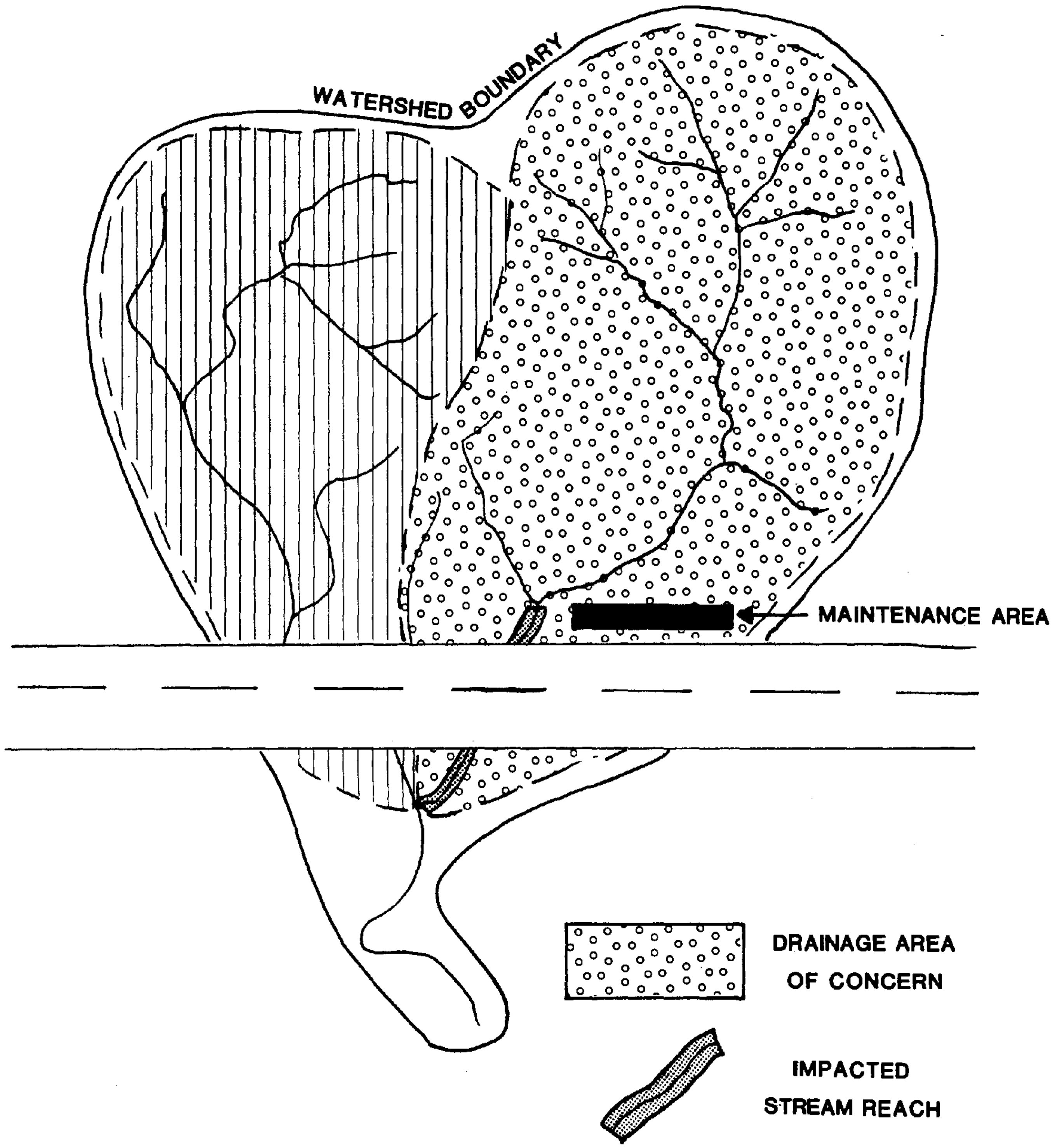


Figure 5. Illustration of drainage area to be used in assessing impacts from highway maintenance activities.

S = the slope-steepness factor, dimensionless ratio
C = the cover factor, dimensionless ratio
P = the erosion control practice factor, dimensionless ratio
S_d = the sediment delivery ratio, dimensionless

a. Rainfall factor (R) expresses the erosion potential of precipitation in an area. Values of the average annual R are plotted in Figure 6. Points lying between the iso-erodents may be approximated by linear interpolation. Use of the average annual R values will yield the average annual load from the area in question.

For the purposes of this assessment a monthly loading comparison would be more appropriate since the maintenance contribution to total basin loading may vary greatly depending upon time of year. Monthly distributions of R factors are available in the USDA Agricultural Handbook No. 282 (Wischmeier and Smith, 1965) or may be calculated using local precipitation records following the methods outlined by McElroy et al. (1976).

b. Soil-erodibility factor (K) is a quantitative measure of the rate at which a soil will erode. It is a function of soil type and composition. K values for the local area may be obtained from the Soil Conservation Service (SCS) or, if soil properties are known (SCS soil survey available), the K factor can be estimated using nomographs in Figure 7.

c. Length (L) and steepness (S) of the slope affect the erosion rate. These two factors are combined into a single factor, LS, which can be estimated using the slope-effect chart (Table 14) or calculated using the method explained in (McElroy et al., 1976).

d. Cover factor (C) takes into account the protection of vegetative cover. Table 15 presents C values to be used.

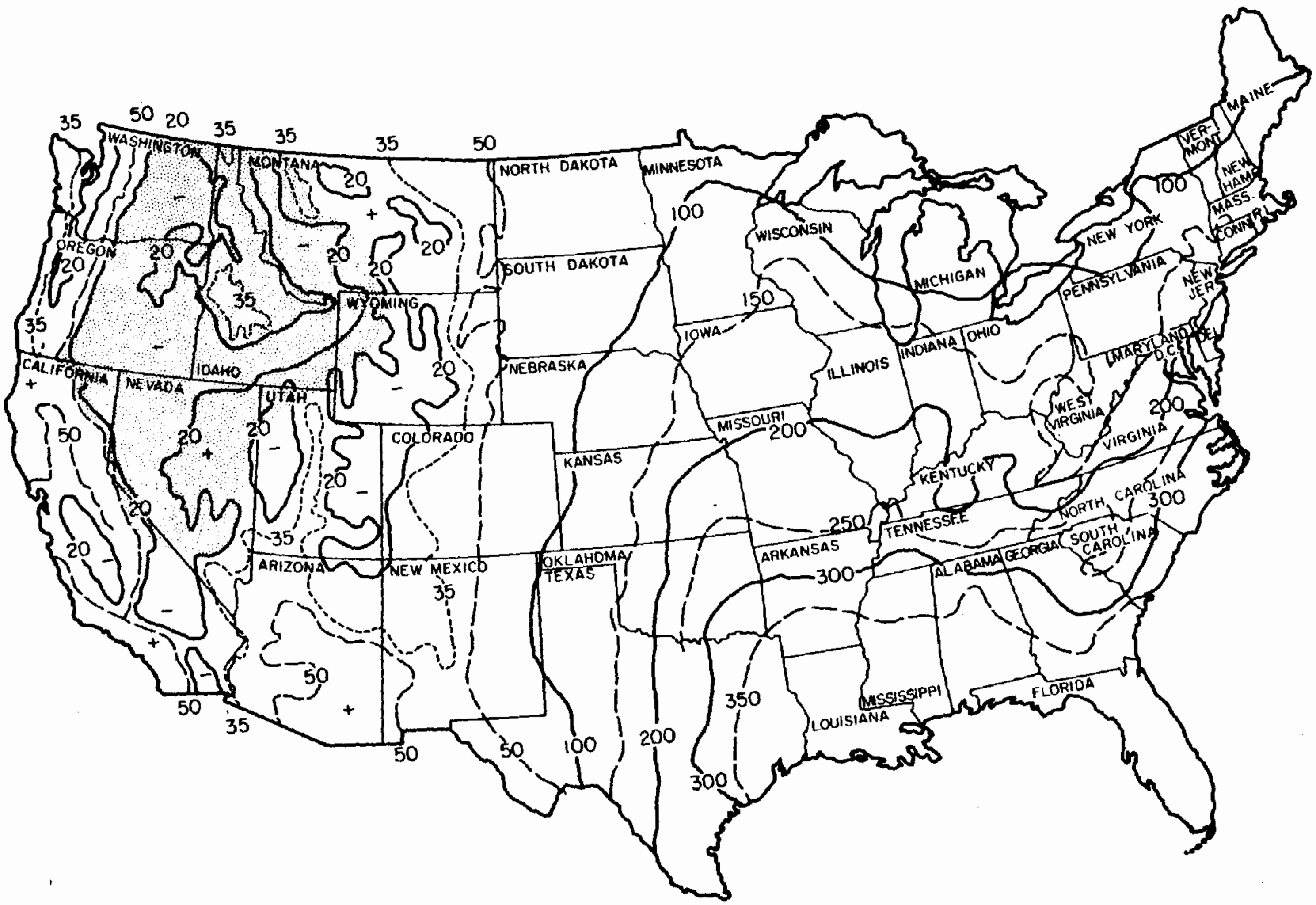


Figure 6. Average annual values of the rainfall-erosivity factor, R.

Source: Stewart et al., 1975

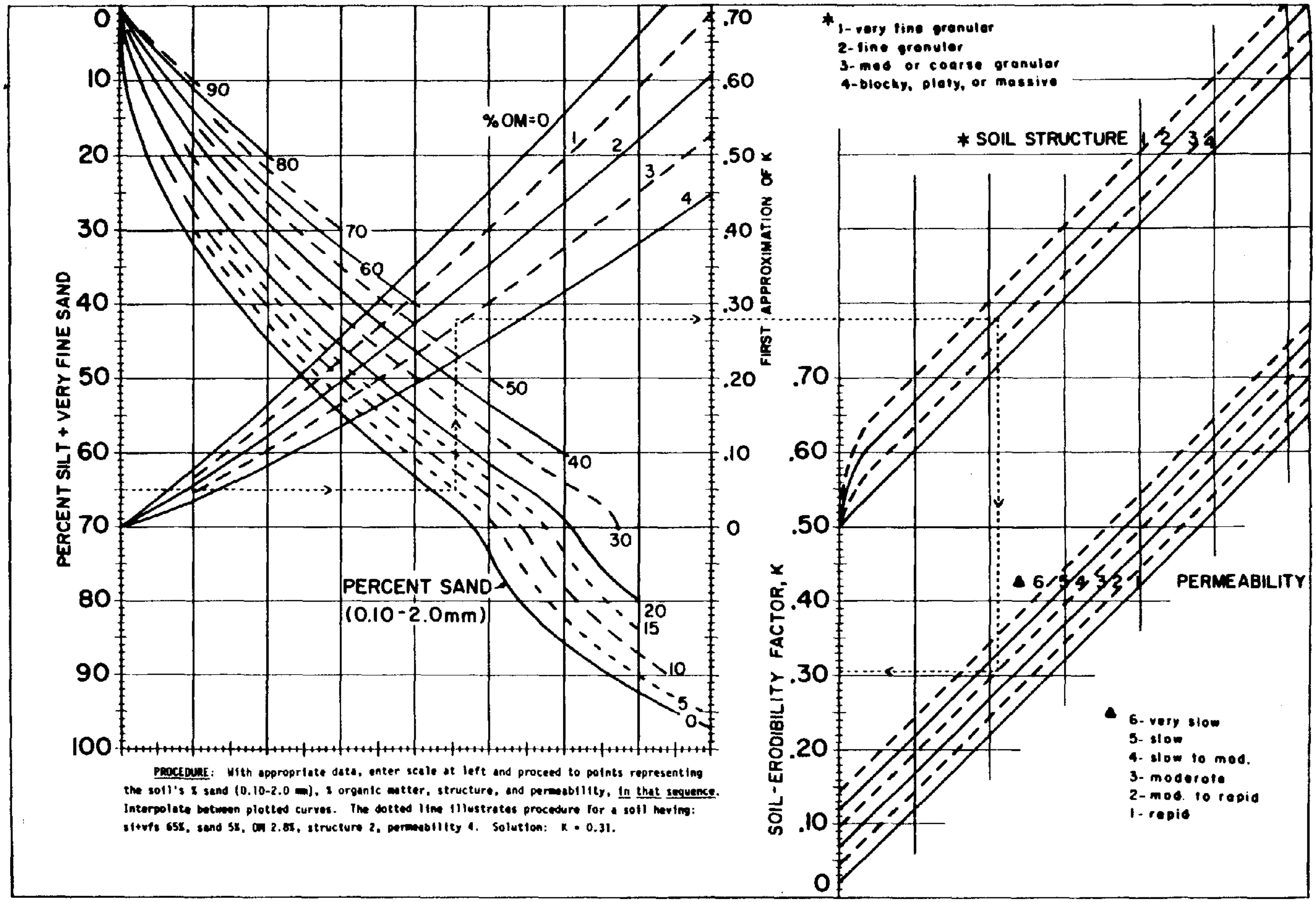


Figure 7. Nomograph for determing soil-erodibility factor, K, for U. S. mainland soils.

Source: Stewart et al., 1975

Table 14. Values of the topographic factor.

% Slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1000
0.5	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17	0.19	0.20
1	0.09	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21	0.22	0.24	0.26
2	0.13	0.16	0.19	0.20	0.23	0.25	0.28	0.31	0.33	0.34	0.38	0.40
3	0.19	0.23	0.26	0.29	0.33	0.35	0.40	0.44	0.47	0.49	0.54	0.57
4	0.23	0.30	0.36	0.40	0.47	0.53	0.62	0.70	0.76	0.82	0.92	1.0
5	0.27	0.38	0.46	0.54	0.66	0.76	0.93	1.1	1.2	1.3	1.5	1.7
6	0.34	0.48	0.58	0.67	0.82	0.95	1.2	1.4	1.5	1.7	1.9	2.1
8	0.50	0.70	0.86	0.99	1.2	1.4	1.7	2.0	2.2	2.4	2.8	3.1
10	0.69	0.97	1.2	1.4	1.7	1.9	2.4	2.7	3.1	3.4	3.9	4.3
12	0.90	1.3	1.6	1.8	2.2	2.6	3.1	3.6	4.0	4.4	5.1	5.7
14	1.2	1.6	2.0	2.3	2.8	3.3	4.0	4.6	5.1	5.6	6.5	7.3
16	1.4	2.0	2.5	2.8	3.5	4.0	4.9	5.7	6.4	7.0	8.0	9.0
18	1.7	2.4	3.0	3.4	4.2	4.9	6.0	6.9	7.7	8.4	9.7	11.0
20	2.0	2.9	3.5	4.1	5.0	5.8	7.1	8.2	9.1	10.0	12.0	13.0
25	3.0	4.2	5.1	5.9	7.2	8.3	10.0	12.0	13.0	14.0	17.0	19.0
30	4.0	5.6	6.9	8.0	9.7	11.0	14.0	16.0	18.0	20.0	23.0	25.0
40	6.3	9.0	11.0	13.0	16.0	18.0	22.0	25.0	28.0	31.0	--	--
50	8.9	13.0	15.0	18.0	22.0	25.0	31.0	--	--	--	--	--
60	12.0	16.0	20.0	23.0	28.0	--	--	--	--	--	--	--

Source: Stewart et al., 1975.

Table 15. Generalized cover factors (c) for various land uses.

Land use			C-Value
Croplands			Varies by area[a]
Woodlands:	Canopy covers 75-100% of area		0.001
Woodlands:	Canopy covers 40-70% of area		0.002-0.004
Woodlands:	Canopy covers 20-35% of area		0.003-0.01
Rangeland:	Canopy of tall weeds or short brush (0.5m height);	25% cover	0.36
		50% cover	0.26
		75% cover	0.17
Rangeland:	Canopy of brush or bushes (2m height);	25% cover	0.40
		50% cover	0.34
		75% cover	0.28
Rangeland:	Canopy of bushes but little low brush (4m height);	25% cover	0.42
		50% cover	0.39
		75% cover	0.36
Rangeland:	No appreciable canopy	--	0.45
Construction/Maintenance sites:	No cover		1.00[b]
	Temporary seedings - first 60 days		0.40
	Temporary seedings - second 60 days		0.05
	Permanent seedings - first 60 days		0.40
	Permanent seedings - second 60 days		0.05
	Sod (laid immediately)		0.01

Source: McElroy et al., 1976.

[a] Contact the local Soil Conservation Service for cropland C-factors within the drainage area.

[b] Mulches applied to bare soil may decrease C-factor greatly, depending on type and application rate.

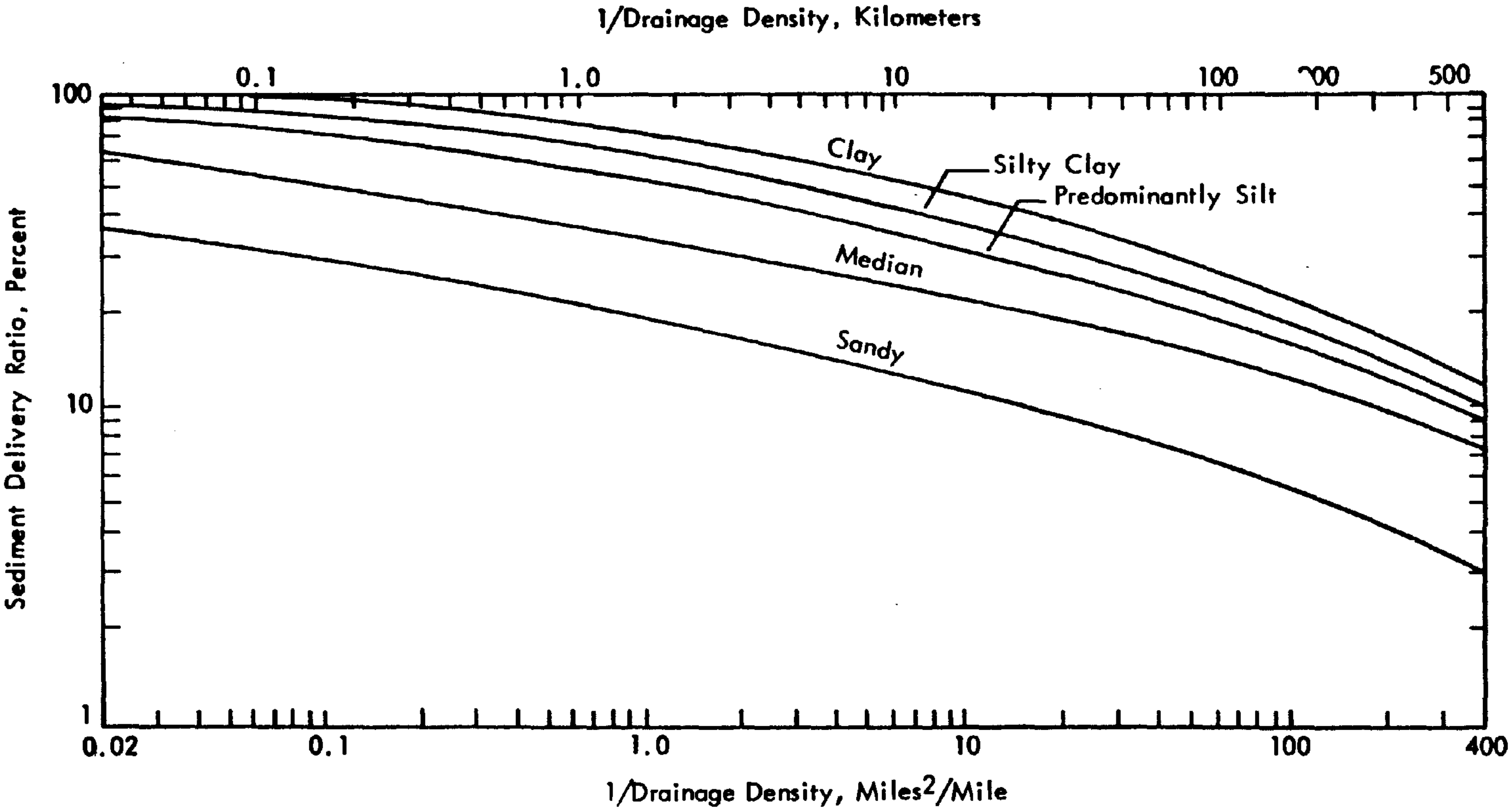


Figure 8. Sediment delivery ratio for relatively homogenous basins.

Source: McElroy et al., 1976

The C factor will vary for each drainage area in question depending on the time of year. As with the R factor, it is best for this assessment to: (1) determine the time of year the maintenance practice will be taking place; and (2) obtain the proper C value for that season from the local SCS. If the drainage area in question consists of land uses with fairly constant cover factors (e.g., woodlands, grasslands, urban areas), then the R factor will govern seasonal variations in erosion rates.

e. The erosion control practice factor (P) accounts for practices which control erosion by influencing drainage patterns, runoff concentrations, and runoff velocity. Table 16 presents P values for various erosion control practices. For this assessment, assume no erosion control practices (P = 1) except for cropland areas.

f. Sediment delivery ratio, S_d, is defined as the portion of the gross erosion which is delivered to the stream.

Table 16. Values of erosion control practice factor, P.

Practice	P factor[a]
Contouring	0.6 - 0.9
Contour strip cropping (rowcrop/meadow)	0.3 - 0.5
Contour listing or ridge planting	0.3 - 0.5
Contour terracing[b]	0.6/n - 0.9/n

Source: Stewart et al., 1975.

[a]Varies due to land slope.

[b]n = number of approximately equal-length intervals into which field is divided by terraces.

(i) For disturbed areas, calculate S_d as if for construction sites.

$S_d = D^{-0.22}$ where D = overland distance between erosion site and receiving water, ft. (13)

$S_d = B^{-0.51}$ where B = percent of drainage basin exposed by the maintenance activity. (14)

For this worst case analysis, calculate the S_d for both equations and use the highest value.

(ii) For the entire drainage basin calculate S_d as follows:

a. Determine soil composition from SCS surveys.

b. Calculate drainage density (DD):

$$DD = \frac{\text{total channel segment lengths}}{\text{basin area}} \quad (15)$$

c. Estimate S_d using Figure 8 or the following equations (Gianessi, Peskin, and Poles, 1980):

Sandy soils: $$S_d = 0.1579\left[\left(\frac{1}{DD}\right)^{-0.2103}\right] \quad (16)$$

Loamy soils: $$S_d = 0.2882\left[\left(\frac{1}{DD}\right)^{-0.1894}\right] \quad (17)$$

Silty soils: $$S_d = 0.4316\left[\left(\frac{1}{DD}\right)^{-0.1784}\right] \quad (18)$$

Silty-clay soils: $$S_d = 0.5120\left[\left(\frac{1}{DD}\right)^{-0.1637}\right] \quad (19)$$

Clay soils: $$S_d = 0.6039\left[\left(\frac{1}{DD}\right)^{-0.1522}\right] \quad (20)$$

Step 2. Calculate the sediment load (YS) from each subarea and sum the loads from all subareas to yield the total sediment load to the stream (use monthly R-value to obtain loads for month in question). Calculate the total sediment load before (YS_B) and after (YS_A)

the maintenance area is exposed, and determine the percent increase in load to the stream due to the maintenance practice.

$$\frac{YS_A - YS_B}{YS_B} \cdot 100 = \text{percent increase} \qquad (21)$$

Step 3. Based on knowledge of the existing resource value of the stream, determine if an increase in sediment load of this magnitude for the time period that the area is expected to remain exposed would have a significant impact on the resource value of the stream. It is assumed that the stream habitat quality already reflects the effects of sediment loads from existing land uses, so it is only necessary to evaluate the increase in sediment loads.

Sample Calculations - Sediment Loading Impact Assessment Method

A. Area Calculations

Step 1. Outline the drainage area on a USGS topographic map.

Step 2. Land-use areas

Type	Area (acres)
Woodland	1.4
Grassland	0.9
Total =	2.3

Step 3. Area disturbed by maintenance practice

length (ft) 1,200 x width (ft) 2 =

2,400 ft^2 x 2.29 x 10^{-5} ft^2/acre =

0.06 acres

B. Sediment loading calculations

Step 1. Sediment loading functions

n = 2			
A_1 = 1.4	A_2 = 0.9	A_3 =	A_4 =
R = 25			
K_1 = 0.31	K_2 = 0.48	K_3 =	K_4 =
L_1 = 0.14	L_2 = 0.20	L_3 =	L_4 =
S_1 = 0.5	S_2 = 0.9	S_3 =	S_4 =
C_1 = 0.003	C_2 = 0.4	C_3 =	C_4 =
P_1 = 1	P_2 = 1	P_3 =	P_4 =

(i) $S_d = D^{-0.22} = 50^{0.22} = 0.42$

$$S_d = B^{-0.51} = \left(\left(\frac{0.06 \text{ acres}}{2.3 \text{ acres}} \right) \cdot 100 \right)^{-0.51} = 0.61$$

(ii) a. Soil composition = 50 percent loam, 50 percent clay

b. Drainage density (DD)

$$DD = \frac{4{,}987 \text{ ft}}{2.3 \text{ acres}} = 2{,}168 \text{ ft/acre}$$

C. Estimate S_d

From Figure 8, S_d = 30 or 0.30

Sandy soils: $S_d = 0.1578 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.2103} =$ ________

Loamy soils: $S_d = 0.2882 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1894} =$ ________

Silty soils: $S_d = 0.4316 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1784} =$ ________

Silty-clay soils: $S_d = 0.5120 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1637} =$ ________

Clay soils: $S_d = 0.6039 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1522} =$ ________

Step 2. Sediment load (YS)

YS_B = 1.4 • (25 • 0.31 • 0.14 • 0.5 • 0.003 • 1 • 0.3) +
0.9 • (25 • 0.48 • 0.20 • 0.9 • 0.4 • 1 • 0.3) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +

YS_B = 0.00071 + 0.23 = 0.23 lb/acre

YS_A = 1.4 • (25 • 0.31 • 0.14 • 0.5 • 0.003 • 1 • 0.6) +
0.9 • (25 • 0.48 • 0.20 • 0.9 • 0.4 • 1 • 0.6) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +
___ • (___ • ___ • ___ • ___ • ___ • ___ • ___) +

YS_A = 0.0014 + 0.47 = 0.47 lb/acre

Percent increase = $\frac{0.47 - 0.23}{0.23} \times 100 =$ 104

Calculation Worksheet - Sediment Loading Impact Assessment Method

A. Area Calculations

Step 1. Outline the drainage area on a USGS topographic map.

Step 2. Land-use areas

Type	Area (acres)
_____	_____
_____	_____
_____	_____
_____	_____
Total =	_____

Step 3. Area disturbed by maintenance practice

length (ft) _____ x width (ft) _____ =

_____ ft^2 x 2.29 x 10^{-5} ft^2/acre =

_____ acres

B. Sediment loading calculations

Step 1. Sediment loading functions

n = _____			
A_1 = _____	A_2 = _____	A_3 = _____	A_4 = _____
R = _____			
K_1 = _____	K_2 = _____	K_3 = _____	K_4 = _____
L_1 = _____	L_2 = _____	L_3 = _____	L_4 = _____
S_1 = _____	S_2 = _____	S_3 = _____	S_4 = _____
C_1 = _____	C_2 = _____	C_3 = _____	C_4 = _____
P_1 = _____	P_2 = _____	P_3 = _____	P_4 = _____

(i) $S_d = D^{-0.22} = \_\_\_\_\_^{\,0.22} = \_\_\_\_\_$

$$S_d = B^{-0.51} = \left(\left(\frac{\_\_\_\_\_ \text{ acres}}{\_\_\_\_\_ \text{ acres}}\right) \cdot 100\right)^{-0.51} = \_\_\_\_\_$$

(ii) a. Soil composition = _______________

b. Drainage density (DD)

$$DD = \frac{\_\_\_\_\_ \text{ ft}}{\_\_\_\_\_ \text{ acres}} = \_\_\_\_\_ \text{ ft/acre}$$

C. Estimate S_d

From Figure 8, S_d = 30 or 0.30

Sandy soils: $S_d = 0.1578 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.2103} =$ ________

Loamy soils: $S_d = 0.2882 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1894} =$ ________

Silty soils: $S_d = 0.4316 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1784} =$ ________

Silty-clay soils: $S_d = 0.5120 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1637} =$ ________

Clay soils: $S_d = 0.6039 \left[\frac{1}{\_\_\_\_\_\_ DD}\right]^{-0.1522} =$ ________

Step 2. Sediment load (YS)

YS_B = ___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

YS_B = ______ + ______ = _____ lb/acre

YS_A = ___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

___ • (_____ • _____ • _____ • _____ • _____ • _____ • ____) +

YS_A = ______ + ______ = _____ lb/acre

Percent increase = $\frac{\_\_\_\_\_\_ - \_\_\_\_\_\_}{\_\_\_\_\_\_}$ x 100 = ______

Nutrient Loading Impact Assessment Method

Phosphates and nitrates (nutrient salts) are attached to sediments. For this reason, any increase in sediment load to a stream may be accompanied by an increase in nutrient loads. The following equations can be used to estimate the increase in the nutrient loads to the stream due to the maintenance activity.

Step 1. Nitrogen loading function (McElroy et al., 1976):

$$YN_E = a \cdot yS \cdot N_T \cdot r_N \cdot A \tag{22}$$

where YN_E = nitrogen loss to surface waters by erosion, lbs/unit time (month)

a = constant (10 for metric and 20 for English)

yS = sediment load from surface erosion per unit area ($yS \cdot A = YS$ calculated in Sediment Loading Impact Assessment Method)

N_T = total nitrogen concentration in soil, percent by weight

r_N = nitrogen enrichment ratio;

$$\frac{\text{N content in eroded soil}}{\text{N content in uneroded soil}}$$

A = area of nitrogen sources

a. Derive yS from sediment loading calculations

b. N_T varies with location and time. The value for local area may be obtained from local agencies (USDA, SCS, USGS, etc.). As a second choice, a soil atlas will give an average N_T value. If fertilizers will be added as a function of the maintenance practice, increase the N_T value accordingly when calculating YN_E for the maintenance area.

c. r_N is variable according to soil texture and land use. For this assessment assume $r_N = 4.0$ (McElroy et al., 1976).

d. Calculate the nitrogen load increase due to the maintenance activity. Based on knowledge of local conditions, determine if the increase will have a significant impact on the resource value of the receiving waters.

Step 2. Phosphorus loading function (McElroy et al., 1976):

$$YP_E = b \cdot yS \cdot P_T \cdot rp \cdot A \quad (23)$$

where: YP_E = erosion loss of phosphorus to surface water, kg/unit time

b = constant (17 for metric and 34 for English)

yS = sediment load from surface erosion per unit area ($yS \cdot A$ = YS calculated in Sediment Loading Impact Assessment Method)

P_T = total phosphorus content in soil, percent by weight

rp = phosphorus enrichment ratio;

$$\frac{\text{P content in eroded soil}}{\text{P content in uneroded soil}}$$

A = area of phosphorus sources

a. Derive yS from sediment loading calculations.

b. P_T data may be obtained for area from local sources (SCS, USDA, USGS). As a second choice, a soil atlas will give an average P_T value. If fertilizers will be added as a function of the maintenance practice, increase the P_T value accordingly when calculating YP_E for the maintenance area.

c. For this assessment, assume rp = 1.5 (McElroy et al., 1976).

d. Calculate the phosphorus load increase due to the maintenance activity. Based on knowledge of local conditions, determine if the increase will have a significant impact on the resource value of the receiving waters.

Sample Calculations - Nutrient Loading Impact Assessment Method

Step 1. Nitrogen loading function

a = 20
yS = 0.23 lb/acre
N_T = 8
r_N = 4
A = 600 $ft^2 \times 2.29 \times 10^{-5}$ ft^2/acre =
0.01 acre

YN_E = 20 • 0.23 • 8 • 4 • 0.01

YN_E = 147 lb/month

Step 2. Phosphorus loading function

b = 34
yS = 0.23 lb/acre
P_T = 3
rp = 1.5
A = 600 $ft^2 \times 2.29 \times 10^{-5}$ ft^2/acre =
0.01 acre

YP_E = 34 • 0.23 • 3 • 1.5 • 0.01

YP_E = 0.35 lb/month

Calculation Worksheet - Nutrient Loading Impact Assessment Method

Step 1. Nitrogen loading function

a = ________
yS = ________ lb/acre
N_T = ________
r_N = ________
A = ________ $ft^2 \times 2.29 \times 10^{-5}$ ft^2/acre =
________ acre

YN_E = _____ • _____ • _____ • _____ • _____

YN_E = _____ lb/month

Step 2. Phosphorus loading function

b = ________
yS = ________ lb/acre
P_T = ________
rp = ________
A = ________ $ft^2 \times 2.29 \times 10^{-5}$ ft^2/acre =
________ acre

YP_E = _____ • _____ • _____ • _____ • _____

YP_E = _____ lb/month

GLOSSARY

Absorption: Process of being incorporated into or made part of the whole. Substances which are absorbed by sediments become chemically part of the sediments.

Acaricides: Any substance used to destroy arachnids including spiders, mites, and ticks.

Acute toxicity: Effect severe enough to bring about a response (usually lethal) within 24 hours.

Adsorption: Adhesion in a thin layer of molecules to the surfaces of solids with which they are in contact. Substances adsorbed to sediments remain on the surface of the sediment solids rather than being incorporated into the molecules.

Benthic: Of, relating to, or occurring at the bottom of a body of water.

Benthos: Organisms that live on or in the bottom of bodies of water.

Bioaccumulation: The accumulation of a substance which is present in the environment in the tissues of an organism.

Bioconcentration: See bioaccumulation.

Biomagnification: The progressive increase of the level of a substance in organisms through the food chain.

Categorical exclusion: Federal actions which do not individually nor cumulatively have a significant impact on the environment and therefore do not require an environmental assessment or an environmental impact statement.

Chronic toxicity: Toxic effect caused by a lingering stimulus over a long period of time (greater than 24 hours).

Contact herbicide: Herbicide which will kill or affect only the parts of the plants that are covered. These usually provide quick, short-term, nonselective control.

Cutbacks: A mixture of asphalt and petroleum solvents.

EC50 (median effective concentration): A statistical estimate of the concentration of a test material necessary to produce a particular effect (usually immobilization) in 50 percent of the test organisms within a given time.

Emulsifiable concentrates: Pesticide formulation which has been dissolved in a petroleum solvent to form an emulsion. Emulsions can be mixed with water for dispension.

Emulsions: A suspension of asphaltic materials in water.

Environmental assessment (EA): Brief environmental document which defines the scope of the proposed action, identifies alternatives and determines which aspects of the proposed action have the potential for impact.

Environmental impact statement (EIS): Comprehensive environmental document which examines the significance of the potential environmental impacts of a proposed action and presents alternatives to that action.

Eutrophication: Enrichment of water with nutrients, a natural process often accelerated by human activities. Results in a high primary productivity. The process of maturation of a lake from a nutrient-poor to a nutrient-rich body of water.

Finding of no significant impact (FONSI): A written confirmation issued by FHWA of the finding of no significant impact which incorporates the EA and other appropriate environmental documents.

Flowables: Liquid herbicide formulation in which the active ingredient is in solid or semisolid state and has been added to water with a catalyst which allows the solids to remain in suspension.

Foliar systemic: Herbicide which is transported (translocated) from the leaves downward and causes death by its action within the plant's system.

Granules: Dry herbicide formulation designed to be applied in a dry state as pellets to the soil surface.

Growth retardants: Herbicide which acts by slowing the growth of the target vegetation. When applied to turf, it lessens the frequency of mowing.

GLOSSARY (continued)

Habitat: The sum total of environmental conditions of a specific place that is occupied by an organism, population or community.

Half-life: The period of time required for a quantity of some substance to degrade or decay to one-half of its original amount.

Herbicides: Any substance used to destroy plants, especially weeds, or to slow down their growth.

Insecticides: Any substance used to destroy insects.

LC_{50} (median lethal concentration): A statistical estimate of the concentration of a test material necessary to cause death in 50 percent of a test population within a given time.

Leaching: The process of water percolating through the soil. Water movement through the soil may be vertical or horizontal.

Macroinvertebrates: Invertebrates (insects, crustaceans, etc.) which are large enough to be seen with the naked eye.

Mulches: A protective covering (i.e., straw, jute, emulsions) spread on the ground to prevent erosion, control weeds, or enrich the soil.

National Environmental Policy Act (NEPA): Comprehensive environmental legislation enacted by Congress in 1969. NEPA established the Council on Environmental Quality and provides for interdisciplinary efforts to protect and enrich the environment.

Nonresidual: Pesticides which, when applied, break down rapidly and completely in the soil and maintain soil productivity.

Nonselective: Herbicides which kill vegetation with little or no regard to species.

Persistence time: Time required for 90 percent of the pesticides applied to a field to break down and disappear from the soil; time may vary depending on climate and soil.

Pesticides: Any substance or mixture of substances intended for controlling pests such as insects, fungi, weeds, etc.

Postemergent: Herbicides structured to act only through the foliage of plants; plants therefore must emerge from the ground before this herbicide is applied.

Preemergent: Herbicides which act through the root system and can therefore be applied either before or after the plant emerges.

Primary producers: Organisms which make up the base of the aquatic food chain. The primary producers transform light and nutrients into usable, consumable energy products (carbohydrates). They include the algae and macrophytes in a stream or lake.

Record of Decision (ROD): A written, signed document of approval from the FHWA regarding the conclusions included in an environmental impact statement.

Residual herbicides: Herbicides that, when applied, are carried into the soil or water where they dissolve slowly. Most require moisture for activation and will remain active in the soil for a period of time, making the soil nonproductive for growth.

Riprap: A durable material, usually stone, placed on embankment slopes to prevent erosion.

Root systemic: Herbicides which are applied to the soil and are taken into the plant system (translocated) through the roots.

Sedimentation: The action or process of forming or depositing sediments on the stream or lake bottom. Deposited solids may originate outside the aquatic system as eroded soils or within the system as decomposed plant or animal material.

Selective herbicide: Herbicides that control undesirable vegetation without seriously injuring the desirable plants among which they are growing.

Shoreline development index (SDI): An index of the amount of shoreline edge in a lake relative to lake surface area.

Siltation: The deposition of fine soil or clay particles.

Sinuosity Index (SI): An index of the length of a stream channel relative to the length of a meander for a given reach. This is a measure of the degree of meandering or winding of a stream channel.

Spring flooding index (SFI): An index of the duration and frequency of spring flooding in a lake. The index is expressed as the amount of flooded habitat times the number of days of flooding.

Soil sterilants: Herbicides designed to eliminate all vegetative growth in an area. They are often applied along shoulders before asphalt is poured to prevent plant growth which may crack the pavement.

Soluble powders (SP): Powdered chemicals that totally dissolve in water.

State Environmental Policy Act (SEPA): State and local counterparts to NEPA legislation. SEPAs may vary from State to State in their requirements and the extent of their jurisdiction.

Substrate: The base on which an organism lives; most commonly refers to the stream bed or lake bottom.

Synergistic: Having an effect (i.e., toxic) which is greater than the sum of the parts. For example, two chemicals used in combination may be more toxic than either chemical alone or greater than the simple sum of each individual toxic effect.

Taxon: A taxonomic group, e.g., species, genus, or family.

Total suspended solids (TSS): Solids which remain suspended in the water column.

Toxicity: Property of a chemical substance that causes a measurable adverse biological response.

Translocated herbicides: Herbicides that are moved from the leaves downward or from the roots upward.

Turbidity: A measure of the light-scattering ability of matter suspended in water. Turbidity may be caused by clay, silt, organic matter, microorganisms, industrial and/or domestic wastes, and minerals, to name a few.

Wettable powders: Powders that do not dissolve when added to water but form a suspension.

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APPENDIX A

PESTICIDE TOXICITY, FATE, AND BIOCONCENTRATION DATA

Pesticide toxicity, fate, and bioconcentration data are presented in tabular form in Appendix A. Table 17 shows the acute toxicity of pesticides to warmwater fishes; Table 18 summarizes bioaccumulation and other environmental fate data for pesticides used by highway maintenance departments; and Table 19 lists common names and synonyms for pesticides used for roadsides by highway maintenance personnel.

Table 17. Acute toxicity of pesticides to warmwater fishes expressed as a 96-hour LC50 (ppm).[a]

Common name	Chemical name	Formulation[b]	96-Hour LC50 (ppm) Mean	Range	Sources
INSECTICIDES:					
Acephate	O,S-Dimethyl acetylphosphoramidothioate	WP, 75%	26.7	25.5-27.9	Schneider, 1979
Carbaryl	1-Napthyl methylcarbamate	TG, 99.5%	8.75	0.69-20.0	Johnson and Finley, 1980; Schneider, 1979
		OD, 49%	21.8	4.50-39.0	Johnson and Finley, 1980
		WP, 50%	12.8	3.16-42.2	Schneider, 1979
		--	8.21	0.75-20.0	Pimentel, 1971; Stewart et al., 1975
Diazinon	O,O-Diethyl-O-(2-isopropyl-6-methyl-5-pyrimidinyl)phosphorothioate	TG, 89%	0.09	--	Johnson and Finley, 1980
		TG, 92%	0.82	0.17-1.70	Johnson and Finley, 1980
		--	0.08	0.02-0.25	Pimentel, 1971; Stewart et al., 1975
Dicofol	1,1-Bis(p-chlorophenyl)-2,2,2-trichloroethanol	TG, 100%	0.43	0.36-0.52	Johnson and Finley, 1980
		TG, 74.4%	0.07	0.053-0.087	Johnson and Finley, 1980
		WP, 35%	1.87	0.88-3.10	Schneider, 1979
		EC, 2%	46.5	43.6-49.0	Schneider, 1979
		--	0.10	--	Stewart et al., 1975
Dimethoate	O,O-Dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate	G, 95%	10.3	7.50-15.2	Schneider, 1979
		G, 30.5%	85.0	20.3-153	Schneider, 1979
		--	12.9	7.80-18.5	Pimentel, 1971
Malathion	O,O-Dimethyl S-(1,2-dicarboxyethyl) phosphorodithioate	TG, 95%	2.37	0.03-12.9	Johnson and Finley, 1980; Schneider, 1979
		EC, 56%	0.03	--	Schneider, 1979
		--	4.12	0.015-12.9	Stewart et al., 1975; Pimentel, 1979; Eisler, 1970a
Methoxychlor	2,2-Bis(p-methoxyphenyl)-1,1,1-trichloroethane	TG, 89.5%	0.03	0.02-0.06	Johnson and Finley, 1980
		G, 50%	0.01	0.002-0.02	Johnson and Finley, 1980
		EC, 100%	0.02	0.01-0.04	Schneider, 1979
		--	0.05	0.01-0.15	Pimentel, 1971; Eisler, 1970a-b
Tetradifon	p-Chlorophenyl 2,4,5-trichlorophenyl sulphone	TG, 100%	1.39	0.88-2.10	Johnson and Finley, 1980
		WP, 25%	30.9	18.0-47.5	Schneider, 1979
		--	0.89	--	Pimentel, 1971
HERBICIDES:					
2,4-D; acid	2,4-Dichlorophenoxyacetic acid:	G, 100%	54.5	45.0-64.0	Johnson and Finley, 1980
	Acid formulations	TG, 100%	10.6	2.0-18.0	Johnson and Finley, 1980
2,4-D; amines	2,4-Dichlorophenoxyacetic acid:	LC, 49%	172	100-335	Johnson and Finley, 1980
	Dimethylamine salt	LC, 12.5%	106	43.5-160	Schneider, 1979
	Propylenedramine salt	LC, 57%	1.25	0.3-0.8	Pimentel, 1971; Johnson and Finley, 1980
	Dodecyl/tetradodecyl amine salt	OSL, 63%	4.68	2.7-7.4	Johnson and Finley, 1980
	Amine salt of alkyl 2,4-D	EC, 50.7%	13.2	11.2-15.7	Schneider, 1979
		LC, 25.1%	6.78	5.1-9.4	Schneider, 1979
		EC, 12.7%	12.6	10.7-15.0	Schneider, 1979

Table 17. Acute toxicity of pesticides to warmwater fishes expressed as a 96-hour LC50 (ppm).[a] (Continued)

Common name	Chemical name	Formulation[b]	96-Hour LC50 (ppm) Mean	Range	Sources
	Ethanolamine salt	LC, 34%	66.0	58.1-71.0	Schneider, 1979
	Heptylamine salt	LC, 67%	19.8	3.81-71.5	Schneider, 1979
	Octylamine salt	EC, 69.2%	28.0	--	Schneider, 1979
	Triethylamine salt	LC, 50.3%	44.7	40.5-47.5	Schneider, 1979
	Diethylethanolamine salt	LC, 17.5%	19.2	--	Schneider, 1979
2,4-D; esters	2,4-Dichlorophenoxyacetic acid: Butyl ester	LC, 98.4%	0.90	0.24-6.60	Pimentel, 1971; Johnson and Finley, 1980; Schneider, 1979
	Propylglycol butyl ester	LC, 100%	0.80	0.60-1.15	Pimentel, 1971; Johnson and Finley, 1980; Schneider, 1979
	Butoxy ethanal ester	TG, 63%	1.62	0.53-3.30	Johnson and Finley, 1980; Schneider, 1979
	Butoxypropyl ester	LC, 72.5%	6.16	5.35-7.72	Schneider, 1979
		LC, 21.4%	3.09	2.57-3.70	Schneider, 1979
	Isoctyl (2-ethylhexyl)ester	LC, 94.2%	57.6	19.5-96.0	Schneider, 1979
		WP, 85.9%	35.5	31.8-40.9	Schneider, 1979
		EC, 68.7%	24.8	16.4-36.5	Schneider, 1979
		EC, 39.6%	80.9	64.0-101	Schneider, 1979
		EC, 15.2%	4.96	4.29-5.67	Schneider, 1979
		PS, 1.1%	4.11	3.89-4.55	Schneider, 1979
Aminotriazole	3-Amine-1,2,4-triazole	TG, 100%	724	40.5-2633	Pimentel, 1971; Stewart et al., 1975; Johnson and Finley, 1980
		EC, 3.3%	72.6	65.0-80.2	Schneider, 1979
Ammate	Ammonium sulfamate	--	825	--	Pimentel, 1971
Asulam	Methyl 4-aminobenzenesulphonylcarbamate	--	No data	--	--
Atrazine	2-Chloro-4-ethylamino-6-isopropylamino-s-triazine	WP, 40%	12.4	8.05-19.8	Schneider, 1979
		--	5.92	0.36-10.2	Pimentel, 1971; Stewart et al., 1975
Bromacil	5-Bromo-3-sec.-butyl-6-methyluracil	--	56.7	--	Stewart et al., 1975
Bromoxynil	3,5-Dibromo-4-hydroxybenzonitrile	--	41.4	40.5-42.2	Stewart et al., 1975; Pimentel, 1971
Cacodylic acid	Dimethylarsenic acid	TG, 100%	51.7	17.0-100	Stewart et al., 1975; Pimentel, 1971; Johnson and Finley, 1980
Chloflurenol	Methyl-2-chloro-9-hydroxyfluorene-(9)-carboxylate	LC, 12.5%	6.89	6.73-7.05	Schneider, 1979
Dalapon	2.2-Dichloropropionic acid	TG, 75.6%	105	--	Johnson and Finley, 1980
		--	195	75.9-330	Pimentel, 1971; Stewart et al., 1975
	(sodium salt)	TG, 86.5%	233	100-500	Johnson and Finley, 1980

Table 17. Acute toxicity of pesticides to warmwater fishes expressed as a 96-hour LC50 (ppm).[a] (Continued)

Common name	Chemical name	Formulation[b]	96-Hour LC50 (ppm) Mean	Range	Sources
Dicamba	3,6-Dichloro-O-anisic acid	TG, 88%	39.0	28-50	Johnson and Finley, 1980
		--	77.7	28.4-100	Pimentel, 1971
Dichlobenil	2,6-Dichlorobenzonitrile	TG, 98.9%	6.82	5.7-8.3	Johnson and Finley, 1980
		Metabolite, 100%	130	120-140	Johnson and Finley, 1980
		--	12.2	8.1-16.2	Stewart et al., 1975
		G	30.4	16.2-79.2	Pimentel, 1971
		WP	13.6	11.2-15.2	Pimentel, 1971
		D, 99.5%	6.31	5.67-7.60	Schneider, 1979
Dinoseb	2-(sec-butyl)-4,6-dinitrophenol	TG, 95.8%	0.10	0.04-0.40	Johnson and Finley, 1980; Stewart et al., 1975; Woodward, 1976
		LC, 51%	0.12	0.10-0.15	Schneider, 1979
Diquat	1,1%-ethylene-2-2%-bipyridilim ion-bromide salt	LC, 35.3%	59.8	9.96-208	Pimentel, 1971; Stewart et al., 1975
		--	121	60-245	Johnson and Finley, 1980; Schneider, 1979
Diuron	3-(3,4-Dichlorophenyl)-1,1-dimethylurea	TG, 95%	4.30	1.4-8.2	Johnson and Finley, 1980
		WP, 80%	16	--	Stewart et al., 1975
		WP, 28%	46.8	23.8-84.0	Schneider, 1979
		D, 95%	3.02	1.65-4.75	Schneider, 1979
		--	20.9	3.10-59.9	Pimentel, 1971; Stewart et al., 1975
DSMA	Disodium methanearsonate	--	12.2	--	Stewart et al., 1975
Fenac	2,3,6-Trichlorophenylacetic acid	TG, 50%	21.3	11.0-41.0	Johnson and Finley, 1980
		--	13.0	6.08-40.3	Pimentel, 1971
Fenavar	25% Aminotriazone + 33% Bromacil +42% Fenac	--	No data	--	--
Fosamine	(Aminocarbonyl)phosphonic acid	--	No data	--	--
Glyphosate	N-(Phosphonomethyl) glycine	TG, 96.7%	123	97-135	Johnson and Finley, 1980
		LC, 41%	6.73	2.3-13	Johnson and Finley, 1980
Hexazinone	3-Cyclohexyl-6-(dimethylamino) -1-methyl-s-triazine-2,4(1H,3H)-dione	--	>100	--	Johnson and Finley, 1980
Maleic hydrazide	6-Hydroxy-3-(2H)-pyridazinone	--	No data	--	--
Mefluidide	N-(2,4-dimethyl-S-(((trifluoromethyl) sulfonyl)amino)phenyl)acetamide	--	No data	--	--

Table 17. Acute toxicity of pesticides to warmwater fishes expressed as a 96-hour LC50 (ppm).[a] (Continued)

Common name	Chemical name	Formulation[b]	96-Hour LC50 (ppm) Mean	Range	Sources
MSMA	Monosodium methanearsonate	LC, 34.8%	39.1	12.0-100	Johnson and Finley, 1980
		LC, 37.7%	38.0	26.8-49.2	Johnson and Finley, 1980
		--	4.94	0.90-12.2	Anderson et al., 1975; Stewart et al., 1975
Napropamide	2-(alpha Napthoxy)-N, N-diethylpropionamide	--	No data	--	--
Oryzalin	3,5-Dinitro-N[4], N[4]-dipropylsulfanilanide	D, 95%	3.33	3.14-3.45	Schneider, 1979
Oxadiazon	2-tert-butyl-4-(2,4-dichloro-5-isopropyloxyphenyl)-1,3,4-oxadiazaline-5-one	G, 2%	11.2	0.83-26.0	Schneider, 1979
Paraquat	1:1-Dimethyl-4,4'-Bipyridinium (cation) dichloride	LC, 42%	76	13-100	Johnson and Finley, 1980
		EC, 29.1%	47.7	29.0-66.4	Schneider, 1979
		--	449	264-818	Pimentel, 1971
Picloram	4-Amino-3,5,6-trichlorapicolinic acid	TG, 90%	7.68	2.35-23.0	Johnson and Finley, 1980; Woodward, 1976
		G, 24.9%	11.9	7.40-14.4	Schneider, 1979
		G, 10.2%	21.6	--	Schneider, 1979
		--	162	42.2-277	Pimentel, 1971
	Isooctyl ester	TG, 90%	2.7	1.4-4.0	Johnson and Finley, 1980
	Potassium salt	TG, 25%	24.0	1.5-43.6	Johnson and Finley, 1980; Pimentel, 1971
Pramitol	2-Methoxy-4,6-bis(isopropylamino)-s-triazine	--, 25%	28.0	22.4-34.0	Schneider, 1979
		--, 19.9%	4.74	4.62-4.90	Schneider, 1979
		--, 3.6%	3.51	2.94-4.20	Schneider, 1979
		--, 1.6%	22.4	15.5-27.5	Schneider, 1979
Pronamide	3,5-Dichloro-N-(1,1-dimethyl-2-propyl)-benzamide	--	No data	--	--
Simazine	2-Chloro-4,6-bis(ethylamino)-s-triazine	TG, 98.1%	100	--	Johnson and Finley, 1980
		WP, 80%	100	--	Johnson and Finley, 1980
		--	41.1	0.4-85.8	Pimentel, 1971
Tebuthiuron	N-(5(1,1-dimethylethyl)-1,3,4-thiadiazal)-2-yl)-N,N-dimethylurea	--	No data	--	--
Terbutryn	2-(tert-Butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine	WP, 80%	3.83	2.61-4.80	Schneider, 1979
		--	1.76	0.82-2.70	Johnson and Finley, 1980

Table 17. Acute toxicity of pesticides to warmwater fishes expressed as a 96-hour LC50 (ppm).[a] (Continued)

Common name	Chemical name	Formulation[b]	96-Hour LC50 (ppm)		Sources
			Mean	Range	
Trifluralin	a,a,a-Trifluoro-2,6-dinitro-N,N-dipropyl-p-toludine	TG, 95.9%	0.48	0.41-2.20	Johnson and Finley, 1980
		EC, 46%	0.07	--	Johnson and Finley, 1980
		--	0.07	0.009-0.139	Pimentel, 1971
Ureabor	66.5% + Sodium metaborate tetrahydrate	G, 98%	258	100-640	Johnson and Finley, 1980
	30% sodium chlorate + 1.5% bromacil	--	643.5	--	Pimentel, 1971

[a] All LC50 data if for other than 96-hours, were transformed to 96-hour LC50 data using the correction factors developed by the EPA in the "Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life" published in 43 FR 21506 (May 18, 1978).

The correction factors for fish are:

$$\frac{\text{96-hour LC50}}{\text{24-hour LC50}} = 0.66$$

$$\frac{\text{96-hour LC50}}{\text{48-hour LC50}} = 0.81$$

[b] Formulations: TG - technical grade; EC - emulsifiable concentrate; WP - wettable powder; OD - oil dispersion; G - granules; LC - liquid concentrate; OSL - oil soluble liquid; PS - pressurized spray; D - dust. Percents represents amount of active ingredient.

Table 18. Summary of bioaccumulation and other environmental fate data for pesticides used by highway maintenance departments in the United States.

		Summary of data on fate in soil			Summary of data on fate in water	
Common name	Bioaccumulation potential	Adsorption, leaching, and runoff	Chemical and microbial degradation	Photodegradation, volatilization, etc.	Chemical and microbial degradation	Photodegradation
INSECTICIDES:						
Acephate	Slight potential in fish	Readily leached in soil; not strongly adsorbed.	Microbial degradation; half-life from 0.5 to 13 days.	None	No chemical degradation; microbial degradation faster at higher temperature and high pH; degradation faster when sediments are present.	None
Carbaryl	Bioaccumulate in aquatic biota. Ratio of 3.6 and 4.0 for lake trout and Coho salmon, respectively.	Readily adsorbed by organic soils; rapid movement through inorganic soils; adsorption reversible.	Primarily microbial degradation. Rate dependent on soil type, temperature and microorganisms present. Persistence time <1 month.	Photodegradation on soil surfaces.	Hydralyzes rapidly in water at pH >7. No hydrolysis at pH 3-6. Half-life one month at 3.5° C and 3.5 days at 20° C at pH 8. Degrades to 1-napthal, CO_2, and other products.	Rate depends on pH, level of incident radiation and dissolved oxygen. In summer, photodegradation rate may be up to 4 times that of water.
Diazinon	--	--	Persistence time of 3 months.	--	--	
Methoxychlor	--	--	Persistence time of <1 month.	--	--	
HERBICIDES:						
Aminotriazole	Not expected to bioaccumulate due to its high water solubility.	Reversibly adsorbed to soil; adsorption is greater in high organic soils and at low pH. Leaching occurs in sandy soils.	Degradation is dependent on soil moisture, temperature, and pH. Detectable residue persists from several days to 6 months or more.	Limited volatilization. Apparently stable under UV light.	Possible degradation but no specific mechanisms reported. Solubility = >10% wt/vol.	Stable under UV light.

Table 18. Summary of bioaccumulation and other environmental fate data for pesticides used by highway maintenance departments in the United States. (Continued)

Common name	Bioaccumulation potential	Summary of data on fate in soil: Adsorption, leaching, and runoff	Summary of data on fate in soil: Chemical and microbial degradation	Summary of data on fate in soil: Photodegradation, volatilization, etc.	Summary of data on fate in water: Chemical and microbial degradation	Summary of data on fate in water: Photodegradation
Atrazine	Low bioaccumulation in aquatic biota; some bioaccumulation in microorganisms; readily metabolized by mammals with no bioaccumulation of metabolites.	Readily and reversibly adsorbed on soil; adsorption is stronger on high organic soils, low pH, and low temperature. Leaching confined to upper 6 in. of soil in most soil types. Loss of up to 5-10% in runoff may occur if heavy rainfall occurs soon after application.	Persistence time of up to one year depending on climate and soil type. Degrades via chemical (hydrolysis) and microbial (dealkylation) routes.	Photodegradation will occur if prolonged sunlight and high temperatures follow application, but precede precipitation. Volatilization may occur soon after application.	Solubility = 33 ppmw	No data
Dalapon	Little to no bioaccumulation.	Limited adsorption to soils; little leaching beyond upper 6 in. of soil.	Microbial degradation is major route of degradation. Rate dependent upon soil type, temperature, and pH. Persistence time of 2 weeks - several months.	Insignificant	No data	No data
Dicamba	Does not bioaccumulate.	Very mobile herbicide; mobility greatest at high pH. Does not readily adsorb to soils (except clays); readily leached from soils with heavy rainfall.	Primarily microbial degradation; persistence time approximately two months.	No significant photodegradation expected; dimethylamine salt form may volatilize.	Possible hydrolysis but no mechanism known; probable microbial degradation as in soil.	Insignificant photodegradation based on behavior in soils.
Dichlobenil	--	--	Persistence time of 2 months.	--	--	--
Diuron	--	--	Persistence time of 10 months.	--	--	--

Table 18. Summary of bioaccumulation and other environmental fate data for pesticides used by highway maintenance departments in the United States. (Continued)

Common name	Bioaccumulation potential	Summary of data on fate in soil: Adsorption, leaching, and runoff	Summary of data on fate in soil: Chemical and microbial degradation	Summary of data on fate in soil: Photodegradation, volatilization, etc.	Summary of data on fate in water: Chemical and microbial degradation	Summary of data on fate in water: Photodegradation
2,4-D	Does not bioaccumulate.	Adsorbs more strongly to soils with high organic matter; does not readily adsorb to clays; leaching is dependent on formulation, soil properties, and rainfall; salts leach more readily than esters. Runoff potential greatest for esters.	Primarily microbial degradation dependent on soil temperature, moisture, and organic content. Persistence in soil less than one month.	Volatilization depends on vapor pressure - esters more volatile than salts or acids.	Ester hydrolyzes to acid; half life shorter at high pH. Microbial degradation favored in warm, nutrient-rich waters. May remain stable for 6 months in natural waters.	Photodegradation not a major mechanism. Volatilization may be important in low pH waters.
Fenac	--	--	Persistence time of >12 months.	--	--	--
Fosamine	Low accumulation observed in catfish; generally does not bioaccumulate. Metabolize and/or excreted rapidly by animals.	Low mobility herbicide; strongly adsorbed to and not readily leachable from soils high in clay. Loss in runoff expected if heavy rainfall occurs soon after application.	Persistence time of 3-6 months; half-life of one week. Rapidly decomposed by soil microorganisms. Chemical hydrolysis to carbamoylphosphonic acid.	No data on photodegradation. Low volatility.	No hydrolysis after 4 weeks at pH 7 and 9. Less than 3% decomposition at pH 5 and 7.	Insignificant
Glyphosate	Little bioaccumulation in fish. Exposure to 2 mg/l glyphosate yields fish tissue concentrations of 0.6-0.8 μg/kg.	Strongly adsorbed to soils; adsorption highest in soils with high organic content; minimal leaching and runoff.	Decomposed rapidly by soil microorganisms. No appreciable chemical degradation.	Negligible	Microbial degradation is major route; does not degrade via chemical routes. Half life in water approximately 2 weeks.	Negligible

Table 18. Summary of bioaccumulation and other environmental fate data for pesticides used by highway maintenance departments in the United States. (Continued)

		Summary of data on fate in soil			Summary of data on fate in water	
Common name	Bioaccumulation potential	Adsorption, leaching, and runoff	Chemical and microbial degradation	Photodegradation, volatilization, etc.	Chemical and microbial degradation	Photodegradation
Hexazinone	Does not bioaccumulate in fish. Terrestrial invertebrates did bioaccumulate up to two orders of magnitude greater than soil levels; the stream invertebrate studies on bioaccumulation available.	Very mobile, dependent upon soil type.	Degrades by soil microorganisms. Half life ranges from 1-6 months depending on soil type and conditions.	Will photodegrade; half life of 37 days.	Microbial degradation one of major causes of hexazinone reduction in natural waters.	Photodegradation also major cause of reduction; in lab 3% degraded in 5 weeks; rate slower in natural waters with sediments present.
MSMA	Bioaccumulation has been observed. Bioconcentration not expected.	Converted to arsenate in soil which is tightly bound; little leaching.	Primarily microbial degradation; persistence time of 12 months; half life of degradation products (inorganic arsenic compounds) is six years.	None	Microbial degradation converts MSMA to organic and inorganic arsenic compounds. May adsorb to sediments in water.	None
Paraquat	--	--	Persistence of >24 months.	--	--	--
Picloram	Accumulation factors of 0.25 - 0.50 for catfish; not accumulated in invertebrates or their food chain.	Mobility is a function of soil type, pH, rainfall and application rate. Adsorption greatest in high organic content soils. Seldom leaches below 20-30 cm in soil; runoff likely if heavy rainfall occurs within 1-2 months of application.	Half life varies from one to 13 months based on soil type and climate. Primarily microbial degradation. Persistence time of 18 months.	Photodecomposes on soil surfaces.	Not readily degraded in water by microorganisms. Stable to hydrolysis.	Phytolysis half-life of 5-60 days in water.

Table 18. Summary of bioaccumulation and other environmental fate data for pesticides used by highway maintenance departments in the United States. (Continued)

Common name	Bioaccumulation potential	Summary of data on fate in soil: Adsorption, leaching, and runoff	Summary of data on fate in soil: Chemical and microbial degradation	Summary of data on fate in soil: Photodegradation, volatilization, etc.	Summary of data on fate in water: Chemical and microbial degradation	Summary of data on fate in water: Photodegradation
Simazine	Accumulation of one to four times the water concentration.	Low mobility; strongly adsorbed on soils high in organic content and in clay soils at low pH. High runoff potential after heavy rainfall soon after application.	Half-life of 4 to 6 months depending on soil type and climate. Persistence time of 12 months. Less persistent in soils high in organic matter content. Degrades via chemical and microbial routes.	Insignificant.	Half life of 50-70 days in water depending on temperature and pH. Half-life of 4 months at 70° C and pH 7; shorter at increasing and decreasing pH. Microbial degradation insignificant in water.	Insignificant.
Trifluralin	--	--	Persistence = 6 months.	--	--	--

Source: Ghassemi et al., 1981; Wauchope, 1978.

Table 19. Index listing of common names and synonyms for pesticides used by highway maintenance personnel on roadsides in the United States.

Table 19. Index listing of common names and synonyms for pesticides used by highway maintenance personnel on roadsides in the United States. (Continued)

Table 19. Index listing of common names and synonyms for pesticides used by highway maintenance personnel on roadsides in the United States. (Continued)

Prebane, see TERBUTRYN
Preflan, see TEBUTHIURON
Prefmid, see TEBUTHIURON
Primatol, see PRAMITOL
Primatol A, see ATRAZINE
Primatol S, see SIMAZINE
Primaze, see ATRAZINE
Princep, see SIMAZINE
Printop, see SIMAZINE
Prometon, see PRAMITOL
Prometone, see PRAMITOL
PRONAMIDE
Proprop, see DALAPON
Propyzamide, see PRONAMIDE

-R-

Radapon, see DALAPON
Radazin, see ATRAZINE
Rad-E-Cate, see CACODYLIC ACID
Ravion, see CARBARYL
Ravyon, see CARBARYL
Rebelate, see DIMETHOATE
Reglone, see DIQUAT
Regulox, see MALEIC HYDRAZIDE
Retard, see MALEIC HYDRAZIDE
Rogor, see DIMETHOATE
Ronstar, see OXADIAZON
Roundup, see GLYPHOSATE
Roxion, see DIMETHOATE
Royal MH-30, see MALEIC HYDRAZIDE
Rycelan, see ORYZALIN
Rycelon, see ORYZALIN
Ryzelan, see ORYZALIN

-S-

Sarolex, see DIAZINON
Septene, see CARBARYL
Sevin, see CARBARYL
Simadex, see SIMAZINE
Simanex, see SIMAZINE
SIMAZINE
Simtrol, see SIMAZINE
Slo-gro, see MALEIC HYDRAZIDE
Spark, see DINOSEB
Spectracide, see DIAZINON
Spike, see TEBUTHIURON
Sproutoff, see MALEIC HYDRAZIDE
Sproutstop, see MALEIC HYDRAZIDE
Stuntman, see MALEIC HYDRAZIDE
Super De-Sprout, see MALEIC HYDRAZIDE
Surflan, see ORYZALIN
Sweep, see PARAQUAT

-T-

Tebulan, see TEBUTHIURON
TEBUTHIURON
Tedion, see TETRADIFON
TERBUTRYN
Tercyl, see CARBARYL
TETRADIFON
Tetradiphon, see TETRADIFON
Tiurolan, see TEBUTHIURON
Torch, see BROMOXYNIL
Tordon, see PICLORAM
Tornado, see ACEPHATE
Treficon, see TRIFLURALIN
Treflam, see TRIFLURALIN
Treflan, see TRIFLURALIN
Trefanocide elancolan, see TRIFLURALIN
Tricarnam, see CARBARYL
Trident, see TRIFLURALIN
TRIFLURALIN
Triflurex, see TRIFLURALIN
Trim, see TRIFLURALIN
Trimetron, see DIMETHOATE

-U, V-

Unipon, see DALAPON
UREABOR
Urox B, see BROMACIL
Urox-HX, see BROMACIL
Vectal, see ATRAZINE
Velpar, see HEXAZINONE
Vertan, see 2,4-D
Vorax, see SIMAZINE
Vondalhyde, see MALEIC HYDRAZIDE
Vondrax, see MALEIC HYDRAZIDE

-W, X, Y, Z-

Weedar-AT, see AMINOTRIAZOLE
Weedar-C4, see 2,4-D
Weedazal, see AMINOTRIAZOLE
Weed-B-Gon, see 2,4-D
Weed-E-Rad, see MSMA
Weed-E-Rad 360, see DSMA
Weed-Hoe-108, see MSMA
Weed-Hoe-120, see MSMA
Weedone, see 2,4-D
Zeapur, see SIMAZINE
Zeazin, see ATRAZINE
Zithiol, see MALATHION

Source: Thomson, 1981a-b; Thomson, 1982.

APPENDIX B

FUNCTIONAL CURVES FOR HABITAT EVALUATION ASSESSMENT METHODS

Appendix B contains functional curves for various parameters, to be used in conjunction with the habitat evaluation in the Assessment Methods section of this manual (Figures 9 through 22).

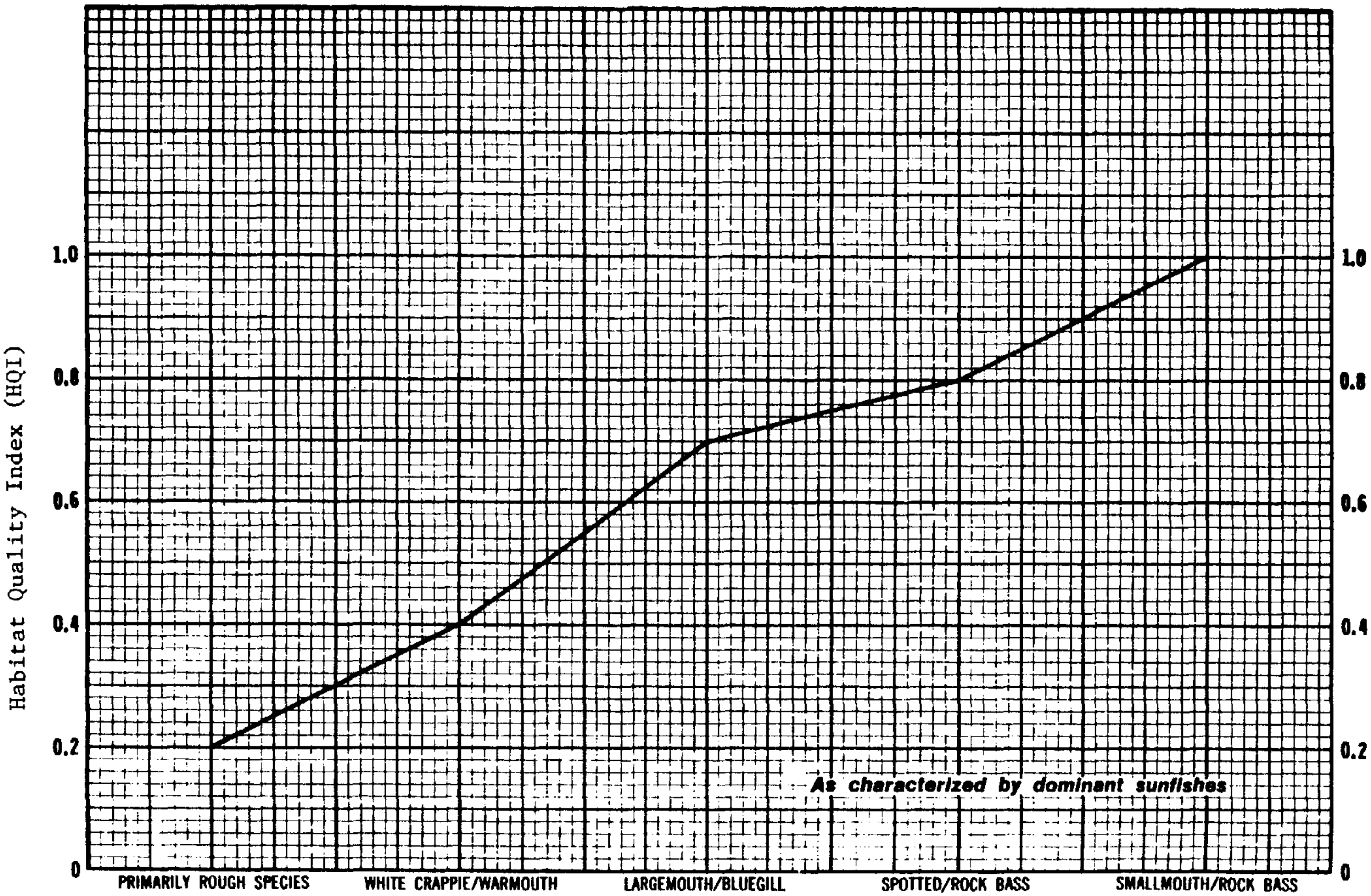

Figure 9. Functional curve for stream fish species associations.

Source: COE, 1980

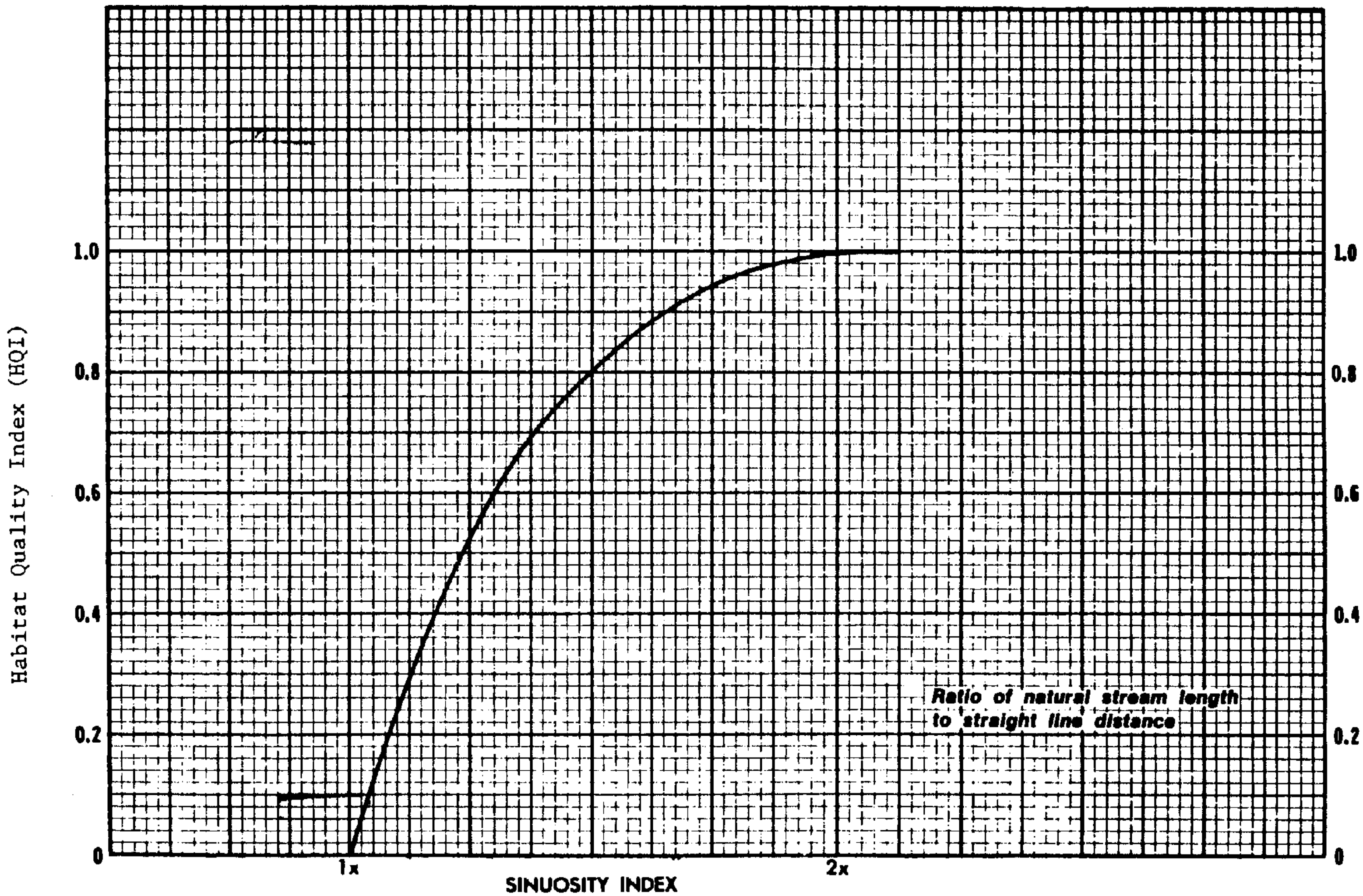

Figure 10. Functional curve for stream sinuosity index.

Source: COE, 1980

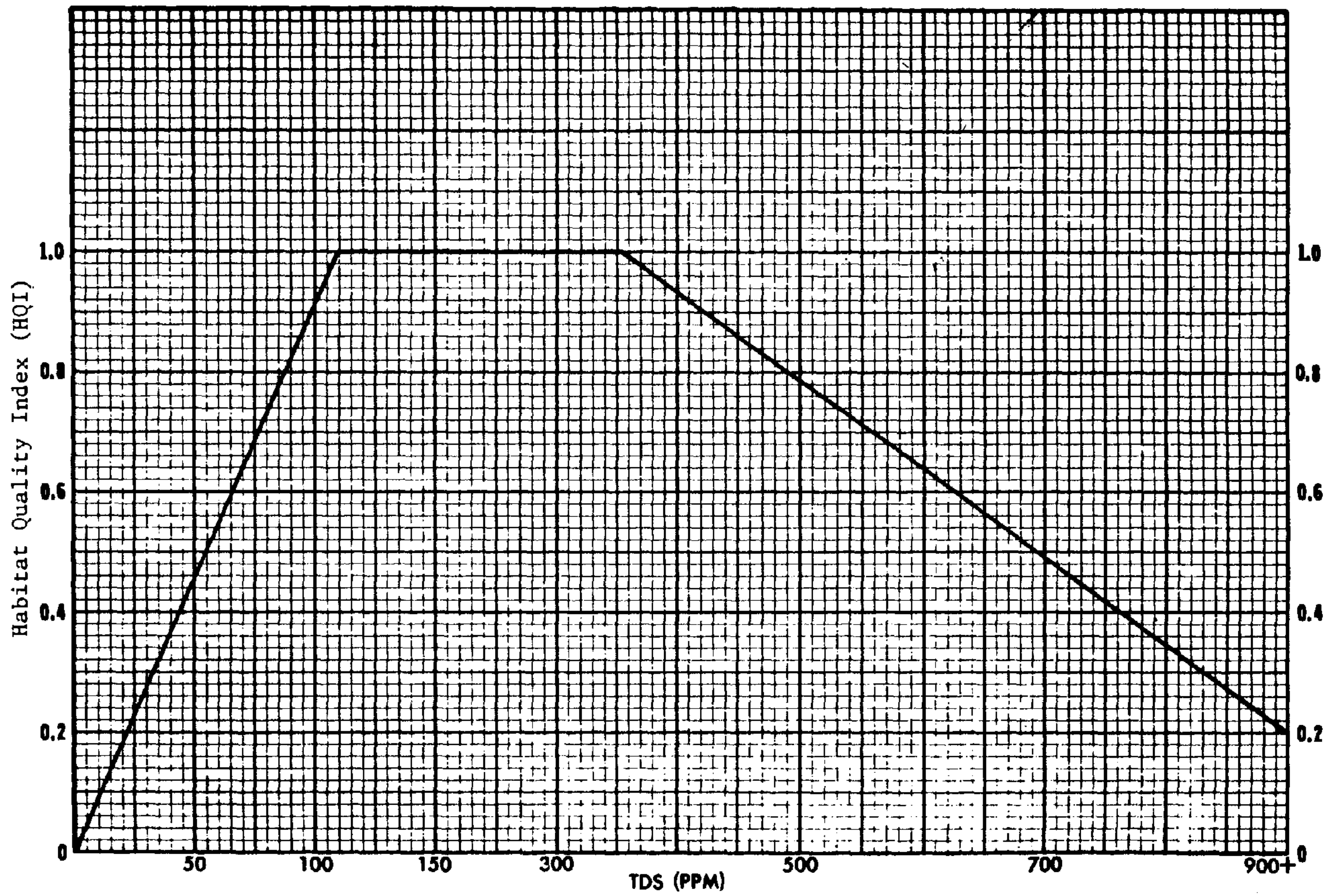

Figure 11. Functional curve for stream total dissolved solids.

Source: COE, 1980

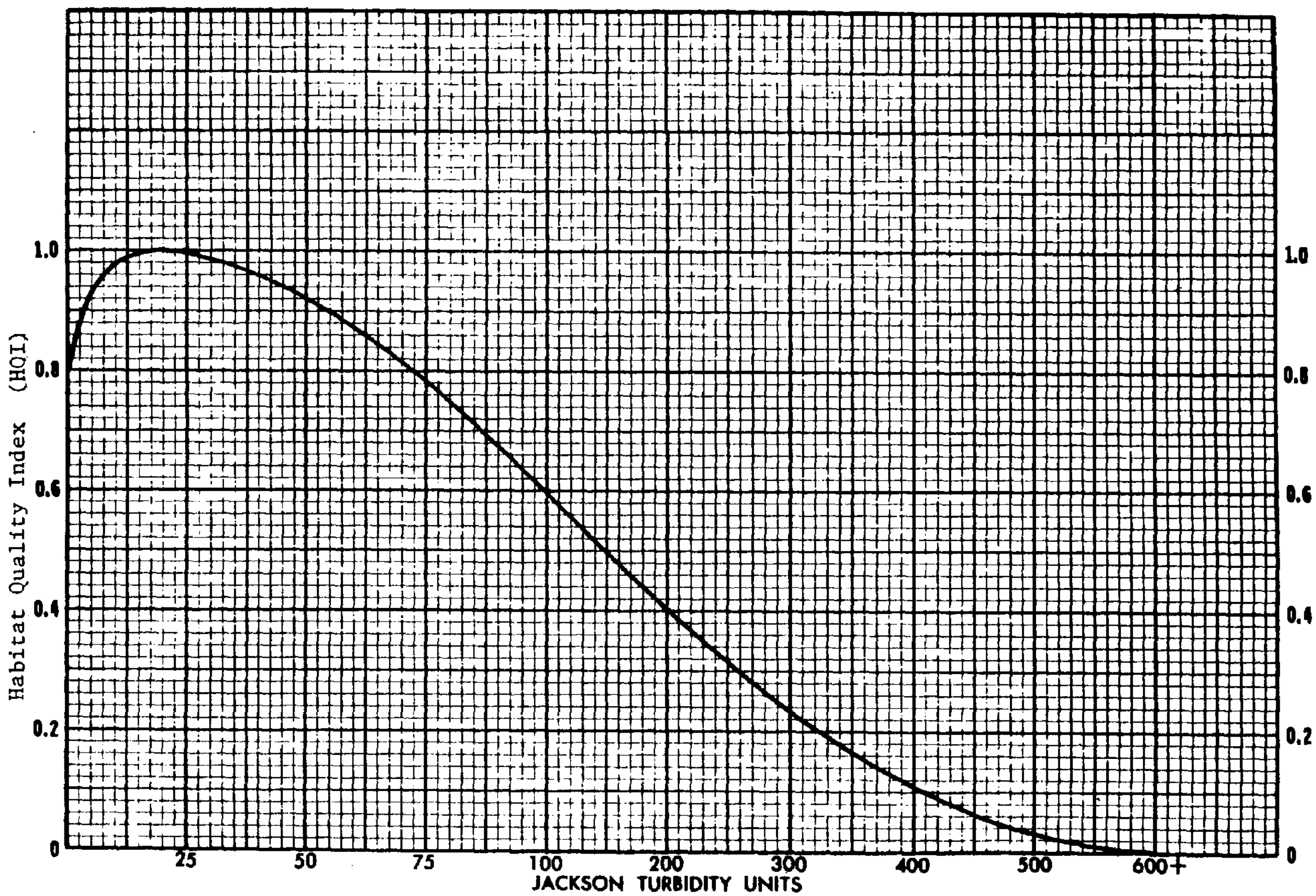

Figure 12. Functional curve for stream turbidity.

Source: COE, 1980

Figure 13. Functional curve for stream chemical type.

Source: COE, 1980

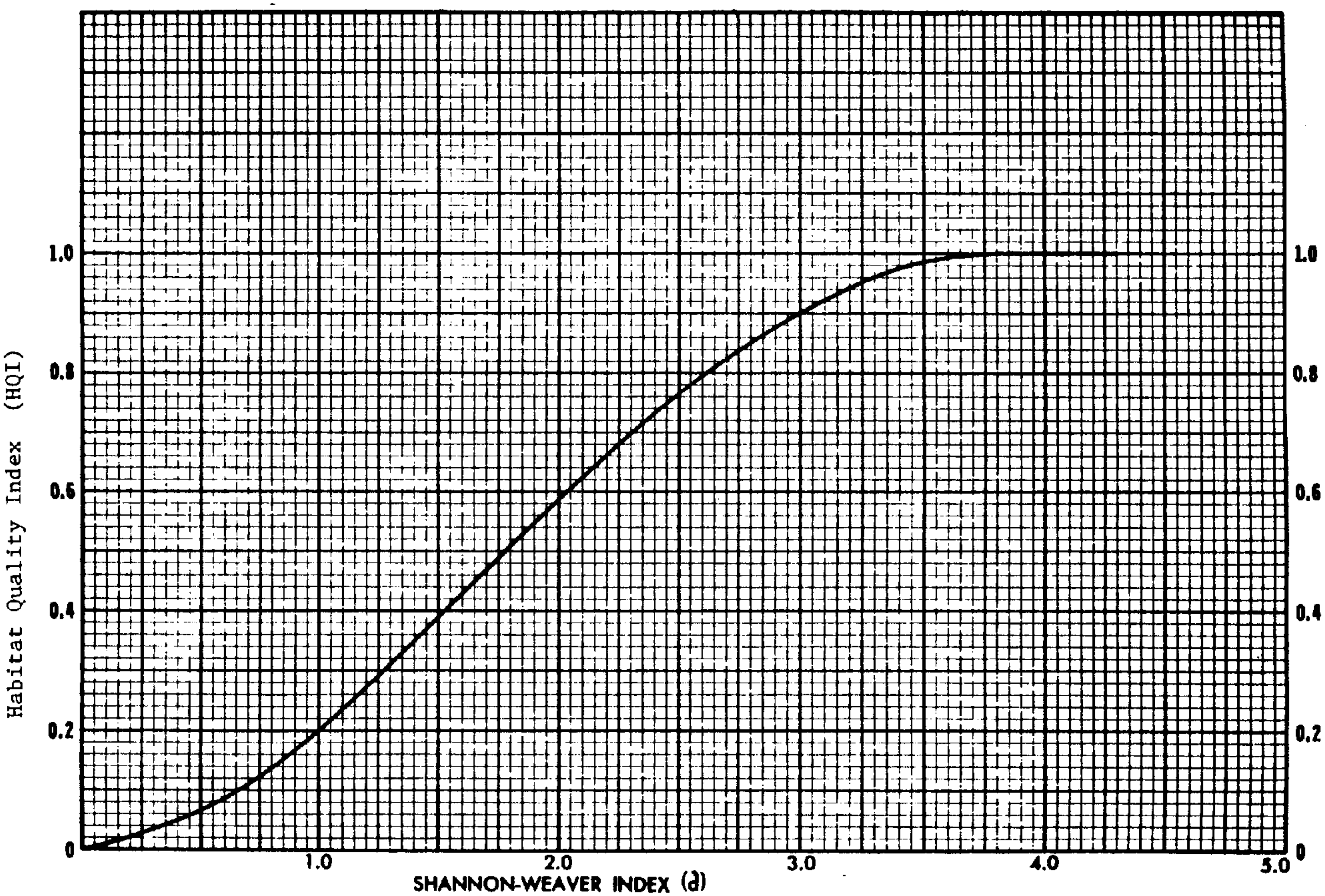

Figure 14. Functional curve for stream benthic diversity.

Source: COE, 1980

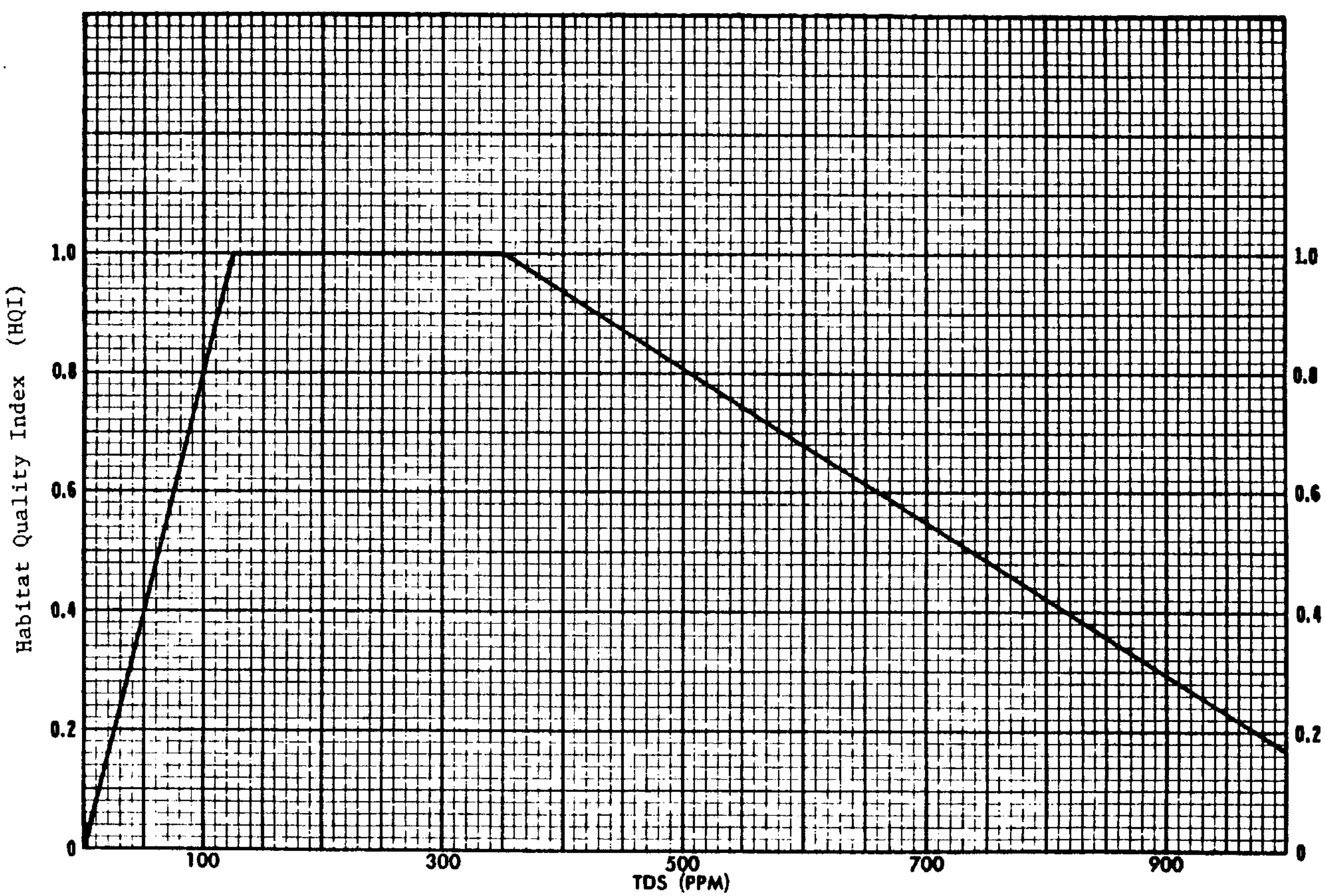

Figure 15. Functional curve for lake total dissolved solids.

Source: COE, 1980

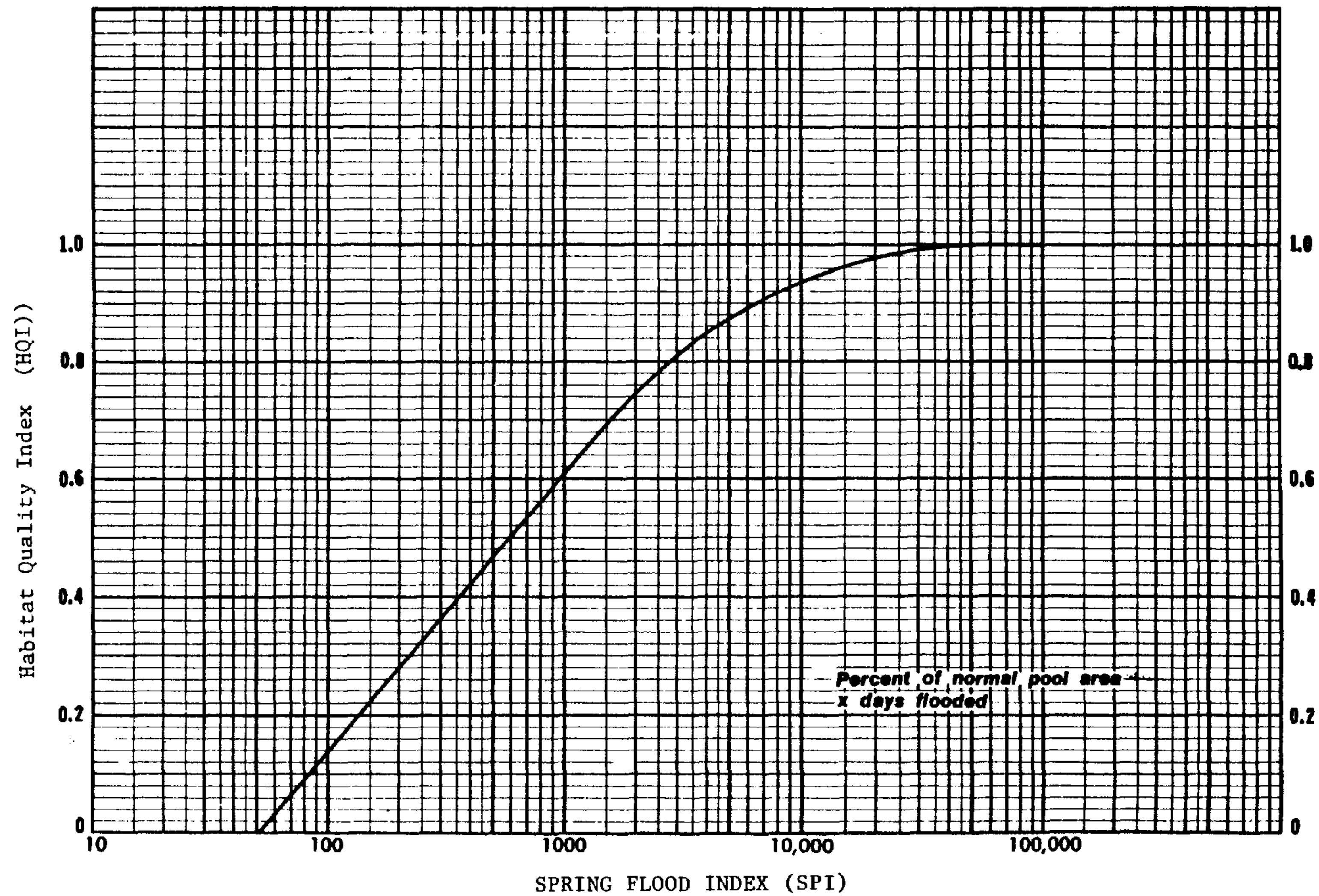

Figure 16. Functional curve for lake spring flooding index.

Source: COE, 1980

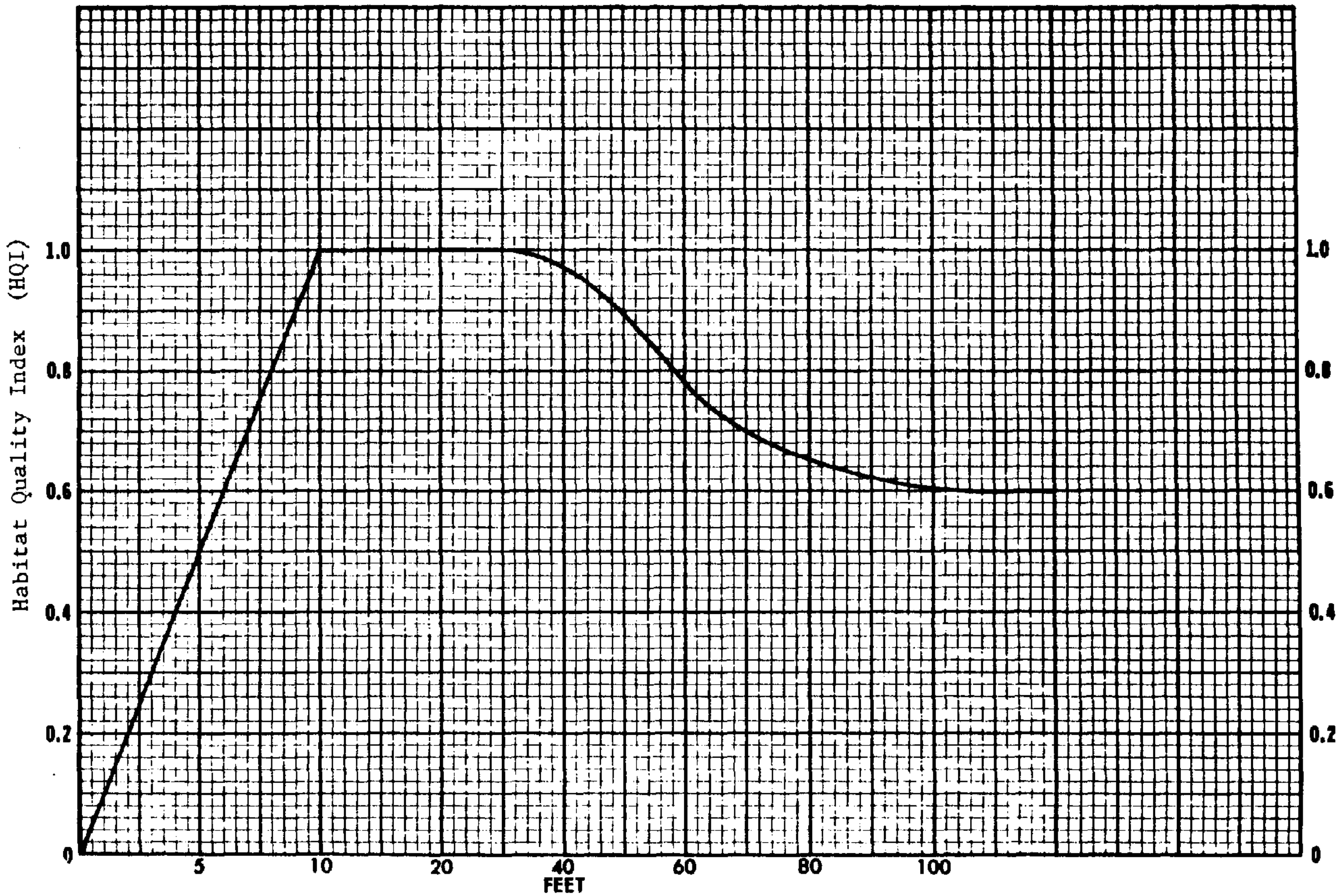

Figure 17. Functional curve for lake mean depth.

Source: COE, 1980

Figure 18. Functional curve for lake chemical type.

Source: COE, 1980

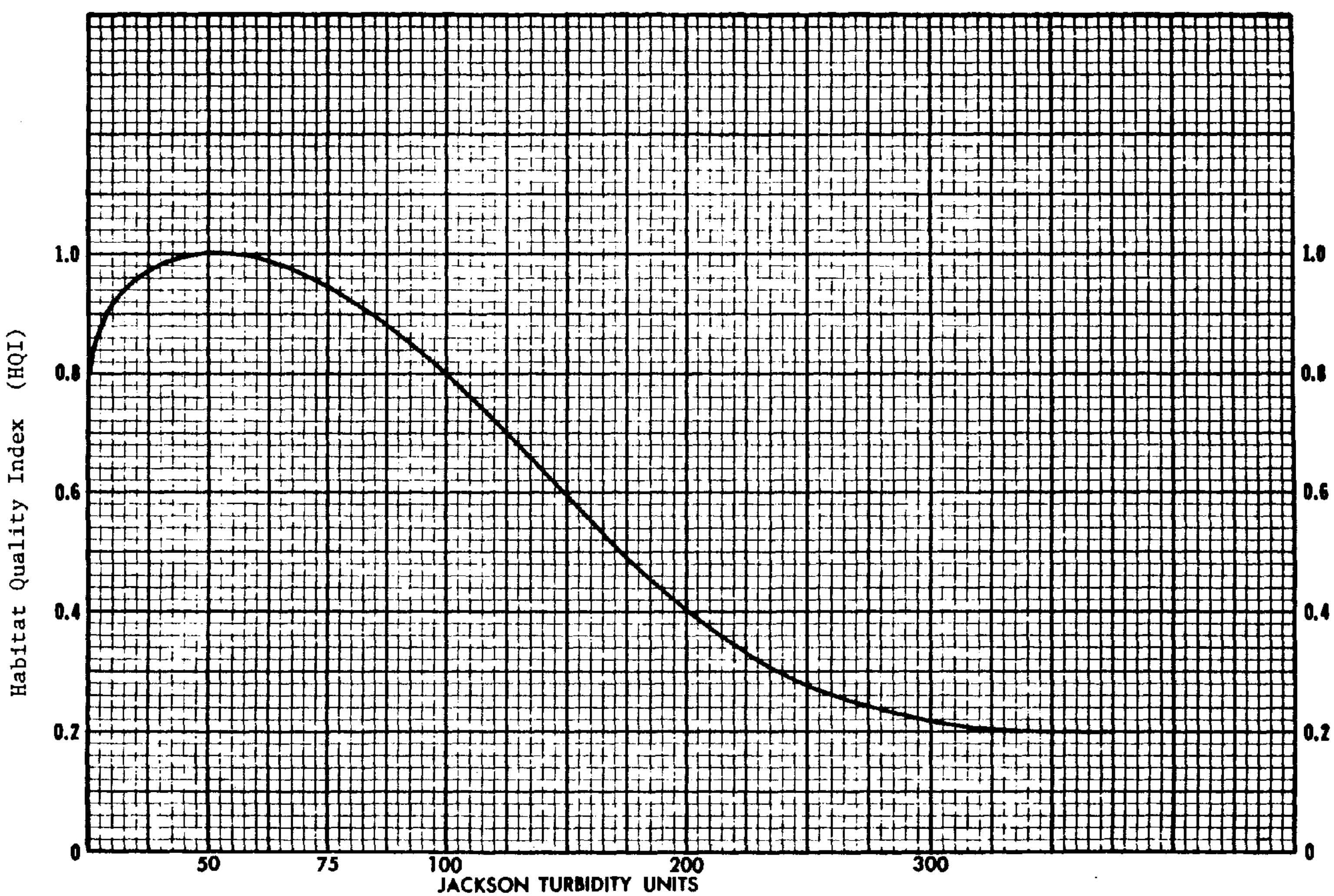

Figure 19. Functional curve for lake turbidity.

Source: COE, 1980

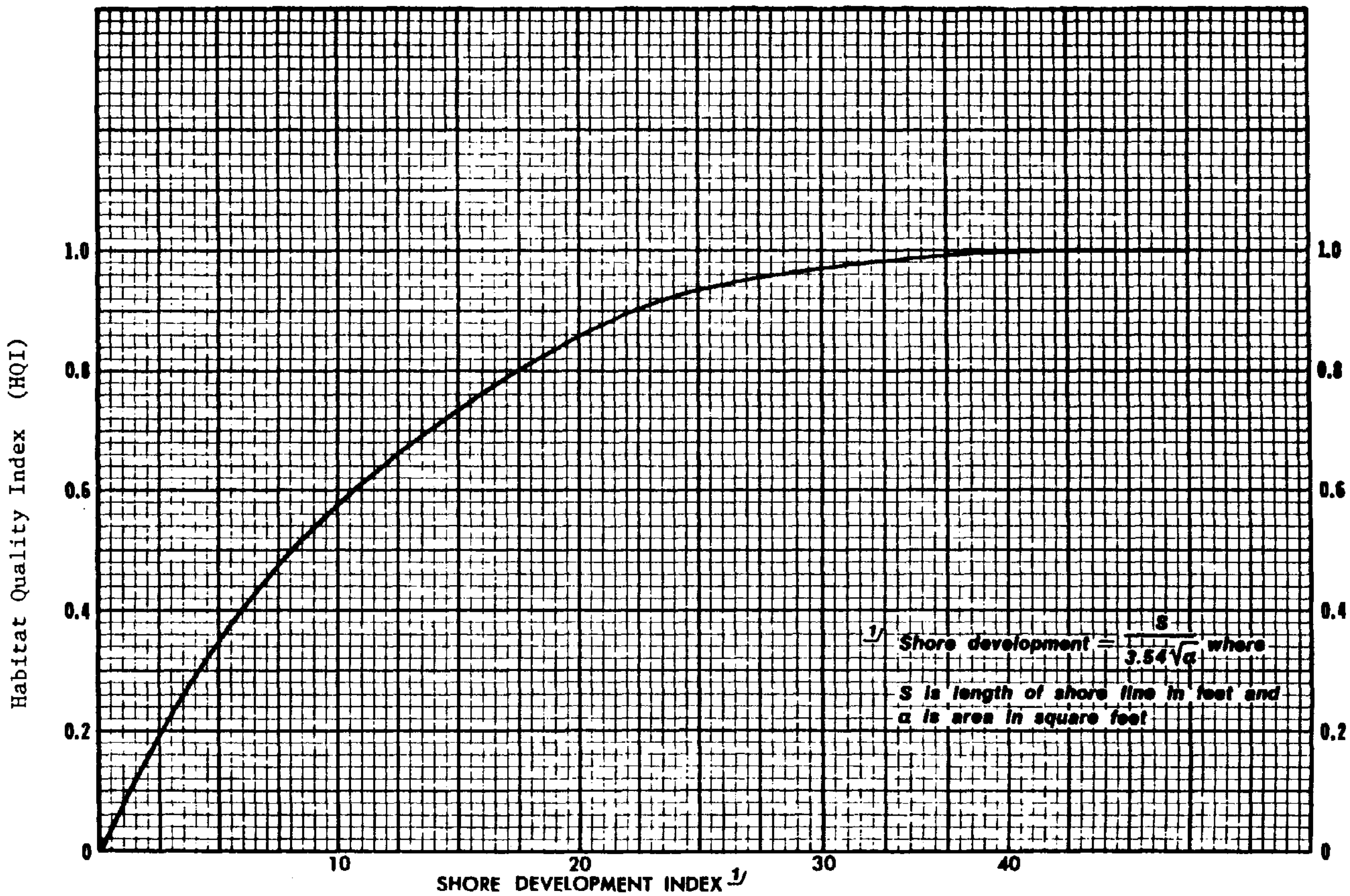

Figure 20. Functional curve for lake shore development index.

Source: COE, 1980

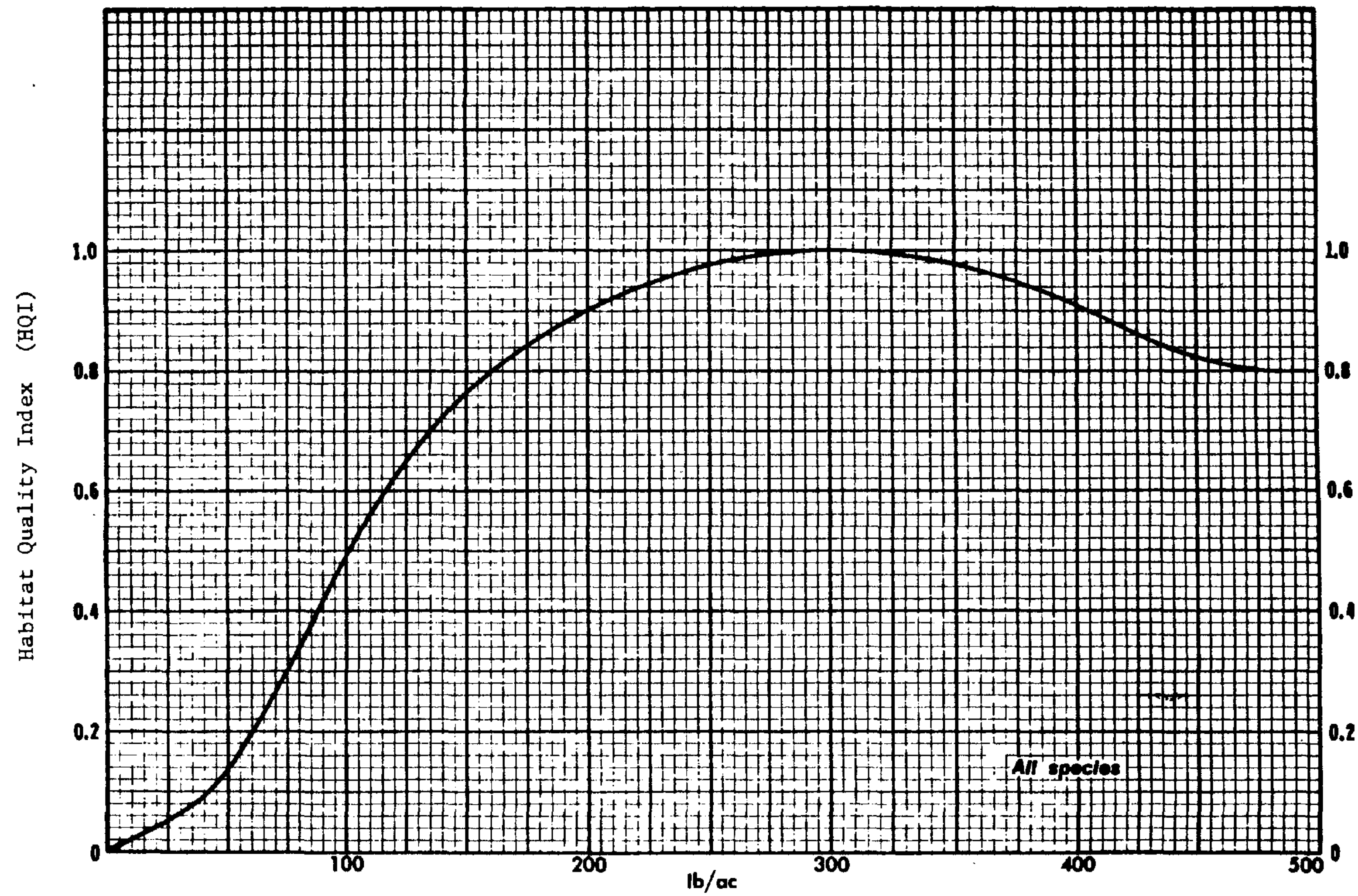

Figure 21. Functional curve for lake standing crop of fishes.

Source: COE, 1980

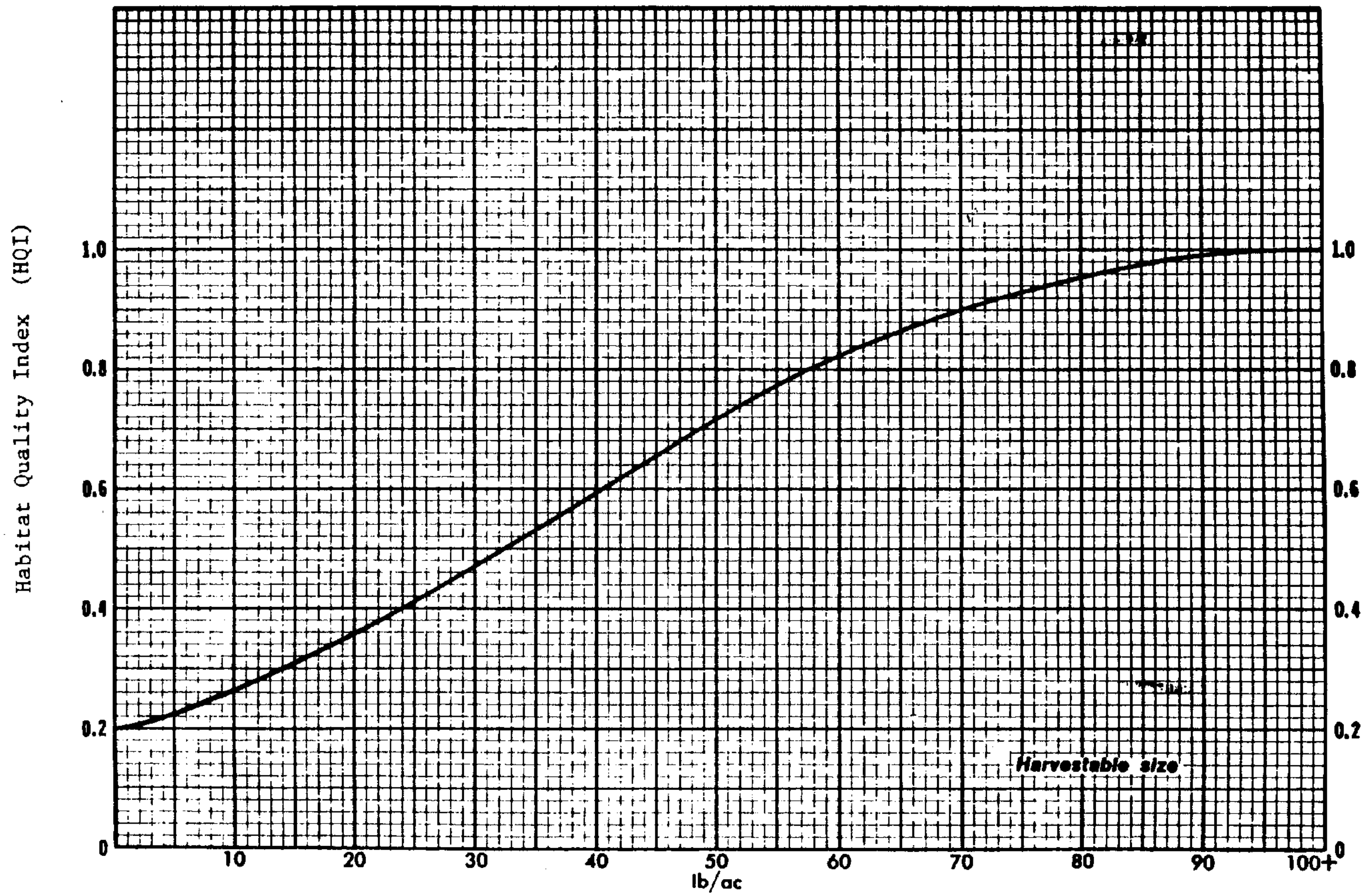

Figure 22. Functional curve for lake standing crop of sport fishes.

Source: COE, 1980

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