WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Draft Environmental Impact Statement

Cleanup Standards

July 1990

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ECOLOGY

Draft Environmental Impact Statement

Cleanup Standards

Amendments to the Model Toxics Control Act Cleanup Regulation

Chapter 173-340 WAC

Prepared by
Toxics Cleanup Program
Washington Department of Ecology
Mail Stop PV-11
Olympia, Washington 98504-8711

June 27, 1990

Dear Interested Persons:

The Department of Ecology has proposed amendments and new sections to the Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC. The proposed rule includes the detailed requirements for establishing cleanup standards and selecting cleanup actions, and defines the requirements for leaking underground storage tank (LUST) corrective actions.

The proposed regulation and draft EIS are being issued to obtain public review and comment prior to final adoption in November 1990. Written comments on the proposed regulation and draft EIS must be received at the Department of Ecology office no later than 5:00 p.m. on Monday, September 17. Informational meetings will be held the week of August 13 and public hearings will be held on September 6, 10 and 11. A schedule of the meetings and hearings is included in the Fact Sheet which appears just before the Table of Contents in the draft EIS.

The first two chapters of the draft EIS provide a description of background information necessary to understand the history and applicability of cleanup levels at hazardous waste sites. Chapter 3 discusses issues affecting setting cleanup levels and Ecology's resolution of these issues in the regulation. Chapter 4 discusses the six alternatives for setting cleanup levels, and the issues associated with each alternative. An overview of the affected environment appears in Chapter 5. Chapter 6 through 13 examines impacts of the cleanup standard alternatives. Chapter 14 evaluates the alternatives for setting cleanup levels and lays out the preferred alternative. Finally, Chapter 15 describes the opportunities for public comment and involvement in both the EIS process and the rule adoption process.

The Department of Ecology welcomes and encourages comments on the proposed regulation and draft EIS.

Sincerely,

Carol L. Fleskes

Carol Fleskes, Manager
Toxics Cleanup Program

WASHINGTON STATE DEPARTMENT OF ECOLOGY

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Fact Sheet

Name of Proposal

Cleanup Standards

Nature of Proposal

The proposed action is to adopt amendments and new sections to the Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC). The cleanup standards amendment establishes numerical cleanup levels for relatively straightforward cleanup actions and provides a process for establishing site-specific cleanup levels at more complex sites. The regulation also specifies basic requirements for cleanup actions, specifies criteria for selecting among alternative cleanup actions, and establishes the requirements for leaking underground storage tank corrective actions.

Location of Proposal

The cleanup standards would apply on a statewide basis.

Alternatives

The draft EIS evaluated the following six alternatives for contaminants in each medium:

Background - The cleanup standard is established at the prerelease background concentration of each contaminant in each medium.

Risk-based - The cleanup standard is established at a level determined to be protective of human health and the environment based on the results of an endangerment assessment.

Applicable or relevant and appropriate requirements (ARARs) - The ARAR with the lowest concentration is chosen as the cleanup standard after all ARARs have been determined.

Technology-Based - The cleanup standard is established at the lowest concentration level that is achievable by available cleanup technology.

Combination - This is the preferred alternative. The cleanup standard is established at the lowest of the risk-based and ARAR concentrations, providing that both are higher than the natural background concentration of the contaminant. Otherwise, the natural background concentration is chosen.

No-Action - The no-action alternative is equivalent to the ARAR alternative.

Lead Agency

Washington State Department of Ecology

Responsible Official

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Subsequent Environmental Review

Individual hazardous waste sites will be reviewed for compliance with SEPA.

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Required Approvals Adoption by the Washington State Department of Ecology.

Date of Issue 27 July 1990

Date Comments are Due to Ecology 17 September 1990, 5:00 p.m.

Dates and Locations of Public Meetings Public hearings, followed by informational meetings, will be held at 7:00 p.m. in:

- Seattle: Thursday, 6 September 1990, Mountaineers Club Skagit Room, 300 3rd Avenue West
- Richland: Monday, 10 September 1990, Federal Building Auditorium, 825 Jawdin Avenue
- Spokane: Tuesday, 11 September 1990, Spokane County Health District Building, Conference Room 140, West 1101 College Street.

Additional information meetings will be held in:

- Tacoma: Monday, 13 September 1990, Tacoma World Trade Center Conference Room, 3600 Port of Tacoma Road, ~~7:00~~ 1:00 p.m.
- Vancouver: Tuesday, 14 September 1990, Clark County Public Utilities District Community Room, 1200 Fort Vancouver Way, 7:00 p.m.
- Seattle: Wednesday, 16 September 1990, Mountaineers Club Tahoma Room, 300 3rd Avenue West, 7:00 p.m.
- Lacey: Thursday, 16 August 1990, Energy Facility Site Evaluation Council Hearing Room, Rowe 6, Building 1, 4224 Sixth Avenue South, 1:00 p.m.

Date of Final Action Effective December 1990 (date may be subject to change).

Location of Background Information

Technical documents referenced in Draft EIS available through:

Washington State Department of Ecology
Toxics Cleanup Program
Woodland Square
4415 Woodview Drive Southeast
Lacey, WA 98503

Cost of Document

The Draft EIS and Technical Appendices are available for no charge, with a limit of one per person. Additional copies may be purchased for the cost of reproduction.

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List of Acronyms

ACR	acute/chronic ratio
AET	apparent effects threshold
AKART	all known, available, and reasonable methods of treatment
ARAR	applicable or relevant and appropriate requirement
ASIL	acceptable source impact levels
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CPF	carcinogenic potency factor
DWEL	drinking water equivalent level
Ecology	Washington Department of Ecology
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
IRIS	Integrated Risk Information System
MCL	maximum contaminant level
MCLG	maximum contaminant level goals
MEPAS	Multimedia Environmental Pollutant Assessment System
MTC	maximum tolerable concentration
MTCA	Model Toxics Control Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
OSHA	Occupational Safety and Health Act
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PLP	potentially liable party
PNHWAC	Pacific Northwest Hazardous Waste Advisory Council
PQL	practical quantitation limits
PSAPCA	Puget Sound Air Pollution Control Agency
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RfD	reference dose
SARA	Superfund Amendments and Authorization Act
SEPA	State Environmental Policy Act
SIC	standard industrial classification
SMIS	Site Management Information System
TEAM	Total Exposure Assessment Methodology
TSD	treatment, storage, and disposal (facilities)
WAC	Washington Administrative Code

Technical Summary

This environmental impact statement (EIS) addresses the alternatives for setting cleanup standards for hazardous substances under the Model Toxics Control Act (MTCA) (Chapter 70.105D RCW). The proposed cleanup standards amendments establish numerical cleanup levels for relatively straightforward cleanup actions and provides a process for establishing site-specific cleanup levels at more complex sites. These rules will be applied to hazardous substances in ground water, surface water, marine water, soil, and air. Marine sediments are being considered in a separate EIS being prepared by the Department.

Ecology is developing a comprehensive regulation, the Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC), which provides the overall implementation framework. This regulation is being developed in two phases. The Phase I portion defines the administrative process for identifying, investigating, and cleaning up hazardous waste sites. Phase I became effective on May 4, 1990.

Phase II includes the provisions for establishing cleanup levels, selecting cleanup actions, and performing leaking underground storage tank (LUST) corrective actions. The Phase II amendments to the MTCA Cleanup Regulation are the proposed agency action being evaluated in this EIS.

Background Information

Over the last ten years, Ecology has used several statutory authorities to require site cleanups. Throughout the late 1970s and early 1980s, the state Water Pollution Control Act (Chapter 90.48 RCW) and state Hazardous Waste Management Act (Chapter 70.105 RCW) were used as the primary authorities for cleanup of hazardous waste sites. In 1984, Ecology developed a final cleanup policy with technical criteria for determining cleanup levels on a site-specific basis. This 1984 policy is generally referred to as the *How Clean Is Clean* policy. (The complete text of the *How Clean Is Clean* policy is provided in Appendix E.)

Passage of the state's Hazardous Waste Cleanup Act in 1987 provided a comprehensive statutory authority covering the identification, characterization, and cleanup of hazardous waste sites. This law also create a trust fund, financed by a new tax on hazardous substances, to support the state program. The Hazardous Waste Cleanup Act of 1987 was in effect for 16 months before being replaced by the Model Toxics Control Act which became effective in March 1989.

The Model Toxics Control Act

In November 1988, Washington voters passed the Model Toxics Control Act (MTCA). This statute, subsequently codified as Chapter 70.105D RCW, establishes the basic authorities and requirements for cleaning up hazardous waste sites in a manner that will protect human health and the environment. It also includes a tax on hazardous substances to finance the state program. RCW 70.105D.030(2)(d) directs Ecology to adopt and enforce:

"*...minimum cleanup standards for remedial actions at least as stringent as the federal cleanup standards under section 121 of the federal cleanup law, 42 U.S.C. 9621 and at least as stringent as all applicable state and federal laws, including health-based standards under state and federal law...*"

With respect to selecting remedial actions for individual sites, RCW 70.105D.030(1)(b) specifies that "....[in] conducting, providing for, or requiring remedial actions, the department shall give preference to permanent solutions to the maximum extent practicable and shall provide for or require adequate monitoring to ensure the effectiveness of the remedial action..."

The Federal Cleanup Law

The Federal cleanup law referenced in RCW 70.105D.030(2)(d) is the Comprehensive Environmental Response Compensation and Liability Act of 1980 as amended by the Superfund Amendments and Reauthorization Act of 1986 (hereinafter referred to as CERCLA). Under Section 121(b) of CERCLA, EPA is required to "...select a remedial action that is protective of human health and the environment, that is cost-effective, and that utilizes permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable...."(A complete summary of the Section 121 of CERCLA is provided in Appendix D).

Section 121(d) specifies that protection of human health and the environment is to be achieved, at least in part, by identification and compliance with "applicable or relevant and appropriate standard, requirement, or criteria, or limitation ....for a hazardous substance, pollutant, contaminant, remedial action, or location...." (commonly referred to as ARARs).

Two other subsections in Section 121 of CERCLA have been discussed in the context of the Model Toxics Control Act. First, Section 121(d)(4) specifies that EPA may waive compliance with ARARs in limited situations, as long as the cleanup is protective of human health and the environment. The second provision is Section 121(c) which provides that if EPA "...selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, [EPA] shall review such remedial action no less frequently than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented..."

Applicable State and Federal Laws

RCW 70.105D.030(2)(d) specifies that minimum cleanup standards shall be at least as stringent as "applicable state and federal laws". This term is similar, but not identical, to the federal term, "applicable or relevant and appropriate requirements" (ARARs). As discussed in Chapters 3 and 4, Ecology has proposed to define "applicable state and federal laws" to include both "legally applicable" and "relevant and appropriate" requirements.

Section 121(d) refers to ARARs, but does not define them. The definition is found in the National Contingency Plan (EPA, 1990) which establishes a two-step process for identifying ARARs. Under this process, a requirement is first evaluated to determine if it is legally applicable. The basic criterion for determining whether a requirement is applicable is that it applies as a matter of law. For example, the state's water quality standards are legally applicable requirements for waters of the state. If a particular requirement is not legally applicable, it may be judged to be "relevant and appropriate." A law or regulation is relevant and appropriate if it addresses problems "...sufficiently similar to those encountered at the CERCLA site that it's use is well suited to the particular site..." For example, drinking water standards are legally applicable requirements for drinking water at the tap. However, these standards are usually judged to be relevant and appropriate requirements for ground water or surface water that represents a current or potential source of drinking water.

Ecology's Regulatory Goals

The development of the draft cleanup standard amendments involved the consideration and balancing of a number of issues and interests. The proposed amendments were developed to satisfy the following six goals or objectives:

- Remediation of contaminated sites to levels that are protective of human health and the environment. Ecology's foremost goal was to develop standards that are protective of human health and the environment. Protection is defined to include both current and future generations and susceptible subgroups, such as small children, that are particularly sensitive to hazardous substances;

- Scientifically and legally defensible cleanup standards. An important goal was to develop standards that are scientifically and legally defensible. Toward that end, Ecology reviewed the scientific literature and consulted with members of the Science Advisory Board and other individuals experienced in the areas of risk assessment. Where conflicting opinions or recommendations exist, Ecology has attempted to balance the various positions to arrive at a scientifically defensible and workable approach;

- Performance of cleanup actions in a manner that is consistent with existing state and federal regulatory programs. The MTCA requires that minimum cleanup standards be at least as stringent as applicable state and federal laws. In developing the proposed amendments, Ecology has attempted to rely on requirements established under these other authorities and avoid creating duplicative requirements. However, hazardous waste cleanup sites are frequently more complex than situations addressed by existing programs. Consequently, Ecology has attempted to provide an approach that supplements existing requirements to address situations where multi-media contamination and mixtures of hazardous substances are present;

- Efficient cleanup of contaminated sites. An important objective of the proposed amendments is to increase the efficiency of site cleanup. In particular, the proposed amendments represent an attempt to reduce the amount of flexibility in the present system which serves to heighten uncertainty rather than predictability, resolve certain key policy issues, and a create system which focuses available funds on site cleanup rather than site negotiation or litigation;

- Use of a consistent approach for assessing and managing health risks. In the past, there has been considerable variability in both the quality and methodologies used to develop cleanup levels. Through the development of the proposed amendments, Ecology hopes to ensure that consistent procedures are used to assess and manage health risks;

- Provide some flexibility to address individual site characteristics. In developing the proposed amendments, Ecology has tried to balance the goals of regulatory consistency and efficiency with the need to provide some flexibility to address individual site characteristics.

Ecology's Rulemaking Approach

In developing the cleanup standards, Ecology has also attempted to address the concerns and opinions of a wide range of interest groups. Ecology formed the Cleanup Standards Work Group to facilitate discussion during the development of the proposed amendments. Formed in March 1989, the work group is composed of representatives from environmental groups, business, Indian Tribes, and other government agencies. Also in March 1989, the Department held a series of scoping workshops to obtain public comments and opinions on issues related to the development of the cleanup standards and the preparation of this EIS.

Under RCW 70.105D.030(4), Ecology was required to establish a five-meber Science Advisory Board. The Board is specifically charged with providing objective scientific advice on cleanup standards and other scientific matters. The five member Board was appointed in April 1989.

During the last year, Ecology has prepared several review drafts of the cleanup standard amendments which were distributed for review by the Board and the Work Group. In March 1990, the Department distributed a draft of the standards for public review and comment. A series of nine public workshops were held to solicit public comment and discuss concerns. Ecology incorporated changes into cleanup standard amendments as a result of public comment and filed the proposed standards with the Code Revisor concurrently with publishing the draft EIS. The amendments will be officially issued as a proposed rule in the State Register on August 1, 1990. The amendments and the EIS will undergo formal public review prior to completion.

The Proposed Amendments

The proposed action is an amendment to the Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC). The proposed cleanup standards amendments would establish numerical cleanup levels for relatively straightforward cleanup actions and provide a process for establishing site-specific cleanup levels at more complex sites. These rules will be applied to hazardous substances in ground water, surface water, marine water, soil, and air. The proposed amendments also include provisions for selecting cleanup actions and performing leaking underground storage tank (LUST) corrective actions.

The proposed amendments would apply to owners and operators of facilities (commonly referred to as hazardous waste sites) where there has been a release or threatened release of hazardous substances that may pose a threat to human health or the environment. These facilities include locations where hazardous substances have entered ground water, fresh and marine surface water, soils, air, sediments, or combinations of these media.

The proposed amendments include a number of key provisions which are summarized below. The complete regulation is available upon request from the Department.

General Requirements

There are four sections within the proposed amendments that include cleanup provisions that apply to hazardous substances in all media. These include:

General Procedures - WAC 173-340-700 introduces the concepts of compliance cleanup levels and conditional cleanup levels and defines how the cleanup levels sections relate to other portions of the regulation. Compliance cleanup levels are defined as concentrations that are protective of human health and the environment under unrestricted site use conditions. Conditional cleanup levels are defined as concentrations that are protective under limited site use conditions (for example, industrial site use). In both cases, cleanup levels would be based on reasonable maximum exposure scenarios and the highest beneficial use of a particular state resource such as surface water. The reasonable maximum exposure is defined as the highest exposure that is reasonably expected to occur at the cleanup site taking into account both current and potential future site use.

General Principles - WAC 173-340-705 defines the policies and procedures that Ecology will utilize to ensure that cleanup levels are established and implemented in a scientific and technically sound manner.

Applicable State and Federal Laws - WAC 173-340-710 defines the criteria for determining what requirements are applicable state and federal laws. Ecology has proposed to define this term to include both "legally applicable" and "relevant and appropriate" requirements. The proposed definitions for these terms and criteria for judging individuals laws and regulations are virtually identical to provisions included in the National Contingency Plan (EPA, 1990).

Definitions - WAC 173-340-200 has been amended to incorporate those terms that are unique to cleanup standards and LUST portions of the regulation.

Cleanup Levels

There are six sections that provide more detailed procedures for establishing cleanup levels in the various environmental media. Each section defines the reasonable maximum exposure for that media, applicable state and federal laws, risk assessment procedures for hazardous substances, and points of compliance. The six sections include:

- Ground Water Cleanup Standards - WAC 173-340-720
- Surface Water Cleanup Standards - WAC 173-340-730
- Soil Cleanup Standards - WAC 173-340-740
- Industrial Soil Cleanup Standards - WAC 173-340-745
- Cleanup Standards to Protect Air Quality - WAC 173-340-750
- Sediments Cleanup Standards - WAC 173-340-760

The sediment cleanup standards are being reserved until Ecology's Sediment Management Unit has developed regulations that will define a comprehensive approach for managing sediments.

Selection of Cleanup Actions

There are five sections that specify requirements for selecting and implementing cleanup actions. These include:

Selection of Cleanup Actions - WAC 173-340-360 defines the basic requirements for cleanup actions under this chapter and procedures for documenting cleanup decisions. Under the proposed amendments, cleanup actions must be protective of human health and the environment (including compliance with cleanup standards), comply with applicable state and federal laws, and provide for monitoring to assure the effectiveness of the cleanup. When selecting from among several alternatives which fulfill these basic requirements, the cleanup action must use permanent solutions to the maximum extent practicable, be practicable for the site, provide for a reasonable restoration time frame, and consider public concerns.

Periodic Review - WAC 173-340-420 defines the requirements for periodically reviewing cleanup actions. The proposed amendments specify that in situations where residual hazardous substances exceed compliance cleanup levels or if conditional points of compliance are approved, the Department shall review the cleanup action at least once every five years to assure that human health and the environment is being protected.

Institutional Controls - WAC 173-340-440 defines the general requirements for restricting site use where hazardous substances are left onsite as part of the cleanup action. Under the proposed amendments, institutional controls which restrict the use of the site and affected natural resources shall be required when residual levels of hazardous substances exceed compliance cleanup levels or a conditional point of compliance is established. The institutional controls shall be described in a restrictive covenant which, which at a minimum, shall specify appropriate site use restrictions to protect human health and the environment and maintain the integrity of cleanup measures.

Leaking Underground Storage Tanks - WAC 173-340-450 responds to the need to address the corrective action requirements outlined in the federal Underground Storage Tank rules. The proposed amendments specify additional requirements for UST owners and operators regulated under Chapter 90.76 RCW. These include reporting of confirmed releases within 24 hours, followup investigations, free product removal and immediate assessment and reduction of the threat to human health and the environment at the site. A written report describing the site and remedial actions must be submitted within ninety days of release confirmation. If appropriate, UST owners and operators must also conduct and report and additional cleanup actions.

Analytical Procedures - WAC 173-340-830 defines standard analytical methods for use in the investigation and cleanup of hazardous waste sites.

Issues Associated With The Proposed Amendments

Issues that affect the approach to setting cleanup levels were widely discussed during the drafting of the proposed amendments. Comments on many of the issues were specifically solicited as part of public workshops and scoping meetings. The Science Advisory Board and internal (Ecology) and external work groups devoted much of their time to careful examination of these issues. Ecology also requested opinions from the Attorney General's Office regarding several legal issues. Several of the most important issues are briefly identified below and are discussed in detail in Chapter 3.

Appropriate Level of Protection for Human Health and the Environment

The choice of what level of protection to use in setting cleanup levels is one of the most important management decisions associated with the cleanup standard amendments. With respect to noncarcinogens, Ecology is proposing to define protection of human health in terms of concentrations that prevent all known or anticipated acute or chronic toxic effects. For carcinogens, Ecology is proposing to define protection in terms of a range of acceptable cancer risk from 1 in 1,000,000 to 1 in 100,000. These proposals are similar to approaches being used by other regulatory programs within Ecology, consistent with other state and federal cleanup programs, and similar to levels of protection that have been required at individual cleanup sites in this state and other parts of the country.

Methods For Characterizing and Quantifying Human Health and Environmental Risks

Ecology has proposed rules which define the detailed procedures for establishing site-specific cleanup levels. These procedures are modeled upon the methods developed by the U.S. Environmental Protection Agency and other groups and individuals experienced in risk assessment procedures. The Department recognizes that there are many areas of controversy associated with risk assessment (whether risk assessments should use worst-case or average exposure assumptions, what approaches should be used to extrapolate from high level exposures in test animals to low level exposures in the human population, etc) and will continue to monitor future developments in these areas. Methods for assessing risks to ecological communities are still in the early stages of development.

Methods for Characterizing and Considering Scientific Uncertainty

A number of different types of uncertainties must be considered when performing risk assessments. These uncertainties include uncertainties in variables used to predict exposure and toxicity, uncertainties associated with regression models, uncertainties in predicting the toxicity of a contaminant to a species from tests on another species, and uncertainties in the exposure models. A variety of methods can be used to characterize and communicate these uncertainties so that appropriate risk management decisions can be made.

Uniform Statewide vs. Site-Specific Standards

In developing the proposed amendments, Ecology has attempted to design an approach which provides a workable balance between (1) approaches that specify uniform cleanup levels that would be applied to all sites within the state and (2) approaches that require cleanup levels be developed on a site-by-site basis. In striking that balance, the Department has evaluated the trade-offs between flexibility and predictability/consistency. For example, as the standards become more flexible, the ability to consider site-specific conditions is increased. However, as flexibility is increased, regulatory predictability is reduced and the possibility of unwarranted differences in cleanup levels across sites increased. Increased flexibility also places greater technical review and negotiation demands on Ecology staff, consultants, and the regulated community. The simplicity or complexity of the cleanup levels will also be affected by the choice of uniform vs. site-specific standards. In general, the use of a site-specific approach increases the length and complexity of the regulations. This is particularly troublesome for small businesses. However, if the procedures for establishing site-specific cleanup levels are not clearly specified in the regulations, the effects of site conditions on cleanup levels could become subject to competing interpretations, adversely affecting the clarity and implementability of the regulations.

Definition of Applicable or Relevant and Appropriate Requirements

RCW 70.105D.030(2)(d) requires that the cleanup standards be at least as stringent as Section 121 of SARA and all applicable state and federal laws, including health-based standards under state and federal law. Two primary issues are associated with this requirement. First, there is the issue of what constitutes an applicable state and federal law. As noted above, Ecology has proposed to define the term "applicable state and federal laws" to include both "legally applicable" and "relevant and appropriate" requirements. Ecology has proposed to adopt the federal definitions for these terms as specified in the National Contingency Plan (U.S. EPA 1990b). Second, there is the issue of whether Ecology should provide the flexibility to waive compliance with applicable state and federal laws on a site-specific basis. Although such provisions appear in the federal cleanup law and the previous state law, the MTCA is silent on this issue. Given the explicit provisions in the previous state law and the lack of such provisions in MTCA, provisions for waiving compliance with applicable state and federal laws were not incorporated into the proposed amendments.

Statutory Preference for Permanent Solutions

When selecting cleanup actions for particular sites, the MTCA requires that Ecology give preference to permanent solutions to the maximum extent practicable. Ecology has proposed to define permanent solutions as those cleanup actions which require no further actions (including long-term monitoring) at the cleanup site or at an offsite location where hazardous substances from the site might be taken for treatment or disposal (such as a landfill). A determination of whether a cleanup action for a particular site is permanent to the maximum extent practicable is based on a evaluation of several factors including technical feasibility, overall protection of human health and the environment, and cleanup costs.

Relationship Between Cleanup Levels and Technical Feasibility

Technical feasibility is defined as "....capable of being designed, constructed, and implemented in a reliable and effective manner, regardless of cost..." With respect to the relationship between technical feasibility and cleanup levels, two situations may arise. First, technically feasible levels may represent concentrations that are below health-based levels. In these situations, cleanup levels could be technology-based. This is consistent with the philosophy behind the state's antidegradation policy. On the other hand, technically feasible levels may represent concentrations substantially above health-based levels. Ecology recognizes that such situations may arise and the proposed rules provide some flexibility to modify compliance cleanup levels based on considerations of technical feasibility. The Department also recognizes that currently available analytical procedures place practical constraints on its ability to enforce cleanup level requirements and the proposed amendments address those constraints. Finally, the proposed amendments provide considerable flexibility to address technical feasibility through the selection of cleanup actions for a particular site.

Role of Cost in Selecting Cleanup Levels and Cleanup Actions

Costs have traditionally been one of the primary concerns in defining cleanup levels and selecting cleanup actions to achieve those levels. In contrast to the federal cleanup law, the MTCA does not include specific language regarding the role of cleanup costs in making these determinations. Only in the requirement that Ecology give preference to permanent solutions to the maximum extent practicable does the MTCA include a provision that could be interpreted to include cost considerations. Despite the statutory silence on this issue, Ecology believes it has the discretionary authority to consider cleanup costs in making these determinations as long as the overriding requirement to protect human health and the environment is satisfied. The proposed amendments provide some flexibility to modify site-specific cleanup levels within a constrained range where it can be demonstrated that the incremental costs associated with attaining a more stringent cleanup level are substantial and disproportionate to the incremental benefits. However, cleanup costs cannot serve as a justification for establishing cleanup levels that are less stringent than the minimum requirements specified in the rule. The proposed amendments also specify that practicability, which considers cleanup costs, is one factor in selecting cleanup actions.

Points of Compliance and Restoration Time Frames

Demonstrating compliance with established cleanup levels at a site is an important component of cleanup actions. Compliance monitoring and demonstration of compliance are covered under the procedural regulations of the MTCA (see WAC 173-340-410). The definition of compliance with cleanup levels requires establishing both the points of compliance and the schedule for compliance. These factors may be considered in determining the scope of required compliance monitoring.

State Environmental Policy Act Review of Site-Specific Cleanup Decisions

In contrast to the federal cleanup law and the previous state law, the MTCA does not explicitly exempt site cleanup decisions and actions from complying with permit or regulatory review requirements, including the State Environmental Policy Act (SEPA). Consequently, proposed cleanup actions at state hazardous waste sites will be subject to SEPA review. SEPA compliance may involve a determination of nonsignificance (DNS), preparation of a mitigated DNS, or the preparation of an EIS.

Relationship Between the Federal Superfund Program and the Model Toxics Control Act

The federal Superfund program and the MTCA have very similar goals for hazardous waste site cleanup. A given hazardous waste site in Washington may be subject to cleanup under either or both of these programs. In those instances, the MTCA cleanup regulations will be considered legally applicable requirements.

Procedures for Updating and Revising Cleanup Levels

Ecology is committed to assuring that sound scientific judgment is used in establishing cleanup levels for hazardous substances. Concerns have been expressed that the proposed amendments do not provide the flexibility to incorporate new scientific information. To address these concerns, Ecology has explicitly provided several mechanisms to responding the expanding scientific knowledge and important scientific developments. First, WAC 173-340-705(6) states that Ecology shall consider new scientific information when establishing cleanup levels. Second, WAC 173-340-705(3) will require Ecology to review and, if appropriate, revise the cleanup standards no less frequently than once every five years. Third, the proposed amendments include several provisions for utilizing new scientific information on a site-specific basis. For example, the most up-to-date toxicity values (reference doses and carcinogenic potency factors) will be utilized at individual sites.

Description Of Alternatives

Six alternative approaches to developing cleanup standards are evaluated in this EIS. These alternatives are described below:

Background Alternative - Cleanup levels would be set at levels equal to the background concentration or practical quantitation limit of each hazardous substance in each medium. Under this alternative, background would be defined as the concentration or level of a hazardous substance in the environment at or near the facility that cannot be attributed to any release from the site or other human activities in the local area.

Risk-based Alternative - Cleanup levels would be set at levels that are protective of human health and the environment as determined through an assessment of the health risks associated with each hazardous substance in each medium (for example, ground water). Cleanup levels for individual hazardous substances would then be modified to take into account mixtures of hazardous substances and exposure via more than one medium.

Applicable State and Federal Laws Alternative - Cleanup levels would be set at levels that meet or exceed standards established under applicable state and federal laws, including Section 121 of CERCLA/SARA. Section 121 requires the use of all legally applicable or relevant and appropriate requirements (ARARs) for each hazardous substance in each medium. The ARAR with the lowest concentration would be used to establish the cleanup level.

Technology-based Alternative - Cleanup levels would be set at concentrations that can be achieved through the application of best available cleanup technologies.

Combination Alternative - Cleanup levels would be set at risk-based concentrations which are at least as stringent as applicable state and federal laws. These levels may be modified within a limited range based on considerations of technical feasibility and background concentrations. Cleanup levels would be established for each hazardous substance in each medium and then modified to take into account mixtures of hazardous substances and exposure via more than one medium.

No-action Alternative - No new standards would be set for cleanup of hazardous waste sites. Because Ecology is currently required by law to promulgate cleanup levels, this alternative is not considered to be a legal option. However, even if Ecology declined to adopt new cleanup levels, the use of the strictest ARARs would still be required by the MTCA. Therefore, for the purposes of this EIS, the no-action alternative is equivalent to the ARAR alternative and will not be evaluated separately.

A detailed discussion of the standard-setting process for each alternative can be found in Chapter 4. As an illustration, example concentrations for each alternative are derived for four hazardous substances: cadmium, benzene, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons. These sections are meant to show how standards would be derived under each alternative. Many of the alternatives include processes for modifying general standards based on site-specific considerations.

Affected Environment

The affected environment includes the physical, biological, and built environment of Washington. The following specific elements of the environment may be affected by the proposed amendments:

Physical

- Ground water
- Surface water
- Marine water
- Soil
- Air

Biological

- Human health
- Plants and animals

Built

- Land Use
- Transportation.

Each of these elements of the environment is described, including location, sensitivity, and current state of the environment, in Chapter 5.

Environmental Impacts of the Alternatives

In Chapters 6-13, the environmental impacts of the alternatives are evaluated. The impacts considered in this EIS can be divided into three categories. First, there are the impacts associated with the implementation of cleanup actions. These are addressed in Chapter 7 and include impacts on human health, plants and animals, land use, and transportation. Second, there are long-term impacts on human health, plants and animals, land use, ground water, surface water, marine water, soil, and air (Table ES-1) that are associated with the residual levels of hazardous substances which may remain at a site following the completion of a cleanup action. Finally, the EIS addresses several potential impacts of the alternatives on state programs and planning (programmatic impacts).

The proposed amendments will influence the nature and magnitude of adverse environmental impacts by specifying requirements for the following:

- *Selection of cleanup levels* - The long-term environmental impacts associated with residual levels of hazardous substances tend to be directly related to cleanup levels for a particular site. More stringent cleanup levels are generally associated with lower environmental impacts. This contrasts with the general relationship between cleanup levels and the short-term environmental impacts which occur during a cleanup actions. In these cases, environmental impacts tend to be inversely related to the cleanup levels (i.e. the more stringent the cleanup level, the greater the potential for short-term adverse environmental impacts).

- *Selection of cleanup actions.* The Model Toxics Control Act expresses a preference for the use of permanent solutions to the maximum extent practicable. Permanent solutions generally involve the use of some type of treatment technology (incineration, bioremediation, etc). Treatment technologies frequently have a greater potential for short term adverse impacts relative to cleanup actions which rely solely on capping and other containment technologies. However, the long-term protection associated with the use of permanent solutions is usually superior to containment options.

The evaluation of the environmental impacts associated with the alternatives is semiquantitative in nature. The relative impacts of each alternative were estimated and determinations made as to whether the alternative will increase the potential for adverse impacts relative to the ARAR/No Action Alternative. Example cleanup levels are provided to illustrate possible impacts under five typical site scenarios. The relative impacts found to be associated with each alternative are described below.

Background Alternative

For most hazardous substances, the Background Alternative is the most stringent alternative and would generally result in the lowest cleanup levels. Specifically, cleanup levels under this alternative would be more stringent than those established under the ARAR/No Action Alternative. The following impacts associated with the Background Alternative have been identified.

Impacts During Site Cleanup

Relative to the ARAR/No Action Alternative, implementation of the Background Alternative would generally require the excavation, transport, treatment, and disposal of larger areas and increased volumes of soil. Longer restoration times would generally be required for ground water and soil treatment. This alternative would also result in larger amounts of treated or partially treated wastewater being discharged to waters of the state.

In terms of human health impacts, this alternative would generally result in increased risks among onsite workers and offsite populations due to the release and subsequent inhalation of vapors and particulates or direct contact with exposed soils. At sites with contaminated drinking water supplies, provision of alternate water supplies may result in increased health risks at sites where elevated levels of hazardous substances do not exceed health-based standards. This alternative will generally have the greatest impact on truck-related fatalities, although the incremental increase appears to be minimal.

Most cleanup actions are likely to have some impacts on plants and animals. Of the alternatives considered in the EIS, this alternative will generally result in the greatest impacts on plants and animals (habitat destruction, loss of topsoil, etc) However, in most cases, the impacts that occur during cleanup actions will be of minimal significance because the majority of cleanup sites are industrial in nature and plant and animal communities will already have been significantly impacted as a result of past practices.

Most site uses are incompatible with the contamination problems present at hazardous waste sites. Implementation of the background alternative might further limit land use as a result of short-term increases in the releases of hazardous substances or physical interferences associated with use of heavy equipment. While cleanup actions under the background alternative are not expected to result in significant incremental impacts on land use (relative to the contaminated conditions), this alternative would generally increase the length of time needed to complete the cleanup actions, thus extending the duration of impacts on site use.

Implementation of this alternative would be expected to result in significant increases in local traffic impacts. However, it appears that the incremental impacts on long-distance hauling and hazardous waste spills would be of minimal significance.

Impacts Following Completion of Cleanup Actions

Relative to the ARAR/No Action Alternative, implementation of the Background Alternative would result in lower residual levels of hazardous substances. Consequently, this would generally result in reduced long-term impacts on human health, plants and animals, and land uses. However, the use of cleanup levels that are below technically feasible levels could result in permanent land and water use restrictions for long periods of time.

The Background Alternative includes the use of practical quantitation limits (PQLs) for synthetic organic hazardous substances. These PQLs are not always protective of the full range of uses in the media being evaluated. In Chapters 9 and 11, it was concluded that there may be situations where the Background Alternative would result in minor impacts on human health from synthetic carcinogens, and minor impacts on the use of certain areas for fishing, due to human health concerns over the possible bioaccumulation of synthetic organic hazardous substances in fish and shellfish. In addition, the use of PQLs for synthetic organic hazardous substances could allow more contamination of surface water and air than other alternatives (Chapter 8).

Programmatic Impacts

The increased amounts of soil excavated under this alternative could result in a need for increased landfill or incinerator capacity (Chapter 12). Such impacts could be significant, depending on the number of sites remediated each year and the passage of various laws regulating the landfilling of hazardous wastes. In addition, strict cleanup levels such as those under the background alternative would require greater use of Ecology's resources at each site, limiting the number of sites that could be addressed each year and potentially postponing action at some sites (Chapter 12). Deferral of action at sites could result in significant environmental impacts from uncontrolled releases of hazardous substances to the environment. These impacts would likely be greater than impacts remaining after cleanup using any of the cleanup levels alternatives.

Risk-Based Alternative

The following significant impacts associated with the risk-based alternative have been identified.

Impacts During Site Cleanup

Implementation of the Risk-based Alternative would generally require the excavation, transport, treatment, and disposal of areas and volumes of soil similar to those under the ARAR/No Action Alternative. For carcinogens, longer restoration times would generally be required for ground water and soil treatment; for noncarcinogens, the reverse relationship would apply. This alternative could also result in larger amounts of treated or partially treated wastewater being discharged to waters of the state.

In terms of human health impacts, this alternative would generally result in risks among onsite workers and offsite populations due to the release and subsequent inhalation of vapors and particulates or direct contact with exposed soils that are similar to those under the ARAR/No Action Alternative. At sites with contaminated drinking water supplies, provision of alternate water supplies may result in increased health risks at sites where contamination levels exceed the risk-based cleanup levels, but do not exceed health-based standards. This alternative will generally have impacts on truck-related fatalities that are similar to the ARAR/No Action Alternative.

Most cleanup actions are likely to have some impacts on plants and animals. This alternative will generally result in impacts similar to those with the ARAR/No Action Alternative. However, in most cases, the impacts during cleanup actions will be of minimal significance because the majority of cleanup sites are industrial in nature and plant and animal communities will already have been significantly impacted as a result of past practices.

Most site uses are incompatible with the contamination problems present at hazardous waste sites. Implementation of the Risk-Based Alternative might further limit land use as a result of short-term increases in the releases of hazardous substances or physical interferences associated with use of heavy equipment. While cleanup actions under this alternative are not expected to result in significant incremental impacts on land use (relative to the contaminated conditions), this alternative could increase the length of time needed to complete the cleanup actions, thus extending the duration of impacts on site use.

Implementation of this alternative would be expected to result in local traffic impacts similar to those in the ARAR/No Action Alternative. However, it appears that the incremental impacts on long-distance truck hauling and hazardous waste spills would be of minimal significance.

Impacts Following Completion of Cleanup Actions

Application of the Risk-Based Alternative often results in concentrations for noncarcinogens that are quite high relative to other alternatives, and these concentrations often exceed ARARs for these hazardous substances. Because secondary MCLs for drinking water are exceeded for some hazardous substances, there could be loss of use of drinking water resources in the vicinity of some hazardous waste sites (Chapter 11).

In addition, compared to other alternatives, the Risk-Based Alternative would allow the most contamination by noncarcinogens of marine water and soil, and would allow minor contamination of ground water and surface water by noncarcinogens (Chapter 8). In particular, risk-based standards in soil could result in significant ground water contamination and associated risks to human health (Chapter 9). Additional impacts would be predicted if PQLs were used to determine compliance with these standards.

Programmatic Impacts

More stringent cleanup levels for some carcinogens and the increased use of treatment technologies could increase the need for incinerator and other treatment facilities (Chapter 12). Such impacts could be significant, depending on the number of sites remediated each year and the passage of various laws regulating the landfilling of hazardous wastes. In addition, strict cleanup levels such as those for some carcinogens under this alternative may require greater use of Ecology's resources at each site, limiting the number of sites that could be addressed each year and potentially postponing action at some sites (Chapter 12). Deferral of action at sites could result in significant environmental impacts from uncontrolled releases of hazardous substances to the environment. In general, these impacts would likely be similar to the impacts associated with the ARAR/No Action Alternative.

ARAR Alternative

The following impacts associated with the ARAR Alternative have been identified.

Impacts During Site Cleanup

Implementation of this alternative would generally require the excavation, transport, treatment, and disposal of areas and volumes of soil similar to those under current policies. Restoration times required for ground water and soil treatment would generally be the same as under current policies.

In terms of human health impacts, this alternative would generally result in some risks among onsite workers and offsite populations due to the release and subsequent inhalation of vapors and particulates or direct contact with exposed soils. The shift to greater use of treatment technologies may increase those risks relative to the current situation. This alternative would result in some continued impacts on truck-related fatalities, although the incremental increase appears to be minimal.

Most cleanup actions are likely to have some impacts on plants and animals. This alternative will generally result in some impacts on plants and animals. However, in most cases, these impacts during cleanup actions will be of minimal significance because the majority of cleanup sites are industrial in nature and plant and animal communities will already have been significantly impacted as a result of past practices.

Implementation of this alternative would be expected to result in continued local traffic impacts. However, it appears that the incremental impacts on long-distance hauling and hazardous waste spills would be of minimal significance.

Impacts Following the Completion of Cleanup Actions

Standards based on ARARs for certain media would be higher than those for other alternatives. For instance, ARARs for hazardous substances in air and for volatile organic compounds in marine water would be high relative to alternative standards. ARARs also would be higher than some of the other alternatives in ground water. ARARs in soil would be particularly high because very few health-based ARARs exist for soil (Chapter 8).

Minor impacts on human health could be expected from the ARAR Alternative, because in many cases, the ARAR Alternative is not as stringent as the Risk-Based Alternative for carcinogens. Even when corrected for the protection of ground water, the ARAR Alternative for soil could result in some human health risk from ground water contaminated by leachate from soil (Chapter 9). Minor impacts on plants and animals are also expected because of the lack of ARARs for plants and animals in several environmental media, and because studies reviewed in Chapter 10 suggest that the Maximum Tolerable Concentration (MTCs) for some species are somewhat lower than the available ARARs.

Programmatic Impacts

Implementation of this alternative is not anticipated to result in programmatic impacts which significantly differ from those under current policies. A shift to increased use of treatment technologies may reduce available capacity.

Technology-Based Alternative

The following impacts associated with the Technology-Based Alternative were identified.

Impacts During Site Cleanup

In general, the Technology-Based Alternative results in the least impacts during remedial alternatives, in part because the cleanup levels are less stringent, and in part because excavation of soil would be required less often than for other alternatives. However, one impact of the Technology-Based Alternative during remediation does affect the environment disproportionately. Because the technology-based standards are often higher than those of other alternatives, waste streams from remedial technologies at a site might contain higher concentrations of hazardous substances than they would under the other alternatives.

These hazardous substances in the waste stream, if released to the environment, could cause toxic effects in wildlife near the site, particularly aquatic life (Chapter 7).

Impacts Following Completion of Cleanup Actions

Compared with other alternatives, the Technology-Based Alternative would allow the greatest contamination of air and surface water and minor contamination of marine water. Technology-based standards would be particularly high relative to those for other alternatives for metals in marine water and soil and for volatile organic compounds in air.

Compared with all of the other alternatives, the Technology-Based Alternative would likely result in the most significant impacts on human and ecological health and land and natural resource use (Chapters 9, 10, and 11). Significant impacts on human health and plants and animals are expected because for metals and carcinogens, the

Technology-Based Alternative often could not provide concentrations that are as protective as risk-based concentrations. The technology-based concentrations would often be 3-5 orders of magnitude above risk-based levels. It is estimated that the Technology-Based Alternative would result in standards that would not be protective of plants and animals for approximately half of the hazardous substances for which toxicity data exist (Chapter 10).

Because of these risks to human health and the environment, many land uses are expected to be impaired, including agriculture and ranching (from contamination of water and soil), hunting of waterfowl and fishing (from contamination of marine water and fresh water), and residential uses (from contamination of all media) (Chapter 11). Ground water could be restricted from use as drinking water because of exceedance of MCLs. Fisheries could be closed because of concerns about accumulation of organic hazardous substances in fish and shellfish (Chapter 11).

Programmatic Impacts

In general, the Technology-based Alternative is not expected to result in significant programmatic impacts relative to the ARAR/No Action Alternative. Increased use of treatment technologies may impact treatment and incinerator capacity.

Combination Alternative

The following impacts associated with the combination alternative were identified.

Impacts During Site Cleanup

Implementation of the Combination Alternative would generally require the excavation, transport, treatment, and disposal of areas and volumes of soil similar to those under the ARAR/No Action Alternative. For carcinogens, longer restoration times would generally be required for ground water and soil treatment. This alternative could also result in larger amounts of treated or partially treated wastewater being discharged to waters of the state.

In terms of human health impacts, this alternative would generally result in risks among onsite workers and offsite populations due to the release and subsequent inhalation of vapors and particulates or direct contact with exposed soils that are similar to those under the ARAR/No Action Alternative. However increased use of treatment technologies may increase worker exposures at some sites. This alternative will generally have impacts on truck-related fatalities that are similar to the ARAR/No Action Alternative.

Most cleanup actions are likely to have some impacts on plants and animals. This alternative will generally result in impacts similar to those with the ARAR/No Action Alternative. However, in most cases, the impacts during cleanup actions will be of minimal significance because the majority of cleanup sites are industrial in nature and plant and animal communities will already have been significantly impacted as a result of past practices.

Most site uses are incompatible with the contamination problems present at hazardous waste sites. Implementation of the Combination Alternative might further limit land use as a result of short-term increases in the releases of hazardous substances or physical interferences associated with use of heavy equipment. While cleanup actions under this alternative are not expected to result in significant incremental impacts on land use (relative to the contaminated conditions), this alternative could increase the length of time needed to complete the cleanup actions, thus extending the duration of impacts on site use.

Implementation of this alternative would be expected to result in local traffic impacts similar to those in the ARAR/No Action Alternative. However, it appears that the incremental impacts on long-distance truck hauling and hazardous waste spills would be of minimal significance.

Impacts Following Completion of Cleanup Actions

Few significant impacts on human health, the environment, or land and natural resource use were identified. However, because the combination alternative does not require the use of a concentration lower than the risk-based or ARAR concentrations, and because standards are not used that would be below PQLs, the combination alternative allows minor contamination by noncarcinogens of marine water, soil, and air, compared with the other alternatives.

The combination alternative includes the use of PQLs to determine compliance with the cleanup levels. These PQLs are not always protective of the full range of uses in the media being evaluated. In Chapters 9 and 11, it was determined that the use of PQLs as standards could have minor impacts on human health from synthetic carcinogens and on the use of certain areas for fishing, due to human health concerns over the possible bioaccumulation of synthetic organic hazardous substances in fish and shellfish.

Programmatic Impacts

The increased use of treatment technologies would increase the need for incinerator and other treatment facilities (Chapter 12). Such impacts could be significant, depending on the number of sites remediated each year and the passage of various laws regulating the landfilling of hazardous wastes. In addition, strict cleanup levels such as those for some carcinogens under this alternative may require greater use of Ecology's resources at each site, limiting the number of sites that could be addressed each year and potentially postponing action at some sites (Chapter 12). Deferral of action at sites could result in significant environmental impacts from uncontrolled releases of hazardous substances to the environment. In general, these impacts would likely be similar to the impacts associated with the ARAR/No Action Alternative.

Mitigation Measures

In general, cleanup actions represent measures to mitigate the problems associated with past releases of hazardous substances. However, in performing those actions, there is always the potential to increase existing problems or create new problems. Most of the impacts identified in this EIS can be mitigated through the use of one or more mitigation measures; a number of potential mitigation measures were identified in Chapters 7 through 13. The actual measures used at a particular site will depend upon the hazardous substances present, the environmental setting, and the type of cleanup technologies utilized at the site. Specific mitigation measures can be developed and evaluated on a site-specific basis.

Unavoidable Adverse Impacts

The correction of contamination problems at hazardous waste cleanup sites will generally result in some unavoidable adverse impacts. In general, Ecology will be faced with balancing short-term adverse impacts

associated with the actual cleanup action and long-term impacts associated with residual levels of hazardous substances. The proposed amendments have been structured in a manner that facilitates site-specific decisions which minimize overall impacts.

Regulatory Evaluation of the Alternatives

The alternatives are evaluated according to the impacts of the alternatives and several additional criteria. The criteria used in addition to the environmental impacts are divided into three classes:

Threshold criteria represent the direct goals of the MTCA: protection of human health and the environment, and compliance of the standards with all ARARs. An alternative must meet these primary goals before being considered further. *Threshold criteria* are as follows:

- Protection of human health
- Protection of the environment
- Compliance with ARARs

Balancing criteria represent practical considerations that affect how easily an alternative can be implemented as a process for developing standards. Some of these criteria also reflect goals and priorities of the MTCA and Ecology. *Balancing criteria* are as follows:

- Technical feasibility and enforceability
- Preference for permanent solutions
- Cross-media impacts
- Addresses hazardous substances interactions
- Applicability to all hazardous substances and media
- Scientific uncertainty

Modifying criteria reflect issues of public acceptance and perceptions that do not directly reflect the goals and priorities of the MTCA and Ecology. These criteria are given less weight, but may affect the outcome of the evaluation if the alternatives are ranked similarly under the preceding sets of criteria. *Modifying criteria* are as follows:

- Regulatory precedence
- Understandability
- Consistency.

The results of this analysis are presented in Table ES-2. Based on this analysis, the combination alternative is considered to provide the most appropriate approach for establishing cleanup levels at hazardous waste sites. It provides an approach that is protective of human health and the environment, one that fulfills the statutory requirements in the MTCA, while also addressing the practical constraints associated with cleaning up hazardous waste sites.

Chapter 1
Introduction

Awareness of the risks and impacts associated with hazardous waste sites has grown over the past 40 years. During this time, public concern over releases of hazardous substances into the environment has also grown. News coverage of the discovery, investigation, and cleanup of hazardous waste sites has become a prominent, almost daily occurrence. As problems have emerged at site after site, the consequences of inappropriate handling and disposal of hazardous substances have become more apparent.

The citizens' initiative in Washington that led to the passage of the state's Model Toxics Control Act (MTCA) in November 1988 grew out of concern over threats posed by hazardous substance releases. The initiative also reflected the controversy surrounding existing approaches to the problem. A new approach to cleaning up hazardous waste sites was needed.

The main purpose of the MTCA, as stated in the act, is to "raise sufficient funds to clean up all hazardous waste sites and to prevent the creation of future hazards due to improper disposal of toxic waste into the state's land and waters." The Washington Department of Ecology (Ecology) has been given full authority to implement and enforce the MTCA.

Ecology is developing a comprehensive regulation (the MTCA Cleanup Regulation) which provides the overall implementation framework. This regulation is being developed in two phases:

- The Phase I portion defines the administrative process for identifying, investigating, and cleaning up hazardous waste sites. Phase I became effective on 4 May 1990.
- Phase II includes provisions for establishing cleanup levels, selecting cleanup actions, and performing leaking underground storage tank corrective action.

The adoption of the Phase II amendments to the MTCA Cleanup Regulations is the proposed agency action being considered in this EIS.

Defining the levels of cleanup that must be met at a site in order to adequately protect human health and the environment is one part of the MTCA regulations concerning the cleanup of hazardous waste sites. At the heart of this issue is the question first posed in Ecology's Final Cleanup Policy of 1984, "How clean is clean enough?" For a number of years prior to the MTCA, Ecology managed a cleanup program for hazardous waste sites, using previous statutes and policies. The adoption of cleanup levels under the MTCA therefore does not represent a new kind of action. Instead, it is a new set of regulations addressing site cleanup that meets the requirements of the MTCA. The regulations proposed by Ecology will modify existing approaches to determining *how clean is clean* for hazardous waste sites. These regulations will be available for public review concurrently with this document.

As part of the MTCA, Ecology is required to adopt regulations defining *minimum cleanup levels* for all sites regulated by the MTCA. In the draft regulations, the minimum cleanup levels are referred to as *compliance cleanup levels*. Compliance cleanup levels are defined as concentrations that are protective of human health and the environment under unrestricted site use conditions. The draft regulations also include provisions for establishing *conditional cleanup levels*. Conditional cleanup levels are defined as concentrations that are protective of human health under limited site use conditions (for example, industrial site use).

It is the alternative approaches for setting these compliance cleanup levels that are evaluated in this environmental impact statement (EIS). Numerical compliance cleanup levels for many hazardous substances are included in the draft regulations, based on the preferred alternative approach. These numerical standards can be used at small sites where cleanup is routine or at sites where numerical standards exist for all the chemicals at the site. Otherwise, numerical standards must be determined for the site using site-specific studies and risk assessment consistent with the preferred alternative.

Ecology's Goals for the Amendments to the Model Toxics Control Act Cleanup Regulations

The development of the draft cleanup levels involved the consideration and balancing of a number of issues and interests. The proposed rules were developed to satisfy six principal goals, discussed below.

- **Remediation of contaminated sites within the state of Washington to levels that are protective of human health and the environment.** The foremost goal was to develop standards that are protective of human health and the environment. For noncarcinogens, Ecology is proposing to define protection of human health in terms of concentrations that prevent all known or anticipated acute or chronic toxic effects to the human population, including most sensitive subgroups. Because the existence of a no-effect level for carcinogens has not been demonstrated, protection of human health for carcinogens has been defined in terms of an acceptable risk or probability of developing cancer. Ecology is proposing to define an acceptable risk range for exposure to carcinogens as an incremental lifetime cancer risk of between 1 in 1,000,000 and 1 in 100,000. For ecological effects, protection is defined as concentrations or levels of hazardous substances that are protective of a healthy and diverse aquatic or terrestrial community and are protective of threatened or endangered species.

- **Scientifically and legally defensible cleanup levels.** An important goal is to develop cleanup levels that are scientifically and legally defensible. Toward that end, Ecology has reviewed guidance documents prepared by the U.S. Environmental Protection Agency (EPA) and other expert groups such as the National Academy of Sciences. In addition, throughout the rulemaking process, Ecology has received numerous comments on risk assessment procedures from members of Ecology's Science Advisory Board and other individuals experienced in the field of risk assessment. When recommendations conflict, Ecology has attempted to balance the various recommendations to arrive at a scientifically defensible and workable approach.

- **Performance of cleanup actions in a manner consistent with existing state and federal regulatory programs.** The state of Washington has implemented a number of regulatory programs which address environmental contamination in specific media, including air, surface water, ground water, and sediments. An important goal in developing cleanup levels under the MTCA was to be consistent with these existing programs. Site cleanup actions would, at a minimum, meet any applicable or suitably similar standards developed under those programs. This requirement follows from a minimum requirement under the MTCA specifying that cleanup levels must be at least as stringent as applicable state and federal laws. However, in developing requirements for cleanup actions, Ecology has recognized that hazardous waste sites are frequently more complex than the situations commonly addressed by existing media-specific programs. Consequently, Ecology believes sole reliance on standards and guidelines that address situations involving single hazardous substances or single media might be inadequate to protect human health and the environment at hazardous waste cleanup sites, where multi-media contamination and mixtures of hazardous substances are often present.

- **Efficient cleanup of contaminated sites within the state of Washington.** It has been Ecology's experience that the present system for establishing cleanup levels contains too much flexibility. This flexibility, in combination with the often opposing views of risks to human health and the environment that are voiced by government agencies, the regulated community, and affected citizens, has resulted in a system in which competing interests find too many opportunities to slow down the process. An important objective of the amendments is to reduce the amount of flexibility in the present system, resolve certain key policy issues as part of the regulation, and create a system that is more consistent across all sites.

  In addition, by creating a simplified method for establishing cleanup levels at smaller sites, Ecology hopes to minimize the investigation and evaluation costs to those performing small site cleanups. These costs will be minimized by relying, whenever possible, on numerical sets of standards or guidelines. In doing so, Ecology hopes to ensure that funds are used primarily for site cleanup rather than site negotiation or litigation.

- **Use of a consistent approach to assessing and managing health risks.** In the past, there has been considerable variability in both the quality and methods used to prepare risk assessments. In developing these regulations, Ecology hopes to ensure that consistent procedures are used to assess and manage risks at contaminated sites.

- **Provision of some flexibility to address individual site characteristics.** Ecology believes it is important to provide some flexibility to address individual site characteristics.

However, this flexibility to modify the minimum cleanup levels has been generally constrained in the proposed regulations to a defined and limited range of concentrations.

Amendments to the Model Toxics Control Act Cleanup Regulations

Ecology is proposing amendments to the MTCA Cleanup Regulations (Chapter 173-340 WAC). These amendments include the detailed requirements for establishing cleanup levels, selecting cleanup actions, and performing LUST corrective actions. The amendments include the following sections:

General Requirements

There are four sections in the Phase II regulation that will include cleanup provisions that apply to hazardous substances in all media. These include:

General Procedures—WAC 173-340-700 introduces the concepts of compliance cleanup levels and conditional cleanup levels and defines how the cleanup levels sections relate to other portions of the regulation.

General Principles—WAC 173-340-705 defines the policies and principles that Ecology will utilize to ensure that cleanup levels are established and implemented in a scientifically and technically sound manner.

Applicable State and Federal Laws—WAC 173-340-710 defines the criteria for determining what requirements are legally applicable or relevant and appropriate.

Definitions—WAC 173-340-200 will also be amended to incorporate those terms that are unique to the cleanup levels and LUST portions of the regulation.

Cleanup Levels

There are six sections that will provide more detailed procedures for establishing cleanup levels in the various environmental media. These include:

- Ground Water Cleanup Standards (WAC 173-340-720)
- Surface Water Cleanup Standards (WAC 173-340-730)
- Soil Cleanup Standards (WAC 173-340-740)
- Industrial Soil Cleanup Standards (WAC 173-340-745)
- Cleanup Standards to Protect Air Quality (WAC 173-340-750)
- Sediment Cleanup Standards (WAC 173-340-760).

The sediment cleanup levels are being reserved until Ecology's Sediment Management Unit has developed regulations that will define a comprehensive approach for managing sediments.

Selection of Cleanup Actions

There are five sections that will specify requirements for selecting and implementing cleanup actions. These include:

Selection of Cleanup Actions—WAC 173-340-360 defines the basic requirements for cleanup actions under this chapter and procedures for documenting cleanup decisions.

Periodic Review—WAC 173-340-420 defines the requirements for periodically reviewing cleanup actions.

Institutional Controls—WAC 173-340-440 defines the general requirements for restricting site usage when hazardous substances are left onsite as part of the cleanup action.

Leaking Underground Storage Tanks—WAC 173-340-450 responds to the need to address the corrective action requirements outlined in the federal Underground Storage Tank rules. This will include 24-hour release reporting, follow-up investigation, free product removal, and immediate assessment and reduction of the threat to human health and the environment.

Laboratory Analysis Procedures—WAC 173-340-830 defines standard analytical methods for use in performing cleanup actions.

The Environmental Impact Statement

This EIS evaluates approaches to defining minimum cleanup levels for hazardous waste sites. Six alternatives for setting cleanup levels are evaluated, and, based on this evaluation, a preferred alternative is recommended. A separate EIS defining minimum cleanup levels for the cleanup of contaminated sediments has also been prepared. The EIS for the cleanup of sediments will also be available for public review in 1990.

While the concepts presented in this EIS are not easily explained using brief or simple terms, every effort has been made to make this document understandable to readers who do not have technical backgrounds. However, certain sections, for example, those discussing issues associated with risk assessment, may require a greater familiarity with technical material. Whenever possible, more detailed technical information has been referenced within the main body of the text and presented in a set of technical appendices as Volume II of the EIS.

Chapter 1, the introduction, explains the main purpose of this document, presents Ecology's goals for the cleanup levels, gives a summary of the draft amendments, and describes the structure of the EIS.

Background information helpful for understanding the history and applicability of the cleanup levels is presented in Chapter 2 of this EIS. First, hazardous waste sites that will be subject to the minimum cleanup levels are defined and reviewed. Next, steps involved in the identification, investigation, and cleanup of hazardous waste sites are described. The development of cleanup policy prior to the MTCA and the relationship of existing cleanup levels to other state and federal regulations are described, and a summary of the approaches taken by several other states in setting cleanup levels is presented.

In Chapter 3, issues associated with setting hazardous waste site cleanup levels are presented and discussed. These include issues associated with the trade-off between flexibility and consistency, the protectiveness and uncertainty of risk assessment, and the relationship of these cleanup levels to other aspects of state and federal environmental programs. These issues are discussed and the options available to Ecology for addressing the issues are outlined. The resolution of these issues in the regulations is discussed. Issues associated with particular alternatives are identified and discussed further in Chapter 4.

The alternatives for setting cleanup levels are identified and described in Chapter 4. First, the development of the alternatives is discussed. Next, the general nature of each alternative and the precedents for its use are described. Following this description is an identification of issues related to that alternative and the various ways in which the alternative could be implemented. The rationale for choosing the exact form of the alternative used in this EIS is provided. Finally, the methods that would be used to derive cleanup levels under the alternative are described.

An overview of the affected environment is presented in Chapter 5. Potentially significant impacts of these alternatives are examined in Chapters 6-13. Impacts from remediation at hazardous waste sites and residual impacts to human health, plants and animals, land use, transportation, and the five regulated environmental media (ground water, surface water, marine water, soil, and air) are discussed. In addition, impacts on state resources and programs are described.

In Chapter 14, the alternatives for setting cleanup levels at hazardous waste sites are evaluated, and the preferred alternative is identified. The evaluation of the alternatives includes consideration of the environmental impacts as well as other criteria developed by Ecology. The criteria are divided into three levels of importance, following a hierarchy similar to that used by EPA for evaluating alternatives at hazardous waste sites. The alternatives are discussed under each criterion in a narrative fashion, and, where possible, each alternative is assigned a score of high, medium, low, or unpredictable. A summary of the scores is presented in the form of a matrix. These criteria and the environmental impacts of the alternatives are considered in choosing the preferred alternative.

A discussion of opportunities for public comment and involvement in both the EIS process and the rule adoption process is contained in Chapter 15.

Volume II of the EIS is a set of technical appendices. These appendices include:

- **Appendix A** - List of materials that meet the MTCA definition of hazardous substances
- **Appendix B** - List of hazardous waste sites in Washington State
- **Appendix C** - Tables providing information about the hazardous waste sites
- **Appendix D** - CERCLA/SARA Section 121
- **Appendix E** - 1984 *How Clean is Clean* Policy
- **Appendix F** - The Model Toxics Control Act, Chapter 70.105D RCW
- **Appendix G** - Omitted
- **Appendix H** - Site scenarios and modeling data
- **Appendix I** - Analysis of remedial technologies and achievable cleanup levels
- **Appendix J** - Distribution list.

These appendices are described in more detail in subsequent chapters.

Chapter 2
Background Information

The following sections provide background information about the characteristics, locations, and past and present management of hazardous waste sites in Washington state.

Definition of Hazardous Waste Sites

The MTCA applies to all facilities, commonly known as hazardous waste sites, where there has been a release or threatened release of hazardous substances that may pose a threat to human health or the environment. These facilities include locations where hazardous substances have entered ground water, fresh and marine surface water, soils, air, sediments, or combinations of these media. The two terms *hazardous substances* and *release* are defined below.

Hazardous substances are broadly defined in the MTCA as all dangerous and extremely hazardous wastes identified under the state hazardous and solid waste amendments, Chapter 70.105 Revised Code of Washington (RCW). Also included in this definition are hazardous substances defined in the state's dangerous waste rules, Chapter 173-303 Washington Administrative Code (WAC), and the federal Comprehensive Environmental Response, Compensation and Liability Act and federal Superfund Amendments and Reauthorization Act (commonly abbreviated as CERCLA/SARA and known as the Superfund program). The MTCA definition also includes petroleum or petroleum products, and other substances determined by Ecology to "present a threat to human health or the environment if released into the environment." A list of materials meeting the MTCA definition of hazardous substances is provided in Appendix A of this document.

The MTCA defines *release* as "any intentional or unintentional entry of hazardous substances into the environment, including but not limited to the abandonment or disposal of containers of hazardous substances."

Description of Hazardous Waste Sites in Washington

In 1988, Ecology developed and began operating the Site Management Information System (SMIS), a database system containing information on all potential hazardous waste sites in the state. A list of these sites and their locations appears in Appendix B. SMIS is maintained within Ecology's Toxics Cleanup Program (formerly the Hazardous Waste Investigations and Cleanup Program).

SMIS contains both technical and management information. Information about existing sites that is developed in Ecology's regional offices or at headquarters is entered monthly into SMIS. As new sites or potential sites are discovered, they are added to the database. SMIS provides the best available means of summarizing what is known about sites to which the proposed cleanup levels under the MTCA may apply.

Contained in the SMIS database is a diverse assortment of site types and hazardous substances. The diversity of sites and substances is illustrated by the following examples that represent the six most frequent types of sites:

- Leachate and gas migration from an unlined, municipal solid waste landfill threaten nearby drinking water supplies and residential populations
- Soil and ground water are contaminated with petroleum products from leaking underground storage tanks
- Spills and poor management practices at a chemical manufacturing facility result in contaminated soil and ground water
- Metals from the disposal of electroplating sludges and rinsewaters are released to soils and ground water
- Pentachlorophenol and creosote containing mixtures of polycyclic aromatic hydrocarbons (PAHs) are released to soil, surface water, and sediment at a wood treatment facility
- Spills and improper handling of materials at an agricultural chemicals facility lead to pesticide and herbicide contamination of soil and threaten nearby surface waters.

The SMIS database included a total of 725 hazardous waste sites as of 1 October 1989. New cleanup levels will primarily be applied to the 521 active sites on this list. The remaining 204 sites either do not pose a threat to human health or the environment, are fully cleaned up, or are cleaned up and subject to long-term monitoring. The new cleanup levels would be considered during periodic review of these sites. All further summaries of information from SMIS presented herein are based only on the 521 active sites to which the proposed cleanup levels apply.

Active sites (summarized by county in Table 1) are located in 32 of the state's 39 counties. A site location map is provided as Figure 1. This figure shows that sites on the hazardous waste site list are concentrated in the most heavily populated areas of the state. Only 16 percent of the sites are in counties east of the Cascade Mountains. The remaining 84 percent are in western Washington counties. More than half (55 percent) of the hazardous waste sites are located in King, Pierce, and Clark counties.

Additional technical information from the SMIS database has been tabulated and presented in Appendix C of this document. These tables provide a quick overview of site types, affected media, and hazardous substances by class. Collectively, they provide the most accurate characterization of hazardous waste site cleanup problems in Washington that is currently available.

The tables show, for example, that:

- Soil and ground water are the affected media most commonly identified in the database; each is listed for more than three-fourths of all sites in the state. Surface water is listed as the affected medium at approximately one-half of all sites, sediments at one-quarter of the sites, and air at one-eighth of the sites in the database. Drinking water is listed as an affected medium for about one-third of all sites.

- Statewide, the most frequently identified classes of hazardous substances are metals (46 percent of all state sites) and petroleum products (39 percent). Halogenated organic compounds (24 percent) and nonchlorinated solvents (21 percent) have also been identified at many sites. The least common hazardous substance classes are PAH compounds (18 percent), pesticides (17 percent), polychlorinated biphenyl (PCB) mixtures (14 percent), and phenolic compounds (14 percent).

TABLE 1. NUMBER OF MTCA SITES BY COUNTY[a]

County	Number of Sites
Adams	4
Asotin	1
Benton	9
Chelan	5
Clallam	4
Clark	39
Cowlitz	17
Douglas	2
Ferry	1
Franklin	2
Grant	4
Grays Harbor	10
Island	7
Jefferson	3
King	154
Kitsap	18
Kittitas	1
Lewis	10
Mason	5
Okanogan	7
Pacific	4
Pierce	94
Skagit	9
Skamania	1
Snohomish	22
Spokane	18
Stevens	3
Thurston	20
Walla Walla	1
Whatcom	22
Whitman	2
Yakima	22
TOTAL	**521**

[a] SMIS database summary (October 1989).

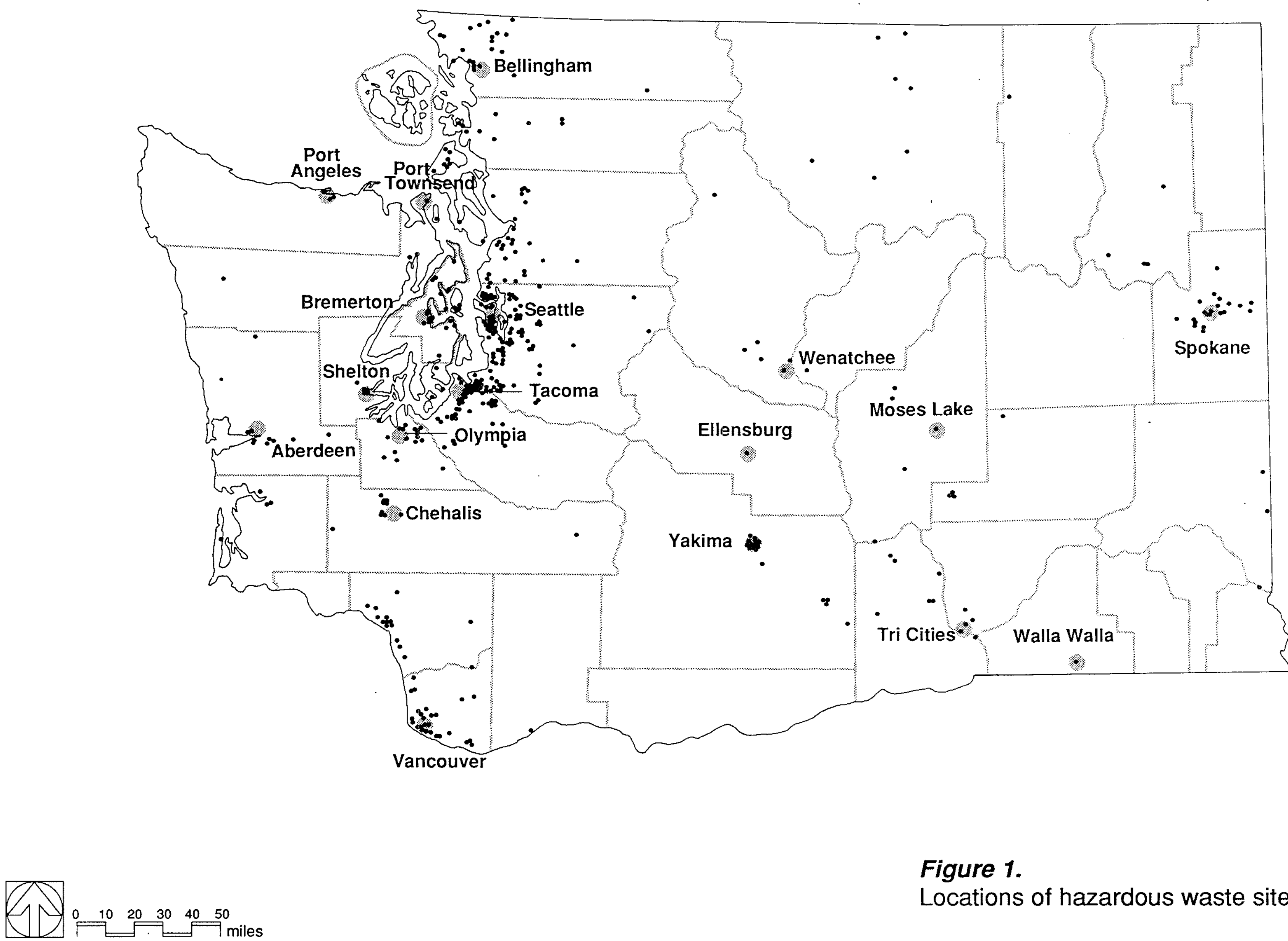


Figure 1.
Locations of hazardous waste sites

- Certain waste management practices appear to be concentrated in portions of the state. For instance, major pesticide application and disposal sites are not common in King, Pierce, or Clark counties, but mainly occur in areas of the state dominated by agricultural land use. In the pesticide disposal category, 16 of 18 sites are located in eastern counties.

- Urban counties have relatively higher frequencies of contamination by metals, petroleum products, PCB mixtures, and PAH compounds, while rural counties have relatively higher frequencies of contamination by pesticides and solvents in both ground water and soils.

The distribution of sites can also be analyzed by comparing the types of industries that were present at the sites. Standard industrial classification (SIC) codes have been entered in the SMIS database for approximately 65 percent of the 521 active sites. These codes identify the type of business at the site. Approximately 100 different SIC codes are represented, reflecting the diversity of site activities.

SIC code information is also summarized in tables in Appendix C. Site distributions across the state clearly differ among the SIC code categories. Ore mining sites exist mainly in northeastern Washington counties, while coal mining sites are found only in western Washington. Most lumber and wood products and wood preserving sites are located in the Puget Sound region or southwestern portions of the state. Chemical companies are found mainly in King and Pierce counties, with the exception of agricultural chemical or pesticide-handling sites, which are located predominantly in eastern agricultural counties. Petroleum and coal product sites are found across the state. Landfill sites also occur in almost every county. Primary metal fabricating and electroplating sites generally are located in urban areas. Military sites are located predominantly in rural and unpopulated areas.

There are pronounced variations in the distribution of hazardous substance classes across the SIC categories. Phenolic compounds, for example, are more commonly associated with wood preserving and lumber and wood products sites than other sites. Similarly, metals are associated with mining and electroplating sites.

Identification, Evaluation, and Remediation of Hazardous Waste Sites

Each step in the process used to identify, evaluate, and remediate threats posed by hazardous waste sites in Washington is described in the MTCA cleanup regulation, Chapter 173-340 WAC. Steps leading to the remediation of hazardous waste sites are briefly described below.

Site Discovery

Site discovery is a comprehensive attempt to identify and inventory potential hazardous waste sites throughout the state. Hazardous waste sites are identified through historical research, review of current local and state governmental agency records and files, and local community involvement. The SMIS database is one product of these activities. Occasionally, contamination is discovered before its source is identified. Sites may be added to the list for possible investigation and cleanup at any time based on information from any available source.

By law, facility owners and operators are required to report release of known hazardous substances to Ecology within 90 days of discovery. All other persons are encouraged to report any relevant information to the department. Any person who conducts an interim action or cleanup action independently, without coordination or oversight by Ecology, is also required to submit a written report to Ecology within 90 days of completing that action.

Initial Investigation

WAC 173-340-310 requires Ecology to conduct an initial investigation within 90 days of when the site is discovered. At a minimum, the initial investigation must include a site visit and documentation of existing conditions. Upon completion of the initial investigation, Ecology determines the need for a site hazard assessment, emergency cleanup action, interim action, or no further action. Ecology sends notice letters to the site owner, operator, and any other potentially liable persons (PLPs) if further cleanup action is required. In some cases, an emergency action is required to mitigate an immediate threat to human health or the environment posed by the release or threatened release of hazardous substances.

Site Hazard Assessment

If the site appears to be contaminated, a site hazard assessment is performed. A site hazard assessment is a preliminary compilation of site information that characterizes the nature of the hazardous substance release or threatened release and potential risks posed by the site (WAC 173-340-320). Limited sampling data and other site information are collected as needed to identify hazardous substances that are present, confirm releases, provide some information on the extent and concentration of hazardous substances, identify site characteristics that affect hazardous substance migration, identify potential hazardous substance receptors and exposure routes, and develop a hazard ranking score for the site.

Hazard Ranking and Site Listing

The Washington Ranking Method (Ecology 1989g,h) is used by the state to objectively assess the relative degree of hazard to human health and the environment from hazardous waste sites. A ranking score for each site is determined from the information developed during the site hazard assessment. These scores are based on the types and amounts of hazardous substances found on the site; hazardous substance migration potential through air, surface water, and ground water; and the proximity of the site to populated areas and sensitive environments.

All sites where further cleanup action is necessary are listed on the state's hazardous sites list. This list is currently under development and will be published in the fall of 1990. Hazard ranking scores and site status are provided for all sites on the list. Public notice and the opportunity to comment are provided whenever Ecology proposes to remove a site from the list. A site is removed only when cleanup actions are completed and cleanup levels have been achieved, or if new information shows the original listing was inappropriate.

Remedial Investigation and Feasibility Study

Through site remedial investigations and feasibility studies, site information is collected and evaluated so that an appropriate and protective action can be selected. The remedial investigation and feasibility study are often integrated into a single report. The scope of these studies may vary from site to site, depending on the amount of information needed to select a cleanup action.

During a site remedial investigation, the nature, extent, magnitude, and possible consequences of a release or threatened release of hazardous substances are determined. During the feasibility study, a range of alternative cleanup actions is developed to mitigate or correct the problems identified during the remedial investigation.

Cleanup levels for the cleanup action are defined, and impacts associated with various alternative actions are evaluated. These cleanup alternatives are then evaluated according to the degree of protection of human health and the environment, effectiveness, compliance with other applicable or relevant and appropriate requirements (ARARs), cost, community acceptability, and other criteria.

Interim Actions

In certain instances, obvious cleanup actions (for example, the removal of source materials or the temporary capping of a site) may be taken before a remedial investigation and feasibility study are completed (WAC 173-340-430). Interim actions may provide partial solutions to existing or threatened releases of hazardous substances, or prevent problems from substantially worsening (and remedies from increasing in cost) before the remedial investigation and the feasibility study are completed. These actions may be needed to allow a site hazard assessment or remedial investigation to be completed or a final cleanup action to be properly designed.

Cleanup Actions

Ecology will select a final cleanup action based on the site information developed in the remedial investigation and feasibility study. Cleanup actions will have to meet the cleanup levels specified in WAC 173-340-700 through 173-340-760. The chosen cleanup action alternative must also protect human health and the environment, meet state and federal standards, use permanent solutions to the maximum extent practicable, provide adequate monitoring to ensure the effectiveness of the cleanup action, and be appropriate for conditions at the site. Along with the proposed cleanup levels, Ecology is proposing to amend WAC 173-340-360 to provide more detailed requirements for selecting cleanup actions.

At certain sites, cleanup actions may be classified by Ecology as routine cleanup actions. Routine cleanup of these sites may be approved based on a simplified remedial investigation and feasibility study that includes evaluation of a limited number of cleanup alternatives. The cleanup method must be obvious, reliable, and effective in achieving cleanup levels. Routine cleanup actions are limited to those cases where an EIS is not required.

Ecology will prepare and issue for public comment a draft cleanup action plan for each site. After comments are reviewed and any necessary changes are made, a final cleanup action plan will be issued describing the selected alternative and explaining how it meets the requirements listed above.

Monitoring

Monitoring of environmental media, remedial technologies, and containment structures is included as part of the cleanup action plan to provide data confirming that actions are protective and effective. *Protection monitoring* is designed to confirm that human health and the environment are protected during the period of construction, operation, and maintenance of remedial operations. *Performance monitoring* is designed to determine whether cleanup actions have achieved cleanup levels. The long-term effectiveness of cleanup actions is evaluated by *compliance monitoring*, which may include field visits, sampling and laboratory analysis, data evaluation, and document review. Compliance monitoring plans must be prepared and submitted to Ecology for review and approval before cleanup actions are started.

If hazardous substances are allowed to remain at a site, Ecology will review the site at least once every 5 years to ensure that the cleanup action continues to protect human health and the environment.

Public Participation

WAC 173-340-600 requires that a public participation plan will be developed as part of the overall site investigation and cleanup process to provide information and meaningful opportunities for participation by the public. Notices and information will be sent to interested and affected citizens to keep them informed of site investigation activities. Opportunities for public comment are provided at the major site investigation milestones. Ecology also maintains and regularly publishes a site register with information on all active site investigations and hazard ranking scores. Independent cleanup actions reported to the department are also identified in the site register.

Regulations Addressing Hazardous Waste

A number of regulations have been promulgated by federal and state agencies to address the problems associated with hazardous substances. These regulations can be divided into two broad types. The first group of regulations has created a program to manage hazardous wastes, regulating every aspect of these substances from their manufacture to their eventual use or disposal. The second group of regulations provides for the investigation and cleanup of sites where uncontrolled or historic releases of hazardous substances may have occurred. The following discussion of federal and state programs describes both groups of regulations.

Federal Programs

The federal statute creating the program for management of hazardous wastes is the Resource Conservation and Recovery Act (RCRA). The federal program was revised by the Hazardous and Solid Waste Amendments of 1984 (40 CFR 280). Washington state has adopted additional dangerous waste regulations for the management of active hazardous waste facilities. These state dangerous waste regulations are stricter in some instances than the federal regulations under RCRA.

The federal program for the investigation and remediation of inactive sites (CERCLA) was created to protect human health and the environment from exposure to hazardous substances. CERCLA established a program to investigate and respond to releases and threatened releases of hazardous substances, both on land and water, and to ensure that identified sites are cleaned up by responsible parties or, where such parties are not known or cannot complete cleanups, by the government. A hazardous substance trust fund (Superfund) was created by Congress to pay for the required actions. Site cleanup actions authorized by CERCLA are supported by enforcement and cost recovery provisions, based on the principle that the parties responsible for the release should bear the costs of cleanup.

The key section of CERCLA/SARA dealing with cleanup levels is Section 121, which is referenced in the MTCA requirement for minimum cleanup levels [MTCA Section 3, Subdivision (2)(d)]. (The full text of CERCLA/SARA Section 121 is provided for reference in Appendix D.)

CERCLA/SARA Section 121 defines the basic requirements to be met by cleanup actions as protection of human health and the environment, cost-effectiveness, and compliance with the National Contingency Plan. Cleanup actions must, to the maximum extent practicable, use permanent solutions. There is a preference for cleanup actions that use treatment to permanently and significantly reduce the volume, toxicity, or mobility of hazardous substances. Offsite transport and disposal without treatment is therefore the least preferred option. Selection of remedies that do not reflect this preference for treatment and permanent solutions must be explained and supported in the record of decision.

State Programs

Ecology has used several statutory authorities as a basis for site cleanups. Throughout the 1970s and early 1980s, the state Water Pollution Control Act (Chapter 90.48 RCW) and state Hazardous Waste Management Act (Chapter 70.105B RCW) were used as the primary authorities for cleanup of hazardous waste sites. In 1984, Ecology developed a final cleanup policy with technical criteria for determining cleanup levels on a site-specific basis. This 1984 policy is generally referred to as the *How Clean Is Clean* policy. (The complete text of the *How Clean Is Clean* policy is provided in Appendix E.)

Passage of the state's Hazardous Waste Management Act in 1987 provided a comprehensive statutory authority covering the identification, characterization, and cleanup of hazardous waste sites. A fund financed by a new tax on hazardous substances was created to support the state program. The statute included a provision, similar to SARA, stipulating that cleanups performed by Ecology or by PLPs under a settlement agreement were exempt from obtaining required permits and completing an EIS under the State Environmental Policy Act (SEPA). Provisions were included for both mandatory and discretionary covenants not to sue, under various types and levels of cleanup. The legislation went into effect in October 1987.

Thirteen months after the Hazardous Waste Cleanup Act of 1987 went into effect, the voters approved Initiative 97. This initiative was enacted as the MTCA, which served as a replacement for the state's hazardous waste site cleanup program. The MTCA provides a wholly independent authority, outside of CERCLA, for the state to require and enforce cleanup actions at hazardous waste sites. Until cleanup levels rules are adopted, Ecology is using the 1984 *How Clean Is Clean* policy and a risk assessment approach similar to that developed by EPA under CERCLA to determine cleanup levels for hazardous waste sites in Washington on a case-by-case basis.

Unlike the 1987 Hazardous Waste Cleanup Act and the federal program as amended by SARA, the MTCA contains no permit exemptions. Therefore, actions taken to achieve cleanup levels are subject to all permitting requirements, including SEPA review. The SEPA review can address any potential environmental or human health impacts that would result from application of the cleanup levels on a site-specific basis. The impacts of the regulations as a whole are addressed in this EIS. In addition, any covenants not to sue must include a reopener clause. This reopener clause allows

Ecology to require additional cleanup if new facts are discovered or if a treatment technology fails to adequately protect human health or the environment.

The MTCA requires cleanup levels to be at least as stringent as standards under Section 121 of CERCLA/SARA. CERCLA/SARA requires the use of all ARARs. ARARs include other state and federal standards that meet one of the two tests below:

- **Applicable**—Standards or criteria are applicable if they specifically address a hazardous substance, pollutant, hazardous substance, cleanup action, location, or other circumstance at the site.
- **Relevant and appropriate**—Standards or criteria are relevant and appropriate if, failing the above test, they nevertheless address problems or situations sufficiently similar to those encountered at the site that their use is well-suited to the site.

Cleanup levels established under the MTCA will be considered applicable requirements under CERCLA/SARA Section 121 and will therefore apply to all federal sites in the state as well. Several other Washington state programs also have developed or are developing criteria for the protection of the environment. The relationship of these other programs to MTCA cleanup levels is briefly reviewed below.

Ground Water Quality Standards

The *1987 Ground Water Quality Management Strategy* (Ecology 1987) identified the development and adoption of statewide standards for ground water quality as a state priority. Statutory authority for Ecology to adopt such regulations is provided in the state Water Pollution Control Act (Chapter 90.48 RCW). Regulations providing ground water quality standards are currently being developed by Ecology's Water Quality Program. Proposed rules are expected to be issued by the end of 1990; this section reflects the status of the draft rules as of June 1990.

Washington has an antidegradation policy for ground water quality under the Water Pollution Control Act. With few exceptions, all beneficial uses of ground water are to be maintained and protected, and existing water quality is to be protected against degradation. No degradation that is injurious to existing uses or long-term environmental health is allowed in any case. Degradation of water quality in outstanding natural resources, such as state and national parks, recreation areas, wildlife areas, scenic rivers, or areas of ecological significance is also not allowed.

Numerical criteria that protect the highest beneficial use will be established for each aquifer class. These criteria set the concentration of each hazardous substance that cannot be exceeded in the ground water. Criteria for most ground water aquifers will be based on the State Board of Health's maximum contaminant level (MCL) standards for drinking water, including both primary and secondary standards.

Enforcement limits (a lower number used to regulate a discharge) and nonenforceable *early warning values* are both incorporated into the proposed rule. Enforcement limits will be set on a case-by-case basis as close as possible to background concentrations. Early warning values are set lower than enforcement limits, providing the means for early detection and prevention of ground water quality problems. Ecology must be notified whenever these early warning values are exceeded, so that further evaluations can be performed and the appropriate preventive steps taken.

WAC 173-200-050 (Ground Water Quality Standards) specifies that enforcement limits for cleanup actions under the MTCA will be established under Chapter 173-340 WAC of the proposed amendments. Ground water criteria under the proposed rule will be applicable requirements for MTCA sites. Early warning values will not be ARARs under MTCA.

Surface Water Quality Standards

Under the state Water Pollution Control Act (Chapter 90.48 RCW as amended), Ecology is directed to issue water quality standards for surface waters of the state. Surface water quality standards were first developed and issued as regulations (Chapter 173-201 WAC) in 1967. These regulations were most recently revised in 1988.

Washington state's antidegradation policy for surface water quality under the Water Pollution Control Act requires existing and potential beneficial uses be maintained and protected from further degradation. Exceptions are allowed where 1) all known, available, and reasonable methods of treatment (AKART) are used, 2) there are overriding considerations of public interest, and 3) modifications of the standards would occur on a short-term basis for certain activities. No degradation that is injurious to existing uses or long-term environmental health is allowed in any case. Additionally, no degradation of water quality is allowable in state and national parks, recreation areas, wildlife areas, scenic rivers, or areas of outstanding ecological significance.

Surface water standards have been developed by Ecology to protect present and potential future uses of surface water resources. The standards set limits on allowable degradation of surface water when some water quality impacts would result even after application of AKART.

The EPA ambient water quality criteria for 25 listed hazardous substances have been adopted as surface water quality standards for toxic substances under WAC 173-201-047, following a recommendation in the Puget Sound Water Quality Management Plan. The regulations also include a general requirement that "toxic, radioactive, or deleterious material concentrations shall be below those which may adversely affect characteristic water uses, cause acute or chronic conditions to the aquatic biota, or adversely affect public health."

The surface water quality standards are generally applied through permits for authorized discharges under Chapter 90.48 RCW. In the last year, most permits have also been written to include bioassay requirements to identify potential aquatic impacts from toxic substances. Discharge permits may include authorized mixing zones within which the standards for water quality may not fully apply (that is, the point of full compliance is at the boundary of the authorized dilution zone).

The existing surface water quality standards of Chapter 173-201 WAC are applicable requirements for cleanup actions under the MTCA.

Dangerous Waste Regulations

The Hazardous Waste Management Act (Chapter 70.105 RCW) provides statutory authority for the state to establish and manage a hazardous waste program. Ecology has developed rules for the state hazardous waste program under the state's dangerous waste regulations (Chapter 173-303 WAC).

The Dangerous Waste Regulations define procedures for designating wastes as hazardous. Two levels of hazardous wastes, *dangerous wastes* and *extremely hazardous wastes*, have been defined. However, the term *dangerous wastes* is often used generically to include both levels. The basic procedures for designation under WAC 173-303-070 include reference to dangerous waste lists (for discarded chemical products, dangerous waste sources, infectious wastes, and waste mixtures) and the comparison of waste properties to defined dangerous waste criteria.

Ecology has the authority to require and oversee the cleanup of all spills or releases of dangerous wastes or hazardous substances. Corrective actions may be required to remedy historic releases at permitted operating facilities. Facility closure requirements are designed to ensure that residual contamination is cleaned up and that no threats to human health or the environment remain when facilities cease operation. Long-term monitoring is one of several closure requirements for land disposal facilities.

The priorities of the dangerous waste regulations for handling dangerous waste are similar to those of the MTCA. They are listed below in decreasing order of preference:

- Source reduction
- Recycling
- Physical, chemical, and biological treatment
- Incineration
- Stabilization and solidification
- Land disposal.

Land disposal of dangerous wastes is the least preferred alternative for waste management. Restrictions exist on land disposal of certain wastes, such as liquid or ignitable and reactive wastes. However, recent EPA guidance states that these restrictions may not apply to cleanup of hazardous waste sites.

State dangerous waste regulations are applicable requirements for MTCA sites. These applicable requirements include the designation of rules for dangerous wastes, as well as location-specific and action-specific requirements for handling dangerous wastes. Cleanup levels have generally been set at lower concentrations than those that define dangerous wastes under Chapter 173-303 WAC.

Air Toxics Regulations

The federal Clean Air Act includes provisions for setting standards for toxic air hazardous substances under the National Emission Standards for Hazardous Air Pollutants (NESHAP) program. However, very few standards have been set under NESHAP. In 1984, Ecology began developing a state program for control of toxic air hazardous substances. This action was consistent with federal policy allowing each state to establish its own regulatory framework for controlling such hazardous substances (U.S. EPA 1985). The current state program (Ecology 1990) exists as draft guidelines that have not been formally adopted as policy or rules. Ecology plans to continue development of the guidelines and to adopt them as regulations. This section reflects the status of these rules in June 1990.

As a result of these regulations, all new sources and substantial modifications to existing sources of toxic air emissions will be registered, potential emissions identified, and toxic air emissions controlled with best available control technology. In addition, acceptable source impact levels (ASILs) established by Ecology will be used as screening levels to determine if a source is in compliance with the regulation. If a source is not in compliance, it may either reduce its emissions or show, through a site-specific health risk assessment, that its emissions do not result in appreciable risk to human health.

Ecology's draft guidelines already include more than 500 specific compounds for which ASILs are proposed. The proposed Washington ASILs are ambient concentration limits set at numerical levels that are likely to be without appreciable risk of harmful effects to humans during a lifetime.

The Washington ASILs will become applicable as cleanup levels once they are formally adopted. Prior to adoption, they will be used as requirements to be considered for proposed cleanup actions under the MTCA. The ASILs will apply to permitting of cleanup actions (for example, air stripping towers) as well as to air quality after cleanup.

Sediment Management Standards

The Washington legislature passed the Puget Sound Water Quality Act (Chapter 90.70 RCW) in 1985. The act created the Puget Sound Water Quality Authority (the Authority), which was charged with the task of developing a comprehensive water quality plan for Puget Sound and updating that plan every 2 years. The first Puget Sound Water Quality Management Plan (the Plan) was adopted by the Authority in 1987 and updated in 1988. The Authority is currently finalizing the Plan to meet the requirements of EPA's National Estuary Program. The final Plan is scheduled for adoption in 1991 as the state and federal Comprehensive Conservation and Management Plan for Puget Sound.

The current Plan includes several elements related to sediment quality. In particular, plan element P-2, from the municipal and industrial discharges program, directs Ecology "to develop and adopt by regulation standards for identifying and designating sediments that have acute or chronic adverse effects on biological resources or pose a significant health risk to humans."

The Plan envisions several uses of the sediment quality standards. The standards will be used as the sediment quality goal for several multiple discharge permit programs: the municipal and industrial discharges program, the stormwater and combined sewer overflow program, and the nonpoint source discharge control program. Discharge permits issued by Ecology will include monitoring and treatment requirements and effluent limitations sufficient to prevent exceedances of the sediment quality standards in receiving waters. Sediment impact (dilution) zones authorized under state Water Pollution Control Law (Chapter 90.48 RCW) and included in element P-3 of the Plan, will be allowed because of technical and economic limitations of treatment methods.

Plan element P-2 also recommends that an inventory of areas where sediment quality exceeds the applicable standards be established. In addition, plan element S-7 recommends the development of a cleanup decision process to rank and prioritize contaminated sediment sites for cleanup actions, including source control or sediment cleanup actions, or both. As a key part of this decision process, Ecology will be developing cleanup levels for sediments.

The Sediment Management Unit within Ecology's Environmental Review and Sediment Management Section is developing draft Sediment Management Standards (proposed Chapter 173-204 WAC) that will incorporate recommendations from plan elements P-2, P-3, and S-7. Preliminary review drafts of the Sediment Management Standards have been circulated by Ecology for public review and comment, and extensive public involvement has occurred since mid-1988. Final regulations are currently scheduled to be proposed for adoption in July 1990 and adopted in September 1990. The standards will include chemical concentrations and biological criteria.

The Sediment Management Standards, when adopted, will become applicable requirements under the MTCA. Ecology has not included sediment cleanup levels in the proposed regulations at this time, given the advanced stage of development of comprehensive sediment management standards. It is Ecology's intent to incorporate the Sediment Management Standards by reference into the MTCA Cleanup Regulation once the sediment regulations have been adopted.

Leaking Underground Storage Tanks

The federal Hazardous and Solid Waste Amendments of 1984 established an underground storage tank program as part of RCRA. EPA issued final regulations (40 CFR 280; 53 Federal Register 37082-37247) implementing this program in 1988. Ecology, through its solid and hazardous waste program, is developing a state program consistent with the federal underground storage tank program, as defined in the 1988 technical regulations. Statutory authority for this state program was provided during the 1989 Washington legislative session. State regulations are being drafted, and adoption is expected in 1990. It is expected that EPA will delegate authority for the federal program to Ecology after the state regulations are adopted.

The federal regulations apply to underground storage tank systems, including connected underground piping, that contain petroleum or hazardous substances. The regulations establish requirements for both new and existing tank systems to prevent, detect, and clean up any releases of petroleum or hazardous substances.

Existing substandard tank systems must be upgraded or closed by 1998. Closure of a tank system is accomplished by removing the tank and connected piping from the ground or by removing all product, cleaning the tank system, filling it with an inert substance, and closing the system to all future outside access. At the time of closure, an assessment must be performed to determine whether any releases have occurred.

Federal rules require owners and operators to clean up soil and ground water as necessary to protect human health and the environment. State rules must be "no less stringent" than the federal rules. Any suspected releases during the operating lifetime of the system must be reported, investigated, and (if confirmed) corrected. Where a release is confirmed, corrective action must follow the underground storage tank section of MTCA rules.

Releases of petroleum products from underground storage tank systems are subject to the requirements of the MTCA. Therefore, the cleanup levels established under the MTCA will be applicable to any releases from underground storage tank systems in Washington. The requirements of the regulations being developed by Ecology for underground storage tank systems will also be applicable requirements for regulated tanks at MTCA sites.

Washington Health Advisories

Through the Board of Health, the Department of Health (formerly within the Washington Department of Social and Health Services) has statutory authority to set standards for drinking water quality. All other guidance from the Department of Health is issued in the form of health advisories, which are not enforceable standards. Health advisories can be developed for any hazardous substance in any environmental medium, under the department's broad mandate to protect public health.

In many cases, health advisories are issued in response to requests from Ecology or other state agencies regarding sites with hazardous substances for which there are no existing standards. For example, drinking water guidance levels, which were designed for hazardous substances without MCLs or other criteria, were developed in coordination with Ecology.

Except for drinking water standards, which are applicable requirements, all health advisories issued by the Washington Department of Health are requirements to be considered when developing cleanup levels for hazardous waste sites.

Chapter 3
Significant Issues Regarding Cleanup Levels

Any approach for the development of hazardous waste site cleanup levels must consider important technical, policy, and procedural issues. Twelve of these issues are identified and discussed below. Although they are discussed individually, these issues interact in complex ways. In order to achieve timely, appropriate, and effective site cleanups, options for addressing each of these major issues must be chosen and incorporated into the cleanup levels promulgated by Ecology.

Issues that affect the approach to setting cleanup levels were widely discussed during the drafting of the regulations. Comments on many of the issues were specifically solicited as part of public workshops and scoping meetings. The Science Advisory Board and internal (Ecology) and external work groups devoted much of their time to careful examination of these issues. Ecology also requested opinions from the Attorney General's office regarding several legal issues. The contributions of all of these parties to the identification of issues related to the cleanup levels, and the evaluation of options for addressing them, are acknowledged. Experience with applying previous cleanup levels to federal and state hazardous waste sites also provided a practical basis for issues evaluation.

There is now extensive literature discussing significant issues related to the development of cleanup levels. Selected references, many of which summarize relevant portions of the available literature, are provided in the discussions below. These references are provided for readers interested in greater detail than is presented in the brief discussions below.

A strong division between matters of science and matters of policy has been recommended for addressing environmental hazards (NAS 1983; Ruckelshaus 1983). This separation of risk assessment (science) and risk management (policy) has been adopted by Ecology in the development of the cleanup levels under the MTCA. The inclusion of issues related to both science and policy concerns in the discussions below should not obscure the separation of risk assessment and risk management in site cleanup decisions.

Experience in reaching cleanup decisions at federal Superfund sites, and especially the use of risk assessments in determining cleanup levels, is reviewed by Zamuda (1989). A review of records of decision at Superfund sites was also performed as part of the development of MTCA cleanup levels (PTI 1989b) and provides a compilation of actual decisions that have been reached by EPA. A recent review of Superfund experience (OTA 1989) provides a somewhat different perspective and is critical of several aspects of the way cleanup decisions have been reached under Superfund. The Office of Technology Assessment (OTA) review recommends limiting the flexibility in determining cleanup levels through adoption of minimum cleanup levels and standardized approaches, among numerous other recommendations. The revised National Contingency Plan (8 March 1990; U.S. EPA 1990b) defines the current procedures for determining cleanup levels at federal Superfund sites; discussion of many issues raised during revision of the National Contingency Plan is provided in the preamble to that regulation (see 55 Federal Register 8666 et seq., 8 March 1990).

Appropriate Level of Protection for Human Health and the Environment

The complete elimination of all risks posed by hazardous waste sites has sometimes been suggested as a goal. However, it is not generally achievable, nor is it usually considered necessary. Everyday activities are not risk-free; people have been described as "living in a sea of common risks." At some relatively small level, many risks are considered acceptable. Similarly, some site impacts or estimated risks may be considered too small to require cleanup action or protection. If zero risk is not the basis for defining appropriate protection, how should "acceptable risk" be defined?

Establishing an acceptable level of protection requires consideration of human values and does not lend itself easily to mechanical calculation. The acceptable level of protection is the essential policy question for site cleanups, and is therefore part of risk management rather than risk assessment. Many factors other than the calculation of estimated risks are involved in the choice of an appropriate level of protection (NAS 1983; Deisler 1988; Ricci and Molton 1985; Dwyer and Ricci 1989; Paustenbach 1989a).

Human Health Risks

Human health risks are generally divided into cancer and noncancer risks. For noncancer health risks, thresholds of exposure for noncarcinogens, below which adverse health effects do not occur, are assumed to exist. Those exposure thresholds are obvious candidates for defining adequate protection of human health. In practice, the uncertainties in determining exposure thresholds from toxicology studies, as well as the contributions from multiple hazardous substances or from multiple sources of a single hazardous substance, are additional factors that must be considered when setting cleanup levels.

Uncertainty factors are commonly used in combination with thresholds to provide protective standards, because thresholds address only the exposure to one hazardous substance from the site being regulated. Site-related exposure to a single hazardous substance may contribute all or only part of the allowable dose for that hazardous substance, depending on whether contributions from other sources are included in the risk assessment. The total dose received by a part of the body may include contributions from background sources or from multiple hazardous substances with similar effects. Derivations of thresholds for noncancer health effects may include consideration of common background exposures (for example, from dietary sources); they may also consider the possible cumulative effects from exposures to multiple hazardous substances. Therefore, establishing adequately protective cleanup levels for noncancer health risks is more involved than adopting established thresholds for exposures to single hazardous substances. However, in principle, the appropriate level of protection can be set at a level at which no adverse health effects are expected to occur.

For cancer health risks, any level of exposure to a carcinogenic hazardous substance is assumed to result in some risk. Unlike the situation for noncancer health risks discussed above, the only way to achieve zero risk is to totally eliminate hazardous substance exposures. Determining the level of continuing exposure and risk after cleanup that is considered acceptable has been approached in at least three different ways, discussed below:

- Using precedents and experience from other regulatory programs, based on actions taken or not taken to regulate estimated risks

- Comparing estimated risks from other settings, including normal daily activities, to those from exposures at hazardous waste sites
- Evaluating public perceptions of acceptable risks.

Precedents for Determining Acceptable Risk

The revised National Contingency Plan (U.S. EPA 1990b) identifies a range of acceptable risk, based on individual lifetime cancer risks, of $1x10^{-4}$ to $1x10^{-6}$ for federal Superfund sites. These numbers correspond to a probability of 1 in 10,000 to 1 in 1,000,000 of getting cancer over the course of a lifetime. The $1x10^{-6}$ risk represents the starting point for acceptable risk, reflecting EPA's preference for the lower end of the stated range. The previous National Contingency Plan used a somewhat broader risk range of $1x10^{-4}$ to $1x10^{-7}$, but actual site cleanup levels were not based on the lower end of this range, at risks less than $1x10^{-6}$ (PTI 1989b; U.S. EPA 1990b). The review of site records of decision (PTI 1989b) indicates that acceptable risks, as reflected in cleanup decisions, were less variable than the range included in the National Contingency Plan would suggest. Most cleanup actions were based on an acceptable risk of $1x10^{-5}$ to $1x10^{-6}$.

A review of 132 federal regulatory decisions that included cancer risk estimates provides a much broader perspective on what has been judged to be unacceptable cancer risk requiring some type of regulatory action (Travis et al. 1987). Analysis of the pattern of these decisions, according to the authors, shows a surprising degree of consistency in federal regulatory decisions regarding acceptable risks. Individual risks above $4x10^{-3}$ were always regulated; individual risks below $1x10^{-6}$ were never regulated. When risks were between these upper and lower bounds, regulatory actions were taken in some cases but not in others. At these sites, the cost-effectiveness of regulating (cost per cancer case avoided) is cited by the authors as the primary factor affecting the decision. These cutoff levels for action also changed according to the size of the populations affected; the larger the population, the smaller the level of acceptable risks. Thus, based on past federal agency actions, at least two measures of cancer risk are used to describe what is acceptable: the lifetime risk to the individual and the incidence (number of cancers) in an exposed population.

A variation of this approach considers human health risks remaining after regulatory actions are taken (Travis and Hattemer-Frey 1988). Based on actions related to 36 carcinogenic hazardous substances, the authors conclude that 70 percent of the regulations allow risks above $1x10^{-6}$ and about 30 percent exceed $1x10^{-4}$. It is assumed that those risks were determined to be acceptable, since they were allowed by the regulations. Dwyer and Ricci (1989) have commented on these results, noting, for example, that factors such as the benefits derived from use of products containing these hazardous substances are not explicitly considered in the study. Dwyer and Ricci generally emphasize that the acceptability of risks depends on context and on many factors beyond the numerical risk level, such as familiarity with the risk, benefits from allowing the risk, and whether the risk is a voluntary one. In addition, such comparisons do not take into account the variety of laws and regulations under which regulatory decisions are made. The various laws and regulations differ with respect to what factors must be taken into consideration in defining an appropriate level of protection.

Comparisons of Acceptable Risks

A second approach that has been proposed for evaluating what risks are acceptable is the comparison of risks from different types of activities. These comparisons may be broad or limited to a similar class of activities (Covello 1989; Wilson and Crouch 1987). This approach assumes that comparative risks are easier to understand than numerical statements of probabilities. In addition, it assumes that levels of risk associated with common daily activities are considered acceptable. Estimated risks for such actions as driving a car, breathing urban air, drinking water that has been disinfected using chlorination, flying in an airplane, having a diagnostic x-ray taken, or eating typical foods are commonly used in these comparisons (Covello 1989). Risks from smoking, drinking alcoholic beverages, or other potentially injurious actions may also be included, although they may not necessarily be used to define accepted risks.

Carcinogenic substances and exposures are in fact relatively common. Ames (1983) has emphasized the presence of naturally occurring carcinogenic hazardous substances in food. Ames et al. (1989) reviewed the level of exposures to carcinogens from various sources. Total individual lifetime risks of having cancer are about 1 in 4, and risks of dying of cancer are about 1 in 5; these risks include substantial contributions from lifestyle choices, such as smoking and diet. Judicial review of EPA rulemaking has suggested that everyday risks from activities such as driving a car or breathing urban air should be considered in defining acceptable risks (Marchant and Danzeisen 1989; Travis and Hattemer-Frey 1988). The estimated risks of dying in a car accident or developing cancer from drinking chlorinated water, among other common activities, are high in comparison to many risks that have led to regulatory actions.

Comparative risk evaluations have been criticized as being too narrowly focused on numerical risk estimates, ignoring many additional subjective factors that influence the acceptability of a risk (Covello 1989; Dwyer and Ricci 1989).

Public Perceptions of Acceptable Risk

The third approach for evaluating risk acceptability, and perhaps the most intuitively appealing, is simply to ask people what they consider acceptable. Detailed studies of the perception of risks have been performed over the past 20 years (Slovic 1987; Morgan 1986), both to improve risk communication and to understand public risk perceptions and responses to perceived risks. The results have demonstrated that even though risk perceptions are biased in some ways, they incorporate in a meaningful way a large number of factors that cannot be estimated numerically (Slovic 1987; Covello 1989). These factors include whether risks are voluntary or imposed, who benefits and who bears the risks, whether alternatives are available, how much control one has over the activity resulting in risk, and whether effects are immediate or delayed.

Risk perception research indicates that answers to the question "What is an acceptable risk?" depend greatly on context and involve many more considerations than just a statement of numerical risk (probability). The characteristics of risks from hazardous waste sites differ in many respects from more common risks (for example, being involuntary, uncertain, or of low direct benefit to affected persons), and thus may not be acceptable even at similar or lower levels of risk (Covello 1989).

Cancer risks can be expressed numerically in different ways. The two most common measures are the probability of one individual developing cancer and the expected number of cancer cases within an exposed population. Other less common measures also can be used, for example, the number of years that a lifetime is shortened. These different measures of risk are not equivalent, and the choice of an appropriate level of protection depends on the measure of risk chosen. For instance, establishing an individual lifetime risk of 1×10^{-6} as acceptable implies different population risks for two sites with different sizes of exposed populations. Conversely, using a single population risk value (one cancer death in a community per year, for example) to define acceptable risk implies that different individual risks would be acceptable at sites with different exposed populations.

Individual cancer risks vary depending on the amount of exposure a person receives. Acceptable risks can be determined based on typical exposures or less common, higher exposures; that is, protection can be defined for the typically exposed individual or for the most exposed individual. The MTCA states in its declaration of policy that "each individual has a fundamental and inalienable right to a healthful environment." Ecology believes that this statement should be considered in defining an appropriate level of protection for the MTCA cleanup levels.

Combined individual and population risk measures can be used to determine acceptable risks. Travis et al. (1987) indicate that acceptable individual risks as reflected in regulatory actions by federal agencies vary depending on the number of people exposed. Allowing individual risks to vary according to how many other persons are exposed has been criticized by some as inappropriate and inequitable (Marchant and Danzeisen 1989). EPA has also proposed for public comment a variety of risk measures to be used for determining acceptable risk (Marchant and Danzeisen 1989), including both individual and population-based measures of risk. It is noted that for most hazardous waste sites, the potentially exposed population is small and therefore the potential for widespread harm is usually also small, regardless of the magnitude of individual lifetime risks.

Risks Below Background Levels or Practical Quantitation Limits

Hazardous substance concentrations that correspond to acceptable risk levels, based on any method of estimating risk, may be below background concentrations or practical quantitation limits. Whether these risk levels should be used to set cleanup levels needs to be considered. In the case of risk levels below background concentrations, cleanups below background would not be expected to be effective in the long term, and may be considered inappropriate and inequitable. Adjustment of acceptable risk levels up to background may be warranted, because those risk levels are common and unavoidable.

Cleanups to protective levels that are below practical quantitation limits, on the other hand, may simply be impossible to implement and enforce, even if not considered inappropriate or inequitable. The practical quantitation limit could be adopted as a cleanup level, effectively increasing the level of acceptable risk, or it could be used as an interim standard for cleanup actions without changing the lower acceptable risk level. If used as an interim standard, periodic site review could result in additional action if analytical methods improved over time. The latter approach has been proposed in the amendments to the cleanup regulations [see WAC 173-340-700(5)]. Changing the appropriate level of protection based on a technical limitation is quite different from changing it because of common and unavoidable background exposures.

Ecological Health Risks

Apart from human health risks, appropriate levels of protection for plants and animals are also of concern for site cleanup decisions. The definition of environmental protection depends on the measures of ecological effects chosen and whether individual organisms or ecosystems are chosen to protect. Bioaccumulation, mortality, reproductive failures, changes in abundance or biological community structure, and other effects can be used as measures of impacts to be protected against. Not all measurable impacts are considered worthy of protection; that is, there may be a level of acceptable environmental impact just as there is a level of acceptable human health risk. Such acceptable impact levels are established based on value judgments about the significance of any measurable or estimated changes in ecological systems.

Unlike human health risks, where individual risks have usually been considered important, many ecological impacts are typically considered on the level of populations rather than individuals. Available standards are generally used to define levels of concern, and these are considered adequate levels of protection from environmental impacts. For example, bioassay data that determine concentrations in water at which statistically significant effects on fish mortality occur are used to develop an ambient water quality criterion, which is considered a protective concentration against impacts to aquatic life. There are not enough available standards to protect against environmental effects that may be of interest. For instance, very few standards are available to protect terrestrial plants and animals. The available standards may also consider hazardous substances singly rather than as mixtures, or be based on test results for species that do not occur at a site. For all of these reasons, site-specific testing may be required to establish appropriately protective standards.

Summary - The Proposed Rule

The determination of appropriate levels of protection is a policy issue, not a scientific one. This issue in effect changes the question "How clean is clean?" to "How safe is safe?" The zero risk response answers that question "only absolutely safe is safe." All nonzero risk responses determine a level that is "safe enough" based on value judgments about the significance of remaining risks or impacts.

The options for setting appropriate levels of protection for human health risks are summarized as follows. For noncancer risks, the appropriate level of protection is generally that which results in no adverse health effects, based on the existence of thresholds. In rare cases, some small level of impact may be considered acceptable (for example, when the adverse effect itself is not considered very harmful, is short-term, or is easily reversible). The protective level allowing no adverse health effects may be set at the estimated threshold (often including an uncertainty factor) or at some fraction of that threshold to account for background sources or multiple hazardous substance exposures. Ecology has proposed that the level of protection for noncarcinogens correspond to no acute or chronic toxic effects on human health, assuming a reasonable maximum exposure.

Appropriate levels of protection for cancer risks may be set based on lifetime individual cancer risk, population incidence, or on combined measures. For example, acceptable risks could be defined as individual risks of $1x10^{-5}$ (most exposed individual), individual risks of $1x10^{-6}$ (average exposed individual), or total cancer incidence in the exposed population of 1 case per 70 years. Using a combined measure, acceptable risk could be defined as individual risks of $1x10^{-4}$ if the exposed population was less than 50 people, $1x10^{-5}$ if it was between 50 and 500 people, and $1x10^{-6}$ if it was more than 500 people. For carcinogens, Ecology has proposed that an individual risk of $1x10^{-6}$ be used to establish compliance cleanup levels for individual hazardous substances unless health-based concentrations are specified in applicable state and federal laws.

The total individual risk associated with exposure to multiple hazardous substances and/or multiple routes of exposure cannot exceed $1x10^{-5}$. The proposed rule identifies several situations where concentrations for individual hazardous substances might be established at a $1x10^{-5}$ risk level (using conditional cleanup levels). However, the overall limit of $1x10^{-5}$ risk would still apply and, consequently, cleanup levels based on exposure to a single hazardous substance would be adjusted downward to take into account the presence of multiple hazardous substances and multiple exposure pathways.

Finally, the establishment of appropriate levels of protection for environmental impacts requires defining measures of ecological effects, the level at which these effects are of concern (to individuals or ecosystems), and the degree of impact that is considered significant. Available standards or procedures for site-specific testing may be adopted to define an appropriate numerical standard. Under the proposed rule, Ecology would use existing standards, where available, and would require site-specific ecological risk assessments when existing standards are not considered sufficient to protect aquatic and terrestrial life. Ecology has begun development of a framework for establishing ecologically based cleanup levels.

Methods for Characterizing and Quantifying Human Health and Environmental Risks

For a chosen level of protection, the cleanup levels depend on the methods used to estimate potential exposures and risks. The cleanup levels regulations therefore must consider the available methods for measuring exposures, toxicity, and risk. Because variability across the methods used will affect calculated cleanup levels, the appropriateness of allowing such variability within the regulations must also be considered.

Human Health Risk Assessment

Assessments of human health risks have been included in numerous federal regulatory programs. During the early 1980s, the issue of consistency in the methods used to perform such risk assessments and establish regulatory standards was carefully examined (NAS 1983). It was recommended that a standard approach to risk assessment be provided in the form of written guidelines.

EPA subsequently developed a series of guidance documents specifying the methods to be used for human health risk assessments. In 1986, guidelines were issued for assessing the risks of carcinogens, mutagens, developmental toxicants, and hazardous substance mixtures, as well as guidelines for performing exposure assessments (U.S. EPA 1986b-f). Risk assessment guidelines for human health evaluations at Superfund sites were most recently issued in 1989 (U.S. EPA 1989i), substantially revising an earlier manual. The *Superfund Human Health Evaluation Manual* incorporates a large number of other technical guidance documents issued by EPA regarding exposure modeling (for example, U.S. EPA 1988f, 1989c) and toxicity evaluations (for example, U.S. EPA 1990a). Cumulatively, these documents provide a detailed description of the methods used by EPA to quantify human health risks from hazardous substance exposures.

EPA Region 10 has also developed a set of written guidelines (U.S. EPA 1990c) for conducting risk assessments at sites within the region, including all sites in Washington. These Region 10 guidelines, like the *Superfund Human Health Evaluation Manual*, identify exposure assessment, toxicity assessment, and risk characterization as basic steps in the quantification of human health risks. This approach was established by the National Academy of Sciences (1983). The Region 10 guidelines include detailed specification of parameter values to be used in exposure assessments. Paustenbach (1989c) provides a collection of case studies that apply EPA methods of risk assessment to specific sites or exposure situations.

The methods described in the EPA guidelines are for quantifying individual risks. Population risk, or the estimated incidence of adverse human health effects, can be estimated by combining demographic information with individual risk estimates. The traditional focus within Superfund and other environmental regulatory programs on individual risks is distinctly different from a conventional public health approach that emphasizes prevalence of effects within a population.

Consistency of methods used to measure risks under the MTCA with the methods developed in the federal Superfund program is desirable. The use of reference doses and cancer potency factors (also called slope factors) to describe the toxicity of noncarcinogenic and carcinogenic hazardous substances, respectively, is now fairly standard. The major issue involved with their use is the conservatism and uncertainty associated with them (discussed in the next section). There has been greater variability in the approaches used to estimate exposure. That variability includes both the exposure pathways and routes considered and the numerical values to be used for specific parameters.

Exposure models should represent the processes that lead to hazardous substance exposures. These processes include both the behavior of hazardous substances in the environment (fate and transport) and the activities and physical characteristics of individuals who may be exposed (for example, body weight, frequency of time spent in contaminated areas, and amount of soil ingested daily). Each pathway that potentially leads to exposure is modeled separately. Issues involved in exposure modeling include 1) what pathways to include, 2) what model to use to represent each pathway of exposure (the variables and their relationships), and 3) what numerical values to assign to each of the modeled variables or parameters (Severn 1987).

The choices made for these three aspects of exposure assessments have often been criticized in evaluations of completed risk assessments (Commoner 1989; Paustenbach et al. 1986). Such criticisms have stated both that the resulting exposure estimates are overestimates and that they are underestimates. Where guidelines have not specified exposure modeling approaches in detail, the variability in exposure modeling approaches has been great. One of the goals of recent EPA guidelines (U.S. EPA 1989i, 1990c) has been to limit that variability, for example, by specifying the numerical values of parameters to be used in exposure models.

At sites where exposures to many different hazardous substances may occur, risk assessment methods can include techniques to screen the hazardous substances and identify those primarily responsible for risks (U.S. EPA 1989i). Detailed risk assessments are then performed only for those hazardous substances. The available methods have generally assumed that similar types of risks can be added when there are exposures to multiple hazardous substances, unless specific information is available to support alternative assumptions. Cleanup levels must take into account the additivity of risks from different exposure pathways and hazardous substances by dividing the total acceptable risk among them.

Alternative approaches for measuring hazardous substance exposures and risks are being studied and tested on specific problems. Although they have not yet been developed to the point where they can be incorporated in risk assessment guidelines, these developing methods may, in the future, change the way in which risk assessments are performed and alter estimates of risks. One alternative approach, called physiologically based pharmacokinetic modeling, focuses in detail on the metabolic pathways and processes that determine the dose of a hazardous substance that actually reaches a target organ from ingestion, inhalation, or dermal contact (Menzel 1987; NAS 1989; Krewski et al. 1989; Anderson 1989; Paustenbach 1989a). Detailed PBPK models may require that a large number of variables be estimated to calculate target organ doses.

New approaches to measuring hazardous substance exposures by individuals are also being developed. A technique called the Total Exposure Assessment Methodology (TEAM) has been used by EPA to investigate exposures actually being experienced by individuals (Ott 1985; Wallace et al. 1986). The results of such careful monitoring studies may improve exposure modeling approaches. In the TEAM approach, the varying levels of exposure experienced as a result of people's activities, as well as hazardous substance movement, are considered in arriving at a total effective exposure measurement (Ott 1985).

Ecological Risk Assessment

Although there is extensive literature available on methods of measuring and quantifying environmental impacts to human health, the guidelines for measuring ecological risk are not as fully developed. U.S. EPA (1989h) has prepared an environmental evaluation manual for Superfund risk assessments, as well as a reference volume of field and laboratory ecological assessment methods (U.S. EPA 1989b). The latter document provides guidelines for site-specific testing for ecological impacts. EPA Region 10 has also issued guidelines for environmental evaluations at Superfund sites in the region (U.S. EPA 1989j).

Current approaches used by EPA for ecological risk assessment are discussed by Bascietto et al. (1990). The identification of environmental effects of potential concern is an important component of environmental risk assessments. Various effects are being studied in aquatic and wildlife toxicology investigations (Cairns and Mount 1990; Hoffman et al. 1990). In Superfund site evaluations, existing regulations (for example, ambient water quality criteria) or available information from the literature that defines concentrations of concern are typically compared with hazardous substance concentrations at a site as a method for evaluating potential environmental risks.

Summary - The Proposed Rule

Methods of estimating human health risks can be summarized as follows. For human health evaluations, it is assumed that published EPA toxicity values are used, including uncertainty assessments as appropriate. The options for exposure assessments, using standard approaches as defined in existing guidelines, include:

- Allowing site-specific development of exposure assessments, within the general framework of the guidelines
- Specifying the models and pathways of concern to be used in deriving cleanup levels
- Specifying the exposure models and pathways and also the numerical values of parameters within those models
- Specifying conditions under which a site-specific deviation from a defined method included in the regulation can be used.

The primary options for estimating environmental risks are whether to specify the available numerical criteria to be used as threshold values in assessing risks, and whether or not to define the ecological effects to be protected against and used in defining ecologically based cleanup levels. In assessing environmental risks, Ecology will use existing standards where appropriate. Additional site-specific risk assessment will be required at some sites to determine concentrations that will result in no adverse effects on the protection or propagation of other aquatic and terrestrial life. Ecology has begun development of a systematic approach to characterizing ecological risk at hazardous waste sites.

The proposed rule reflects Ecology's opinion that the latter method provides the best balance between consistency and flexibility in the regulations. The methods included in the proposed rule are similar, but not identical, to the methods used by EPA at federal Superfund sites. Ecology will consider the use of developing methods of human health evaluation on a case-by-case basis. With regard to exposures to multiple hazardous substances at a site, risks can either be evaluated for individual hazardous substances or additivity of similar risks can be assumed. Ecology has chosen to assume additivity of risks from multiple hazardous substances and multiple exposures at a site to provide a conservative level of protection.

Methods for Characterizing and Considering Scientific Uncertainty

Risk assessments combine many different types of information to estimate risks. Hazardous substance concentrations and behavior (fate and transport), toxicity values for hazardous substances, human physiological parameters, and human behaviors and activities are all used in risk assessment. Specific numerical values for many parameters related to all of these types of information are used to estimate risks, yet all of these parameters are subject to uncertainty and variability. One of the most discussed issues with respect to standard methods for risk assessment is the effect of these uncertainties on risk estimates and on risk management decisions.

The uncertainties associated with risk assessment are unavoidable, although additional information may reduce the uncertainties associated with certain variables or even the overall uncertainties in the estimates. With respect to cleanup levels, uncertainties in risk estimates affect opinions about the proper assumptions to use (for example, average exposures or maximum exposures) and the degree of conservatism associated with these assumptions.

The proposed rule reflects Ecology's opinion that the cleanup levels should be established to be protective both now and in the future. Therefore, potential exposures and land uses that could reasonably occur in the future, as well as existing exposures, need to be considered when deriving cleanup levels. The MTCA declaration of policy also emphasizes each individual's right to a healthful environment; Ecology interprets that declaration of statutory intent to require protection of each individual rather than the average individual. The uncertainty with respect to possible exposures and varying individual risk levels is addressed by proposing conservative and protective cleanup levels in the MTCA regulations. Consideration of the trade-off between the effects of overestimation vs. underestimation of risks is guided by Ecology's interpretation of the MTCA.

Several types of uncertainties in risk assessments have been identified (Gelpe and Tarlock 1974; Morgan 1986; U.S. EPA 1989i; Finkel 1990). The uncertainties associated with estimates of hazardous substance toxicity are well-studied and address the differences between:

- The responses of laboratory animals and humans
- High doses measured in the laboratory and low doses typically encountered in the environment
- Populations and individuals of varying susceptibility
- Continuous doses and intermittent doses.

The approaches developed by EPA for estimating hazardous substance toxicity and dealing with associated uncertainty are generally adopted for risk assessments. These uncertainties can be quite large (Cothern et al. 1986; Kodell et al. 1987), but they are typically ignored in the estimation of risks.

The uncertainties in exposure estimates reflect hazardous substance behavior, human activities, and physiological measurements. U.S. EPA (1989i) has adopted the concept of "reasonable maximum exposures" as a basis for risk assessments under the Superfund program, defined as the maximum exposures reasonably expected to occur (see also U.S. EPA 1986c). To determine a reasonable maximum exposure estimate, the assumptions associated with all of the variables in an exposure estimate are evaluated and the uncertainties within each variable are considered.

For both exposure and toxicity assessments, it is as important to evaluate what is not included as it is to evaluate what is included when determining uncertainties (Finkel 1989; Paustenbach 1989b). For instance, the exclusion of hazardous substances for which there is no available toxicity information, the exclusion of a potential pathway for exposure (for example, food or indoor air exposures), or the assumption that hazardous substances do not degrade in a certain environment can strongly overestimate or underestimate the uncertainties associated with the resulting risk estimates.

The overall degree of conservatism in risk assessments performed using a standard approach (for example, U.S. EPA 1989i) has been criticized by many reviewers as extreme and unwarranted (Paustenbach 1989b; Maxim 1989; Paustenbach et al. 1986; Anderson 1989). This criticism focuses on the use of many conservative values within the risk assessment which combine to produce a highly conservative result. On the other hand, some authors have responded by pointing out ways in which risk assessment results may not be conservative at all, and have offered additional defenses of the approach (Commoner 1989; Finkel 1989). Both sides in this debate agree that methods for dealing with uncertainty need to be developed so that risk assessments provide appropriate information for risk management decisions. Both sides also have warned about the misuse of uncertainties in risk assessments to manipulate results to fit preestablished judgments or policies (Commoner 1989; Paustenbach 1989b). The lack of consistency in the numerical values used for parameters in risk assessment calculations, caused in part by large uncertainties, has also resulted in inconsistent results from one site to another. This is one of the major reasons for EPA's attempt to standardize many of the assumptions used in risk assessments (U.S. EPA 1989i, 1990a).

Methods for characterizing uncertainties in risk assessments have been discussed by U.S. EPA (1986c) and by numerous risk assessment practitioners (Morgan et al. 1985; Morgan 1986; Paustenbach 1989c; Finkel 1990). The methods that have been used or recommended vary widely in the amount of effort required as well as in the amount of additional information needed to perform them. An issue that has been raised is whether some of these methods really reduce uncertainties, since they themselves require numerous assumptions that are subject to substantial uncertainties.

Methods used to characterize uncertainties include upper bound estimates (based on ranges of possible parameter values), various mathematical methods of assessing uncertainties (including propagation of errors, Monte Carlo evaluation, and sensitivity analysis), and the use of expert opinions to narrow the range of uncertainties. Finkel (1990) describes visual methods of presenting risk assessment data that help communicate uncertainties in the results. Finkel has also argued strongly for detailed mathematical estimation of uncertainties in risk estimates to provide appropriate information for risk management decision-makers. This recommendation is supported by a hypothetical example contrasting risk assessments with and without such mathematical evaluations of uncertainties. Recent technical papers on exposure and risk estimation (Morgan et al. 1985; McKone 1987; McKone and Ryan 1989) also provide examples of the statistical evaluation of uncertainties.

Considering uncertainties when making risk management decisions can be very important. For instance, there is a difference between a risk estimated from a dose of 15 times the no-effect level with an uncertainty factor of 10 and a risk estimated from a dose slightly above the no-effect level with an uncertainty factor of 1,000. Decisions on appropriate cleanup levels may take such uncertainty information into account.

Information from detailed evaluations of uncertainties in risk assessments is often left out when presenting a summary of the results, which may focus only on single numbers calculated from reasonable maximum exposures. All of the uncertainty information developed for a risk assessment should be made available to decision-makers; summaries of the results may eliminate the information needed to reach an appropriate decision.

Summary - The Proposed Rule

The options for characterizing uncertainty may be summarized as follows:

- Nonnumerical evaluations of uncertainties may be performed that identify the contributing factors, their probable direction of uncertainty, and their possible magnitude
- Conservative assumptions can be used and standardized across risk assessments to estimate reasonable maximum exposures and risks; these results can be used as upper bounds on risks in making risk management decisions

- Mathematical approaches can be used to determine the uncertainty distribution for overall risk estimates; these approaches may require a large amount of additional information or assumptions to perform
- Sensitivity analyses of specific risk assessment variables can be performed to provide partial estimation of uncertainties
- Expert opinions can be used to construct subjective uncertainty evaluations.

Ecology has chosen to use conservative assumptions to provide a reasonable maximum estimate of risk. This approach is widely used by EPA and other regulatory agencies. Ecology believes that this approach is consistent with the intent of the MTCA to provide standards that are protective of each individual, not only the average individual.

Uniform Statewide vs. Site-Specific Standards

Hazardous waste sites may differ from one another in many ways. In some sense, every site could be considered unique. The significance of the differences among sites for establishing cleanup levels needs to be considered. Cleanup levels could be designed to take into account differences among sites; in the extreme case, this could require cleanup levels to be defined specifically for each and every site. At the other extreme, cleanup levels could be made uniform for all sites, ignoring the differences among them. The degree to which the cleanup levels should be modified because of site-specific characteristics is an important issue for consideration.

The issue of uniform vs. site-specific standards includes several important considerations. The first consideration is flexibility within the regulation. As the standards become more flexible, the ability to consider site-specific conditions is increased. Balancing consideration of flexibility is consistency. Allowing cleanup levels to be determined on a site-specific basis may result in large and sometimes unwarranted differences in cleanup levels across sites. The simplicity or complexity of the cleanup levels will also be affected by the choice of uniform vs. site-specific standards. Considering numerous site-specific factors when determining cleanup levels increases the complexity of the regulations. However, if not clearly specified in the regulations, the effects of site conditions on cleanup levels could become subject to competing interpretations, affecting the clarity and implementability of the regulations.

Under the federal Superfund program, a detailed process for developing site-specific cleanup levels is described in the National Contingency Plan (U.S. EPA 1990b). The OTA (1989), in its review of Superfund, criticizes the practice of treating each site as unique. The flexibility introduced by this approach is considered by OTA to be excessive and to lead to inconsistent cleanups at similar sites. OTA suggests that the flexibility available within Superfund has been used to allow cost considerations and technology selection to influence the cleanup levels selected for sites. OTA also finds that site differences are not extreme enough to warrant treating sites as unique.

The review of site records of decision under Superfund shows that for many sites the cleanup levels for specific hazardous substances in specific media do not vary greatly. In part, this reflects the fact that cleanup levels are based on the same ARARs at different sites. It also may result from using a similar exposure scenario (future onsite residential land use, for example) for risk assessment at most sites, thus eliminating actual differences across sites in exposure scenarios based on existing conditions. For the same assumed future exposure scenario, a standard risk assessment method will result in similar cleanup levels. Relatively small differences in methods (for example, in specific exposure modeling assumptions) will result in only small variation in cleanup levels. The similarities in cleanup levels from many records of decision support the idea that site differences may not be so great that they require treating sites uniquely.

The types of site differences that may affect appropriate cleanup levels are those that affect exposure to hazardous substances. These include such factors as land use, population, activities at the site, the locations of existing or future contamination, resource uses (such as the use of ground water for drinking water, crop irrigation, or stock watering), and site conditions affecting hazardous substance fate and migration. Cleanup levels could take these factors into account by establishing a site classification scheme and establishing different standards for each type of site, but that approach could be overly complex. To the extent that important site differences are geographically based, standards could be set for different geographic areas of the state. In this general site classification approach, site-specific cleanup levels would reflect differences among sites, but they could still be based on identical levels of protection (acceptable risk). It would also be possible to base the acceptable risk level on one or more site characteristics; for example, residential and industrial sites could have different sets of standards. However, concerns of fairness may be raised whenever acceptable risk levels are adjusted based on site-specific characteristics.

Site ground water characteristics offer a good example of a site-specific factor that could justify changing cleanup levels. Cleanup levels for ground water are commonly based on the possible use of ground water for drinking water. At a specific site, ground water yields may be incapable of supplying sufficient water for domestic uses, or ground water quality may be naturally degraded making it unsuitable for drinking water. If hazardous substance migration is also limited, so that other nearby drinking water sources such as deep aquifers are not affected, cleanup levels based on drinking water use may be considered inappropriate and alternate cleanup levels may be justified.

With respect to uniform vs. site-specific cleanup levels, several options are available:

- Cleanup levels could be determined on an entirely site-specific basis, with varying levels of detail in the regulations regarding the factors to be considered or the process to be used to make site-specific determinations
- A classification scheme could be established to provide cleanup levels that differ according to site types
- Numerical standards could be uniformly applied to all sites
- A uniform set of cleanup levels could be established as a point of departure (minimum cleanup levels), with a limited degree of flexibility incorporated to take site-specific factors into account.

Ecology believes that the final option, using a uniform set of minimum cleanup levels with some flexibility, provides the best balance between flexibility and consistency in applying standards statewide. For example, the proposed rule provides the flexibility to consider the current and potential future uses of ground water and to establish cleanup levels that are protective of those uses. In addition, the proposed rule distinguishes between residential and industrial sites for establishing soil cleanup levels.

The flexibility associated with establishing cleanup levels is constrained within a fairly narrow range of options. In contrast, greater flexibility is allowed when selecting a cleanup action under WAC 173-340-360. Ecology believes that greater flexibility is needed to consider site-specific factors at that stage of the cleanup process.

Definition of Applicable or Relevant and Appropriate Requirements

Section 3, Subdivision (2)(d) of the MTCA requires that the cleanup levels be at least as stringent as Section 121 of SARA and "all applicable state and federal laws, including health-based standards under state and federal law." This language regarding "applicable" laws and standards is somewhat different than the language used in the National Contingency Plan (U.S. EPA 1990b) and the federal Superfund statute, which refer to "applicable or relevant and appropriate requirements (ARARs)." Determining which laws and standards should be used to establish cleanup levels under the MTCA is an important legal issue in light of the cleanup levels requirements of the MTCA cited above. A second issue is the extent to which waivers of compliance with applicable requirements will be allowed under the cleanup levels regulations. The MTCA does not include any language specifically addressing waivers of compliance with cleanup levels. Ecology bases its conclusions regarding these issues on written opinions of the State Attorney General's Office (Manning 1989), as well as on the department's own interpretations of compliance with cleanup levels.

Definition of Applicable State and Federal Laws

Section 121 of SARA identifies the cleanup levels that must be met by any adopted cleanup action at Superfund sites. Among those requirements are compliance with the standards included in either legally applicable or relevant and appropriate requirements under federal or state laws and regulations. Thus, the requirement under MTCA that cleanup levels be at least as stringent as those under Section 121 of SARA incorporates both legally applicable and relevant and appropriate requirements. An ARAR must be consistently applied by a state or federal agency to be eligible for use in establishing a cleanup level.

The statement that cleanup levels must be "at least as stringent as" cited requirements is interpreted to allow Ecology discretionary authority to adopt stricter cleanup levels, but not standards that are less strict. For example, even though nonpromulgated guidelines or policy statements such as health advisories do not meet the definition of laws or standards included under Section 3, Subdivision (2)(d) of the MTCA, and are therefore not statutory requirements, Ecology can decide to include them as cleanup levels requirements. The issue of local requirements was considered during development of the proposed rules. In general, local requirements would not qualify as ARARs. However, many of these requirements could be imposed during permitting of cleanup actions.

Waivers of Compliance with ARARs

There are six conditions included under Section 121 of SARA that can justify a waiver of compliance with ARARs: interim remedies, greater environmental impacts from compliance, technical impracticability, an alternative that provides equivalent performance, inconsistent application of state ARARs, and fund balancing for responses at other sites. It is the opinion of the Attorney General's Office that these waivers are not incorporated into the MTCA cleanup levels requirements (Manning 1989). Waivers or variances that are defined within the ARARs themselves are considered by Ecology to be potentially available for determining site cleanup levels under the MTCA, if the substantive waiver provisions are met. Two additional conditions are identified in the proposed rule that can result in a cleanup level based on an ARAR being modified upward at a particular site. The first condition is when the ARAR standard is below natural background concentrations at the site; the second is when it is below measurable concentrations using approved analytical methods. The latter case does not represent a true waiver, but instead represents a temporary constraint on enforcing the ARAR. The cleanup level would still be the ARAR, and more stringent cleanup measures may be required in the future.

Under the provisions for periodic review of sites where hazardous substances remain after cleanup actions, new or revised ARARs can be evaluated with respect to requiring additional site cleanup actions, possibly subject to some limitations under the settlement agreement provisions of Section 4, Subdivision (4)(c) of the MTCA.

ARARs vs. Risk-Based Standards

Health-based ARARs may result in higher cleanup levels than those resulting from application of the risk assessment methods incorporated into the proposed regulations. This could occur, for example, if new scientific information not applied in development of the ARAR became available, if a different level of protection were chosen, or if the health risk assessment methods differed. In these cases, Ecology believes that under the MTCA it has discretionary authority to choose the stricter risk-based value as a basis for establishing a cleanup level. If the ARAR-based value is lower, on the other hand, Ecology believes it is mandated by the statute to set cleanup levels at least as stringent as that ARAR value. Ecology proposes to use ARARs to establish cleanup levels except in situations where the total cancer risk associated with those cleanup levels would be greater than $1x10^{-5}$ for carcinogens or greater than a hazard index of 1.0 for noncarcinogens.

Statutory Preference for Permanent Solutions

The long-term effectiveness of site cleanup actions is a major concern. The MTCA states as a declaration of policy that "the beneficial stewardship of the land, air, and waters of the state is a solemn obligation of the present generation for the benefit of future generations." Section 3, Subdivision (1)(b) of the MTCA states further that in conducting cleanup actions "[Ecology] shall give preference to permanent solutions to the maximum extent practicable." The definitions of both "permanent" and "to the maximum extent practicable" are required for interpretation of the MTCA regulations. Moreover, the relationship between permanent solutions and the cleanup levels needs to be clarified.

Given the statutory preference for permanent remedies under MTCA, the definition of technologies that qualify as permanent is very important. The OTA (1989) discusses the application of the concept of permanent remedies under Superfund and criticizes as overly broad the extent to which EPA has defined remedies to be permanent. OTA disagrees with the use of "degrees of permanence" and separates technologies offering reductions in waste volume or hazardous substance mobility from those that destroy or detoxify hazardous substances. Only the latter category are viewed by OTA as justifiably being called permanent.

The use of permanent solutions is addressed in the proposed rule under *Selection of Cleanup Actions* (WAC 173-340-360). Ecology believes that permanent remedies are best described by the idea that their successful application would result in no further actions being required at a site or at an offsite location where hazardous substances from the site would be taken for treatment or disposal (such as a landfill). This action-oriented definition of permanence is consistent with the desire to ensure long-term effectiveness and protection. Under such a definition, recovery and reuse of hazardous materials, or processes that break hazardous substance bonds and thereby permanently destroy or detoxify hazardous substance substances, would qualify as permanent. In the proposed rule, Ecology has established a set of preferences for various cleanup technologies. The list (from most preferred to least preferred) is:

- Reuse or recycle
- Destruction or detoxification
- Separation or volume reduction
- Immobilization
- Onsite or offsite disposal, isolation, or containment
- Land-use restrictions and monitoring.

Cleanup actions at a site will generally require use of several different technologies; for example, when permanent treatment (detoxification or destruction) methods do not fully achieve the site cleanup levels and immobilization, containment, or institutional measures may also be required. Immobilization and containment options for hazardous wastes, while they may have useful applications in site cleanups, do not qualify as permanent under Ecology's proposed definition. However, at some sites, such measures may represent permanent solutions "to the maximum extent practicable." Further site actions would be required when these technologies are used at a site. At a minimum, these actions would include continued monitoring of the effectiveness of the cleanup action. Active controls of hazardous substance release or migration may also be required at some future time and, ultimately, further cleanup actions may be needed if immobilization or containment options prove not to be as effective as planned.

Ecology believes that cleanup levels should be established based on considerations of protection of human health and the environment. Once cleanup levels for a site are selected, available cleanup actions are identified and evaluated and an appropriate remedy is selected. Cleanup actions considered typically include both permanent and nonpermanent alternatives, although it is conceivable that at a given site no permanent alternatives would be identified. The availability, cost, reliability, or other characteristics of permanent vs. nonpermanent remedies are therefore issues to be considered in the selection of remedy, but not in the establishment of appropriate cleanup levels.

The statutory preference for permanent remedies is not absolute; rather, it is qualified by the phrase "to the maximum extent practicable." Therefore, it is appropriate to consider factors defining practicability that could justifiably lead to selection of a nonpermanent remedy over a permanent remedy. Treatment technologies are rapidly being developed in response to site remediation needs. Technologies for permanent treatment of hazardous substances may be innovative and relatively unproven. Even established technologies may have technical limitations for site-specific uses (OTA 1989; U.S. EPA 1990b). The effectiveness, reliability, and degree of risk involved in using a permanent remedy need to be considered when determining whether it will work at a particular site. Especially for newer technologies, only a limited capacity or number of treatment facilities may be available; therefore, availability and schedule issues should also be considered.

Probably the most discussed factor related to permanent cleanup action technologies is the costs of cleanup technologies relative to alternative measures such as containment, stabilization, or land-use restrictions. The degree to which higher costs for permanent remedies are justified, and the point at which higher costs make a remedy not practicable, is an important factor. OTA (1989) discusses this issue and notes that proper cost comparisons need to include all potential future (deferred) costs of the nonpermanent alternatives, because further actions will be required, to one degree or another, for all nonpermanent remedies.

Under the proposed rule, evaluation of factors such as those discussed above will determine whether permanent cleanup alternatives are practicable and selected at a site. When permanent solutions are either not available, are available but not selected because they are judged to be not practicable, or are available and selected but provide only a partial means of compliance with the established cleanup levels, additional controls will be needed. In these cases, continued site monitoring and site management will be required, and the site will be subject to periodic review by Ecology to assess the continued protectiveness of the total cleanup action.

New treatment technologies that meet the definition of permanent solutions are expected to become available in the future. At sites where permanent solutions are not used to achieve cleanup levels, and new permanent solutions become available, Ecology may evaluate these new remedies as part of periodic site reviews. Ecology believes that evaluation is subject to the same statutory preference for permanent solutions; that is, under periodic site reviews, a nonpermanent solution may be replaced by a permanent one, subject to considerations of practicability and possibly to constraints of covenants not to sue under settlement agreements with potentially liable persons.

Relationship between Cleanup Levels and Technical Feasibility

Technical feasibility is defined as the capability of a technology to remediate a specific hazardous waste problem, without regard to cost or other factors that may affect the practicability of applying that remedial measure at a given site. For example, destruction of many organic compounds by incineration is technically feasible, but incineration of metals is not. In a given case, incineration of organic hazardous substances may or may not be a practicable solution. It may have questionable efficiency, result in dangerous products of combustion, be unavailable for onsite use within a reasonable period of time, or cost substantially more than other treatment alternatives.

Considering the full range of cleanup alternatives available for a site, technical feasibility may set a lower limit on the concentration levels that can be achieved. If that lower limit is higher than the established cleanup levels for the site, the standards cannot currently be achieved. Examples of potential cleanup levels that are below technically feasible treatment levels include risk-based standards and background concentrations of hazardous substances such as DDT and PCBs. At a minimum, land-use restrictions would be adopted for such sites if the cleanup levels remained at levels below those technically feasible. Whether the cleanup levels should be modified upward in cases where the available alternatives cannot meet the cleanup levels is an issue to be considered.

Modifying Cleanup Levels Upward Based on Technical Feasibility

Modifying cleanup levels upward based on technical feasibility would change the level of protectiveness of the standards. Some limited flexibility to modify standards and protectiveness may result if protectiveness is defined as a range, rather than as a single value. Technical feasibility could then be used as one factor to determine where in the acceptable risk range site-specific cleanup levels would be established.

Technical feasibility is also subject to change; as technologies improve and new treatment techniques are developed, technically feasible levels may be expected to decrease. Periodic reviews of sites where cleanup levels could not be met except by the use of containment or land-use restrictions could be conducted to review the status of technical feasibility and take additional cleanup actions, if appropriate. This could result in permanent cleanup actions replacing nonpermanent alternatives, possibly subject to constraints imposed by settlement agreements.

Some cleanup measures are almost always technically feasible at a site. Often it is the less permanent alternatives that are more feasible. Land-use restrictions and containment approaches are generally feasible at sites; detoxification and destruction methods (the more permanent methods generally associated with treating wastes) may generally be less feasible or practicable.

The extent to which a determination of technical feasibility or practicability should be affected by ongoing activities at a site should be considered. Existing structures that are still in use or operations at active sites can impede the application of some cleanup methods. For example, it may not be possible to excavate soils for treatment without shutting down site activities and destroying existing structures that are still in use. Whether these conflicts result in a decision to change cleanup levels, change the selected cleanup action, or affect existing site use in order to accomplish cleanup in a timely manner are issues to be addressed on a site-specific basis.

Modifying Cleanup Levels Downward Based on Technical Feasibility

Technically feasible alternatives may, in some cases, reach hazardous substance concentrations that are well below the cleanup levels established based on health standards, ARARs, or risk assessment approaches. Another issue for consideration is whether cleanup actions should be performed to the lowest concentration technically feasible, even when such technically feasible (or technically practicable) levels are well below the concentrations considered protective of human health and the environment. The adoption of this approach would effectively incorporate a minimum degradation, maximum cleanup philosophy into the cleanup levels regulations.

The adoption of cleanup levels based on lower technically feasible (rather than higher risk-based) concentrations would change the basis on which cleanup levels are established. Ecology believes it has discretionary authority under the MTCA to adopt this approach, although the statute itself emphasizes protectiveness and does not address technical feasibility (except indirectly by requiring that permanent solutions be used to the maximum extent practicable). The major considerations are whether state regulations based on antidegradation principles require such an approach, whether it is justifiable in terms of benefits, and how the adoption of technical feasibility as the criterion for establishing cleanup levels would affect cost concerns.

The issue of using antidegradation provisions and AKART as ARARs has been discussed during development of the proposed cleanup levels. It should be noted that AKART is closer to the idea of technical practicability than technical feasibility, since it incorporates the idea of reasonable methods of treatment. Cost concerns could be taken into account in adopting a technology-based approach to establishing cleanup levels by using technical practicability rather than technical feasibility as the criterion. Lowering cleanup levels to technically practicable concentrations would result in levels of protection for some hazardous substances that are low in comparison with past cleanup decisions, and that may vary widely among sites. The major justification for this approach would be to limit degradation of the environment rather than to protect human and ecological health.

Summary - The Proposed Rule

The options for incorporating technical feasibility or practicability into the cleanup levels regulations may be summarized as follows:

- The evaluation of technical feasibility could be held separate from decisions on cleanup levels and used only in the selection of remedy (in this approach, cleanup levels would be based solely on protectiveness)
- Technical feasibility could be used as one factor in determining cleanup levels within a range constrained by acceptable risks
- Reevaluation of technical feasibility during periodic site reviews could lead to additional site cleanup actions based on lower technically feasible concentration levels.

The latter two options have been incorporated by Ecology into the proposed regulations. Technical feasibility is one of the five conditions that may be used to justify establishing a conditional cleanup level under WAC 173-340-700(5). However, technical feasibility can never be used to justify cleanup levels that exceed a risk of 1×10^{-5} for carcinogens or a hazard index of 1.0 for noncarcinogens.

Cleanup actions that would result in concentrations exceeding these risk-based levels would generally be considered interim actions. During the periodic reviews required under WAC 173-340-420, the technical feasibility of additional treatment of residual hazardous substances at such sites would be considered.

Role of Cost in Selecting Cleanup Levels and Cleanup Actions

Costs have traditionally been one of the primary concerns in achieving remediation of hazardous waste sites. Both the potentially large costs involved in site cleanups and the large variability in costs, depending on the remediation goals and cleanup approach selected, have contributed to these concerns.

Under the federal Superfund program, cleanup actions are required by statute to be cost-effective. That requirement is reflected in the National Contingency Plan (U.S. EPA 1990b). EPA has provided a lengthy discussion of the role of costs and cost-effectiveness within Superfund in the preamble to the recently revised National Contingency Plan (8 March 1990; 55 Federal Register 8666 et seq.). Among the primary points of that discussion are that costs are used only to select from cleanup action alternatives that are determined to be protective, and that cost-effectiveness is defined as effectiveness proportional to costs.

The MTCA, in contrast to the Superfund statutes, does not include any language regarding cleanup action costs or cost-effectiveness. Only in its requirement that Ecology give preference to permanent solutions "to the maximum extent practicable" does the MTCA make a statement that could be interpreted to include cost considerations.

In the opinion of the State Attorney General's Office, the reference to Section 121 of SARA in the MTCA requirement for promulgation of cleanup levels does not incorporate the cost provisions of the federal Superfund law into MTCA. Therefore, Ecology is not bound by statute to consider costs, either in setting cleanup levels or in selecting site cleanup actions. However, Ecology has discretionary authority under the MTCA to consider costs with respect to either of those actions, so long as the overriding goal of the MTCA to protect human health and the environment is met. Therefore, the potential role of costs in establishing cleanup levels or selecting site cleanup actions is an issue to be considered in development of the cleanup levels regulations.

Ecology believes that cleanup levels should ideally be based solely on levels required for protection of human health and the environment. As a general principle, costs should play no role in the selection of cleanup levels; rather, they should be one of several factors considered in the selection of appropriate cleanup actions to meet standards established for a site. The approach taken by Ecology in the proposed rules establishes initial compliance cleanup levels, but allows a limited degree of flexibility to define less strict conditional compliance levels, depending in part on technical practicability. There are two ways in which costs can affect the choice of cleanup levels within this range. First, if Ecology decides to accept conditional cleanup levels for a site based on the unavailability of technically practicable alternatives to meet compliance cleanup levels, then practicability evaluations, which include consideration of costs, will become involved in setting cleanup levels. The second is the possibility that costs required for cleanup actions at one site may impair the capability of potentially liable parties to take actions at other sites or address other environmental threats. Ecology may find it desirable to evaluate net benefits and allow adjustment of cleanup levels at a site based on costs, provided that cleanup levels are still protective and that the cost savings result in cleanup actions or other environmental benefits at other sites. In either case, cleanup levels would have to be as stringent as the minimum required under the law.

As a factor considered during the selection of a site cleanup action, costs cannot be allowed to result in the selection of a nonprotective remedy. Ecology agrees with EPA's position that costs can be used only to select from among alternatives that have been determined to be adequately protective. For cleanup alternatives that are equally ranked according to the hierarchy, and that equally satisfy the preference for permanent solutions and the requirement for being protective, the alternative with the lowest cost is preferred.

Costs could be used to justify selection of a lower-ranked alternative over a higher one (for example, a nonpermanent remedy instead of a permanent one) based on an evaluation of additional costs vs. additional effectiveness and on the degree of protection that is achieved. It is Ecology's belief, incorporated in the proposed rules, that the extra costs must be both substantial and disproportionate compared to the gains in effective and permanent cleanup before costs could justify selection of a less permanent cleanup action. The test of whether incremental costs are substantial and disproportionate is used, in part, to determine whether permanent solutions are practicable under the MTCA.

The types of costs that should be included in any evaluation of cleanup action alternatives need to be defined. Ecology proposes to define such costs broadly to include not only direct capital and operation and maintenance costs, but also indirect costs associated with the time needed to achieve compliance (for example, continuing natural resource damages or economic opportunity costs). In this way, the true cost impacts associated with extending time of compliance will be accounted for and cost comparisons among alternatives will be more meaningful and appropriate for use in selection of a site remedy. Other issues, such as the protectiveness, effectiveness, and risk associated with alternatives with longer compliance schedules will also be assessed.

The options for evaluating costs may be summarized as follows:

- Costs may be ignored, both in setting cleanup levels and in selecting cleanup actions, consistent with the lack of a statutory mandate to consider costs
- Costs may be considered in setting an appropriate level of protection within a limited range
- Costs may be used for selection of remedy, after evaluation of additional costs vs. additional effectiveness and degree of permanence among the various alternatives
- Costs may be used as a criterion to define the practicability of permanent solutions.

As noted above, Ecology has proposed implementation of the final three options.

Points of Compliance and Restoration Time Frames

Demonstrating compliance with established cleanup levels at a site is an important component of cleanup actions. Compliance monitoring and demonstration of compliance are covered under the procedural regulations of the MTCA (see WAC 173-340-410). The definition of compliance with cleanup levels requires establishing both the points of compliance and the schedule for compliance. These factors may be considered in determining the scope of required compliance monitoring.

Ecology views the issues of points of compliance and time for compliance as part of the selection and implementation of cleanup actions, not as part of the establishment of appropriate cleanup levels. Cleanup levels are not adjusted based on chosen points or times of compliance; they are established at levels considered necessary for protection of human health and the environment. As a general principle, those protective levels should be achieved everywhere and at the earliest possible time. Under certain circumstances, however, it may be appropriate or necessary to allow limited areas of noncompliance with the cleanup levels, or to allow a period of time for achieving compliance. These exceptions will be allowed only when all practicable methods of treatment have been used.

Cleanup levels may be based on ARARs that incorporate allowable areas of noncompliance, such as dilution or mixing zones or setback requirements. Whenever ARARs include provisions defining points of compliance, they will be considered during selection of a cleanup action. Statements in potential ARARs that require compliance "as close to the source as possible" or that restrict areas of noncompliance to extend "no further than the site boundary" have also been incorporated into the draft MTCA cleanup levels [see WAC 173-340-720(6)].

Technical factors may also affect the selection of appropriate points and time of compliance. Both theoretical considerations and practical experience have shown that remediation of contaminated ground water by pump-and-treat methods is difficult, may be limited in effectiveness, and requires long periods of time to achieve cleanup (Mackay and Cherry 1989; OTA 1989). Allowing a period of time for initial operation of such a pump-and-treat system in order to collect information for optimizing system performance has been strongly recommended. Time of compliance for ground water cleanup using pump-and-treat methods is difficult to predict accurately. In most cases, it is based on modeling of the contamination problem and pumping system performance, so uncertainties in modeling directly affect the predicted time of compliance. The potentially limited effectiveness of pump-and-treat methods has led some authors to characterize them more as tools for managing hazardous substance migration than as tools for active cleanup of ground water (Mackay and Cherry 1989). Boundaries of compliance for ground water cleanup may depend on the ultimate limitations in treatment effectiveness.

Landfills are a special class of hazardous waste site with respect to points of compliance. For many older and inactive landfills, the volume of waste materials present makes removal of wastes or control of leachate generation impractical. Therefore, compliance with ground water cleanup levels beneath the landfill units themselves is often impossible. Boundaries of compliance for landfills, and perhaps for a few other sites with similar limitations for remediation, are intended to be set as close as possible to the waste boundaries. Recognition of potential problems near landfills has already resulted in state regulations restricting the installation of new ground water wells close to operating landfills.

Areas of compliance extend vertically as well as horizontally. A ground water well can withdraw water from any portion of an aquifer. Therefore, it is appropriate for ground water areas of compliance to extend vertically throughout the aquifer. Soil areas of compliance should extend vertically to the extent necessary to be protective against surface contact exposures or significant contamination of ground water.

It is Ecology's goal that areas and periods of noncompliance with cleanup levels be temporary whenever possible. As indicated above, one purpose for allowing a period of noncompliance is to allow for testing and optimization of a remedial technology. Use of new treatment technologies may also be justification for setting a limited schedule for compliance; if the new technology proves ineffective, alternative approaches to cleanup may be required in a timely manner to meet a definite cleanup schedule.

Additional measures such as land-use restrictions will be required until cleanup levels are achieved. Land-use restrictions rank low on the hierarchy of methods for addressing site contamination problems; they will be considered for a long-term approach only when all higher ranking options are found to be inapplicable at a given site. Otherwise, the imposition of land-use restrictions will be temporary, and will only be used until cleanup levels are met.

The OTA, in its recent review of the federal Superfund program (OTA 1989), proposed that a distinction be drawn between sites that pose current threats and those that pose only hypothetical future threats. That distinction would, under OTA's recommendations, require the earliest possible time of compliance for sites with current threats but would allow a more flexible compliance schedule for sites posing only future threats. This approach would set site priorities and establish times of compliance based on the timing of potential human exposures (for example, whether existing ground water wells were threatened or whether cleanup levels were based on hypothetical future ground water use) or environmental risks. In this respect, this approach is similar to site ranking systems, such as EPA's Hazard Ranking System or the Washington Ranking Method, that score sites based on existing populations but not on potential future populations near the site.

Ecology has proposed that points of compliance will generally be defined as throughout the site (no allowable areas of noncompliance). Under certain circumstances, conditional points of compliance may be approved at waste boundaries or at site or property boundaries. For example, a point of compliance could be chosen to be "as close as possible to the waste boundary but in no case further than the property boundary." In some cases, purchase of property to extend the site boundary may be required in order to exercise appropriate (and temporary) land-use restrictions, but it will not be allowed simply to extend the area of noncompliance with cleanup levels.

Compliance schedules that allow for a period of noncompliance will generally be based on technical evaluations of the expected performance of proposed cleanup actions. The factors that Ecology proposes to consider when establishing compliance time frames are listed in WAC 173-340-360. Compliance schedules may incorporate the idea of choosing alternate cleanup actions if the initially proposed action does not achieve timely compliance with established cleanup schedules. The degree of flexibility in setting compliance schedules and the factors to be considered in choosing an appropriate time frame for site restoration are options within the cleanup levels regulations.

Sites at which hazardous wastes remain after cleanup are subject to periodic review under the MTCA; available remediation measures and the extension of compliance schedules will be reevaluated as part of periodic reviews required under WAC 173-340-420.

SEPA Review of Site-Specific Cleanup Decisions

The MTCA does not explicitly exempt site cleanup decisions and actions from complying with permit or regulatory review requirements, including requiring an EIS under SEPA. Therefore, most proposed cleanup actions at state hazardous waste sites and the cleanup levels established for sites will be subject to SEPA review and the preparation of an EIS. At routine sites, a determination of nonsignificance may be made after preparation of an environmental checklist. The level of detail in a site-specific EIS is expected to be greater than in this programmatic EIS, allowing full examination of potential human health or environmental threats from site contamination and documentation of the protectiveness of proposed site-specific cleanup levels.

For routine sites, where potential threats are limited and effective cleanup actions are readily identifiable, the preparation of a site-specific EIS is not expected to be required. An example routine site would be a site where a relatively small release from an underground storage tank has occurred. Cleanup levels for routine sites, and possibly for some other sites, will typically be based on existing ARARs or numerical cleanup levels provided in the proposed rule (Method A Compliance Cleanup Levels). When that is the case, Ecology believes that the cleanup levels will be well-defined and protective and therefore SEPA review of the standards will not be necessary [see WAC 173-340-130(7)].

Cleanup levels for many other sites with more complex or extensive contamination problems, or more sensitive human or ecological communities, are expected to require a site-specific EIS. That EIS will need to address possible pathways of exposure, receptors, or ecological effects that are not specifically included in the proposed rule as a basis for establishing site cleanup levels. For example, food chain exposures are not included in the proposed rule for calculation of cleanup levels. At a specific site, food chain pathways for exposure (for example, use of contaminated ground water for irrigation or consumption of local crops grown in contaminated soils) could be important to consider in establishing cleanup levels. Environmental and ecological impacts from site contamination should also be considered in the site-specific EIS.

One important goal of the MTCA is to ensure that cleanup levels at individual sites are protective of human health and the environment. Site-specific factors beyond those specifically assumed for establishing cleanup levels under the proposed regulations will, for certain sites, affect the determination of protective cleanup levels. Consideration of any and all such factors is not foreclosed under the proposed rule; the site-specific EIS will provide a means of evaluation and documentation of those factors.

Relationship Between the Federal Superfund Program and the Model Toxics Control Act

The federal Superfund program and the MTCA have very similar goals for hazardous waste site cleanup. A given hazardous waste site in Washington may be subject to cleanup under either or both of these programs. The relationship between Superfund and MTCA, particularly with respect to consistency of cleanup levels, should be considered in structuring the cleanup levels regulation.

There are two factors that create direct relationships between Superfund and MTCA cleanup levels. Under the National Contingency Plan for cleaning up Superfund sites (U.S. EPA 1990b), state environmental laws and regulations are considered ARARs for defining site cleanup levels. Once MTCA cleanup level regulations are promulgated and consistently applied by Ecology, they will become ARARs for all federal Superfund sites in the state. In theory, it is possible that one of the waiver provisions of Section 121 of SARA could be used to allow noncompliance with the state standards at a federal Superfund site. Under the National Contingency Plan (40 CFR 300.430), the state would have the right to comment on and discuss with EPA any such proposed waiver. Ultimately, Ecology would have legal authority to take independent action at the site and impose the MTCA cleanup levels.

The second relationship is contained in the MTCA, which requires that cleanup levels adopted under the MTCA be at least as stringent as standards in Section 121 of SARA under the federal Superfund program. This requirement does not preclude the adoption of state standards that are stricter than federal standards.

Sites are nominated to the federal Superfund list based on their Hazard Ranking System score. Either Ecology or EPA can take the lead role at Superfund sites.

Sites subject to cleanup under the MTCA range from relatively minor or routine sites up to Superfund sites. Only a small portion of the total number of state sites is ever expected to be put on the Superfund list. The methods for deriving cleanup levels under the MTCA, however, are based on and generally consistent with the risk assessment guidance developed by EPA for Superfund sites. Therefore, there will be a general consistency in approach across all of the regulated sites. Two aspects of the MTCA regulations as currently proposed are worth noting with respect to sites subject only to state regulation. First, the proposed MTCA rules are designed to be more uniform than Superfund rules, with less flexibility available in determining site-specific cleanup levels. Second, the MTCA rules recognize that the site-specific studies used to determine cleanup levels under Superfund may be inappropriate for smaller and more routine sites. By incorporating specific numerical standards as a starting point for cleanup levels, the MTCA rules provide a well-defined, predictable, and immediately available set of standards for routine sites, avoiding the need for costly and time-consuming site studies.

Procedures for Updating and Revising Cleanup Levels

Section 3, Subsection (2) of the MTCA requires that the cleanup levels be adopted as regulations under the state Administrative Procedures Act (Chapter 34.04 RCW). Section 3, Subsection (2)(d) of the MTCA specifies that the adopted rules are to be periodically updated, but does not define a specific schedule for these updates.

The proposed cleanup levels include a set of hazardous substances chosen because of their frequent occurrence at hazardous waste sites. One reason for revising the rule would be to add cleanup levels for additional hazardous substances to the numerical cleanup levels.

Experience in applying the cleanup levels at hazardous waste sites will provide feedback on the effectiveness and appropriateness of the regulations and will be used to define helpful revisions of the rule. Site experience will also identify hazardous substances that should be considered for addition to the list of hazardous substances having numerical standards in the regulations.

Improvements in risk assessment methodology and new scientific information may also lead to revisions in the regulations, ranging from minor adjustments in parameter values to the adoption of entirely new methods for deriving cleanup levels. Technical changes in sources of information cited in the proposed rule [for example, changes to toxicity parameters in EPA's Integrated Risk Information System (IRIS) (U.S. EPA 1990a)] will automatically be incorporated into the cleanup levels regulations. The reference sources are cited in the regulations "as amended or revised." The numerical standards in the regulations will be required to stay current with changes in IRIS toxicity factors, or other similar changes.

During the next 2 years, Ecology intends to prepare amendments to the regulations to address sediment cleanup actions and appropriate methods of ecological risk assessment. For sediment cleanup actions, Ecology intends to integrate into the regulations the sediment cleanup requirements being developed by Ecology's Sediment Management Unit.

The issue of regulations becoming progressively more outdated and inappropriate by not keeping up with the latest scientific information was discussed by the National Academy of Sciences in its review of federal agency risk assessment practices (NAS 1983). This issue was also raised repeatedly during the development of the proposed cleanup levels. It is Ecology's current intention to formally revise and update the regulations every 5 years, or more frequently if needed. During the period before formal revisions, Ecology intends to use the best scientific information available while maintaining a consistent approach to establishing cleanup levels for hazardous waste sites. The MTCA requires that the cleanup levels be issued as formally adopted regulations; therefore, the option of issuing them in the form of nonregulatory guidelines, which could be more easily updated and revised, is not allowed by the statute.

Chapter 4
Description of the Alternatives

The following sections describe the alternatives to be evaluated for setting cleanup levels for ground water, surface water, marine water, soil, and air at hazardous waste sites in Washington state. First, the development of the alternatives is described. Each alternative is defined, and issues relating specifically to the alternatives are discussed. The method of setting standards that would be used under each of the alternatives is presented, and a discussion is included of how the alternative would be implemented for each medium.

Development of the Alternatives for Setting Hazardous Waste Site Cleanup Levels

The alternative approaches to setting cleanup levels evaluated in this EIS were developed after consideration of a number of factors. First, the basic approaches to setting cleanup levels used in other federal and state programs discussed in Chapter 2 were reviewed. Second, the language of the MTCA was considered. The MTCA did not mandate the use of a specific approach, but certain requirements were identified, such as protection of human health and the environment, and compliance with ARARs. This language suggests that the risk-based and ARAR alternatives would be important to consider. However, other approaches could be used if they met the goals of the MTCA. Third, Ecology's existing *How Clean Is Clean* policy (Ecology 1984) was reviewed.

In addition to the four basic alternatives initially identified, a fifth alternative was considered. This alternative was suggested by MTCA language that required *both* compliance with ARARs *and* protection of human health and the environment. Because risk assessments and ARARs do not always result in the same value for a given hazardous substance, the lower of the values could be used to comply with the language of the MTCA. For different hazardous substances, different alternatives would be lowest. For example, the water quality criterion for the protection of aquatic life results in the lowest value for copper, while the human health-based risk assessment results in the lowest value for benzene. Because of these differences, a fifth alternative was developed that combined elements of more than one basic alternative.

The exact form that this alternative would take was determined in part by the strengths, weaknesses, and impacts of the four basic alternatives, evaluated in this EIS. The combination alternative draws on the strengths of three of these four alternatives (all except the technology-based alternative). The combination alternative is evaluated along with the four basic alternatives and the no-action alternative in the following chapters.

The six alternatives for setting cleanup levels evaluated in this document are:

- **Background Alternative**—Cleanup levels would be set using the background concentration or practical quantitation limit of each hazardous substance in each medium. Background would be defined as the concentration or level of a hazardous substance in the environment at or near the facility that cannot be attributed to any release from the site or other human activities in the local area.

- **Risk-based Alternative**— Cleanup levels would be set through an assessment of risk to human health and the environment for each hazardous substance in each medium. Standards for individual hazardous substances would then be modified to take into account the total risks from hazardous substances when combined.

- **Applicable State and Federal Laws Alternative**—Cleanup levels would be designed to meet or exceed standards established under applicable state and federal laws, including Section 121 of CERCLA/SARA. Section 121 requires the use of all legally applicable or relevant and appropriate requirements (ARARs) for each hazardous substance in each medium. The ARAR with the lowest concentration would be chosen as the standard in each case.

- **Technology-based Alternative**—Cleanup levels would reflect the lowest concentration level that can be achieved by the best available cleanup technology.

- **Combination Alternative**—Cleanup levels would be chosen (using a decision-making flow chart) for each hazardous substance in each medium on a substance-by-substance basis. Standards for individual hazardous substances would then be modified to take into account total risks, where known, of substances when combined.

- **No-action Alternative**—No new standards would be set for cleanup of hazardous waste sites. Because Ecology is currently required by law to promulgate cleanup levels, this alternative is not a legal option. However, even if Ecology declined to adopt new cleanup levels, the use of the strictest ARARs would still be required by the MTCA. Therefore, for the purposes of this EIS, the no-action alternative is equivalent to the ARAR alternative and will not be evaluated separately.

Three types of standards for concentrations are commonly used. These are narrative, process-based, and numerical standards. **Narrative** standards are descriptive and do not include numbers or processes for arriving at numbers. An example of a narrative standard is:

> *"The standard for arsenic shall be set at a level that is protective of human health and the environment."*

Process-based standards describe the methods to be used to arrive at site-specific or hazardous substance-specific concentrations. The process-based standard may describe specific methodologies and assumptions to be used, or it may allow some variation within a range of methodologies or assumptions. An example of a process-based standard is:

> *"The standard for arsenic shall be set for each site at the level that is protective of human health at that site, using the equations and assumptions set forth in Appendix F of this document."*

Numerical standards are specific numbers that are applied at all sites. An example of a numerical standard is:

> *"The standard for arsenic in soil shall be 50 mg/kg."*

The alternatives evaluated in this EIS are combinations of the numerical and process-based approaches to setting standards. In this way, a number may be set as a standard, but these numbers can be modified according to site-specific criteria. A detailed discussion of the standard-setting process for each alternative can be found in the section describing that alternative. As an illustration, example concentrations for each alternative are derived for four hazardous substances: cadmium, benzene, PCBs, and PAHs. These sections are meant to show how standards would be derived under each alternative. Many of the alternatives include processes for modifying general standards based on site-specific considerations. Concentrations generated in this EIS are intended to serve as examples of the range of concentrations that would be applied at various sites. These numbers should not be considered final standards for these hazardous substances.

The Background Alternative

Using the background alternative, cleanup actions would achieve background concentrations of hazardous substances in all affected media. Although simple in concept, implementation of this alternative is complicated by the fact that there are several possible definitions of background. Natural background concentrations are those that existed prior to any human activity, while prerelease background concentrations are those that take preexisting contamination from other releases or human activities into account.

Several states have used background concentrations to define cleanup requirements. Oregon has published rules that require cleanup to natural background concentrations where feasible. In Massachusetts, the statutory cleanup goal is to attain prerelease background concentrations. Site closure requirements for hazardous waste management facilities under Washington's dangerous waste regulations are also defined in terms of prerelease background conditions.

For purposes of defining this alternative, *background concentration* is defined as the concentration of a hazardous substance in the environment at or near the facility that is not attributable to any release at the site or localized human activites. This is similar to the definition of natural background concentrations in the proposed regulations (WAC 173-340-200).

Issues Associated with the Background Alternative

Several issues associated with the background alternative are described below.

The Adoption of Statewide vs. Site-Specific Standards

Many hazardous substances have background concentrations that vary widely from site to site. An important issue associated with the background alternative is whether standards should be set on a statewide or site-specific basis. Statewide standards for individual hazardous substances could be based on a variety of measurements:

- The median or mean of the range of concentrations measured in Washington
- An upper percentile of the range (for example the 90th, 95th, or 99th percentile) below which the remainder of the sites in Washington would be expected to fall
- A multiple of the median or mean, below which most of the sites would be expected to fall.

Because of the wide variation in background concentrations in the state, none of these statewide approaches is entirely satisfactory. The first option would be overly stringent at half the sites in the state, while the other two options would not be stringent enough at most sites.

A site-specific approach to determining background concentrations provides the best solution to this problem. Such an approach would require site operators to prepare individual sampling plans to establish local background levels. Historical records would also be reviewed to determine appropriate prerelease concentrations at each site. This approach would allow for selection of a standard that is neither overprotective nor underprotective, increasing the efficiency and appropriateness of cleanup actions. This approach is incorporated into WAC 173-340-705(11) of the proposed amendments. Further discussion of this issue is provided in Chapter 3, under *Uniform Statewide vs. Site-Specific Standards*.

Appropriate Measure of Background at a Site

Various measures of background have been proposed for use at individual sites. These methods of measurement range from simple averages or ranges to complex statistical representations including calculation of medians or means, percentiles, and standard deviations or confidence intervals around the mean. As discussed above, use of a simple average or 95th percentile concentration may result in a cleanup level that is ambiguous, overprotective or underprotective, and difficult to comply with. For instance, if an average background concentration is used as a standard, each sample at the site would have to be at or below the standard, resulting in an average concentration after cleanup that would actually be below the average natural background concentration at the site.

An alternative is to statistically characterize the natural background at the site, determining its mean and standard deviation. A larger number of samples is typically required to provide a high level of confidence in the results. Compliance with such a standard could have several requirements. For instance, the mean after cleanup should be at or below the background mean, 95 percent of the sample concentrations after cleanup should fall within two standard deviations of the background mean, and the highest measured concentration after cleanup should be within four standard deviations of the mean, or a multiple of the mean. Ecology believes that a statistical measure of background and compliance with background is a more accurate and scientifically defensible approach [see proposed WAC 173-340-700(11)].

Use of Natural vs. Prerelease Background Concentrations

A site-specific background approach can be based on the natural background concentration that was present before any contamination from human activities. It can also be based on the background concentration that was present before hazardous substances were released from the particular site being cleaned up.

In many cases, the true natural background concentration of a hazardous substance in an area is difficult to measure. Widespread, low-level contamination may have been present for decades and no nearby pristine areas may be available for comparison. Efforts to clean up hazardous substances below the level of preexisting background concentrations will not be effective if the other sources of contamination in an area are not addressed. On the other hand, preexisting high levels of background contamination over a large area should not be a justification for continued contamination of that area.

The definition used in this EIS to evaluate the background alternative is a combination of these two possible definitions of background. This definition of background protects against risk from hazardous waste sites by allowing no risk to human health or the environment beyond what was present before contamination of the site. However, setting standards at the prerelease background concentration of a hazardous substance does not necessarily eliminate risk from that hazardous substance. In some cases, the natural background concentration of a hazardous substance (for example, arsenic in Pacific Northwest soils, or radon in granite) or the existence of widespread regional contamination (for example, lead from automobile emissions) may present threats to human health.

Use of Detection Limits or Practical Quantitation Limits as Standards

Standards based on any of the alternative approaches for certain hazardous substances may fall below the lowest achievable detection limit in some media. For these hazardous substances, specific standards cannot be easily set. Most of the hazardous substances that are not detectable (for example, synthetic organic compounds) do not occur naturally and would not ordinarily be found in an uncontaminated environment. Therefore, this issue is particularly relevant to the background approach.

Where background concentrations fall below the lowest achievable detection limit, an appropriate option for setting standards under the background alternative is to set them at or near the limit of detection. Setting standards below detection limits may not be appropriate, because compliance would be difficult to verify using routine analytical techniques. Standards could be defined as specific numerical detection limits based on available analytical techniques. Alternatively, standards could simply be defined in words as the lowest detection limits achievable by technology at the time. This latter option allows for improvement in analytical techniques over time.

Another option is to set standards at practical quantitation limits (PQLs) (for example, 5-10 times the detection limit). In this way, the random error, which is ordinarily high in measurements close to detection limits, can be reduced. Additionally, in instances where no statewide background studies have been performed for certain hazardous substances, it may be appropriate to set standards at the PQL. For the most part, these hazardous substances are synthetic organic compounds, with background concentrations well below the PQL. Nonetheless, site-specific sampling should be performed at cleanup sites to determine whether the actual background ranges for these hazardous substances fall below PQLs. In this situation, the standard would still be the background concentration. However, the PQL would represent the practical limit for enforcement purposes.

Derivation of Cleanup Levels Under the Background Alternative

Standards under the background alternative would be derived using prerelease background concentrations. If the background concentration is less than the PQL, the PQL would be used to determine compliance with the standard. Determination of the prerelease background could be made in one of two ways. For routine sites, a regional background documented in the literature or a background determined for another site in the same general area could be used (assuming data are of a known and acceptable quality). Table 2 lists selected studies that could be used to determine a regional

TABLE 2. SOURCES OF DATA USED TO DETERMINE BACKGROUND CONCENTRATIONS

Medium	Source
Ground water	U.S. Geological Survey (USGS) studies of five regional ground water aquifers in Washington state (USGS 1984, 1985, 1986a,b,d)
	Completed Ground Water Management Area Studies performed by Ecology
	Washington Department of Social and Health Services data on drinking water (DSHS 1985)
	Spokane County data on the Spokane aquifer, a sole-source aquifer under the Clean Water Act (County of Spokane 1988)
	EPA data on pesticide contamination of ground water in western Washington (Williams et al. 1988)
Surface water	USGS National Stream Quality Network (NASQAN) database (Wagner 1989)
	Two studies by Ecology from the Yakima River (Johnson et al. 1986), and Lake Roosevelt (Johnson et al. 1988a)
	Municipality of Metropolitan Seattle (Metro) study of Lake Union (Tomlinson et al. 1977)
	Masters thesis from University of Washington Department of Civil Engineering on Findley Lake, Chester Morse Reservoir, Lake Sammamish, and Lake Washington (Barnes 1976)
Marine water	National Oceanic and Atmospheric Administration study on metals in Puget Sound (Paulson et al. 1988a)
	Metro study on priority pollutants in Puget Sound (Galvin et al. 1984)
Soil	U.S. Department of Agriculture study of pesticide residues and trace metals in soils (Holmgren et al. 1988)
	Ecology study at a site contaminated by pesticides (Norton 1988)
	Two USGS studies (Shacklette and Boerngen 1984; Ebens and Shacklette 1982) that provide information on background concentrations of metals nationwide
	Study on PAH contaminants in soils of various types (Kaiser 1989)
Air	Three Puget Sound Air Pollution Control Agency (PSAPCA) studies on arsenic and lead concentrations in metropolitan areas (PSAPCA 1986, 1987, 1988)
	EPA study on volatile organic compounds in Vancouver, BC air (U.S. EPA 1988g)
	University of Washington Department of Civil Engineering study of PAH compounds and metals in north Seattle (Larson et al. 1988)
	Nationwide study on volatile organic carbons in indoor and outdoor air (Shah and Singh 1988)

background. The following sections discuss these studies in more detail (PTI 1989a). For larger, more complex sites, site-specific background studies and review of historical data might be required. PQLs used to determine compliance with the standard would be no higher than the EPA Contract Laboratory Program quantitation limits. EPA defines the practical quantitation limit as the "concentration at which the hazardous substance can be measured by good laboratories under normal operating conditions, within specified limits of precision and accuracy" (U.S. EPA 1989d).

The following sections discuss selected studies for various media. The example derivations are based on these studies; however, these studies are not meant to provide a complete compilation of available data on background concentrations in the Pacific Northwest. The studies are provided as preliminary sources of data and for illustration of how standards would be derived under the background alternative. It is probable that many sources of regional background data exist that were unavailable for the EIS; Ecology encourages interested persons to provide additional background data to the department for use in finalizing the draft regulations and cleanup levels.

Ground Water

Studies on the concentrations of hazardous substances in ground water are available, covering a variety of regions of the state. Several ongoing U.S. Geological Survey (USGS) and Ecology studies on the remaining regions of the state will be completed within the next few years. These will provide a large, representative database for ground water.

Because metals in soils leach into ground water, the wide range of background concentrations of metals in soils causes a wide range of background concentrations in ground water. Existing studies indicate that metal concentrations in ground water vary from below the hazardous substance's detection limit to 3 orders of magnitude above the detection limit used in the study. Data for copper and zinc are the most variable, varying by 3 orders of magnitude; arsenic varies by 2 orders of magnitude; and lead, chromium, and cadmium vary by 1-1.5 orders of magnitude. In the studies reviewed, organic compounds were not detected in ground water in uncontaminated areas. Therefore, in the absence of a measurable background, standards for organic compounds in ground water would generally be derived from PQLs.

Surface Water

Studies reviewed for surface water are not as extensive as the studies available for ground water. However, a variety of data sets are available, including a national stream quality database (Wagner 1989) and studies on both urban lakes (Tomlinson et al. 1977) and pristine lakes (Johnson et al. 1988a; Barnes 1976).

Metals data exhibit the most variation in surface fresh waters. Background concentrations range from undetected at the detection limit to 2-3 orders of magnitude above the respective detection limits for individual metals. None of the organic hazardous substances has been detected in uncontaminated areas. Therefore, PQLs would be used to determine compliance with standards for organic hazardous substances.

Marine Water

Data from Puget Sound, the only body of marine water for which relevant studies are presently available, may be used to develop cleanup levels for hazardous substances in marine water. Because of existing regionwide contamination in Puget Sound, background concentrations of some hazardous substances in the Pacific Ocean may be lower than these values. Therefore, background standards for cleanup actions in coastal areas of the state may need to be determined on a site-specific basis.

A National Oceanic and Atmospheric Administration (NOAA) study (Paulson et al. 1988b) was conducted in order to determine sources and fates of various metals in Puget Sound. Seven samples were analyzed for lead, copper, and zinc in Puget Sound waters. All of these metals were detected in each of the seven samples, with concentrations varying by 1 order of magnitude or less.

Galvin et al. (1984) provide data for many hazardous substances of concern in Puget Sound. This study could be used to set regional standards for hazardous substances. PQLs would be used as cleanup levels for organic hazardous substances for which no data are available.

Soil

Very few data are readily available on background concentrations of hazardous substances in soil. Therefore, the available data may not be wholly representative of background concentrations in Washington state. Site-specific characterizations of local background concentrations will be important in determining an appropriate background standard. If data are not available, PQLs may be used as standards.

Air

Studies reviewing background concentrations in air include three Puget Sound Air Pollution Control Agency (PSAPCA) studies (PSAPCA 1986, 1987, 1988) and a study from the Department of Civil Engineering at the University of Washington (Larson et al. 1988). Although no data are available for volatile organic compounds in air in Washington state, U.S. EPA (1988g) provides summary information from Vancouver, British Columbia, for trichloroethene, tetrachloroethene, and benzene. Nationwide data on volatile organic compounds are provided by Shah and Singh (1988).

Studies by PSAPCA (1986, 1987, 1988) provide data for ambient levels of arsenic and lead in metropolitan areas. Arsenic concentrations range over 3 orders of magnitude, while lead concentrations range over approximately 4 orders of magnitude. Because arsenic concentrations in the Puget Sound area have historically been higher than those in other areas of the state (U.S. EPA 1989a), the background concentration for arsenic may need to be handled on a site-specific basis.

U.S. EPA (1988g) provides data only on number of samples, frequency of detection, maximum concentrations, and mean concentrations of trichloroethene, tetrachloroethene, and benzene. Therefore, no assessment can be made of the variation in concentration of these volatile organic compounds. Shah and Singh (1988) provide data for trichloroethene, tetrachloroethene, trichloroethane, dichloromethane, benzene, and vinyl chloride. The data for these hazardous substances vary by less than 1 order of magnitude.

Larson et al. (1988) measured the concentration of individual PAH compounds in urban air samples, which exhibit variations of approximately 1-1.5 orders of magnitude. Urban air samples also may contain higher concentrations of PAH compounds than rural areas due to the concentrated use of wood stoves.

Example Derivations

The following example derivations illustrate the method that would be used to develop a cleanup level under the background alternative. Four hazardous substances are used as examples: cadmium, benzene, PCBs, and PAHs. A summary of example standards under the background alternative is provided in Table 3.

Because the studies used were limited, and because background concentrations and PQLs vary among sites, example background concentrations used in this EIS should not be assumed representative

TABLE 3. EXAMPLE STANDARDS FOR THE BACKGROUND ALTERNATIVE

	Ground Water (µg/L)	Surface Water (µg/L)	Marine Water (µg/L)	Soil (mg/kg)	Air (ng/m^3)
Cadmium	5[a]	5[a]	5[a]	0.18	--
Benzene	5[a]	5[a]	5[a]	0.005[a]	9,500
PCBs	1[a]	1[a]	1[a]	0.16[a]	--
PAH compounds	10[a]	10[a]	10[a]	1.5	40

[a] Based on the PQL for this contaminant. Background concentrations are generally below this value.

of actual background concentrations at any particular site. Site-specific studies may be required to determine appropriate background concentrations and PQLs at an individual site.

Cadmium

Cadmium is a naturally occurring metal. Therefore, standards under the background alternative would be primarily based on measured background concentrations. Because of the variation of naturally occurring metals in soils (and therefore ground water), the background concentration of cadmium would fall within a regional range. For the purposes of this illustration, example background concentrations are taken from medians or means reported in the literature described above, depending on the form of the available data.

The median cadmium concentration (1 μg/L) in ground water of Washington state is reported in the USGS studies listed in Table 2. In surface water, the cadmium concentration is below the PQL. In marine water, the mean cadmium concentration in Puget Sound might be used (0.09 μg/L) (Paulson et al. 1988a). Because all three of these concentrations fall into a range below the PQL (5 μg/L), the PQL would likely be used to determine compliance with the standard for cadmium in water media (U.S. EPA 1988d). USGS studies listed in Table 2 also provide background data for cadmium in soils. The median concentration of cadmium reported (0.18 mg/kg) could be used as a regional standard for cadmium at routine sites. There are presently no data on cadmium concentrations in air, and standard PQLs have not been set for analytical methods measuring metals in air. Therefore, no statewide standard for cadmium would be set under the background alternative. Sites at which cadmium is a problem in soils might be required to sample background air to determine what the cleanup level should be.

Benzene

Benzene is a volatile organic compound that is not present in significant quantities in nature. Because in most cases, its prerelease background in water or soil would not be measurable, PQLs would be used to determine compliance with the standard under the background alternative. The PQL for benzene is 5 μg/L in water. In soil, the PQL is 0.005 mg/kg (U.S. EPA 1988e). Many volatile hazardous substances such as benzene are ubiquitous in urban air, and most hazardous waste sites are located in urban areas. Under the prerelease definition of background, the ambient concentration in air would be the cleanup level. U.S. EPA (1988g) reports a mean benzene concentration in Vancouver, British Columbia of 9,500 ng/m^3. This concentration may be representative of urban concentrations in the Pacific Northwest.

PCB Mixtures

Natural background concentrations of PCB mixtures are not quantifiable, although they are now ubiquitous in human populations at low levels. Therefore, PQLs would likely be used under the background alternative for PCB mixtures in water and soil. The PQLs for individual PCBs in water range between 0.5 and 1.0 μg/L. The PQLs for PCBs in soils range between 0.08 and 0.16 mg/kg (U.S. EPA 1988e). No data or PQLs for PCBs in air are available; therefore, standards would be set on a site-specific basis if a PCB problem were suspected.

PAH Compounds

Although PAH compounds are present in nature, and are often present in ambient air due to emissions from vehicles and wood stoves, PAH concentrations in water are usually below the PQL (10 μg/L). The low concentrations of PAH compounds in water may reflect the high affinity of these compounds for particles, which are present in low concentrations in uncontaminated water. Background concentrations could be used to set a standard for PAH compounds in soil and air. PAH concentrations in soil vary widely depending on whether they are measured in urban, agricultural, or rural areas. An average value (Kaiser 1989), measured away from roadways and other urban sources, is approximately 1.5 mg/kg. Average individual PAH concentrations in air measured in Seattle and surrounding areas (most hazardous waste sites in Washington state are located in similar areas) add up to approximately 40 ng/m^3 (Larson et al. 1988).

Risk-Based Alternative

Using the risk-based alternative, cleanup levels would be established at levels that are protective of both human health and the environment. This is done through assessments of risk to human health and the environment, using procedures that relate acceptable levels of hazardous substance exposure to allowable concentrations of hazardous substances in the environment. The standards for residual levels of contamination derived in this way should not exceed the maximum acceptable risk level.

Risk assessment is an established method to estimate the probability of adverse health effects that may result from exposure to a toxic agent. Assessing risks from exposure to toxic hazardous substances consists of the following steps:

- **Hazard identification**—Qualitative evaluation of the potential for a substance to cause adverse health effects (for example, birth defects or cancer) in animals or in humans
- **Dose-response assessment**—Quantitative estimate of the relationship between the dose of a substance and the probability and magnitude of an adverse health effect
- **Exposure assessment**—Characterization of the populations exposed to the toxic hazardous substances of concern; the environmental transport and fate pathways; exposure pathways; and the magnitude, frequency, and duration of exposure
- **Risk characterization**—Estimation of risk for the health effect of concern based on information from the first three steps.

An indication of toxicity is derived from the dose-response relationship measured for the hazardous substance of concern. The form of the dose-response relationship for carcinogens is assumed to be fundamentally different from that for noncarcinogens (U.S. OSTP 1985). The lack of a demonstrated threshold in dose-response relationships for carcinogens (U.S. EPA 1980, 1986b; U.S. OSTP 1985) implies some risk of cancer even at very low doses of the carcinogen. For noncarcinogens, there is usually a dose below which no adverse biological effects are observed. This dose is called a *threshold dose.*

The toxicity of a carcinogen is represented by a *carcinogenic potency factor* (CPF), a measure of the cancer-causing potential of a substance (typically estimated as the upper 95 percent confidence limit of the slope of a straight line calculated by the linearized multistage procedure or another appropriate model). The CPF is calculated from human epidemiology studies or animal bioassays. Correction factors are applied to convert values derived from animal studies to values appropriate for humans.

A noncarcinogen is characterized by a *reference dose* (RfD), an estimate of the daily intake that is unlikely to produce an appreciable risk of adverse health effects during a lifetime, even in sensitive individuals. The reference dose is calculated from the no observed adverse effect level (or the lowest observed adverse effect level, if the former is unknown) in humans or animals by dividing this level by a safety factor of 10-1,000. This safety factor takes into account differences within and between species and differences in the duration of the studies.

CPFs and RfDs are derived separately for oral and inhalation exposure routes when the organs affected by the two routes are different.

Risk in the context of cleanup levels is the chance (probability) that exposure to toxic hazardous substances associated with hazardous waste sites will result in adverse effects to human health and the environment. Health effects of potential concern include carcinogenic and noncarcinogenic effects such as birth defects or nervous system damage from long-term exposure to toxic hazardous substances. The degree of risk is expressed numerically. For example, the most widely used acceptable degree of risk for carcinogens is 1×10^{-6}: the level of exposure that would result in one chance in a million of developing cancer over a lifetime (70 years).

Issues Associated with Health Risk Assessment

The following sections discuss two important issues associated with health risk assessment. A more technical discussion of risk assessment issues is provided in Chapter 3.

Level of Acceptable Risk

In general, the approach to deriving cleanup levels through human health risk assessments is based on methods and guidelines presented in U.S. EPA (1986b-f, 1988f, 1989c). The approach to deriving cleanup levels through ecological risk assessment involves site-specific risk assessments as well as compliance with ecological health-based regulations and guidelines such as ambient water quality criteria for the protection of aquatic life (Warren-Hicks et al. 1989; U.S. EPA 1989h,k).

Several states have adopted human health risk-based approaches to setting cleanup levels at hazardous waste sites. Others, such as California, use site-specific risk assessments to guide cleanup of hazardous waste sites. The allowable degree of risk varies from state to state. When no federal standards or criteria are available, Minnesota uses risk assessments based on an acceptable degree of risk of 1×10^{-5}. In New Jersey, site-specific cleanup levels are set through a combination of background and risk-based approaches, using 1×10^{-6} as the level of acceptable risk. Ohio also requires that site-specific cleanup levels meet a health risk level of 1×10^{-6}.

Under this alternative, acceptable risk to human health would be defined for carcinogens as the $1x10^{-6}$ lifetime cancer risk, and for noncarcinogens as the daily intake rate that is not expected to cause adverse effects over a lifetime exposure (a hazard index of 1.0). The acceptable risk to ecosystem health would be defined as the level that causes no adverse effects in species at the site. Details of assumptions and equations used in the human health risk assessment are presented in Chapter 173-340 WAC.

Protectiveness of the Risk Assessment

Risks from low concentrations of hazardous substances in the environment are often difficult to predict using laboratory experiments. When performing studies of risks to humans or endangered species, health scientists often use models derived from laboratory bioassays on experimental animals such as rats or fish to predict potential health risks. They may also use epidemiological studies of humans exposed to high doses of certain hazardous substances. Consequently, predicting potential health effects in human or animal populations involves many assumptions. Assumptions, in turn, lead to uncertainty in the conclusions of any evaluation of health risk. With this in mind, health scientists generally calculate plausible upper estimates of risk so that error resulting from assumptions will likely be on the protective side.

Derivation of Cleanup Levels Under the Risk-Based Alternative

The following sections describe the derivation of example concentrations under the risk-based alternative. First, the general methods used for human and ecological risk assessment are provided, followed by a discussion of the specific assumptions used for each medium of concern.

Human Health Risk Assessment

For each hazardous substance in a medium, it would be assumed that exposures affecting human health through various pathways and routes (such as drinking tap water, inhaling vapors released from tap water, and dermal contact with tap water) are additive. As such, these pathways and routes result in an additive risk for that hazardous substance. This assumption ensures that the human health risks from various exposure routes for one medium are all accounted for in the target risk level.

It would also be assumed that for each hazardous substance the risks from all media are additive. Thus, the standards used at a site would be reduced to take this assumption into account. For example, the allowable risk and corresponding total exposure to a hazardous substance could be partitioned among media on an equal basis. This procedure establishes the standards for one hazardous substance in several media at a level which, when the risks from the separate media are added together, results in a total human health risk less than or equal to the target level. Unequal partitioning of risks among exposure pathways could also be allowed, provided the target level was still met. The potential combined effects of hazardous substances, where known, would be factored in on a site-specific basis.

Finally, for some hazardous substances, it could be assumed that health effects from inhalation are different from health effects from oral exposure. For example, exposure to some hazardous substances in air does not contribute to the risk from oral exposure. Although a small percentage of the mass of hazardous substances inhaled as particulates can also be swallowed, this contribution to the oral exposure route is considered negligible. CPFs and RfDs derived for the inhalation route of exposure would be used in the risk assessment for air. CPFs and RfDs derived for the oral ingestion route of exposure would be used in the risk assessments for the other media. Exceptions could be made for some hazardous substances, such as benzene and dichloromethane, which affect some of the same target organs through inhalation and oral exposure routes. Inhalation and oral exposure routes for such hazardous substances would be considered additive. Exposure routes considered important on a statewide basis in each medium are shown in Table 4. Additional exposure routes (for example, ingestion of backyard fruits and vegetables) could be important on a site-specific basis.

The proposed standards derived from a human health risk assessment assume an allowable exposure corresponding to a $1x10^{-6}$ lifetime excess cancer risk for carcinogens, or the RfD for noncarcinogens. For carcinogens, the human health risk equals the dose multiplied by the CPF. For noncarcinogens, the evaluation is based on a ratio of the calculated dose to the RfD, known as a hazard quotient. A hazard quotient of 1.0 is used to define the allowable risk for individual contaminants. In other words, the allowable dose for each contaminant alone is equal to the reference dose. However, the sum of the hazard quotients (known as the hazard index), when totaled for all contaminants at a site, must also be less than or equal to 1.0.

The concentration of a hazardous substance present in the environment is used to calculate dose. Therefore, risk assessment equations can be rearranged to calculate hazardous substance concentrations in environmental media. Hazardous substance concentrations

TABLE 4. EXPOSURE ROUTES

Medium	Significant Exposure Routes
Ground water	Drinking water Inhalation of vapors released from tap water Dermal exposure to tap water
Surface water	Drinking water Inhalation of vapors released from tap water Dermal exposure to tap water Ingestion of freshwater fish
Marine water	Ingestion of marine fish and shellfish
Soil	Dermal exposure Ingestion
Air	Inhalation of particulates Inhalation of vapors

reached in this way either correspond to an allowable risk level for carcinogens or to an allowable dose (such as an RfD) for noncarcinogens.

Some general assumptions of the risk assessment approach are used to derive the human health-based values for risk. They can be summarized as follows:

- Adverse effects in experimental animals are representative of adverse effects in humans
- The most sensitive animal species is most appropriate in representing the response of humans
- For each hazardous substance, humans absorb the hazardous substance as efficiently as the experimental animal
- If available, human data are preferable to animal data for estimating risk
- Dose-response models can be extrapolated below the range of experimental observations to yield plausible upper-bound estimates of risk at lower doses
- No threshold dose exists for initiation of carcinogenesis (that is, cancer induction); therefore, cancer can be caused by very low doses of carcinogens
- A threshold dose (for example, no observed adverse effect level) exists for noncarcinogenic effects
- Average doses are an appropriate measure of exposure, even if dose rates vary over time
- In the absence of appropriate metabolic data, the effective (or target organ) dose is assumed to be proportional to the administered dose
- Risks from multiple exposures over time are additive
- Risks from exposures to multiple hazardous substances with the same toxic response (for example, cancer) are additive.

These assumptions apply to all exposure scenarios (sets of assumptions about the fate of hazardous substances, their transport, and exposure routes) used to derive cleanup levels for each environmental medium. Life span, body weight, and ingestion rate vary among individuals, and body weight and ingestion rate vary over an individual's lifetime. For example, because children drink proportionately more water with respect to their body weight, they have greater exposures to hazardous substances in water than do adults. In most cases, the detailed assumptions developed for each human health exposure route and environmental medium apply to a hypothetical typical adult male (exceptions include exposures to which children are particularly vulnerable, such as ingestion of and dermal exposure to hazardous substances on soil). Additional uncertainties inherent in the risk-based standards are associated with other variables used to calculate allowable concentrations, such as estimates of absorption efficiencies, CPFs, and RfDs.

Because of the uncertainties in predicting human health risks, the process of risk assessment uses a series of conservative (protective) assumptions. These assumptions include the use of safety factors to derive RfDs for noncarcinogens and a plausible upper limit of carcinogenic potency for carcinogens. It is assumed that the series of conservative assumptions provides an ultimate assessment that is protective of human health. Even with such assumptions, the potential risk to pregnant women, children, and persons with particular susceptibility to these hazardous substances should be evaluated on a site-specific basis.

Finally, these risk levels relate only to the exposure routes and media listed in Table 4. These exposure routes (represented pictorially in Figure 2) were judged to be the primary exposure routes at most hazardous waste sites. Additional exposure routes not listed (for example, contamination of crops or livestock) may be important at some sites. Potential risks associated with these routes of exposure will be considered on a site-specific basis.

Ecological Risk Assessment

The risks to the health of an ecosystem from contamination in the environment are not easily calculated because different plant and animal species respond differently to hazardous substances. In addition, some species respond differently to certain hazardous substances when environmental conditions, such as pH, chemical hardness of water, and temperature, vary. Therefore, on a statewide basis, previously developed standards that are protective of most plants and animals would be used when available.

Methods for assessing ecological risk on a site-specific basis can be found in documents by Urban and Cook (1986), Norton et al. (1988), Warren-Hicks et al. (1989), and U.S. EPA (1989h,k). Because of the variability of responses to hazardous substances by plants and animals at a site, no single model is appropriate for use at all sites. Ecology is currently evaluating ecological risk models

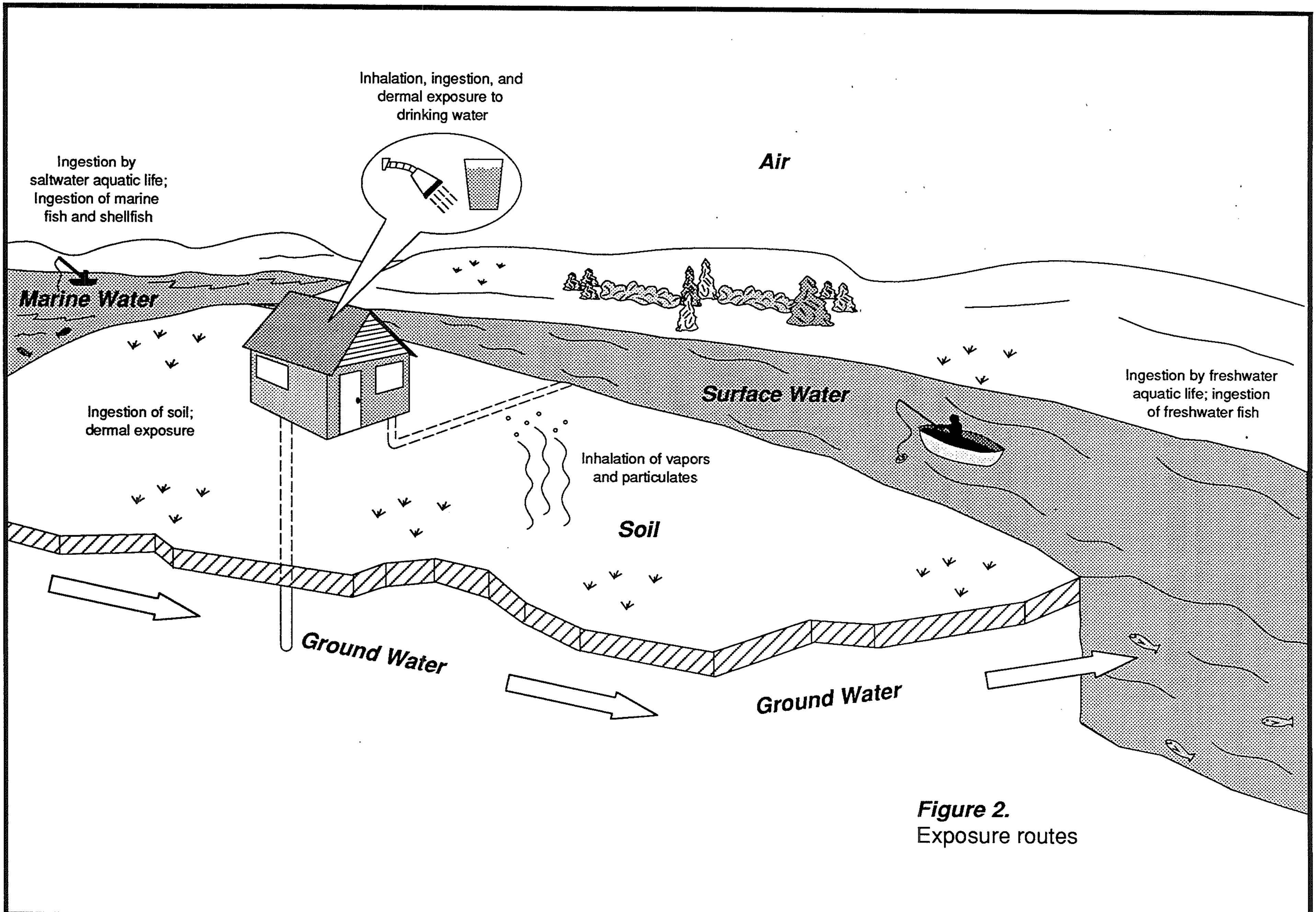


Figure 2.
Exposure routes

for use in developing cleanup levels at hazardous waste sites. The methods reviewed for use are the following [reviewed in PTI (1990)]:

- EPA method for developing site-specific water quality criteria
- EPA pesticide standard evaluation procedure
- Chemical migration risk assessment model
- Terrestrial food chain model
- Apparent effects threshold (AET) approach
- EPA method for determining air quality criteria for ozone.

As part of this project, Ecology is developing criteria for determining which model or risk assessment method is most appropriate at a specific site. Considerations in choosing a model include the following:

- What will the results of the model be used for?
- What media and exposure routes are present at the site?
- What habitats, species, and measures of effects is the model designed to address?
- What data does each model require?
- Can results for one species be applied to other species?
- Has the model been adequately tested and applied to similar situations?
- How are uncertainties treated in the model?

Each of these considerations will affect the choice of which model will be used at a particular site.

Guidelines that can be used to assess risk to plants and animals on a statewide basis include the EPA acute and chronic ambient water quality criteria for the protection of freshwater and saltwater organisms. These criteria are expected to be protective of 95 percent of the aquatic species in the United States (U.S. EPA 1986g). However, these criteria were developed based on average species response and may not be fully protective of sensitive subspecies or life cycle stages. No standards for soil, air, or ground water are presently available for the protection of plants and animals.

Ground Water

Human exposure to hazardous substances in ground water may occur through drinking water, dermal exposure and inhalation of vapors released during showering, cooking, or other domestic activities. The standards for ground water would be based predominantly on the risk to human health posed by drinking contaminated water. Inhalation of hazardous substances released into the air during household activities would be considered for volatile hazardous substances such as trichloroethane, trichloroethene, tetrachloroethene, dichloromethane, benzene, toluene, xylene, ethylbenzene, and vinyl chloride. Dermal exposure to hazardous substances in tap water could also be considered in the development of risk-based standards.

Risks to the environment would not be addressed because it is expected that plants and animals will have minimal contact with ground water.

Surface Water

The risk-based concentrations for surface water would be based primarily on considerations of aquatic toxicity. However, contamination of surface water poses risks to humans when surface water is used as a source of drinking water. At sites where surface water is used as drinking water, MTCA standards developed for ground water based on human health considerations would also apply. Contamination of surface water also poses risks to aquatic organisms and to humans consuming fish caught in contaminated areas. The risk from consumption of freshwater fish would be added to the risk from drinking water exposure routes (if any) to determine the human health-based standard. The human health-based standard would then be compared to the chronic ambient water quality criterion for the protection of freshwater aquatic life, and the lower of the two concentrations would be chosen. This method results in a concentration that is protective of both human health and the environment, within the limits of available data.

Professional judgment should be used in omitting the dermal exposure route from the risk assessment for surface water. It is likely that at most sites, risk to human and environmental health from the dermal exposure route is not large when compared to the risk from routes associated with drinking water, consumption of freshwater fish, and danger to aquatic life.

Marine Water

The risk-based concentrations in marine water would be based either on the risk to saltwater aquatic life or on the risk to human health from the consumption of marine fish and shellfish. For each hazardous substance, the human health and aquatic toxicity concentrations would be compared, and the lower of the two values would be chosen for each hazardous substance. Again, the dermal exposure route is not generally expected to be an important factor in the risk assessment. Because swimming in Puget Sound is generally not a high-frequency activity, the risk to human health from swimming is small compared with the risk from ingestion of fish and shellfish.

Soil

Risk-based concentrations for soil would be based on the risk to human health from ingestion of and dermal contact with soil. The risk-based concentrations for certain hazardous substances in soil (for example, chromium, copper, zinc, trichloroethane, toluene, xylene, and ethylbenzene) are relatively high compared with expected hazardous substance levels at hazardous waste sites. However, these hazardous substances are not considered carcinogenic by oral routes; the high allowable concentrations derived from risk assessment indicate that direct contact with these hazardous substances in soils may present a very low risk to human health.

Standards for hazardous substances would also take into account the effects that their presence in soil has on other media. For instance, the presence of cadmium and chromium in soil may have a large effect on concentrations of these metals in air, a medium in which cadmium and chromium are carcinogenic. Similarly, hazardous substance concentrations in soil may leach into surface and ground water supplies. The protection of ground water would be considered when adopting standards for soils.

The risk to human health based on plant uptake of hazardous substances in soil would not be included in the development of statewide numerical standards. While this route of exposure can be important on a site-specific basis, in the absence of information on local patterns of consumption and land use, its importance cannot be predicted. Although this exposure route is not expected to be as important as the risk from direct contact with and ingestion of soil, it should be evaluated when available data indicate its importance on a site-specific basis. Risks to plants and animals are not addressed because of the lack of data on exposure and toxicity of hazardous substances in soil to organisms in the environment. These risks should also be evaluated on a site-specific basis.

Air

Risk-based standards in air would be based on inhalation of particulates and vapors. Since CPFs or RfDs based on inhalation exposures are lacking for many hazardous substances, their risks due to inhalation cannot be evaluated. The risk-based concentration for nonvolatile hazardous substances would be based on inhalation of particulates only, whereas the risk-based concentration for the volatile hazardous substances would be based on inhalation of particulates and vapors. Potential impacts on plants and animals are not considered when establishing statewide standards because data on exposure and toxicity of hazardous substances in air to organisms in the environment are presently unavailable.

Example Derivations

The following example derivations illustrate the process that would be used to set standards under the risk-based alternative. Risk-based standards would be generally site-specific because of variation in the number of hazardous substances and exposure pathways present at a site. Because risk-based standards for individual hazardous substances would be lower based on additive effects, actual standards at any given site would depend on the number of hazardous substances and exposure pathways at the site. The following example standards are for individual hazardous substances and pathways only, based on methods and equations presented in the draft regulations (Chapter 173-340 WAC). Table 5 summarizes example standards for the risk-based alternative.

Cadmium

The risk-based standard for cadmium in ground water would be based on ingestion of drinking water, corresponding to a concentration of 10 μg/L. In surface water, risk to aquatic life would be considered, resulting in a lower standard of 1.1 μg/L (based on the chronic ambient water quality criterion). In marine water, the risk to aquatic life is again greater than the risk to human health, resulting in a standard of 9.3 μg/L (based on the chronic ambient water quality criterion). In soil, the risk-based standard would be based on dermal contact and ingestion, resulting in a standard of 40 mg/kg. In air, the risk-based concentration is based on inhalation of particulates, resulting in a standard of 1.3 ng/m^3.

Benzene

The risk-based standard for benzene would be based on ingestion and inhalation of hazardous substances in tap water, corresponding to a concentration of 1 μg/L. The risk-based standards for surface water and marine water would be based primarily on consumption of contaminated fish and shellfish, resulting in a concentration of 80 μg/L (if drinking water is also a concern, the 1 μg/L standard

TABLE 5. EXAMPLE STANDARDS FOR THE RISK-BASED ALTERNATIVE

	Ground Water (μg/L)	Surface Water (μg/L)	Marine Water (μg/L)	Soil (mg/kg)	Air (ng/m^3)
Cadmium	10	1.1	9.3	40	1.3
Benzene	1	80	80	32	280
PCBs	0.01	0.00001	0.00001	0.4	1
PAH compounds	0.01	0.031	0.031	0.1	0.7

mentioned above would apply). Risk-based concentrations in soil would be based on direct contact and ingestion of soil, resulting in a concentration of 32 mg/kg. The risk-based standard in air would be based on inhalation of particulates and vapors, corresponding to a concentration of 280 ng/m^3.

PCB Mixtures

The risk-based PCB standard for ground water would be based on ingestion of drinking water, resulting in a concentration of 0.01 μg/L. The standards for surface water and marine water would be based on the consumption of fish and shellfish, corresponding to a concentration of 0.00001 μg/L. The risk-based standard for soil would be based on direct contact and dermal ingestion, resulting in a concentration of 0.4 mg/kg. The risk-based standard for air would be based on inhalation of particulates, resulting in a concentration of 1 ng/m^3.

PAH Compounds

The risk-based standard for PAH compounds in ground water would be based on ingestion of drinking water, resulting in a concentration of 0.01 μg/L. Because bioconcentration factors vary for individual PAH compounds, a risk to human health based on consumption of fish and shellfish is not easily calculated. For this illustration, the ambient water quality criterion based on consumption of fish and shellfish is used, corresponding to a standard of 0.031 μg/L for surface water and marine water. A risk-based standard in soil would be based on direct contact and ingestion of soil, resulting in a concentration of 0.1 mg/kg. In air, the risk-based standard would be based on inhalation of particulates and vapors, resulting in a concentration of 0.7 ng/m^3.

Applicable or Relevant and Appropriate Requirements Alternative

Using the ARAR alternative, cleanup levels would be specifically designed to meet certain federal and state standards for the cleanup of hazardous waste. The MTCA requires Ecology to publish cleanup levels that are "at least as stringent as the cleanup levels under Section 121 of the federal cleanup law, 42 U.S.C. Sec. 9621, and at least as stringent as all applicable state and federal laws, including health-based standards under state and federal law."

Section 121 of CERCLA/SARA requires the use of all applicable or relevant and appropriate requirements. These requirements are commonly called ARARs.

Applicable requirements are legally enforceable requirements that specifically address a hazardous substance, cleanup action, medium, location, use, or other circumstance at the site of interest. *Relevant and appropriate requirements* are those that, while not legally applicable, address situations sufficiently similar to those encountered at a particular site that their use is well suited to the site in question. Ecology proposes to define "applicable state and federal laws" to include both applicable requirements and relevant and appropriate requirements (see WAC 173-340-710).

ARARs are used as cleanup levels in many states. For example, Minnesota, Ohio, Florida, Massachusetts, California, New York, and New Jersey use federal and state laws and regulations, alone or in combination with a risk-based approach, to establish cleanup levels.

Issues Associated with the ARAR Alternative

Many ARARs are available for use in setting cleanup levels. Each has its own purpose and particular factors that were taken into account when the ARAR was developed. ARARs are protective only of the use for which they were intended. Some ARARs address health risk to humans, some address health risk to animals, and others (secondary maximum hazardous substance levels, for example) are not based on health risks at all. These and other issues associated with ARARs are discussed in detail in Chapter 3, under *Definition of Applicable or Relevant and Appropriate Requirements*.

Use of Promulgated Standards vs. Guidelines

In the strict definition of an ARAR, only those standards and regulations that have been promulgated (and therefore have legal force) must be considered. However, when no ARAR is available to regulate the cleanup, or when the guidelines are more protective of human health or the environment than the promulgated standard, guidelines such as water quality criteria are often used.

EPA believes that widely used guidelines and policies are appropriate for use as ARARs. This position is further supported by Section 121 of CERCLA/SARA, which refers to the use of certain water quality criteria, maximum contaminant level goals (MCLGs), and other guidelines as ARARs. Ecology agrees with this position and has identified two guidelines (MCLGs for noncarcinogens and ambient water quality criteria as applicable in the proposed rule (see WAC 173-340-720 and 173-340-730).

Use of All Known, Available, and Reasonable Methods of Treatment

The use of AKART is required by the Water Pollution Control Act (Chapter 90.48 RCW). Although AKART are applicable to setting cleanup levels, they have not yet been specifically defined, nor are they translatable into a set of numerical standards. For these reasons, AKART would not be used as ARARs for setting standards under this alternative. AKART should be treated as ARARs that would need to be applied during the cleanup action phase to meet cleanup levels.

Adoption of Local Standards

Neither the MTCA nor Section 121 of CERCLA/SARA requires that local standards be treated as ARARs. However, in situations where state or federal law requires the development of local standards, those local standards could be considered ARARs. Shoreline management plans are examples of standards that would serve as ARARs on site-specific bases.

Applicability of Waivers and Variances Under Section 121 of CERCLA/SARA

Section 121 contains several waivers to the cleanup levels and ARARs required by CERCLA/SARA. However, based on the legal opinion of the Office of the Attorney General (Manning 1989), Ecology believes that cleanup levels promulgated under the MTCA are not required to incorporate these waivers. This opinion is based on the language of the MTCA, which specifically states that the standards must be at least as stringent as the cleanup levels in Section 121 and applicable state and federal laws, but makes no mention of the waivers. Ecology believes this interpretation is consistent with the history of development and passage of the citizens' initiative.

Inclusion of Waivers and Variances Associated with Other ARARs

ARARs are generally interpreted to include text associated with numerical standards as well as narrative and process-based regulations or sections of regulations. Ecology believes that the waivers and variances included in applicable state and federal laws are a part of the ARARs. Application of these ARARs to hazardous waste sites would be considered on a site-specific basis in a manner similar to the process used at other sites regulated by these ARARs.

Derivation of Cleanup Levels Under the ARAR Alternative

In many cases, more than one ARAR exists for a given hazardous substance in a given medium. Because the MTCA requires that the cleanup levels be at least as stringent as any ARARs, the most stringent ARAR would be chosen as the standard for each hazardous substance. Categories of ARARs that would be considered include those protective of human health, those protective of the ecological community, and those relating to public welfare. The following sections describe the various ARARs to be considered in each medium and explain the purpose and regulatory context of each ARAR.

Ground Water

Several ARARs are available or proposed for hazardous substances in ground water. For hazardous substances governed by multiple ARARs, the lowest concentrations would be selected. Key ARARs for ground water are described below:

Maximum Contaminant Level Goals

MCLGs are nonenforceable guidelines set by EPA at levels where no known or anticipated adverse effects on human health are thought to occur. These guidelines also include adequate margins of safety. Although MCLGs are nonenforceable, they are specifically identified as ARARs by Section 121 of CERCLA/SARA. Category I chemicals (hazardous substances that show strong evidence of carcinogenicity) have MCLGs of zero. For example, these hazardous substances include trichloroethene, tetrachloroethene, benzene, vinyl chloride, PCB mixtures, and ethylene dibromide. Recent EPA guidelines state that MCLGs equal to zero are not appropriate as ARARs for hazardous waste sites. Ecology agrees with this recommendation; therefore, MCLGs equal to zero would not be used as standards for hazardous waste sites under MTCA; if available, MCLs would be used instead.

Category II and III chemicals are those that show equivocal, inadequate, or no evidence of carcinogenicity. The MCLGs for these chemicals are based on EPA's drinking water equivalent level (DWEL) (U.S. EPA 1989f). The DWEL is calculated in the same manner as the drinking water concentration under the risk-based alternative, which is based on an RfD. Because it is assumed that other sources of these hazardous substances will also be present, the MCLG is lowered by a factor, expressed as a percentage, equal to the expected contribution of a hazardous substance from the daily intake of drinking water. This factor can be no more than 80 percent. To take into account inhalation and dermal exposure to volatile organic compounds in tap water, EPA has lowered the guideline for volatile organic compounds to 20 percent of the DWEL.

MCLGs have been proposed or promulgated for many common hazardous substances, including cadmium, chromium, lead, benzene, trichloroethene, tetrachloroethene, toluene, xylene, ethylbenzene, vinyl chloride, ethylene dibromide, pentachlorophenol, and PCB mixtures.

Primary Maximum Contaminant Levels

Primary MCLs are developed by EPA and published in 40 CFR 141. Once they are promulgated by EPA, MCLs are usually incorporated into Washington state's drinking water standards (Chapter 248-54 WAC). Primary MCLs are legally enforceable drinking water standards intended to be as close to MCLGs as feasible, using the best technologies and treatment techniques. Four factors are taken into account in setting the standards: the availability and performance of the technologies for removing the hazardous substance, the cost of the technology, the ability of laboratories to measure the hazardous substance at the MCL, and whether the MCL falls within the range of acceptable risk that EPA considers protective of human health.

It is EPA's responsibility to identify the best available technology that could be used to meet the MCL. Because EPA has determined that available treatment technologies are capable of reducing most inorganic hazardous substances to the MCLG levels in a cost-effective manner, and that these levels are all above achievable detection limits, the proposed MCLGs and MCLs for noncarcinogenic inorganic hazardous substances are identical.

This reasoning holds true for noncarcinogenic organic hazardous substances whose MCLGs are above zero. However, because the ability to analyze for the hazardous substances was taken into account, the proposed MCLs for carcinogenic organic hazardous substances are higher than the proposed MCLGs of zero. Accordingly, the MCLs for these hazardous substances were set at the PQLs of the analytical techniques used to analyze for these hazardous substances in water. For example, primary MCLs have been proposed or promulgated for cadmium, chromium, lead, trichloroethane, trichloroethene, benzene, vinyl chloride, and hexachlorocyclohexane.

Secondary Maximum Contaminant Levels

Secondary MCLs are also developed by EPA, and are nonenforceable guidelines intended to protect public welfare. These guidelines primarily address parameters such as taste, odor, and color that are unrelated to health but affect the acceptability of a drinking water supply. These standards are usually set much lower than primary standards. For example, secondary MCLs have been set for iron, copper, zinc, nitrates, toluene, xylene, ethylbenzene, and pentachlorophenol. Iron and nitrates are typical ground water hazardous substances at landfills; toluene, xylene, and ethylbenzene are commonly found at sites with leaking underground storage tanks. At these and other affected sites, cleanup levels may be based primarily on secondary MCLs. Washington state has usually incorporated final secondary MCLs in the state's drinking water standards (Chapter 248-54 WAC).

Summary

Under the ARAR alternative, the most protective of the above requirements would be used to establish the cleanup level. Under the proposed rule, all of the standards and guidelines described above (with the exception of MCLGs equal to zero) are defined as applicable state and federal laws for ground water that represent a current or potential source of drinking water (WAC 173-340-720).

Surface Water

Because surface water can be considered a source of drinking water, ARARs such as MCLs may also apply to surface waters. In addition, several ambient water quality criteria, published under the Clean Water Act by EPA and adopted as surface water standards by Ecology (Chapter 173-201 WAC), have been developed for the protection of aquatic life and its uses. Ambient water quality criteria are specifically incorporated as ARARs by Section 121 of CERCLA/SARA. These criteria are intended to address all identifiable effects on the health and welfare of aquatic plants and animals as well as the recreational uses of these plants and animals, waters, and shorelines. They may also take into account the effect of the hazardous substance on biological diversity, productivity, and stability of receiving waters (U.S. EPA 1986g). These ARARs for surface water are described below.

Acute Criteria

Acute criteria, which are based solely on studies of acute toxicity to freshwater plants and animals, represent the concentration which, when averaged over a 1-hour period, may not be exceeded more than once every 3 years. These criteria are based on various studies of a variety of taxonomic groups. They are intended to protect 95 percent of the species in North American bodies of water against unacceptable effects. Unacceptable effects include mortality, reduction in growth or reproduction, loss of equilibrium, and abnormal development. The acute value is defined as the 5th percentile of concentrations producing adverse effects, except in instances where a recreationally or commercially important species shows an effect below that value.

In order to provide a safety factor, the acute value is divided by a factor of 2 to obtain the acute criterion. Some acute criteria are promulgated as equations. These equations generate an acute criterion for each hazardous substance, based on the chemical hardness of water. Chemical hardness must be considered, because the bioavailability (and, hence, the toxicity) of many metals decreases as the hardness of the water increases.

Chronic Criteria

Chronic criteria, which are based on studies of chronic toxicity to freshwater plants and animals, represent the concentration of the chemical which, when averaged over a 4-day period, may not be exceeded more than once every 3 years. The chronic criteria can be derived in the same manner as the acute criteria using chronic endpoint studies, or they can be derived by dividing the acute criterion by the acute/chronic ratio (ACR) for each chemical. The ACR is used when insufficient data are available for the more rigorous analysis. The ACR is derived by determining the mean of the ACR for individual species. The ACR cannot be lower than 2. Chronic criteria for metals may also depend on the hardness of the water.

Surface Water Quality Standards

Surface water quality standards for Washington (Chapter 173-201 WAC) have been promulgated under the state Water Pollution Control Act (Chapter 90.48 RCW). Standards for toxic substances are intended to protect all fresh and marine surface waters of the state. State standards are generally identical to the federal ambient water quality criteria for most hazardous substances.

Summary

Under the ARAR alternative, the most protective of the above requirements would be used to establish the cleanup level. In addition, at sites where surface water is an actual or potential source of drinking water, MCLs would also apply.

Marine Water

Marine water is not used for drinking water; therefore, the only applicable ARARs for marine water are water quality criteria for the protection of saltwater plants and animals and their uses and the state surface water quality standards. Definitions of acute and chronic criteria are identical to those for surface water, except that the toxicity studies have been performed on saltwater plants and animals.

Soil

ARARs for hazardous substances in soil (with occasional exceptions such as the ARAR for lead) do not directly address human health or ecological risks. The following sections describe the ARARs available for hazardous substances in soil.

Lead

The ARAR for lead is proposed by the EPA Office of Solid Waste and Emergency Response. This ARAR is based on a 1985 Centers for Disease Control directive that states, "lead in soil and dust appears to be responsible for blood levels in children increasing above background levels when the concentration in the soil or dust exceeds 500 to 1000 ppm" (U.S. EPA 1989e). Interim guidance levels are based on this directive. They are to be used for cleanup actions at Superfund sites and, therefore, are relevant and appropriate to this standard-setting procedure.

Dangerous Waste Regulations

The remaining ARARs for soil are based on the designation of solid material as hazardous waste under the Washington state dangerous waste regulations (Chapter 173-303 WAC). These requirements are therefore not as closely related as other ARARs to the setting of cleanup levels for hazardous waste sites. Many of the hazardous substances of concern are regulated by the dangerous waste regulations. Various criteria for toxicity, persistence of the hazardous substance in the environment, or carcinogenicity may apply. For instance, arsenic, chromium, trichloroethane, trichloroethene, tetrachloroethene, benzene, DDT, and hexachlorocyclohexane are subject to designation as dangerous wastes under the carcinogenic dangerous waste criteria when their concentrations in soil (or other waste) are equal to or greater than 100 ppm. Dichloromethane is subject to designation as a hazardous waste under the halogenated hydrocarbons criterion if its concentration in soil is equal to or greater than 100 ppm. PCB mixtures are subject to designation if their concentration in soil is equal to or greater than 1 ppm. PAH compounds are regulated as extremely hazardous wastes if their concentrations in a substance reach 10,000 ppm.

Although the Washington dangerous waste regulations are directly applicable only to wastes handled or disposed of after 1982, these regulations may be considered relevant and appropriate to wastes handled before 1982. In addition, wastes handled or disposed of under RCRA have been regulated since 1980. These regulations are not intended to set a cleanup level for these substances, but rather to designate when a waste must be treated as specified in the regulations. Under these regulations, if a waste is handled improperly, it must be cleaned up to background levels. Therefore, when hazardous waste levels alone are used as cleanup levels for hazardous waste sites, these ARARs are not necessarily protective of human health or the environment.

Air

The ARARs that would be used to determine cleanup levels for the hazardous substances of concern in air include state and federal standards for ambient air quality and hazardous air pollutant emissions.

National Primary and Secondary Ambient Air Quality Standards

Section 109 of the federal Clean Air Act governs the development of national primary and secondary ambient air quality standards. Primary ambient air quality standards are legally enforceable standards intended to protect public health and leave an adequate margin of safety. Secondary ambient air quality standards are nonenforceable and are intended to protect public welfare from any known or anticipated adverse effects of a hazardous substance. Section 109 states that EPA shall consider the health and welfare implications of the proposed standard. The contribution of the hazardous substance to the total body burden from other sources (such as ingestion and dermal contact) and the combined effects of the hazardous substance in air with hazardous substances in soil, food, and water are taken into account when setting the standard. The standard also includes an adequate margin of safety. Of the hazardous substances regulated under the MTCA, ambient air quality standards have been set only for lead and volatile organic compounds.

Lead

In setting the ambient air quality standard for lead at 1.5 $\mu g/m^3$ (averaged over 3 months), EPA combined the primary and secondary standards into one legally enforceable standard. This standard has been adopted by PSAPCA but not by the state of Washington.

The health goal of this standard is to prevent most children (aged 1-5 years) in the United States from exceeding a blood lead level of 30 $\mu g/dL$ (U.S. EPA 1986a). Young children were chosen because they are particularly sensitive to lead. The standard takes into account the contributions of lead from ingestion of soil, food, drinking water, ink, pesticides, gasoline, and paint.

Detailed epidemiological, animal, and pharmacokinetic studies were reviewed in setting the standard for lead. Based on these studies, EPA determined that blood lead levels above 30 $\mu g/dL$ are associated with nervous system damage and impairment of heme synthesis. In setting the standard, EPA first calculated the daily intake of lead associated with the chosen blood level, then subtracted the daily intake amount of lead that could be attributed to sources other than air. The remaining fraction was determined to be the safe concentration in air. Recent studies have provided evidence of adverse effects in children when blood lead levels are as low as 10-15 $\mu g/dL$ (ATSDR 1988). These studies have led to a reevaluation of this standard by EPA.

Volatile Organic Compounds

Because volatile organic compounds act as precursors to the formation of ozone in air, the emission of volatile organic compounds is controlled by ambient air quality standards. Ozone causes a variety of adverse human health effects, including irritation of the respiratory tract, reduction in lung capacity, reduced resistance to infection, and aggravation of lung disease. Ozone is also related to a variety of other effects such as crop damage, reduction of visibility, and damage to man-made materials.

The national primary and secondary ambient air quality standards for ozone are intended to protect human health and welfare and to take into account sensitive populations. Air quality standards for ozone are established in Title 40, Part 50 of the Code of Federal Regulations. The standard is attained when the number of days in a year with maximum hourly average concentrations of total volatile organic compounds above 0.12 ppm (235 $\mu g/m^3$) is equal to or less than one. This ARAR is applicable to volatile hazardous substances of concern such as trichloroethane, trichloroethene, tetrachloroethene, dichloromethane, benzene, and vinyl chloride.

Emission Standards for Hazardous Air Pollutants

Under Section 112 of the Clean Air Act, EPA is required to establish emission standards for hazardous air pollutants to protect public health at a level that provides an ample margin of safety. The standards specify equipment and procedural requirements where numerical limits have not been established.

Federal emissions standards apply only to sources specifically identified in the regulations. These sources include construction, modification, or operation of new or existing stationary sources. Examples of hazardous substances regulated under those standards include vinyl chloride from chemical manufacturing plants, benzene emissions from equipment leaks, and arsenic from glass manufacturing plants and chemical plants. Because hazardous substances can be regulated by these standards only when emitted from specific sources, federal emission standards cannot be used to set hazardous waste site cleanup levels. In addition, the standards based on these laws are generally less stringent than other available ARARs.

Acceptable Source Impact Levels

Ecology is in the process of developing ASILs for hazardous hazardous substances in air. These levels are still undergoing development and are subject to change. The proposed standards for noncarcinogens are based on threshold limit values developed for the workplace, using a 40-hour work week. ASILs were developed from the threshold limit values by adjusting the concentration downward to take into account total exposures over the course of a full week and by applying an additional safety factor to account for sensitive populations or health effects not represented in the development of threshold limit values. This approach is similar to that used by the Commonwealth of Massachusetts to develop ambient air standards. For carcinogens, CPFs developed by the EPA Carcinogen Assessment Group were used. The Washington proposed standards for carcinogens are annual average concentrations associated with a $1x10^{-6}$ degree of risk (Ecology 1988b).

Occupational Safety and Health Act Regulations

The Occupational Safety and Health Act (OSHA) regulates many hazardous substances of concern in workplace air. Because some of the hazardous waste facilities in Washington may continue to operate after cleanup, these standards must be taken into consideration. However, since OSHA standards are generally not as protective of human health as those of the Clean Air Act and the proposed standards of Washington state, they would generally not be used to set standards for the general public.

Example Derivations

The following sections provide examples of how standards would be derived under the ARAR alternative. Table 6 summarizes example standards for the ARAR alternative.

Cadmium

In ground water, ARARs for cadmium include an MCL and a proposed MCL. Of these, the proposed MCL is the lowest (5 μg/L) and would be used as the ground water standard under the ARAR alternative. In surface water, ARARs include acute and chronic water quality criteria and Washington state surface water quality standards. Of these, the chronic water quality criterion (1.1 μg/L) is the lowest and would be used as the standard. In marine water, acute and chronic water quality criteria are available. The chronic criterion (9.3 μg/L) is lower and would be used as the standard. No ARAR is available for cadmium in soil. In air, the only ARAR that is available for use as a standard is the draft Washington state ASIL (0.56 ng/m^3).

TABLE 6. EXAMPLE STANDARDS FOR THE ARAR ALTERNATIVE

	Ground Water (µg/L)	Surface Water (µg/L)	Marine Water (µg/L)	Soil (mg/kg)	Air (ng/m^3)
Cadmium	5	1.1	9.3	--[a]	0.56
Benzene	5	(5)[b]	--	100	120
PCBs	0.5	0.014	0.03	1	--
PAH compounds	--	--	--	10,000	0.6

[a] No ARAR is available.

[b] Used if drinking water is a concern at the site.

Benzene

For benzene in ground water, an MCLG and an MCL are available. Because the MCLG is set at zero, it would not be used as the standard. Consequently, the MCL (5 μg/L) would be used as the standard under the ARAR alternative. In surface water, the MCL would be used if drinking water were a concern at the site. No additional ARARs are available for benzene in surface water or marine water (not enough data are available to develop acute or chronic aquatic criteria). The Washington state dangerous waste level (100 mg/kg) is available for use in soils. The only ARAR available for benzene in air is the proposed Washington state ASIL (120 ng/m^3).

PCB Mixtures

A proposed MCL (0.5 μg/L) is available for PCB mixtures in ground water. Freshwater acute and chronic criteria are available for PCB mixtures in surface water, in addition to Washington state surface water quality standards. Of these, the chronic criterion (0.014 μg/L) is the lowest. Water quality criteria and surface water quality standards are also available for PCB mixtures in marine water; the lowest ARAR is the chronic criterion (0.03 μg/L). For soil, a Washington state dangerous waste level (1 mg/kg) is available. No ARARs are available for PCBs in air.

PAH Compounds

No ARAR is available for PAH compounds in ground water, surface water, or marine water. In soil, a Washington state extremely hazardous waste level (10,000 mg/kg) is available. PAH compounds are regulated individually by the proposed Washington state ASILs. A representative PAH standard would be that for benzo(a)pyrene (0.6 ng/m^3).

Technology-Based Alternative

Standards derived under the technology-based alternative would reflect the lowest concentration of hazardous substances in media that can be achieved by the best available treatment technology. The process of setting these standards would not take into consideration protection of human health and the environment. Instead, it would focus on the level of cleanup that can actually be achieved using current technology. Setting standards below the limits of technical achievability would require such measures as the containment of hazardous substances onsite, the removal of hazardous substances to an offsite location, or the development of new technologies for the cleanup of hazardous substances.

Technology-based standards are currently used in the Clean Air Act and the Clean Water Act to regulate emissions from automobiles and smokestacks and to establish effluent limits for wastewater treatment plants. In addition, the state Water Pollution Control Act requires the use of AKART for discharges to surface water and ground water.

Issues Associated with the Technology-Based Alternative

Two issues associated with the derivation of example concentrations under the technology-based alternative are identified here. Further discussion of issues related to the use of technical criteria in setting standards is provided in Chapter 3, under *Statutory Preference for Permanent Solutions* and *Relationship Between Cleanup Levels and Technical Feasibility*.

Permanent Technologies

Two possible approaches to deriving technology-based standards exist. One approach bases a standard on what can be achieved by treatment that destroys or permanently removes a hazardous substance from the medium (metals cannot be destroyed). This approach conforms to the MTCA, which contains language favoring permanent solutions to the maximum extent practicable. The other approach bases the standard on technologies that achieve additional containment, isolation, or stabilization of the contaminated medium onsite or offsite. Because these technologies are not considered permanent, they would not be considered in deriving cleanup levels under the technology-based alternative.

Achievability

Under this alternative, the technology-based standards would represent lowest achievable concentrations. However, interference with the treatment method by a mix of hazardous substances or a complex medium could raise the achievable concentration. Actual achievable limits, especially for organic hazardous substances, could be as much as an order of magnitude higher under such conditions. (Achievable limits for inorganic hazardous substances generally do not vary as widely.) Limits of achievability may need to be determined on a site-specific basis.

Derivation of Cleanup Levels Under the Technology-Based Alternative

The achievable concentration for each hazardous substance would be ascertained by reviewing the literature and determining the range of effluent concentrations that could be achieved by various technologies for remediation of each medium. The lowest of these concentrations would be chosen. Many treatment efficiencies depend on the initial concentration of the hazardous substance or are expressed as a percentage of the initial concentration.

Ground Water

Most water treatment technologies reduce the concentration of a hazardous substance to a fraction of the concentration entering the unit, within the operating range of the technology. Therefore, a statewide, technology-based standard would have to be chosen, in part, by making a judgment about the concentrations of hazardous substances likely to be encountered at a hazardous waste site and applying the fractional reduction achieved by a technology to those concentrations (ICF 1989). Additional reduction of hazardous substances can be achieved, generally at a much higher cost, by applying several treatment units in sequence. In addition, treatment efficiencies are affected by chemical hardness, pH, and competing ions. The concentrations that could be achieved by a variety of treatment technologies has been reviewed (ICF 1989). The following technologies were considered:

- Air and steam stripping
- Activated carbon
- Coagulation
- Reverse osmosis
- Biological degradation
- Ion exchange and resin adsorption
- Ultrafiltration
- Ozonation.

Technology-based standards for metals would likely be based on concentrations achievable through coagulation. Volatile organic compounds were found to be reduced to the lowest concentrations by air stripping. PAH compounds, PCB mixtures, pesticides, and pentachlorophenol are reduced to the lowest concentrations through the use of activated carbon.

Surface Water

The technology-based concentrations for surface water would be the same as those proposed for ground water, because the technologies used in the treatment of ground water and surface water are identical.

Marine Water

The treatment methods surveyed for use in cleaning up saltwater are the same treatment methods used for ground water and surface water. The treatment methods that were found to provide the lowest achievable levels in saltwater are the same treatment methods that provide the lowest achievable levels in freshwater. However, in some cases the treatment efficiencies are lowered by the presence of saltwater ions. In particular, salinity affects the efficiency of both air stripping and coagulation by factors of approximately 10 and 2, respectively. Therefore, technology-based standards in marine water for metals and volatile organic compounds would be increased accordingly.

Soil

Determining appropriate technology-based concentrations for hazardous substances in soil is difficult because of the variable nature of soil and the experimental nature of many technologies for the treatment of hazardous substances in soil. The following techniques for reducing hazardous substances in soil were reviewed:

- Incineration
- Soil flushing
- Soil heating
- Chemical dechlorination
- Air stripping
- Biological degradation.

Technologies are also available that immobilize hazardous substances in soils. In this case, the measure of efficiency is the concentration in the extract after a leaching or extraction procedure. Because there are few practical options for permanent removal of metals from soil, these techniques were also investigated. They include the following:

- *In situ* vitrification
- Cementation
- Chemical fixation.

The incineration of organic hazardous substances can reduce hazardous substance concentrations to levels of one-thousandth (10^{-3}) to one-millionth (10^{-6}) of the original concentration, depending on the hazardous substance. Achievable concentrations resulting from this technology are between 1 ppm and 1 ppb in the soil. Because of the ease with which organic hazardous substances in soil can be incinerated, stabilization of these hazardous substances in soil was not considered. However, because metals cannot be destroyed by incineration, stabilization is an option for the containment of metals in soils. Another option for the reduction of metals is soil flushing. Because this is the only option that actually reduces the concentration of metals in soil, the technology-based concentrations for metals in soils would likely be based on levels that can be achieved by soil flushing. The concentrations achievable in the leachate of an extraction test could be used as an alternative set of technology-based standards.

Air

Contamination in air is mainly in two different forms: vapors from volatile organic compounds and hazardous substances adhering to dust particles. Granular activated carbon, the primary method used to remove vapors from air, has been used predominantly to remove volatile organic compounds from the effluent of air strippers. Use of this method results in an achievable concentration in the low ppb range for volatile organic hazardous substances. This value is derived by assuming an average concentration of 1-10 ppm in the effluent of an air stripper and a granular activated carbon removal efficiency of 99.97 percent.

Fugitive dust emissions are controlled by a variety of techniques, including watering, using chemical wetting agents, planting vegetative cover, and capping wastes. It was estimated that the use of chemical stabilization combined with wetting can result in a 90 percent decrease in fugitive dust emissions from wind erosion. Therefore, based on particulate emissions, a technology-based standard for air would be 10 percent of the concentration that would result from the technology-based standard for the same hazardous substance in soil. For volatile organic compounds, the fugitive dust-based concentration and the vapor-based concentration would be added together.

Example Derivations

The following sections provide examples of how standards would be derived under the technology-based alternative. Example standards are summarized in Table 7.

Cadmium

The technology-based standards for cadmium in water media would likely be based on treatment of the water using coagulation. Therefore, the ground water and surface water standards would be 5 μg/L. Because salinity affects this process, the marine water standard would be somewhat higher, around 50 μg/L. The only treatment technology that can remove metals from soils is soil flushing. Use of this technology would allow a standard of 10 mg/kg for cadmium. Air standards would based on the standard that can be achieved in soil and, for cadmium, would be about 1 ng/m^3.

Benzene

Air stripping is the technology that would likely be used to remove benzene and other volatile organic hazardous substances from water. The ground water and surface water standards would be 0.5 μg/L. Because salinity also affects the efficiency of this technology, the standard in marine water would be somewhat higher, 1 μg/L. Incineration is the most effective technology for removing organic hazardous substances from soil. Use of this technology would result in a standard of 0.005 mg/kg or less. Based on this soil standard, a standard of 0.0064 ng/m^3 could be achieved in air.

PCB Mixtures

Treatment with activated carbon is the most efficient technology for the removal of PCB mixtures in water. Use of this method would allow cleanup levels of 0.5 μg/L for ground water, surface water, and marine water (this technology is not substantially affected by salinity). Incineration of soil would allow a PCB standard of 0.001 mg/kg or less. Based on this standard, an air standard of 0.0001 ng/m^3 could be achieved.

PAH Compounds

Treatment with activated carbon would also be used to remove PAH compounds from water, resulting in a standard of 1.0 μg/L for ground water, surface water, and marine water. Incineration of soil would allow a PAH standard of 0.05 mg/kg or less. Based on this standard, an air standard of 0.005 ng/m^3 could be achieved.

TABLE 7. EXAMPLE STANDARDS FOR THE TECHNOLOGY-BASED ALTERNATIVE

	Ground Water (μg/L)	Surface Water (μg/L)	Marine Water (μg/L)	Soil (mg/kg)	Air (ng/m^3)
Cadmium	5	5	50	10	1
Benzene	0.5	0.5	1	0.005	0.0064
PCBs	0.5	0.5	0.5	0.001	0.0001
PAH compounds	1	1	1	0.05	0.005

Combination Alternative

Under the combination alternative, the most appropriate standard would be chosen for each hazardous substance in each medium on a hazardous substance-by-hazardous substance basis. Characteristics of the different alternatives would be considered, then evaluated and ranked according to a set of priorities embodied in a hierarchical decision-making process. Standards for individual hazardous substances would then be modified to take into account total potential risks, where known, of the hazardous substances when combined.

The exact decision-making framework proposed here is unique. However, a similar process is being used by the Commonwealth of Massachusetts. The approach used by Massachusetts to set the appropriate cleanup levels for hazardous waste sites combines the four previously described alternatives. The cleanup goal of Massachusetts is to reduce contamination to prerelease background concentrations, wherever it is technically feasible to do so. Cleanup levels are set using ARARs and risk-based standards developed to protect all reasonable, foreseeable uses of the site and the surrounding environment.

The combination alternative is also similar to the process used under CERCLA to set cleanup levels. Under CERCLA, a combination of risk-assessment techniques and ARARs is used to arrive at a standard for each site.

Issues Associated with the Combination Alternative

The following issues are associated with the combination alternative. The resolution of these issues determines how the cleanup standards will be chosen under this alternative.

Incremental vs. Total Risk

First, it is assumed that an alternative should not be chosen if it results in a value that is below the natural background concentration. This assumption is based on the concept of *incremental risk.* Incremental risk is the additional risk associated with the release of hazardous substances at the site, over and above any risk that is associated with natural background concentrations of hazardous substances at a site. *Total risk* is the risk associated with the site from natural and anthropogenic causes. Because the standards apply to the release of toxic materials, Ecology believes the most appropriate concept to use is that of incremental risk. Because the natural background of a site is not associated with any incremental risk due to the hazardous waste release at the site, concentrations at or below this natural background level will carry an incremental risk of zero. In addition, cleanup below background would be difficult to maintain, due to the natural tendency of hazardous substances in the surrounding area to enter and recontaminate a site.

Routine and Permanent Cleanup Technology

Second, it is assumed that a standard may be set that is not currently achievable using routine and permanent cleanup technology. This assumption takes into account the present inability of permanent technology to achieve acceptable levels for all hazardous substances. A combination of isolation, removal and transport, and land-use control options may be used for these hazardous substances.

Derivation of Standards Under the Combination Alternative

The sequence of steps in the decision-making process under the combination alternative that would lead to the selection of the most appropriate cleanup level for a single hazardous substance is as follows: if one or more ARARs are available for a hazardous substance, the lowest of the ARARs would be used as long as the ARAR is not associated with a risk level greater than $1x10^{-5}$. If the ARAR is associated with a risk level greater than $1x10^{-5}$, or if no health-based ARAR is available, the risk-based concentration ($1x10^{-6}$ risk level for carcinogens and a hazard quotient of 1.0 for non-carcinogens) would be used. Either must be above the natural background concentration; otherwise, the natural background concentration would be used. If a risk-based number is below the PQL for a hazardous substance, the PQL would be used if the risk associated with that PQL is not greater than $1x10^{-5}$. Otherwise, a standard based on a risk of $1x10^{-5}$ would be used. If, for a given hazardous substance, a risk assessment based on CPFs and RfDs cannot be performed and no ARAR is available, the standard must be set through a health risk-based evaluation method. Other methods of risk assessment that do not rely on CPFs and RfDs are available.

Concentrations for individual hazardous substances would be adjusted to take into account exposure to multiple hazardous substances and exposure through multiple exposure pathways. In the majority of cases, cleanup actions must attain a total cancer risk of $1x10^{-5}$ and a hazard index of 1.0. The exception is that cleanup levels for individual hazardous substances would not be established at levels below natural background concentrations. As with all of the alternative approaches, Ecology's ability to enforce a particular cleanup level is constrained by current analytical capabilities. Consequently, a cleanup level would be considered to have been attained if the measured concentration of a hazardous substance was below the PQL. If the PQL is higher than the particular cleanup level, Ecology would evaluate the potential improvements in analytical capabilities during site reviews.

This approach to decision-making used in the combination alternative is easily illustrated by a flowchart (Figure 3). This flowchart contains the two key assumptions based on policy considerations described above. If these assumptions are modified, the steps in the flow chart must be rearranged.

The flowchart shown in Figure 3 would be used to derive standards under the combination alternative. However, concentrations associated with the different alternatives (and therefore with the outcome of applying the combination alternative to each hazardous substance) depend on the number of hazardous substances at each site, the interactions of these hazardous substances, relevant exposure pathways, and other site-specific factors.

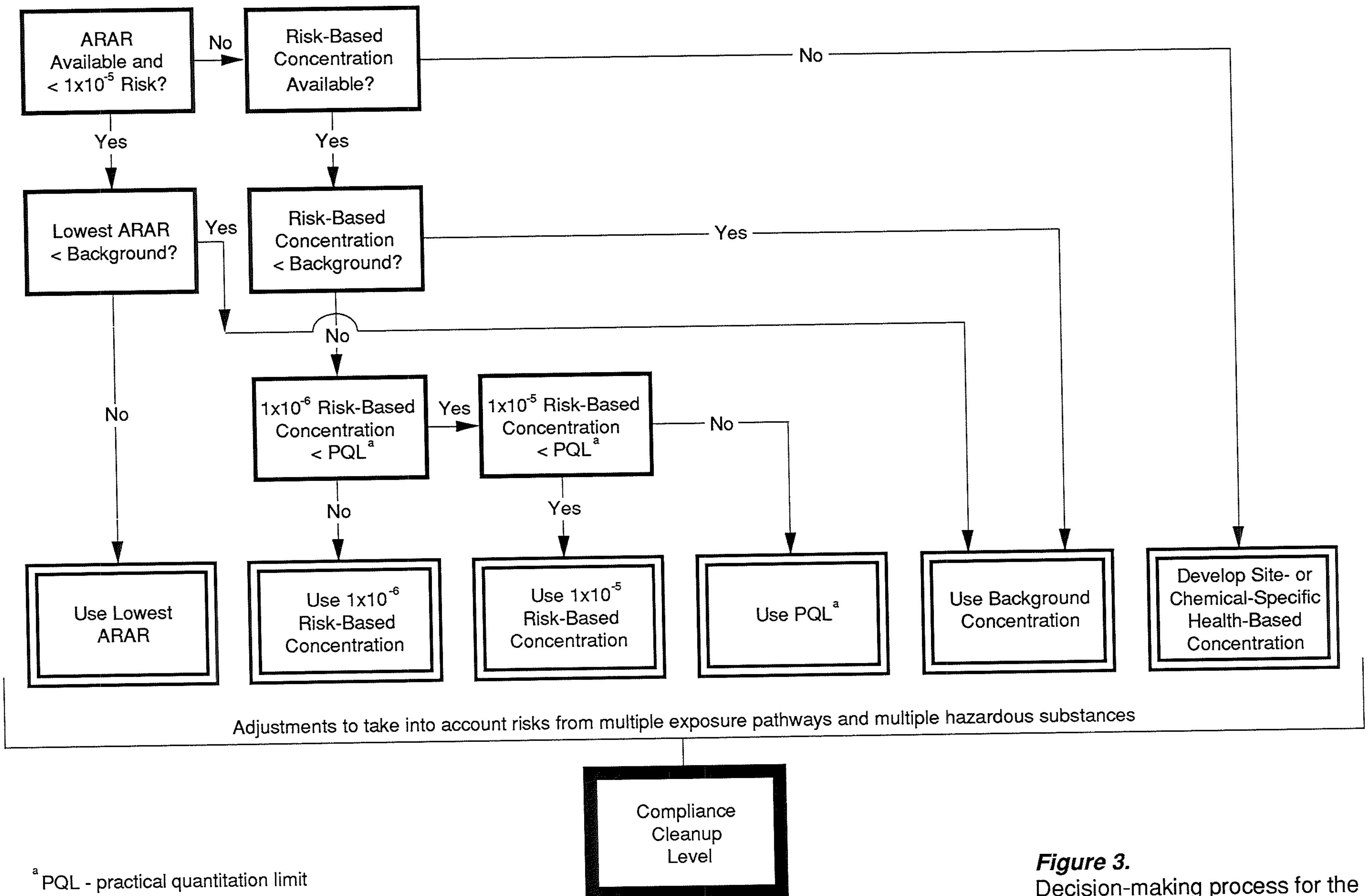
This approach is incorporated into the proposed cleanup rules (Chapter 173-340 WAC). In addition, the proposed rule provides a limited amount of flexibility to modify cleanup levels for individual hazardous substances based on consideration of background concentrations, net environmental impacts, technical feasibility, and technical practicability. The limits on total cancer risk of $1x10^{-5}$ and a hazard index of 1.0 still apply to these conditional cleanup levels.

Example Derivations

In the sections that follow, the flowchart for the combination alternative was applied to determine example standards for four hazardous substances. These example standards should not be considered final standards for these hazardous substances, as the regulations are still in draft form and are subject to change based on public comment. In addition, site-specific factors may cause the standard applied at any particular site to vary from the numerical standards cited in the draft regulations. Table 8 summarizes the example standards for the combination alternative (combination standards).

Cadmium

For cadmium, various ARARs for ground water are available. The lowest ARAR is also equal to the PQL. Therefore, the lowest ARAR (5 μg/L) would be chosen as the standard under the combination alternative. In surface water, the ARAR and risk-based standards are the same. Both are below the PQL, and the PQL is associated with less than $1x10^{-5}$ risk, so the PQL (5 μg/L)



[a] PQL - practical quantitation limit

[b] Other factors may be taken into account during implementation of the compliance cleanup level

Figure 3.
Decision-making process for the combination alternative [b]

TABLE 8. EXAMPLE STANDARDS FOR THE COMBINATION ALTERNATIVE

	Ground Water (μg/L)	Surface Water (μg/L)	Marine Water (μg/L)	Soil (mg/kg)	Air (ng/m^3)
Cadmium	5	5	9.3	0.5	0.56
Benzene	5	80	80	0.5	9,500
PCBs	0.1	0.0001	0.0001	1	1
PAH compounds	0.1	0.31	0.31	1	40

would be chosen as the combination standard. In marine water, the risk-based and ARAR standards are the same (9.3 μg/L), and both are greater than the PQL. Therefore, this concentration would be used as the combination standard. In soil, the ARAR is higher than the PQL. Therefore, the ARAR (0.5 mg/kg) would be used as the combination standard. In air, an ARAR is available, and no PQL is available (the PQL varies depending on the sampling procedure). Therefore, the ARAR (0.56 ng/m^3) would be chosen as the combination standard.

Benzene

In ground water, the ARAR (5 μg/L) would be used as the combination standard. In surface water (excluding consideration of drinking water) and marine water, there is no ARAR. The risk-based standard (80 μg/L) is greater than the PQL and would be used as the combination standard in both surface and marine water. The ARAR for soil (100 mg/kg) is within the $1x10^{-5}$ risk range and above the PQL. However, protection of ground water requires that a standard 100 times the drinking water MCL be used. Therefore, the soil standard under the combination alternative would be 0.5 mg/kg. In air, both the ARAR and the risk-based standards are below the ambient background concentration of most urban areas. The background standard (9,500 ng/m^3) would likely be used as the combination standard.

PCB Mixtures

In ground water, the ARAR is above the $1x10^{-5}$ risk level. Therefore, the $1x10^{-5}$ risk level (0.1 g/L) would be used. ARARs are also above risk-based levels for surface water and marine water; the $1x10^{-5}$ risk level (0.0001 g/L) would be used as the cleanup level. However, the ARAR for soil (1 mg/kg) is within the $1x10^{-6}$ to $1x10^{-5}$ risk range and would be used as the cleanup level. Only a risk-based standard (1 ng/m^3) is available for use as the combination standard for air.

PAH Compounds

There are no ARARs for use as cleanup levels for PAH compounds in water. The $1x10^{-6}$ risk-based levels are below the PQL for water; therefore, $1x10^{-5}$ risk levels would be used as the cleanup levels. For ground water, this level would be 0.1 g/L, and for surface water and marine water, the level would be 0.31 g/L. The ARAR for soil is well above the $1x10^{-5}$ risk level, as is the PQL. Therefore, the $1x10^{-5}$ risk level (1 mg/kg) would be used as the cleanup level. In air, both the risk-based levels and ARARs are below the ambient background of PAH compounds in urban areas; therefore, a background concentration (40 ng/m^3) would likely be used as the combination standard.

No-Action Alternative

Under this alternative, no new cleanup levels for hazardous waste sites would be set. Since the MTCA requires Ecology to promulgate cleanup levels that are at least as stringent as ARARs, the no-action alternative is not a legal option.

In the absence of regulations, and in the period of time preceding the promulgation of these proposed standards, ARARs would apply to any cleanup actions undertaken in the state of Washington. In these situations, the use of the strictest of these ARARs can be considered a reasonable definition of the no-action alternative. The ARARs that would apply in the absence of regulations are the same ARARs considered under the ARAR alternative. For the purposes of this EIS, the no-action alternative is identical to the ARAR alternative. The only difference between the two alternatives is that, under the ARAR alternative, the ARARs would be specifically promulgated under the MTCA. Under the no-action alternative, use of most ARARs would be required under various other state and federal laws.

Chapter 5
Affected Environment

The cleanup levels for hazardous waste sites will affect areas throughout Washington. SEPA defines a list of elements of the environment to be considered in an EIS. The elements of the environment that are expected to be affected by these cleanup levels are listed below:

Physical Environment:

- Ground water
- Surface water
- Marine water
- Soil
- Air

Biological Environment:

- Human health
- Plants and animals

Man-made Environment:

- Land and water use
- Transportation.

The affected environment corresponding to each of these elements is discussed in the following sections.

Ground Water

The location of the administrative and physical boundaries of ground water aquifers in Washington is shown in Figure 4. The alluvial and sedimentary deposits of the Puget Sound and southwestern regions extend into the foothills of the Cascades and are predomi-

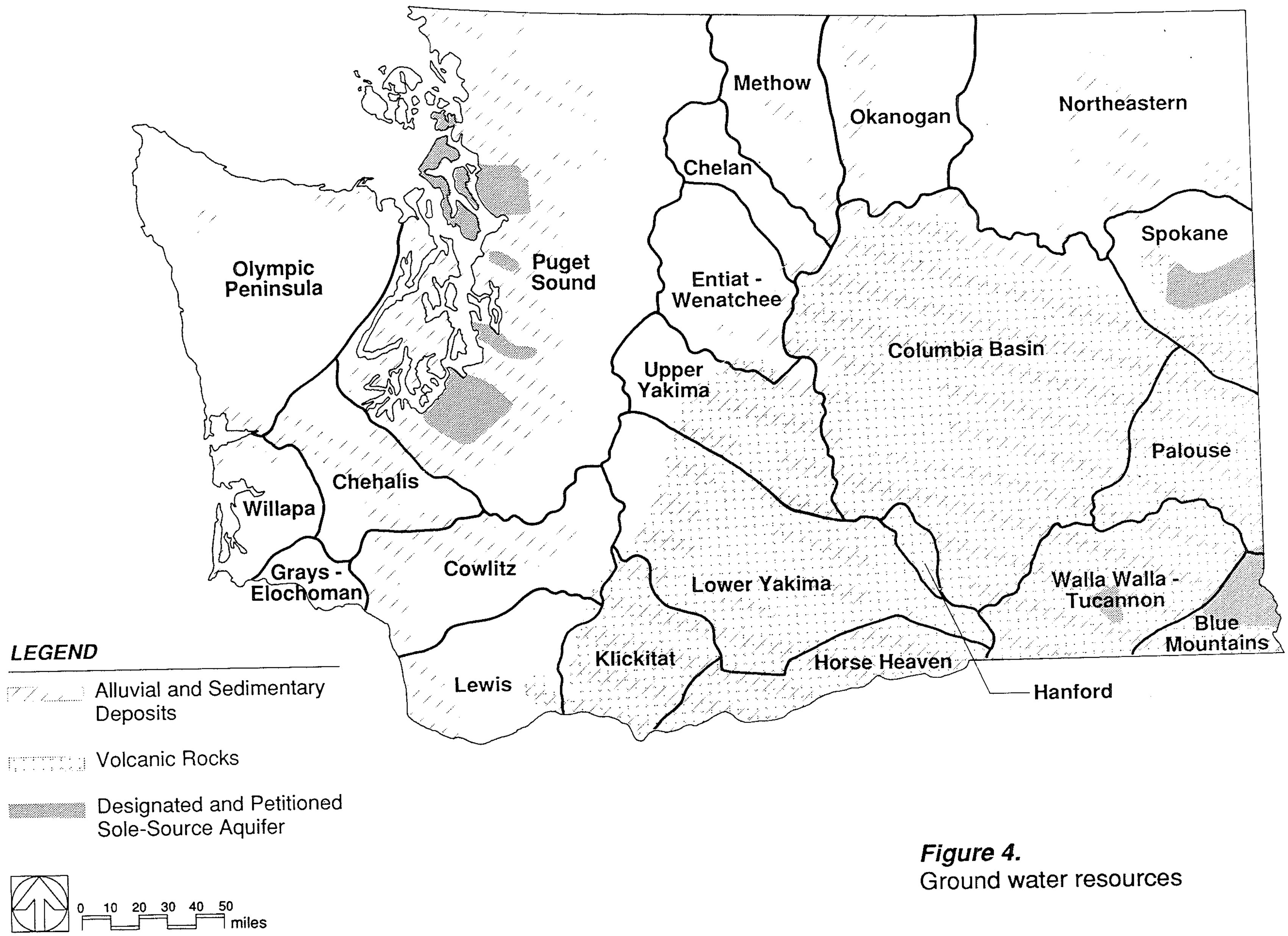


Figure 4.
Ground water resources

nantly associated with glacial till, alluvial deposits along river systems, and marine sands on the eastern side of the Olympic peninsula. The aquifers in the upper Spokane, Northeastern, Okanogan, Methow, Chelan, and Entiat-Wenatchee regions are also associated with glacial till or river sediments. Aquifers in the lower Spokane, Palouse, Blue Mountain, Walla Walla-Tucannon, Horse Heaven, Klickitat, and parts of the lower Yakima, upper Yakima, and Columbia basin regions are associated with basalt overlain with glacial till and alluvial deposits. Areas of the central Columbia basin, most of the lower Yakima region, and part of the upper Yakima region are characterized by basalt extending to the surface (Kimerling and Jackson 1985). Statewide, approximately 80 million acre-feet of ground water is stored in near-surface aquifers. The average annual replenishment of these aquifers is 7.5 million acre-feet (Washington 1989).

Ground water use for human activities in the state is summarized as follows. Nearly equal amounts (one-third each) are used for public water supply and irrigation. Industrial use, livestock watering, and other activities make up the final third. Nonhuman uses of ground water include recharge of rivers during periods of low flow and use of water by rooted plants. Ground water uses that are expected to be impacted by these regulations are discussed in more detail under land and water use.

Sensitive Ground Water Resources

The permeability of the geologic materials overlying an aquifer is one of the factors that determines the susceptibility of the aquifer to contamination. Both alluvial deposits and fractured basalt of the type common in the Columbia River basin are highly permeable (approximately 10^{-5} to 10^{2} cm/sec). Therefore, aquifers overlain by these materials are most sensitive to contamination from hazardous waste sites. Aquifers overlain with glacial till fall into a medium to low range of permeability but can be quite variable (approximately 10^{-10} to 10^{-4} cm/sec). The susceptibility of these aquifers to contamination will vary from site to site (Freeze and Cherry 1979).

An administrative classification under the Safe Drinking Water Act (40 CFR 149) lists aquifers requiring special protection because they are the sole sources of drinking water for large communities. The aquifers designated or petitioned as sole-source aquifers in Washington include aquifers underlying Spokane Valley, Lewiston basin in Asotin County, western Pierce County, Cedar Valley in King County, Cross Valley, the Newberg and Tulalip areas in

Snohomish County, and Whidbey and Camano islands in Island County. These aquifers are shown in Figure 4 (U.S. EPA 1988a).

Past and Current Impacts on Ground Water

A series of studies by USGS (1984, 1985, 1986b,c,d) analyze the ground water quality of the major aquifers of Washington. As part of these studies, hardness, salinity, dissolved solids, iron, manganese, trace metals, nitrate, and fecal coliform bacteria were measured. Of the hazardous substances of concern, analyses were conducted for arsenic, cadmium, chromium, copper, lead, and zinc. The data show isolated exceedances of the secondary MCL for copper and zinc and of the MCLG for lead. These exceedances are likely due to out-of-date plumbing systems and may not reflect actual aquifer conditions. In addition, occasional exceedances of the state or federal standards for drinking water were observed for chromium in the Hanford area and for arsenic in Spokane and Skagit counties. However, most of the ground water aquifers in the state meet all state and federal criteria for the protection of drinking water.

Very limited data are available to characterize the extent of regional aquifer contamination by volatile organic compounds. Data from Clark County (Wagner 1989) show the presence of trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane in some wells, but not at levels above drinking water standards. These three hazardous substances have also been-found in ground water in Spokane County, on some occasions exceeding drinking water standards (USGS 1986a).

Ethylene dibromide is a pesticide that has been found in wells in Thurston, Skagit, and Whatcom counties at levels that are often above the MCLG (DSHS 1985). A study of agricultural chemicals in Whatcom, Franklin, and Yakima counties is underway (Ecology 1989a). Preliminary results show the presence of pesticides, including ethylene dibromide, in approximately one-third of the wells in the study areas of Whatcom and Franklin counties. The presence of atrazine was recorded in one well in Yakima County. These hazardous substances are present primarily in shallow aquifers in agricultural areas. Pesticide concentrations exceeding MCLs were found in seven wells in Whatcom County.

Local ground water contamination resulting from releases from hazardous waste sites is being investigated by Ecology. Current data indicate that approximately 75 percent of the currently listed state hazardous waste sites potentially have ground water contamination. Approximately 50 percent of these sites are associated with contamination by metals, 44 percent by petroleum products, 29 percent by halogenated organic compounds, 24 percent by nonchlorinated solvents, 21 percent by pesticides, 20 percent by PAH compounds, 17 percent by phenols, and 14 percent by PCB mixtures. Rural counties are more likely to have ground water contaminated by pesticides and halogenated organic compounds, while counties with urban areas are more likely to have ground water contaminated by metals, petroleum products, and PAH compounds.

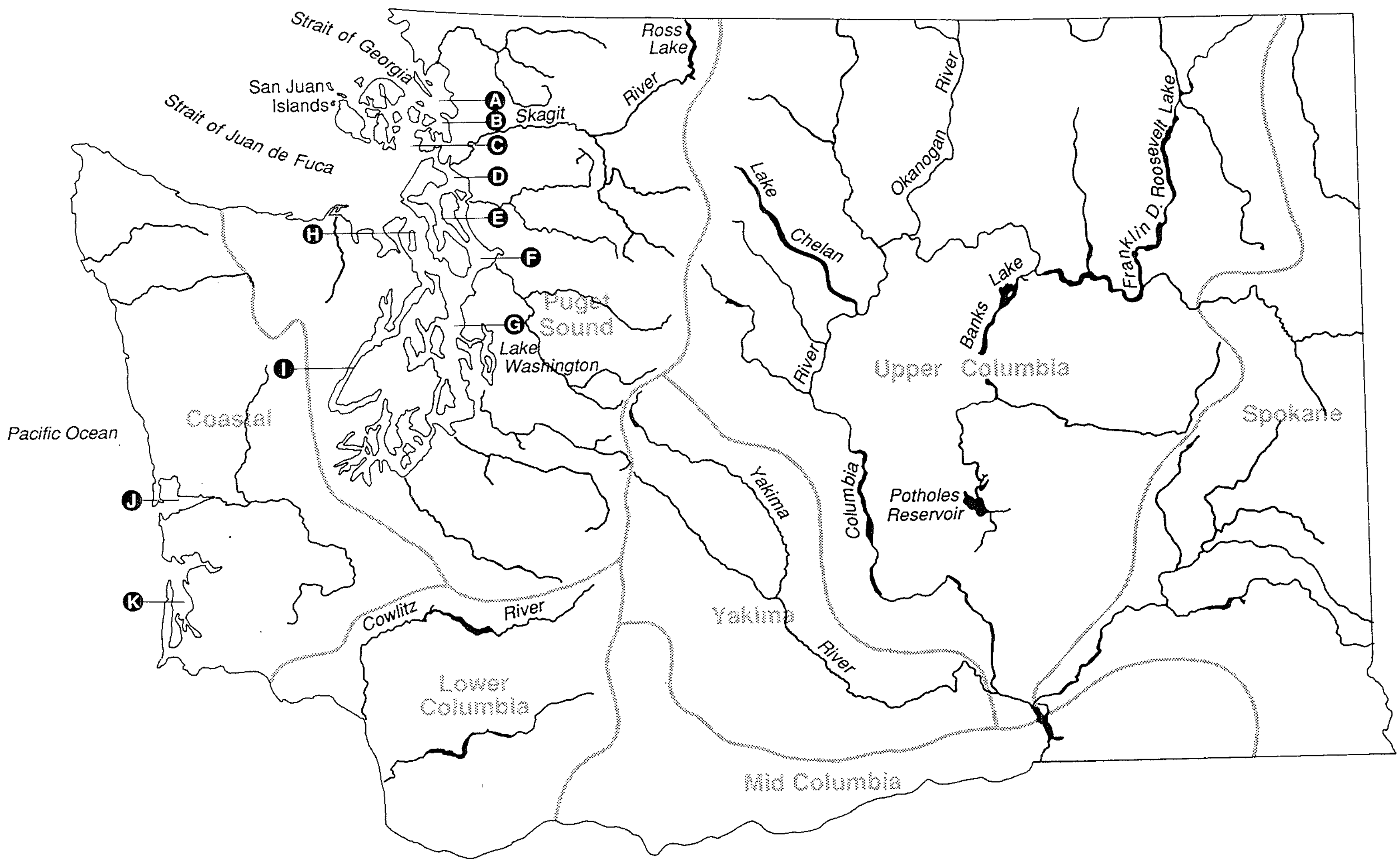
In summary, although the database for hazardous hazardous substances is still quite limited, certain conclusions can be reached. The quality of ground water in Washington is generally good. However, localized ground water contamination problems do exist. These problems are caused by a variety of sources, including agriculture, landfills, industrial hazardous waste sites, and sewage systems.

Surface Water

The locations of the major rivers, lakes, and watershed boundaries in Washington are shown in Figure 5 (Kimerling and Jackson 1985). The state is divided into eight drainage basins, of which the Puget Sound and Upper Columbia are the largest. East of the Cascade Mountains (70 percent of the total land area), surface water drains primarily into the Columbia River. West of the Cascade Mountains and east of the Olympic Mountains (20 percent of the total land area), surface water drains into Puget Sound. West of the Olympics (10 percent of the total land area), surface water drains into the Pacific Ocean. The average annual runoff statewide is 26 inches per year. There are 40,838 miles of river in Washington and over 8,000 lakes (Washington 1989).

Wetlands are a freshwater resource of particular interest to the state because of their capacity to support highly diverse plant and animal species, and because of their ability to dilute stormwater and decrease flooding. Major wetlands are located in river deltas in Puget Sound and along the Pacific coast. Wetlands generally occur on a very small scale. Interested persons are referred to the National Wetlands Inventory maps, available from the U.S. Fish and Wildlife Service, for information on wetlands in local areas.

Surface water use for human activities in the state is summarized as follows. More than 80 percent of surface water consumption is for agriculture, primarily in eastern Washington. Of the remaining use,



LEGEND

- A Bellingham Bay
- B Padilla Bay
- C Rosario Strait
- D Skagit Bay
- E Sarotoga Passage
- F Possession Sound
- G Puget Sound
- H Admiralty Inlet
- I Hood Canal
- J Grays Harbor
- K Willapa Bay

0 10 20 30 40 50 miles

Reference: Kimerling and Jackson (1985)

Figure 5.
Surface water and marine water resources

about one-third is used for public water supply and two-thirds are used for industrial and other uses. In-stream uses of surface water include support of fisheries and aquatic life, wildlife habitat, recreation, generation of hydroelectric power, and navigation. Surface water uses that are expected to be impacted by these regulations are discussed in more detail under land and water use.

Sensitive Surface Water Resources

The state water quality standards (Chapter 173-201 WAC) classify the surface waters of the state according to use. *Class AA* and *Lake Class* are used to designate rivers and lakes, respectively, whose water quality shall exceed criteria for all beneficial uses, including water supply; fish and shellfish migration, rearing, spawning, and harvesting; wildlife habitat; recreation; stock watering; and commerce and navigation. Although any contamination of surface water resources is considered important by Ecology, degradation of Class AA and Lake Class waters is of special concern because of the pristine nature of these waters. The following surface waters are classified AA or Lake Class:

- All surface waters lying within national parks, national forests, and wilderness areas
- All lakes not otherwise classified and their feeder streams
- Reservoirs with a mean detention time of greater than 15 days
- Tributaries to Class AA waters
- Specific rivers designated as Class AA by WAC 173-201-080.

Wetland areas are also provided special protection by various state and federal laws, including Section 404 of the Clean Water Act. In addition, surface waters used as drinking water sources are of special interest. A list of surface water bodies used to provide drinking water can be obtained from the Washington Department of Health.

Past and Current Impacts on Surface Water

WAC 173-201-080 also classifies surface waters of the state that are not suitable for drinking water. These waters have been degraded in most cases by human activities. The classification for these waters is B (good) or C (fair). The following rivers currently have a B classification: Crab Creek and its tributaries, Duwamish River from its mouth to Black River, Hoquiam River from its mouth to the DeKay Road bridge, Mill Creek from its mouth to the 13th

Street bridge in Walla Walla, Palouse River from its mouth to the south fork, Puyallup River from its mouth to river mile 1, Sulphur Creek, Walla Walla River from its mouth to Lowden, and Wishkah River from its mouth to river mile 6. No fresh waters in the state have received the C classification.

EPA Region 10 and Ecology are conducting ongoing assessments of river and lake quality under the Clean Water Act, and preliminary results are available (U.S. EPA 1989g). This study indicates that, of the rivers and lakes studied, 50 percent of the river segments and 78 percent of the lakes were safe for all beneficial uses. However, nearly all (95 percent) of these lakes are threatened with pollution problems. The causes of degradation of river segments were compiled; results show that 32 percent of degradation is caused by agriculture, 23 percent by dams and habitat modifications, 6 percent by urban runoff, 5 percent by silviculture, 5 percent by land disposal, 4 percent by construction, 1 percent by resource extraction, and 24 percent by miscellaneous sources. Degradation of lakes is caused by the following activities: approximately 25 percent by agriculture, 25 percent by urban runoff, and 50 percent by miscellaneous activities. The report concludes that most river degradation in Washington occurs in the eastern part of the state as a result of agricultural activities.

Some information on specific hazardous substances in surface waters is available. Metals concentrations have been measured in Lake Washington (Barnes 1976), Lake Union (Tomlinson et al. 1977), Lake Roosevelt (Johnson et al. 1988a), and the Puyallup and White rivers (USGS 1987). In Lake Washington, one water sample exceeded the water quality criterion for lead for the protection of aquatic life. Lake Union has copper concentrations ranging from 0.04 to 0.4 mg/L, below drinking water standards but above the criterion for the protection of aquatic life. Elevated zinc, copper, and cadmium levels measured in tributaries of Lake Roosevelt are attributed to historical mining activities along the tributaries. However, these levels are below all ARARs. Arsenic, cadmium, and copper concentrations in the Puyallup and White rivers are below drinking water standards but above criteria for the protection of aquatic life. Zinc concentrations are occasionally above the aquatic life criterion, and lead concentrations are consistently above the proposed MCL.

Toxicity from organic compounds has not been as extensively studied. However, there is evidence that the following rivers are impaired by organic compound toxicity (U.S. EPA 1988c, 1989g): some segments of the Columbia River, the ship canal and Lake

Union in Seattle, Spokane River at Long Lake, and Elwha River at the McDonald bridge. Organic compounds were also detected in the Puyallup River (USGS 1987), including methylene chloride, chloroform, toluene, naphthalene, phthalate esters, organic acids, ketones, alcohols, and ethers. Of the hazardous substances of concern, only tetrachloroethene exceeded the MCL. Tetrachloroethene, trichloroethene, benzene, and dichloromethane exceeded water quality criteria for the protection of aquatic life. It is anticipated that more areas will be found impacted by organic compounds as more data are collected.

The presence and persistence of DDT in the Yakima River drainage basin were evaluated by Johnson et al. (1988b). Tributaries identified as sources of DDT in the Yakima River are Birchfield drain, Granger drain, Sulphur Creek, and Spring/Snipes Creek. The concentrations of DDT in these tributaries were below the MCL but well above the criterion for the protection of aquatic life. One water sample in the Yakima River also had a DDT concentration in this range. The DDT concentration in the Yakima River and tributaries has been decreasing since 1970.

The loss of wetland areas has been studied by EPA Region 10 and the U.S. Army Corps of Engineers (U.S. EPA 1989g). In the past 8 years, just under 550 acres of wetlands have been lost from permitted activities. Since 1985, there has been a generally decreasing trend in wetland losses. Most wetlands have been affected in King, Grays Harbor, and Cowlitz counties, accounting for 72 percent of all affected wetlands. For example, the wetlands associated with the Puyallup, Duwamish, Samish, and Lummi rivers have been reduced to less than 10 percent of their original areas (Evans-Hamilton 1987). Most destruction of wetlands is not related to hazardous waste but is caused by dredging, diking, and filling operations; agriculture; development; and highway construction (Washington 1989).

Marine Water

Marine areas of the state include Puget Sound and its inlets, Hood Canal, Admiralty Inlet, Possession Sound, Strait of Juan de Fuca, Rosario Strait, Saratoga Passage, Skagit Bay, Padilla Bay, Bellingham Bay, waters in and around the San Juan Islands, Strait of Georgia, Grays Harbor, Willapa Bay, and the Pacific Ocean off the west coast of the Olympic peninsula. Figure 5 shows these areas.

Uses of marine water include support of fisheries and aquatic life, wildlife habitat, recreation, and navigation. Uses of marine water that are expected to be impacted by these regulations are discussed under land and water use.

Sensitive Marine Water Resources

Chapter 173-201 WAC designates marine water areas of the state whose water quality exceeds standards for all uses. These areas are considered special resources that must be protected against contamination. The following marine waters have been classified AA (extraordinary): Pacific Ocean coastal waters from Ilwaco to Cape Flattery, Hood Canal, Mukilteo, and north Puget Sound west of longitude 122°39'W, Possession Sound south of latitude 47°51'20"N, Puget Sound through Admiralty Inlet, and south Puget Sound south and west to longitude 122°52'30"W (Brisco Point) and longitude 122°51'W (northern tip of Hartstene Island), Sequim Bay south of the entrance, and the Strait of Juan de Fuca.

Past and Current Impacts on Marine Water

Chapter 173-201 WAC also designates marine water that has been degraded by human activities with classifications of B (good) or C (fair). The following marine areas have received a B classification: Budd Inlet south of Priest Point Park, inner Commencement Bay (except City Waterway), inner Everett Harbor, Grays Harbor east of longitude 123°59'W to the Chehalis River at Cosmopolis, and Oakland Bay west of longitude 123°05'W. City Waterway in Commencement Bay south and east of South 11th Street is classified C.

In general, the quality of marine waters in the state is high, except in urban bays. The concentrations of almost all hazardous substances fall well below aquatic toxicity criteria in Puget Sound and in ocean water (Romberg 1984). Arsenic concentrations are above ambient water quality criteria for the protection of human health through ingestion of fish and shellfish but are considered natural to the region.

Several studies have been performed on concentrations of hazardous substances in urban bays. Commencement Bay near Tacoma and Eagle Harbor on Bainbridge Island are now Superfund sites. Historically, concentrations of lead, copper, and zinc in Elliott Bay near Seattle have exceeded water quality criteria. These hazardous substances are thought to have entered the bay from storm drains and shipyards. Subsequently, due to pollution abatement programs, the concentrations of these hazardous substances have decreased to below 1 μg/L for copper and lead and below 5 μg/L for zinc

(Paulson et al. 1989). In Commencement Bay, elevated levels of copper and zinc have been measured, due to industrial activity and a copper smelter (Paulson et al. 1985).

Romberg (1984) found that, compared to ocean water, Puget Sound water had slightly elevated levels of volatile organic compounds, PAH compounds, PCB mixtures, and DDT. The concentrations of these hazardous substances were below water quality criteria (Romberg 1984). Elevated levels of chlorinated phenols, dioxin, and copper are known to affect fish in inner Grays Harbor (U.S. EPA 1989g). Elevated concentrations of PCB mixtures have been found in Elliott Bay, Commencement Bay, and Nisqually Reach (U.S. EPA 1989g).

Soil

Figure 6 shows the distribution of major soil types in Washington state (Kimerling and Jackson 1985). The Olympic peninsula, much of the Cascade range, and northeastern areas of the state are characterized by inceptisols, a soil order with little horizon development. Inceptisols along Puget Sound and the west coast of the Olympic peninsula contain a high degree of organic matter and support predominantly coniferous forests. Inceptisols in the Cascades and northeastern part of the state have high volcanic ash content. Ultisols prevail in southwestern Washington. Ultisols are highly leached acidic soils with extensive clay horizons. Ultisols in Washington are highly organic, are found on steep slopes, and are easily eroded. Alfisols, found north of Portland, Oregon, are reddish-brown, moist, and acidic soils, with moderate organic matter. These alfisols provide good farmland.

On the east side of the Cascades, mollisols predominate. The mollisols in Washington have an organically rich surface and provide good farmland when irrigated. These soils are especially suited for grain and forage. Aridisols are found in the rain shadow of the Cascades, primarily in Yakima and Grant counties. These desert soils are low in organic content and moisture and may contain calcium-rich horizons. Entisols occur along the southern Columbia River basin. These soils are sandy to loamy in texture and can accumulate salts.

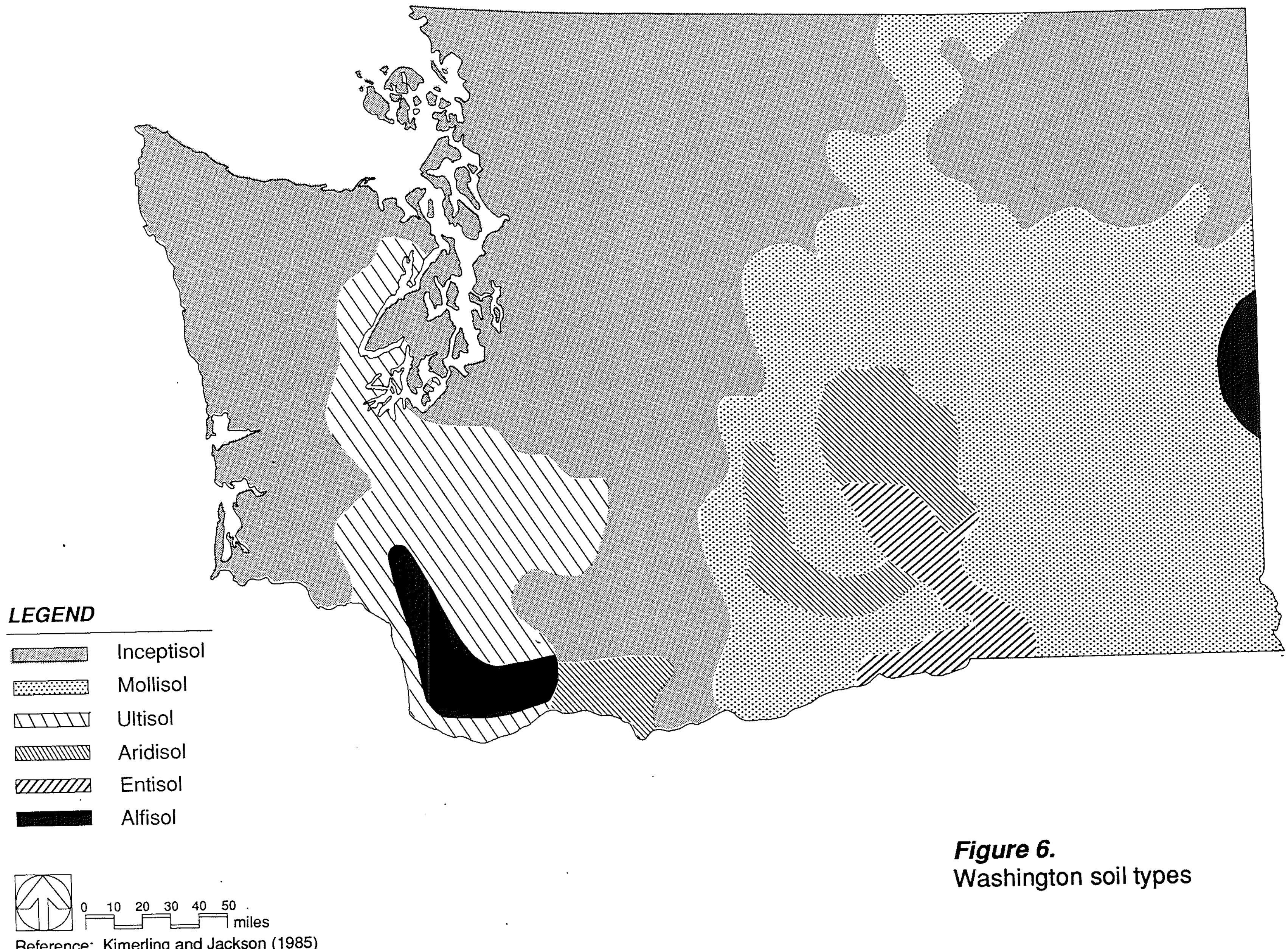


Figure 6.
Washington soil types

Past and Current Impacts on Soil

Widespread contamination of soils has seldom occurred outside urban areas, with the exception of federal facility sites and farmland where pesticides have been used. Contamination of soils by certain metals and organic compounds is ubiquitous in most cities. For instance, lead in gasoline and house paint has significantly contaminated many inner city soils. PAH compounds are emitted by most energy sources, including gasoline, wood-burning stoves, and coal. Because of their presence in gasoline, benzene, ethylbenzene, toluene, and xylene are often found in soils at gas stations. Soil contamination by metals and solvents is a common problem in industrial areas of large cities.

Agricultural use is another source of environmental contamination to the environment. Stevens (1970) compares pesticide concentrations nationwide in areas of regular pesticide use, little pesticide use, and no pesticide use. The regular use areas include two areas in Washington, apple orchards in Wenatchee, and root crop farms near Quincy and Moses Lake. DDT residues near Wenatchee ranged from 46 to 127 mg/kg, a range well above safe concentrations based on risk calculations. Arsenic concentrations from pesticide applications ranged from 32 to 205 mg/kg, again well above the risk-based concentration. By contrast, DDT concentrations near Quincy and Moses Lake were below 3 mg/kg, below the risk-based concentration. Arsenic values were between 1.5 and 27 mg/kg, within an order of magnitude of the risk-based concentration. DDT concentrations in areas of limited use nationwide were below 1 mg/kg. Only one sample from a no-use area contained any DDT. This study was performed in 1970, and it is expected that DDT concentrations have declined since then because of discontinued use. However, this study illustrates a pattern of pesticide contamination in areas of regular use.

Soil contamination from hazardous waste sites is being investigated by Ecology (1989f). Preliminary results indicate that 80 percent of the currently listed state hazardous waste sites may have soil contamination. Of these, 50 percent are associated with contamination by metals, 45 percent by petroleum products, 27 percent by halogenated organic compounds, 23 percent by nonchlorinated solvents, 20 percent by PAH compounds, 19 percent by pesticides, 16 percent by PCB mixtures, and 15 percent by phenols. Some sites have not yet been categorized.

Air

Air in Washington is largely divided into two regions, east and west of the Cascades, based on its characteristics. The prevailing air currents are from the northern Pacific Ocean, moving eastward across the state. These air masses pick up moisture from the Pacific Ocean and lose most of it in the form of rain or snow crossing the Olympics and Cascades. This process accounts for the rainy climate of western Washington and the relatively dry climate of eastern Washington. Because of this difference in precipitation, wet deposition (including scavenging of hazardous substances from the air) is the primary mechanism of hazardous substance deposition in western Washington, whereas dry deposition accounts for a much greater fraction of hazardous substance deposition in eastern Washington.

Sensitive Areas for Air Quality

Air quality in Washington is divided into three regions: Class I, Class II, and nonattainment areas. Classes I and II are administered under the *prevention of significant deterioration* section of the Clean Air Act. Class I areas, considered of special importance, include all national parks and wilderness areas, as well as any Indian reservations that choose to be listed (only the Spokane reservation has applied) (Figure 7). The air pollution regulations in these areas are more stringent than in other areas. The remaining areas of the state that have attained federal air pollution standards are Class II.

The Puget Sound area experiences nighttime inversions in the winter, often lasting well into the day, that trap pollutants emitted in urban areas near the ground. The Cascade Mountains also block pollutant transport, causing a buildup of air hazardous substances along the western foothills of the Cascades. These areas are especially vulnerable to air pollution episodes.

Past and Current Impacts on Air Quality

Of the hazardous substances of concern, arsenic and lead samples have been collected in the Puget Sound area (PSAPCA 1987). Air lead levels have declined significantly since 1980 due to the removal of lead in gasoline. The closing of a secondary lead smelter near Harbor Island in Seattle brought all Puget Sound areas into compliance with the federal ambient air quality standard. The principal source of arsenic in the Puget Sound area was the ASARCO Tacoma smelter in Ruston, which is now closed.

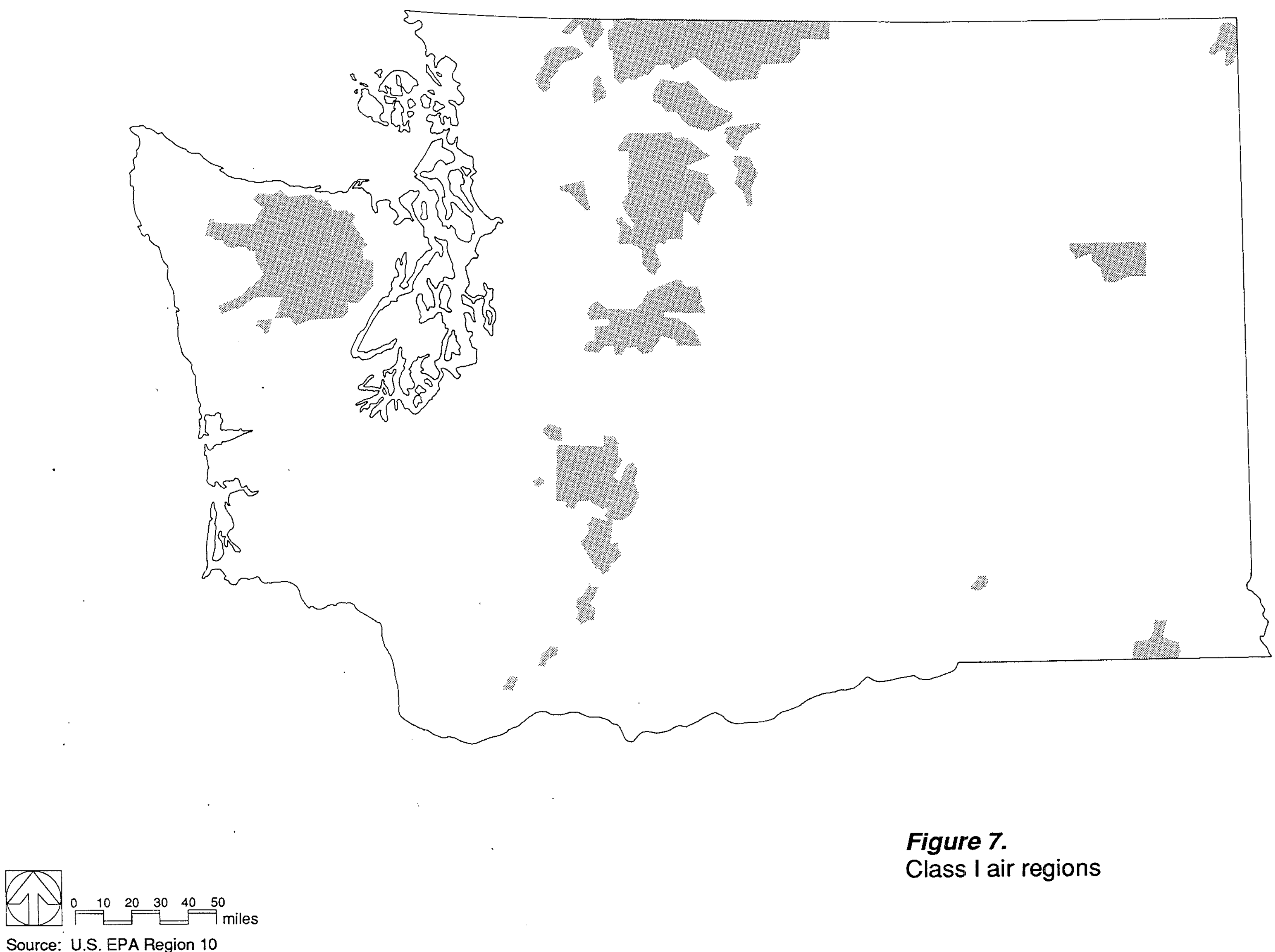


Figure 7.
Class I air regions

The sources of volatile organic compounds and toxic air hazardous substances have been compiled for the Puget Sound area, including King, Pierce, Snohomish, and Kitsap counties (PSAPCA 1987). For these counties, sources were categorized as point sources (industrial smokestacks) and area sources (residences, vehicles, and small businesses). For volatile organic compounds, 95 percent of the total emissions were from area sources; of these, 79 percent were transportation-related. For toxic air hazardous substances, 74 percent of total emissions were from area sources. About 40 percent of area sources were transportation-related and 60 percent were related to small businesses such as dry cleaning, diesel engines, surface coatings, and incineration. Industrial point sources were identified at a wide variety of businesses, with no single category dominating. Existing ambient air levels of benzene, toluene, chromium, arsenic, and dioxins, among others, pose significant health risks in some urban areas of the state (Washington 1989).

Volatile organic compounds are precursors of ozone and are regulated under the federal laws pertaining to ozone. One area of the state, Vancouver, is not in compliance with the federal ozone standard. Therefore, very strict technology-based standards may apply if volatile organic compounds are released during remediation of sites in this area.

An important source of air toxics in urban areas is wood smoke, accounting for up to 80 percent of particulate matter in some areas (Larson et al. 1988). Wood smoke is high in toxic products of incomplete combustion such as PAH compounds, formaldehyde, phenols, and dioxins (Washington 1989). PAH compounds measured in an area of north Seattle reached a median concentration of 38.7 ng/m^3, well above the state standard of 0.6 ng/m^3.

Air quality in some areas of the state is degraded by pollutants that are not regulated by the MTCA, such as sulfur dioxide, carbon monoxide, and total suspended particulates. These hazardous substances, if present in air, may make a person more susceptible to effects from other toxic air hazardous substances. Sulfur dioxide is a common air hazardous substance from pulp mills. Although in the past certain areas of the state experienced sulfur dioxide contamination problems, currently all areas of the state are in compliance.

Several areas of the state are out of compliance with carbon monoxide standards (carbon monoxide is primarily produced from automobile exhaust). These include areas of Seattle, Spokane, Tacoma, Everett, Vancouver, and Yakima. Particulates are an air pollution problem primarily caused by the use of wood stoves for residential heating. Washington state areas where particulate emissions are a problem include Seattle, Kent, Bellevue, Tacoma, Lacey, Yakima, Spokane, Kennewick, and Wallula.

Human Health

One of the principal difficulties in predicting impacts to human health is the diverse nature of human populations. This diversity affects both the potential exposure of any particular individual and that individual's susceptibility. In the following sections, the human population of Washington state is characterized with regard to physical location and the presence and nature of sensitive subpopulations.

Location of Human Populations

In 1987 there were 4,481,100 residents of Washington state. Almost 77 percent of this population was located west of the Cascades, primarily in the Puget Sound area (Figure 8). Three counties (King, Pierce, and Snohomish) held 52 percent of the population. Other significant population centers included Spokane County (7.9 percent), Yakima County (4.1 percent), and Clark and Cowlitz counties along the Columbia River (6.5 percent).

The known hazardous waste sites are concentrated in the areas of greatest population. Over 84 percent of the sites are west of the Cascades, located primarily around Puget Sound, and 52 percent are located in King, Pierce, and Snohomish counties. Spokane County has 3.4 percent of the sites, and Yakima County has another 4.2 percent. Eleven percent are in Clark and Cowlitz counties, primarily along the Columbia River.

Comparison of Figure 1 with Figure 8 illustrates the close correlation between population centers and hazardous waste sites in Washington. This relationship suggests that people are likely to be exposed to hazardous substances released or remaining in the environment as a result of actions taken under this program. Even when people do not reside in the immediate vicinity of a hazardous waste site, residential areas are generally nearby.

As shown in Table 9, population growth in the next 20 years is expected to be centered around Puget Sound and other population centers such as Spokane and Portland, Oregon. In these areas,

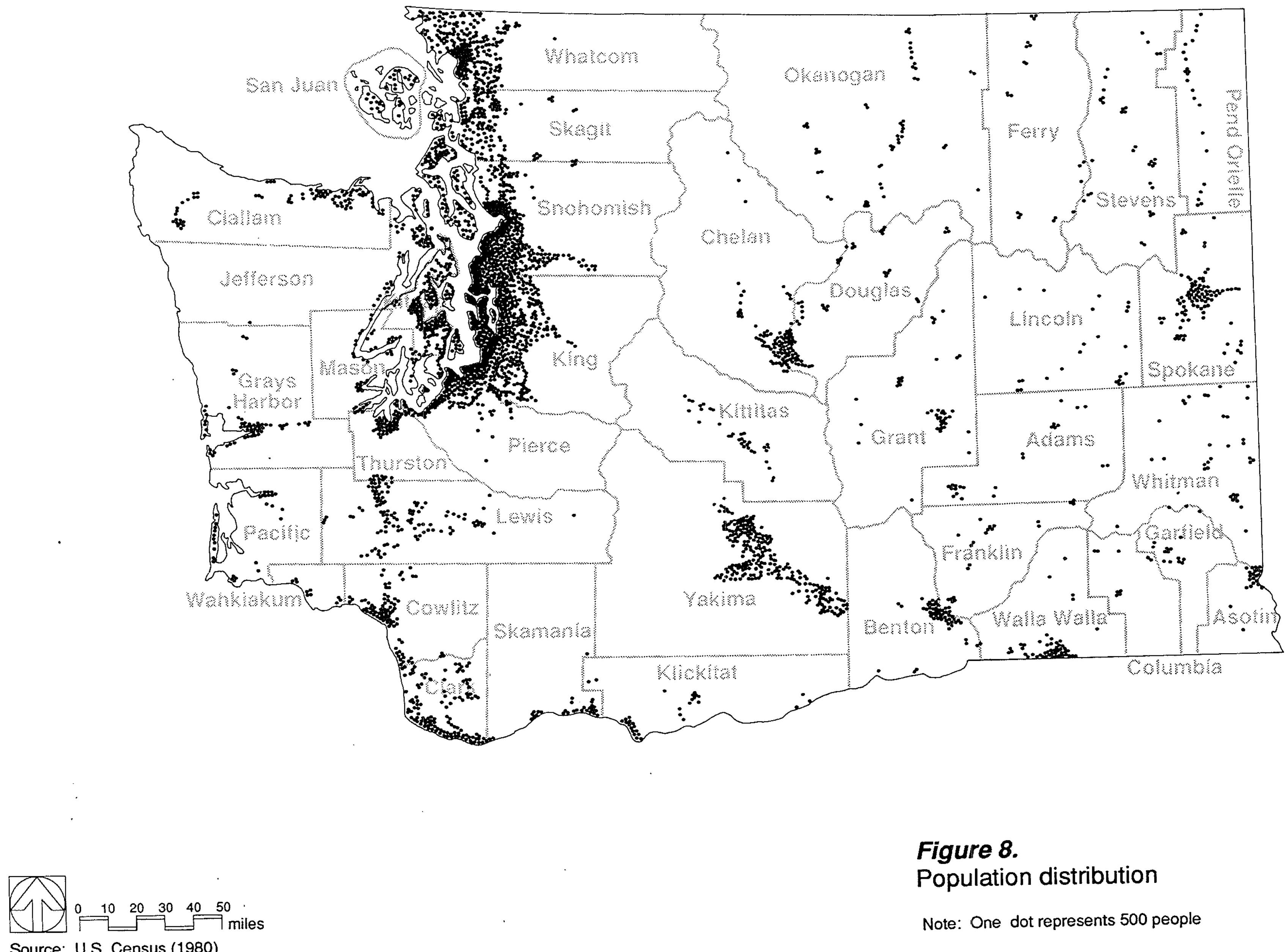


Figure 8.
Population distribution

Note: One dot represents 500 people

TABLE 9. POPULATION FORECAST

County	Region	1988 Population	2010 Population	% Change
Island	Puget Sound	53,400	87,600	+64.1
Snohomish	Puget Sound	409,500	671,200	+63.9
Thurston	Puget Sound	149,300	229,400	+53.6
Jefferson	Olympic Peninsula	18,600	28,400	+52.6
Kitsap	Puget Sound	177,300	267,800	+51.0
San Juan	Puget Sound	9,600	13,900	+44.6
Douglas	Central	24,100	33,300	+38.0
King	Puget Sound	1,413,900	1,947,600	+37.7
Pierce	Puget Sound	547,700	750,100	+36.9
Clark	Southwest	214,500	292,800	+36.5
Grant	Central	52,600	71,600	+36.0
Skagit	Puget Sound	70,800	95,300	+34.5
Mason	Olympic Peninsula	34,800	49,000	+33.2
Whatcom	Puget Sound	119,100	152,100	+27.7
Yakima	East Cascades	186,300	224,800	+20.7
Asotin	East	17,400	20,500	+17.6
Chelan	East Cascades	49,700	63,100	+17.1
Clallam	Olympic Peninsula	54,400	63,600	+16.9
Lewis	Southwest	57,400	62,300	+8.5
Spokane	East	354,100	382,800	+8.1
Cowlitz	Southwest	80,500	84,200	+4.6
Klickitat	Southwest	16,600	17,200	+3.7
Adams	East	14,000	15,800	+2.2
Stevens	North	30,200	30,800	+2.0
Skamania	Southwest	8,000	8,600	+1.3
Kittitas	East Cascades	25,500	25,500	0
Columbia	East	4,100	4,100	0
Ferry	North	6,100	6,100	0
Walla Walla	East	48,300	47,100	-2.5
Pacific	Olympic Peninsula	17,600	17,000	-3.5
Okanogan	North	31,700	30,500	-3.9
Lincoln	East	9,700	9,100	-8.5
Whitman	East	39,000	34,700	-11
Franklin	Central	35,500	30,600	-13.8
Grays Harbor	Olympic Peninsula	63,400	53,000	-16.4
Pend Oreille	North	8,800	7,000	-20.8
Benton	Central	104,100	82,100	-21.1
Garfield	East	2,400	1,800	-25.0
Wahkiakum	Southwest	3,500	1,700	-52.4

Source: Washington Department of Ecology.

population density will increase, especially in the suburbs and rural areas surrounding existing population centers. Certain types of hazardous waste sites, such as landfills, are often located in suburban areas of large cities. As the population around these cities increases, residential areas may expand until they are located near these hazardous waste sites, resulting in increased potential for exposure to hazardous substances.

Sensitive Human Subpopulations

A sensitive member of the population has been defined as "one who will experience an adverse health effect to one or more pollutants, significantly before the general population, because of one or more factors which predispose the individual to the harmful effects" (U.S. EPA 1984). For example, embryos and fetuses, children, reproductively active individuals, and aging populations may be more sensitive than average to hazardous substances in the environment. People with nutritional deficiencies, illnesses, previous exposures (often occupational), and certain genetic traits may respond differently to hazardous substances in the environment. Guidelines for acceptable levels of exposure must be stringent enough to protect these sensitive members of the population. All people fall into one or more of these groups for some part of their lives; it has been estimated that at any given time, 10-20 percent of a population is more sensitive than average to effects of hazardous substances in the environment (U.S. EPA 1984).

Typical examples of sensitive subpopulations are children and senior citizens. Both older people and children may be expected to have differences in metabolism compared to the rest of the population, which might affect their reactions to hazardous substances. Older people are expected to have a higher incidence of preexisting diseases that could cause them to be more sensitive to effects of hazardous substances. Small children have greater sensitivity to some hazardous substances because their bodies are still growing and developing. The developmental toxicity of lead is an example of such sensitivity. In addition, children generally receive higher doses than adults when exposed to the same concentration of a hazardous substance because they have higher intake rates. For example, a resting 6-year-old child inhales twice as much air as a resting adult per kilogram of body weight (U.S. EPA 1989c). Also, small children are likely to receive higher doses of hazardous substances in soil because of high rates of hand-to-mouth activity.

Healthy adults of an intermediate age may also experience differences in sensitivity because of differences in metabolism or differences in behavior. Hattis et al. (1987) estimate that differences in metabolism (how efficiently the body detoxifies and eliminates a hazardous substance) in normal healthy adults may be as much as 10-fold. Differences in behavior may also affect the dose that a person receives from a contaminated area. For example, an avid fisherman who catches and eats fish every weekend from a particular contaminated area will have a higher exposure to hazardous substances from that area than a person who never eats fish from that area.

Plants and Animals

Plants and animals of concern are found throughout the terrestrial, marine, and freshwater environments in Washington state. Terrestrial plants can be exposed to hazardous substances in soil, ground water, or air. Animals come into contact with hazardous substances in soil, surface water, and the plants they eat. Birds can be exposed through both terrestrial and aquatic food and water sources.

The freshwater environment includes all streams, lakes, rivers, and wetlands. Algae, grasses, and wetland vegetation are the principal plants in this environment. Aquatic plants are primarily exposed to hazardous substances is surface water, although exposures to air and sediment hazardous substances are also possible. Freshwater fish are primarily exposed to hazardous substances in surface water. Insect larvae and other invertebrates in the freshwater environment would be exposed primarily to hazardous substances in sediment. Sediments are addressed in a separate EIS.

The marine environment to be considered includes the waters of Puget Sound and areas along the Pacific coast. Marine sediment, water, and the sea-surface microlayer are exposure pathways that affect different types of aquatic plants and animals (for example, invertebrates and bottom-dwelling fish are exposed to sediments, free-swimming fish and marine mammals are exposed to water, and invertebrate larvae are present in the sea-surface microlayer).

Sensitive Areas

Geographic areas of special concern are those in which threatened or endangered species are found. Endangered species are those that are in danger of becoming extinct throughout all or a significant portion of their ranges. Threatened species are those that may become endangered in the foreseeable future. The distribution of threatened and endangered species is shown in Figure 9. The

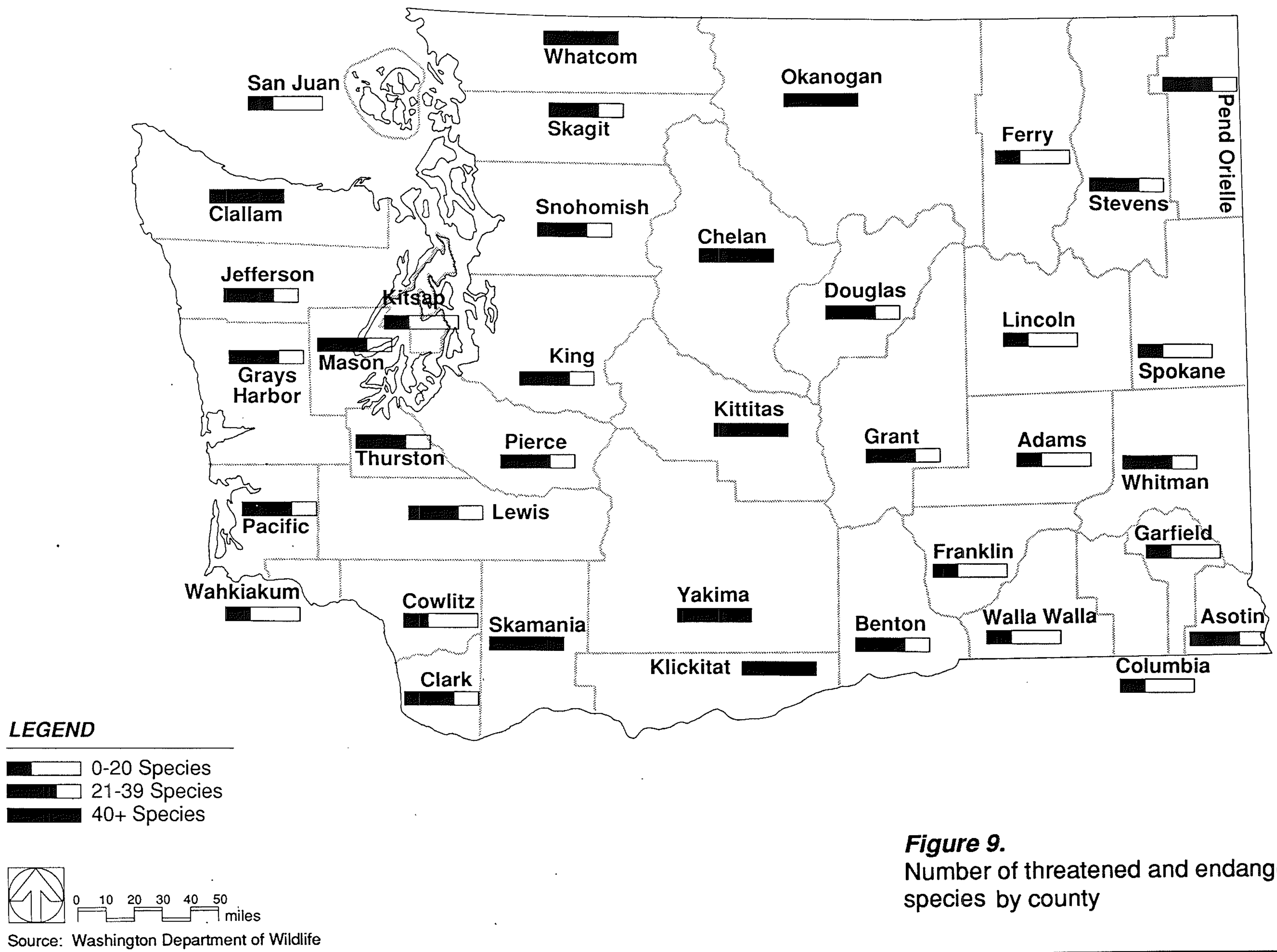


Figure 9.
Number of threatened and endangered species by county

highest numbers of these species are found in the Olympics and the Cascades, reflecting the specialized nature of many species inhabiting these temperate rain forests. Threatened and endangered plants and animals of Washington are listed in Tables 10 and 11,

Additional sensitive species occurring in Washington state are listed in the nongame data system of the Washington Department of Wildlife. The distribution of sensitive ecosystems has been mapped by the U.S. Army Corps of Engineers and is shown in Figure 10. Species may be identified as sensitive based on limited habitat, low abundance, or special exposures or sensitivities to harmful influences. Sensitive ecosystems include unique or critical habitats, as well as wildlife refuges, game parks, and wildlife recreation areas.

Land and Water Use

The distribution and intensity of land and water uses in the state of Washington are defined primarily by the distribution of natural resources and the population. The varied and rich natural resource base of Washington supports a wide variety of land and water uses ranging from consumptive uses such as drinking water, fisheries, forestry, and agriculture to nonconsumptive uses such as recreation and tourism.

The uses of water and land that may be affected by these regulations have been organized into the following sections:

- Drinking water
- Fisheries
- Agriculture
- Ranching
- Recreation
- Hunting
- Forests and logging
- Residential, commercial, and industrial areas.

TABLE 10. THREATENED AND ENDANGERED PLANT SPECIES

Common Name	Scientific Name	Status[a]
Onion, Blue Mt.	*Allium dictuon*	T
Wormwood, northern	*Artemisia campestris*	T
Aster, Jessica's	*Aster jessicae*	T
Milk-vetch, Columbia	*Astragalus columbianus*	T
Milk-vetch, Cotton's	*Astragalus cottonii*	T
Milk-vetch, Ames	*Astragalus pulsiferae*	T
Milk-vetch, Whited's	*Astragalus sinuatus*	E
Reedgrass, thickglume	*Calamagrostis crassiglumis*	T
Sego lily, long-bearded	*Calochortus longebarbatus*	T
Indian-paintbrush, obscure	*Castilleja cryptantha*	T
Indian-paintbrush, golden	*Castilleja levisecta*	E
Corydalis, Clackamas	*Corydalis aquae-gelidae*	T
Lady's-slipper, yellow	*Cypripedium calceolus*	E
Lady's-slipper, clustered	*Cypripedium fasciculatum*	T
Larkspur, pale	*Delphinium leucophaeum*	T
Larkspur, Wenatchee	*Delphinium viridescens*	E
Eatonella	*Eatonella nivea*	T
Daisy, basalt	*Erigeron basalticus*	T
Daisy, Howell's	*Erigeron howellii*	T
Coyote-thistle, Oregon	*Eryngium petiolatum*	T
Stickseed, showy	*Hackelia venusta*	E
Goldenweed, Palouse	*Haplopappus liatriformis*	T
Howellia	*Howellia aquatilis*	E
Twayblade	*Liparis loeselii*	E
Desert-parsley, Rollins'	*Lomatium rollinsii*	T
Desert-parsley, Suksdorf's	*Lomatium suksdorfii*	T
Desert-parsley, Hoover's	*Lomatium tuberosum*	T
Lupine, Sabin's	*Lupinus sabinii*	T
Lupine, Kincaid's sulfur	*Lupinus sulphureus*	T
Microseris, coast	*Microseris bigelovii*	T
Navarretia, marigold	*Navarretia tagetina*	T
Adder's-tongue	*Ophioglossum vulgatum*	T
Beardtongue, Barrett's	*Penstemon barrettiae*	T
Rockmat, Chelan	*Petrophytum cinerascens*	T
Phacelia, sticky	*Phacelia lenta*	T
Bog-orchid, Choriso	*Platanthera chorisiana*	T
Bluegrass, seacliff	*Poa pachypholis*	T
Polemonium, Washington	*Polemonium pectinatum*	E
Buttercup, obscure	*Ranunculus reconditus*	T
Yellowcress, persistentsepal	*Rorippa columbiae*	E
Raspberry, northwest	*Rubus nigerrimus*	T
Checker-mallow, hairy-stemmed	*Sidalcea hirtipes*	T
Checker-mallow, Oregon	*Sidalcea oregana*	T
Silene, Seely's	*Silene seelyi*	T
Silene, Spalding's	*Silene spaldingii*	T
Blue-eyed grass, pale	*Sisyrinchium sarmentosum*	T
Sullivantia, Oregon	*Sullivantia oregana*	T
Tauschia, Hoover's	*Tauschia hooveri*	T
Clover, Thompson's	*Trifolium thompsonii*	T

Source: Washington Department of Natural Resources.

[a] T - threatened
E - endangered.

TABLE 11. THREATENED AND ENDANGERED ANIMAL SPECIES

Common Name	Scientific Name	Status[a]
Oregon silverspot fritillary	*Speyeria zerene hippolyta*	T
Leatherback	*Dermochelys coriacea*	E
American white pelican	*Pelecanus erythrorhynchos*	E
Western pond turtle	*Clemmys marmorata*	T
Green turtle	*Chelonia mydas*	T
Brown pelican	*Pelacanus occidentalis*	E
Peregrin falcon	*Falco peregrinus*	E
Bald eagle	*Haliaeetus leucocephalus*	T
Ferruginous hawk	*Buteo regalis*	T
Sandhill crane	*Grus canadensis*	E
Snowy plover	*Charadrius alexandrinus*	E
Upland sandpiper	*Bartramia longicauda*	E
Spotted owl	*Strix occidentalis*	E
Pygmy rabbit	*Sylvilagus idahoensis*	T
Woodland caribou	*Rangifer tarandus*	E
Gray wolf	*Canis lupus*	E
Grizzly bear	*Ursus arctos*	E
Sea otter	*Enhydra lutris*	E
Gray whale	*Eschrichtius robustus*	E
Sei whale	*Balaenoptera borealis*	E
Fin whale	*Balaenoptera physalus*	E
Blue whale	*Balaenoptera musculus*	E
Hump-backed whale	*Megaptera novaeangliae*	E
Black right whale	*Balaena glacialis*	E
Sperm whale	*Physeter macrocephalus*	E

Source: Washington Department of Wildlife.

[a] T - threatened
E - endangered.

Figure 10.
Sensitive ecosystems

Drinking water and fisheries are primarily water-related resources, while cropland, ranches, recreational areas, and hunting areas are resources related to both water and land. Land-based resources include forests and residential, commercial, and industrial areas. Certain other uses of water, such as navigation and hydroelectric power generation, are not expected to be affected by water quality and are therefore not addressed in this EIS. Natural resources have been described in previous sections of this chapter; this section describes the affected environment that supports human uses of water and land.

Drinking Water

One of the most important water resources to humans is drinking water. Based on data for drinking water systems with 100 or more connections, 69 percent of the state's drinking water comes from ground water (DOH 1989). However, the use of ground water and surface water varies considerably among counties (Figure 11). For example, 13 counties (primarily in eastern Washington) derive all of their drinking water from ground water, and 11 counties (primarily in western Washington) derive most of their drinking water from surface water. No counties depend solely on surface water as a source of drinking water (DOH 1989). Table 12 summarizes water use by source and by county. Statewide, 11 percent of water use is for domestic use.

Fisheries

Some of the most important natural resources commercially harvested in Washington come from the state's fisheries. Fisheries are also important for their recreational value. The nontribal commercial harvest of fish and shellfish occurs exclusively in marine waters of the state (Puget Sound, the Strait of Juan de Fuca, and along the coast including Grays Harbor and Willapa Bay) and in the Columbia River (upstream to the Vancouver area). The fish species of highest commercial value include salmon, black cod, sole, flounder, pollock, and halibut. The 1988 values of the commercial harvest of these fish totaled $80,884,000 for salmon, $10,589,000 for other anadromous fish, and $44,173,000 for marine fish (DOF 1987). Important shellfish harvests include hardshell clam, geoduck, crab, Pacific oyster, mussel, octopus, scallop, crayfish, sea cucumber, sea urchin, and shrimp (DOF 1987). The value in 1987 of the statewide commercial shellfish harvest was $44,296,000.

The most important recreational fishery in the state is the salmon fishery. Salmon are caught recreationally from marine waters, estuaries, and major rivers throughout the state (Figure 12). Anglers pursue salmon from the shore, by private boat, and by charter

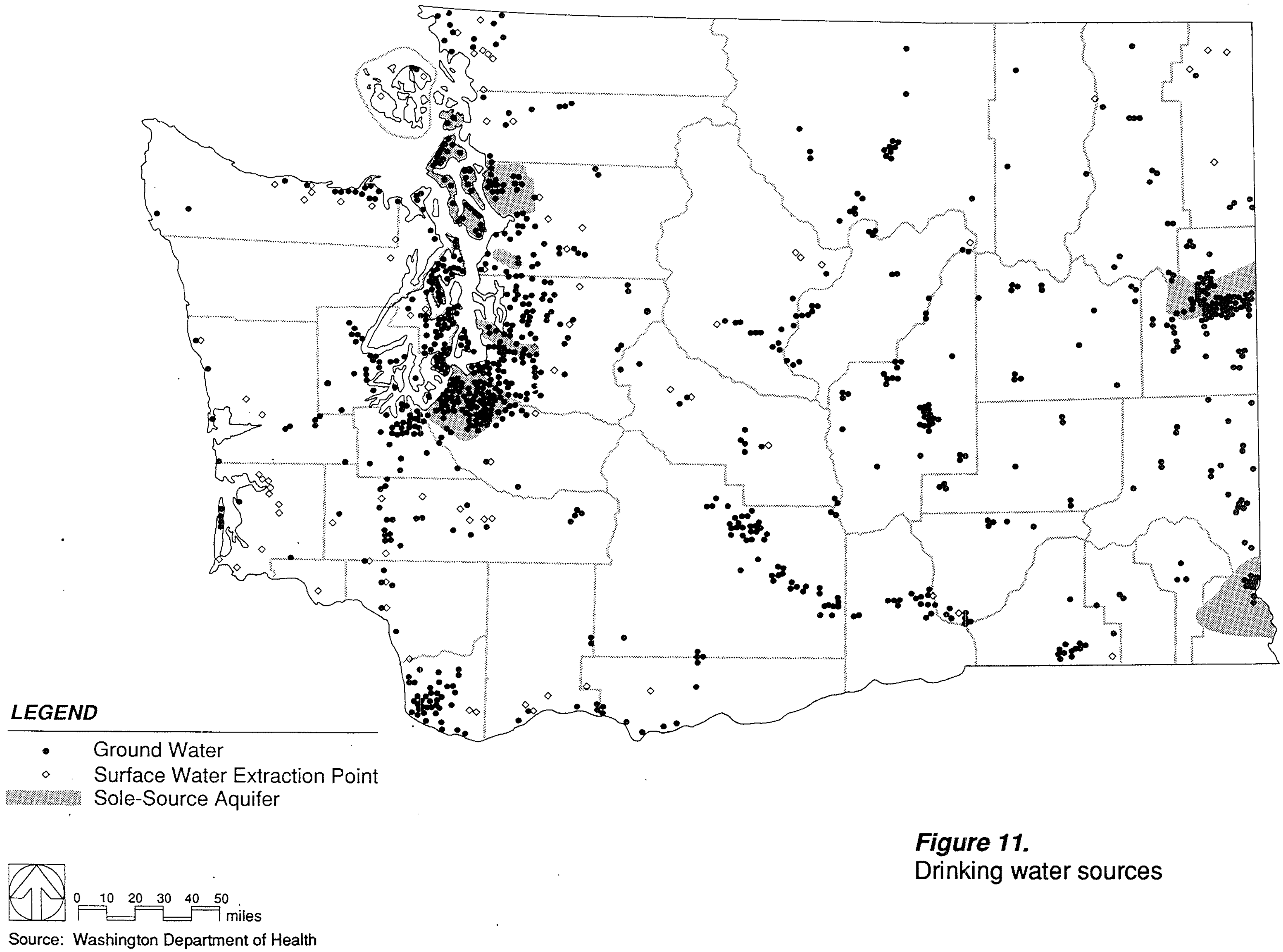


Figure 11.
Drinking water sources

TABLE 12. SOURCES OF DRINKING WATER BY COUNTY

County	Surface Water		Ground Water	
	Gallons per Minute	Percent of Total	Gallons per Minute	Percent of Total
Adams	0	0	14,680	100
Asotin	0	0	19,199	100
Benton	26,033	41	37,207	59
Chelan	10,640	22	38,016	78
Clallam	14,547	36	25,950	64
Clark	0	0	69,478	100
Columbia	0	0	2,810	100
Cowlitz	16,350	78	4,617	22
Douglas	0	0	11,007	100
Ferry	0	0	1,692	100
Franklin	12,500	61	7,940	39
Garfield	0	0	2,378	100
Grant	0	0	61,776	100
Grays Harbor	5,700	31	12,495	69
Island	0	0	9,964	100
Jefferson	17,800	88	2,421	12
King	229,616	64	127,309	36
Kitsap	17,483	33	35,520	67
Kittitas	2,500	17	12,425	83
Klickitat	1,600	21	5,928	79
Lewis	9,329	49	9,727	51
Lincoln	0	0	11,510	100
Mason	0	0	13,853	100
Okanogan	2,000	12	15,225	88
Pacific	5,735	85	974	15
Pend Oreille	3,300	69	1,508	31
Pierce	60,500	20	242,091	80
San Juan	1,265	75	420	25
Skagit	46,950	85	8,495	15
Skamania	1,675	54	1,425	46
Snohomish	94,474	79	24,941	21
Spokane	0	0	443,748	100
Stevens	1,200	7	15,912	93
Thurston	0	0	37,693	100
Wahkiakum	350	54	300	46
Walla Walla	10,300	21	38,389	79
Whatcom	45,664	77	13,314	23
Whitman	0	0	22,853	100
Yakima	13,900	23	46,153	77
TOTAL	**651,411**	**31**	**1,451,343**	**69**

Reference: DOH (1989).

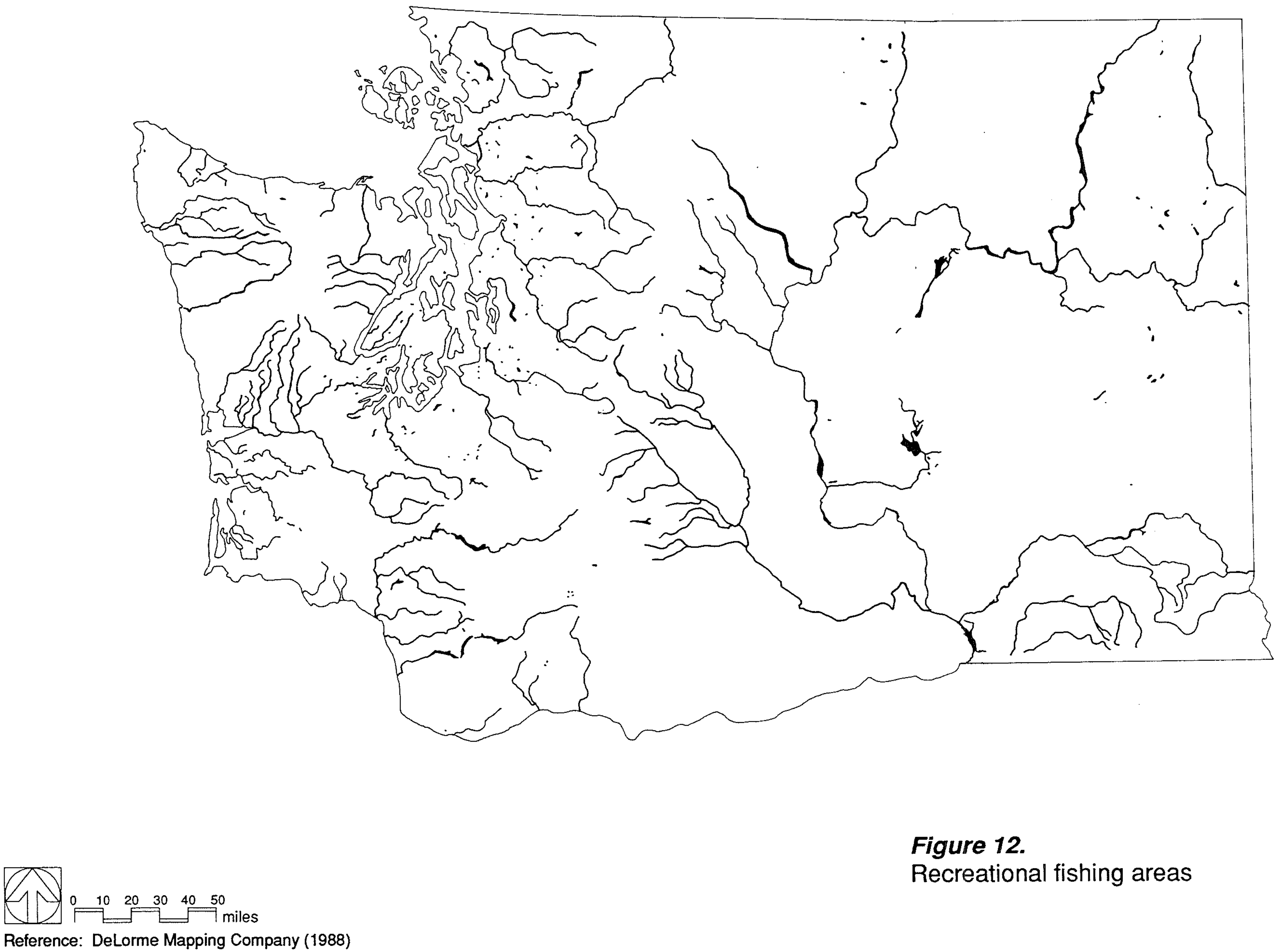


Figure 12.
Recreational fishing areas

boat. Other marine and estuarine fish sought by recreational anglers include halibut, sole, flounder, rockfish, cod, pollock, whiting, and sculpin. The total 1987 recreational catch in Puget Sound was 747,488 fish. The 1987 recreational catch along the coast was 390,704 fish (DOF 1987).

In addition to marine fisheries, there is statewide freshwater fishing for trout, bass, catfish, dolly varden, walleye, and perch. Freshwater game fish are pursued by anglers in all major river systems of the state, in a large number of mountain lakes ranging in elevation from a few hundred feet to over 10,000 feet, and in lakes and reservoirs in eastern Washington (Figure 12). Data have not been collected to determine the value and number of fish caught recreationally. The Washington Department of Wildlife issued 665,000 fishing licenses from January through October 1989 (DOW 1989). The Puget Sound region is the area of the state used most intensively for the recreational harvest of shellfish. In 1986, 3,324,900 pounds of hardshell clams was harvested in Puget Sound. In Hood Canal, 57,700 pounds of oysters and 120,317 pounds of shrimp were harvested in 1987. In 1987, 2,447,000 razor clams were harvested along ocean beaches (DOF 1987).

Numerous Indian tribes across the state harvest fish and shellfish in commercial and subsistence fisheries. The salmon and steelhead fisheries are the most important tribal commercial harvest. In 1987, 4,500,000 salmon were harvested in Washington by Indian tribes, accounting for approximately 50 percent of the salmon harvest in Washington. This tribal harvest includes commercial, ceremonial, and subsistence uses (MacDonald 1989). The largest tribal fisheries are those of the Lummi, Swinomish, Tulalip, Skokomish, Squaxin, Makah, Suquamish, Port Gamble Clallam, Puyallup, Quinault, Upper Skagit, Muckelshoot, Nooksack, and Yakima tribes, each landing over 100,000 salmon in 1987 (DOF 1987). Eighty-one percent of these salmon were harvested in marine areas and 19 percent were taken from rivers (DOF 1987). No reliable data are available to quantify the value of tribal subsistence fisheries. The total value of these fisheries includes the monetary value (market value) of the catch plus spiritual and cultural values attributed to the resource by the tribes.

Agriculture

Agriculture plays a major role in land and water use in Washington state. Figure 13 shows the distribution of cropland in Washington. In 1982, there was a total of 7,793,400 acres of cropland, making up 25.8 percent of the total land area of the state (Kimerling and

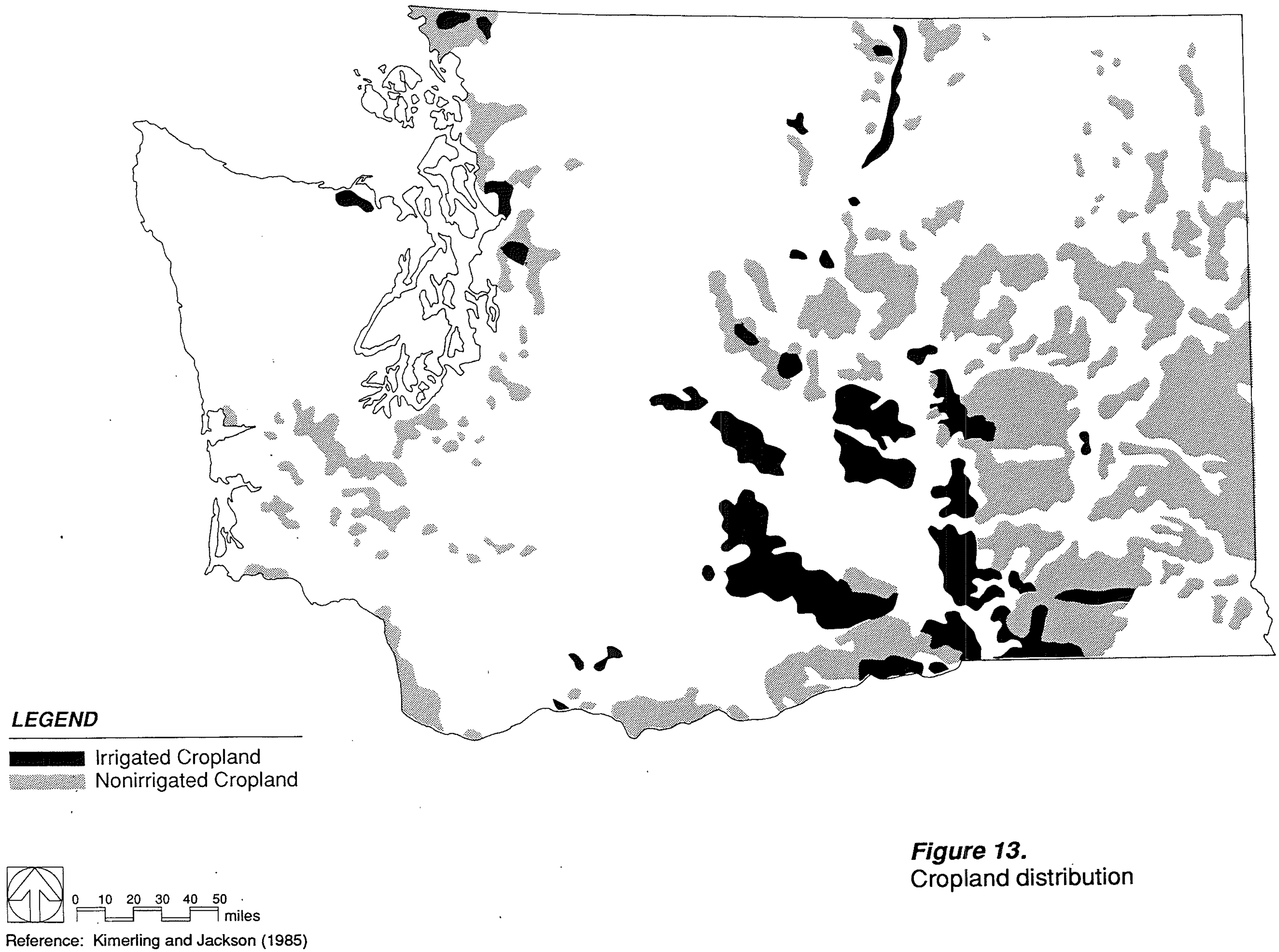


Figure 13.
Cropland distribution

Jackson 1985). Agricultural businesses in Washington grossed $934 million in 1988 (DOR 1989).

In 1982, approximately 21 percent of all cropland (1,653,400 acres) was irrigated (Kimerling and Jackson 1985). Surface water is the primary source of irrigation water in eastern Washington. In western washington, ground water is the primary source. There is no interregional distribution system for irrigation water. Therefore, most irrigated cropland is located near major surface water bodies.

Of the 6,140,000 acres of nonirrigated cropland in the state, most is located east of the Cascade Mountains. Western Washington contains areas of nonirrigated cropland distributed in relatively small patches in the alluvial plains of most major river systems. There is little nonirrigated cropland on the Olympic peninsula.

Ranching

In general, areas used for ranching (including cattle ranching, dairy production, and poultry production) are the same as those used for cropland, because of similar requirements for good pasture and water for livestock. Land devoted to ranching covers 16 percent of the state (Washington 1989). In eastern Washington, large areas near the Yakima River and Columbia River (particularly in Walla Walla County) and a large area spanning almost the entire width of Okanogan County are used for ranching. Other smaller ranching areas are found in nearly every other eastern Washington county with the possible exception of Chelan County. Relatively small ranching areas in western Washington can be found near major river systems. Most of the Puget lowlands and much of Lewis, Grays Harbor, and Thurston counties are used for ranching (excluding urban areas, cropland, and national forests). In 1986, there were 1,300,000 cattle, 50,000 hogs, 59,000 sheep, and 5,700,000 poultry raised in Washington (Hoffman 1989).

Recreation

There are many national and state parks in Washington. On the Olympic peninsula, the Olympic National Park occupies an area of 911,416 acres including the central Olympic mountain range and a strip 2 miles wide along the Pacific coast from just south of Neah Bay to Queets. Mount Rainier National Park occupies 235,404 acres within the Snoqualmie National Forest. North Cascades National Park occupies 504,554 acres of the Cascade Mountains, extending from the Canadian border to Lake Chelan. North Cascades National Park includes the Ross Lake and Lake Chelan national recreation areas. There are over 130 state parks and historic parks scattered throughout the state. Other important recreational areas in Washington include:

- Pacific Crest National Scenic Trail extending along the crest of the Cascade Mountain range the entire length of the state
- Coulee Dam National Recreation Area extending northward along the Columbia River (Franklin D. Roosevelt Lake) north of the Grand Coulee Dam at Electric City
- Mount St. Helens National Volcanic Monument encompassing 110,000 acres around Mount St. Helens between the towns of Glenoma and Cougar.

Hunting

All major public hunting areas of the state are within national forests and wildlife areas. An unknown amount of private land is also used for hunting. In the first 10 months of 1989, 357,000 big game licenses were issued (DOW 1989). Animals hunted include bear, cougar, moose, deer, elk, antelope, mountain goat, sheep, rabbit, and numerous game birds including quail, pheasant, turkey, Canada geese, and several duck species.

Forests and Logging

Forest lands cover 56 percent of the state. Approximately one-half of the forested area is contained within nine national forests and other public lands (Washington 1989). The Olympic National Forest in Clallam, Jefferson, and Mason counties consists of 649,975 acres of woodland on the north, east, and south sides of the Olympic National Park. National forest land spans the entire length of the Cascade range, where there is a total of 6,790,156 acres in four national forests (Mount Baker-Snoqualmie, Okanogan, Wenatchee, and Gifford Pinchot). The other national forest areas consist of a portion of the Okanogan National Forest in Okanogan and Ferry counties, the Colville and Kaniksu national forests (1,215,304 acres) in Ferry and Pend Oreille counties, and the Umatilla National Forest in Columbia and Asotin counties (1,400,000 acres in Washington and Oregon). These forests support a logging industry with gross revenues in 1988 of $109 million. The logging industry, in turn, supports lumber, wood, and paper products industries that grossed $9 billion in 1988 (DOR 1989).

Residential, Commercial, and Industrial Areas

Residential, commercial, and industrial land uses are concentrated in and around urban centers, which cover approximately 7 percent of the state's area (Washington 1989). Approximately 75 percent of Washington's population resides in the Puget Sound area, concentrated in the Seattle-Tacoma corridor. These and other urban centers in eastern and western Washington are shown on Figure 1.

Transportation

Areas where transportation impacts may occur are defined by the physical distribution of hazardous waste sites and by the locations of available disposal or treatment facilities. Transportation corridors between hazardous waste sites and disposal or treatment locations would bear the greatest impacts from cleanup operations. Hazardous waste sites are distributed throughout the state but are most numerous in the areas of Puget Sound, Vancouver, Yakima, Spokane, and Longview. Landfilling of hazardous wastes is frequently used as a disposal method. Currently, the primary hazardous waste landfill in the Washington-Idaho-Oregon area is located in Arlington, Oregon approximately 125 miles due east of Portland, adjacent to the Columbia River (Figure 14).

The highways used to transport wastes to Arlington, Oregon are a combination of interstate and U.S. highways (Figure 14). Wastes from the Puget Sound region are mainly transported along Interstate-5 to Interstate-205 near Portland and then along Interstate-84 in Oregon. Interstate-405 may also be used in the Seattle area. These roads would carry most of the truck traffic related to the cleanup of hazardous waste sites.

Wastes coming from central Washington would travel along Interstate-82 and U.S. 97. Population densities are very low in this region with the exception of Ellensburg, Yakima, Richland, Pasco, and Kennewick. Hazardous waste sites located near Spokane send remedial wastes to Arlington via Interstate-90 and U.S. 395. Interstate-84 in Oregon would be used to some degree by all vehicles coming from Washington.

Because the MTCA mandates a preference for permanent solutions to hazardous waste problems, incineration of wastes may become a preferred treatment method. Private parties have suggested possible locations for hazardous waste incinerators near Vantage and Lind in southeastern Washington (Figure 14). Both of these potential sites are located in semiarid desert with sparse populations. Any hazardous wastes from the Puget Sound region would be transported on Interstate-90 across Snoqualmie Pass (3,010-foot elevation) in

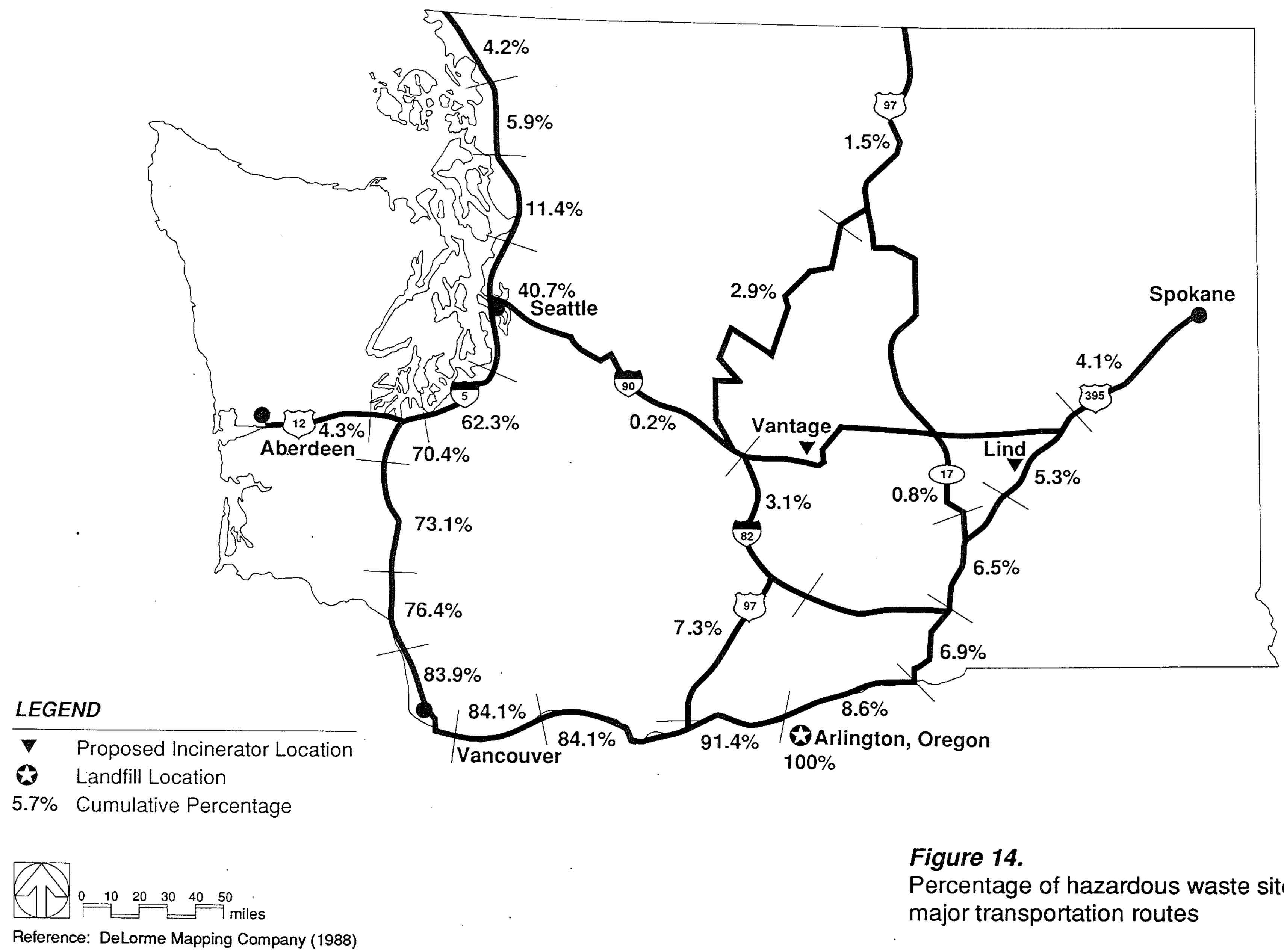


Figure 14.
Percentage of hazardous waste sites along major transportation routes

the Cascade Mountains approximately 40 miles east of Seattle. Sites in the southwest portion of the state would use Interstate-84, U.S. 97, Interstate-82, and Interstate-90 to reach Vantage. Wastes transported to Lind would travel along Interstate-84, U.S. 395, and State Route 17. Sites in central Washington would send wastes along Interstate-82 and Interstate-90 to Vantage and Interstate-82, Interstate-90, U.S. 395, and S.R. 17 to Lind.

Sensitive Routes

Sensitive routes are specific highways or transportation corridors that are susceptible to increases in traffic congestion or accidents. Congestion may result from population densities, natural features, or construction activities. Specific routes that are sensitive to high levels of traffic because of population centers include the Interstate-5 corridor between Everett and Olympia, Interstate-5 and Interstate-205 near Vancouver, Interstate-90 near Seattle and Spokane, and U.S. 395 near the tri-cities. These areas experience restricted traffic flow at all hours and peak congestion during rush hour travel periods. High traffic flows in these areas may be exacerbated by additional traffic impacts from site remediation activities. Natural features along traffic hauling routes include passes over the Cascade Mountains (for example, Snoqualmie Pass on Interstate-90 and Satus Pass on U.S. 97). Hauling routes on these highways are sensitive to increased traffic because both passes are difficult to cross in the winter months and may be closed during severe weather.

No specific routes are subject to more construction than others, and construction activities may occur along any of these routes at any time. A route under construction is likely to be negatively impacted by additional trucks carrying hazardous wastes from cleanup activities. For example, the main hauling route along Interstate-5 and Interstate-405 has had ongoing construction activities near south Seattle and Olympia.

Chapter 6
Overview of Environmental Impacts

This section describes methods used to evaluate the significant impacts associated with each alternative for setting hazardous waste site cleanup levels. The focus of the analysis is on differences among the alternatives. The types of impacts addressed in the evaluation are defined and methods for evaluation of the significance of each impact are described.

The purpose of this analysis under SEPA is to document significant environmental impacts associated with this regulatory action and to clearly set forth the environmental impacts associated with each alternative, so that an informed selection among the alternatives can be made. Although the primary purpose of the regulations is to promote cleanup of the environment, thereby producing primarily positive impacts on the environment, the remediation process and the choice of one standard over another may have negative or relatively negative impacts.

Types of Impacts

The discussion of impacts in the next chapters is organized according to major types of impacts. Each element of the environment affected by that impact is addressed separately as a subheading. First, impacts during cleanup actions are discussed. Residual contamination of environmental media is then discussed. Long-term impacts associated with human health, plants and animals, and land and water use are described in the next three chapters. The discussion of impacts concludes with a chapter on programmatic impacts. Table 13 summarizes the impacts considered and measures of those impacts.

Impacts During Cleanup Actions

Cleanup actions at a hazardous waste site often require isolation and treatment of water or soil. During the period of remediation, this water or soil is unavailable for use. Although these effects last only a short time compared with the environmental effects of residual contamination, they may result in loss of use of the resource for a substantial period of time. An example is the treatment of ground

TABLE 13. IMPACTS AND MEASURES OF IMPACTS

Chapter	Impact	Measure
7. Remedial Actions	Onsite worker health	Site-specific[a]
	Offsite populations	Site-specific[a]
	Traffic injuries	Volume of wastes hauled and
	Loss of habitat	Amount of soil excavated or water pumped
	Disruption of habitat	Site-specific[a]
	Land and water use	Area or volume unavailable, time unavailable
	Local transportation	Site-specific[a]
	Long-distance transportation	Volume of wastes hauled and traffic volume statistics
8. Natural Resources	Contamination of ground water Contamination of surface water Contamination of marine water Contamination of soil Contamination of air	Comparison of residual concentrations with area background concentrations
9. Human Health	Risk of getting cancer or experiencing adverse health effects	Comparison of risks from residual concentrations with acceptable risk (1×10^{-6})
10. Plants and Animals	Adverse effects on individual or community	Comparison of residual concentrations with no adverse effect levels
11. Land and Water Use	Drinking water	Comparison of ground water and surface water concentrations with MCLs
	Agriculture	Location of resources and modeling of risks from irrigation water
	Ranching	Modeling of risks from water
	Hunting	Location of resources and risk to waterfowl from surface water
	Fishing	Toxicity of water to fish and risk to humans of eating fish
	Forests and logging	Location of resources
	Residential land use	Risk to human health
	Recreation	Location of resources, risk to human health
12. Programmatic Impacts	Capacity of treatment, storage, and disposal facilities	Strictness of cleanup standards
	Property transfers	Strictness of cleanup standards
	State resources	Strictness of cleanup standards

[a] Impacts vary greatly from site to site and can largely be mitigated by appropriate actions at the site.

water aquifers, which are generally remediated through the use of a pump-and-treat method, where the water is pumped out of the ground, filtered or treated, and generally returned to surface water. Such a method, depending on the extent of contamination, may take 10 years or more to clean up the site. During this time, the aquifer is isolated and the ground water is unavailable for use. Measures of these impacts include the area or volume of a resource that is unavailable for use and the length of time that it is unavailable for use.

Additional elements of the environment that are impacted by cleanup actions include human health, plants and animals, and transportation. Human health may be impacted by spills or other releases of hazardous substances during cleanup actions, by injuries and accidents sustained during onsite activities, or through transportation of wastes to treatment, storage, and disposal sites. Human health impacts sustained onsite are best measured and addressed in a site-specific EIS. Human health injuries related to long-distance transportation of wastes can be measured by projecting the volume of waste to be hauled and applying accident statistics.

Plants and animals may be affected by activities at the site through temporary or permanent noise, vibration, dust, loss of habitat, and release of hazardous substances during cleanup actions. These impacts can be measured by comparing the amount of habitat loss and disruption that would occur under each of the alternatives. Impacts on both local and long-distance traffic volume may occur as a result of site remediation. Local traffic impacts are best addressed in a site-specific EIS. Traffic volume impacts from long-distance trucking of site wastes can be measured by projecting the volume of wastes to be hauled and applying traffic volume statistics for areas expected to be most heavily affected.

Impacts on Natural Resources

Long-term chemical or physical impacts on natural resources result from residual contamination left in place after remediation. These impacts are not related to use of the environmental media but simply reflect the fact that resources are now contaminated that were pristine or less contaminated before the release. Inclusion of these impacts recognizes that there is inherent value in the cleanliness of resources, regardless of whether the resources are used by humans, plants, or animals. Impacts on the uses of these resources are addressed in later sections. The measure of these impacts is how much higher the levels of residual contamination are than the natural concentration levels of the hazardous substances.

Impacts on Human Health

In this section, all long-term impacts to human health as a result of concentrations of hazardous substances remaining after remediation are addressed. These primarily include risks associated with residential exposure to residual hazardous substances in air, food, drinking water, soil, and surface water. Impacts to human health are measured by comparing the risk from residual hazardous substances to an acceptable risk range of $1x10^{-6}$ to $1x10^{-5}$.

Impacts on Plants and Animals

Residual contamination may also affect the health and abundance of plants and animals living near the site. Plants and animals can be affected by hazardous substances in the soil, air, surface water, or ground water. In this section, the long-term impacts of the alternative cleanup levels on ecological health are discussed. Impacts to ecological health are measured by comparing concentrations that would be left in the environment to concentrations levels that have been determined to have little or no health effects in ecological studies.

Impacts on Land and Water Use

The concentrations of hazardous substances left in place after remediation may have an effect on the subsequent use that can be made of the affected environmental media. For instance, less stringent cleanup levels may leave a ground water aquifer or surface water system unfit for drinking water use or agricultural use. Residual concentrations of hazardous substances in soil or water may make a habitat unfit for plants or animals. On the other hand, more stringent cleanup levels set at levels that are not technically achievable may result in long-term land use restrictions. For instance, a site may be fenced off, unavailable for any use. Alternatively, the site may be capped or paved in order to prevent infiltration, limiting the site to urban uses. The impacts on land and water use are measured by comparing residual concentrations to concentrations that would result in loss of use of a resource; for example, MCLs for drinking water.

Programmatic Impacts

Programmatic impacts refer to impacts on regulatory programs administered by the state or other government bodies. Although government programs are not considered an element of the environment, they are important to address. The approach chosen for setting cleanup levels will have a significant effect on state planning for hazardous waste cleanup programs and treatment and disposal facilities. The cleanup levels will determine the extent to which each site must be cleaned up, affecting the time and resources that must be committed to each site. More stringent cleanup levels will require larger expenditures of resources, limiting the number of state-funded cleanups each year. Deferral of site cleanups due to a resulting lack of funds may leave some sites unremediated for longer amounts of time, possibly causing greater harm to the environment.

The willingness of responsible parties to cooperate and fund site cleanups will depend on whether the cleanup levels appear reasonable to them. The choice of the cleanup levels will therefore affect the amount of litigation that may occur. The choice of cleanup levels will also have an effect on state planning for the siting of hazardous waste landfills and treatment facilities, such as incinerators. Because these impacts are difficult to measure, the relative impacts are determined by comparing the strictness of the alternative approaches for setting cleanup levels and discussing the expected effect of more strict standards.

Approach to Impact Assessment

The overall approach to the assessment of impacts consists of identifying potential impacts, defining measures of those impacts, compiling data from available sources, and performing other evaluations to determine the possible occurrence and magnitude of impacts and to assess the significance of impacts.

An exhaustive evaluation of the full range of possible impacts is infeasible, considering the potential impacts of both cleanup actions and residual contamination in the environment. The following factors, at a minimum, must be addressed in any assessment of all potential impacts:

- Site conditions (for example, land use and hydrogeologic conditions) everywhere in the state
- The large number of potential hazardous substances
- The various contaminated media
- The full range of uses of environmental resources and types of receptors
- The variety of impacts that are possible
- Various measures of the impacts
- All potential types of cleanup actions.

The significance of many impacts depends on the conditions at each site. Because of this variability, some impacts are addressed on a statewide basis, when the data are sufficient to perform such an evaluation. Other impacts are identified whose significance will vary greatly from site to site, and examples are given of conditions in which these impacts could be significant. These impacts should be addressed in a site-specific EIS.

Ecology's intent is that the minimum cleanup levels promulgated under the MTCA be adequately protective for the sites in the state. Several methods could be used to evaluate the protectiveness and the significant impacts of the alternatives for setting the cleanup levels. These methods, described below, provide various types of information and can be used in combination with each other.

The main approach used to characterize impacts in the draft EIS is a qualitative assessment of the differences between the alternatives relative to their ability to meet criteria that Ecology considers protective. Because the standards and the preferred alternative are presently in draft form, a qualitative assessment was considered appropriate. Once the regulations are finalized, following public comment and internal review, additional quantitative assessments of impacts will be included in the final EIS.

As one method of analysis, risk-based comparisons can be performed (for example, in the case of human health). For some potential impacts, ARARs already exist that reflect the risks associated with hazardous substances (for example, ambient water quality criteria). In most cases, these ARARs were designed to be protective for at least 95 percent of the populations they regulate. Where available, ARARs provide a relatively straightforward method of evaluating the potential for impacts. For the remaining impacts, available information is reviewed to determine the concentrations that might cause that impact (for example, hazardous substance concentrations in soil that are harmful to crops). If these values could be exceeded by standards derived under the various alternative approaches, the locations of known hazardous waste sites are compared with the location of the resource to be protected. If the locations are nearby, the potential for impact is considered significant. Although the hazardous waste sites used for this analysis do not include all future sites to be regulated, the assumption is made that future sites will be located in similar areas.

A useful tool for evaluating the impacts of alternative cleanup levels is the use of example site scenarios. Site scenarios are chosen that are representative of the most common types of hazardous waste sites in Washington. In addition, the site scenarios include a wide range of locations, hazardous substances, and types of impacts. Using the site scenarios, impacts of various residual concentrations can be predicted using ARARs and risk-based criteria, receptor information, and hazardous substance transport modeling. The five sites used in this evaluation of impacts are briefly described in a section below. A more detailed description of the sites and modeling data are presented in Appendix H.

This modeling approach predicts the magnitude and extent of impacts on the environment from the residual concentrations that would be left at known hazardous waste sites in Washington under each alternative. This approach requires various kinds of data about the sites, such as location; size; hazardous substances present; initial concentrations of hazardous substances; geologic, hydrologic, and meteorologic conditions at the site; and locations of sensitive receptors nearby. Currently, only data on location, size, and type of business are available for most of the existing or proposed sites. Locations and characteristics of unknown sites cannot be predicted. Consequently, any parameters used in modeling must be based on professional judgment of likely values for those parameters. Such values may not be representative of average or protective conditions at hazardous waste sites in Washington. Therefore, modeling results indicate relative, rather than quantitative, magnitudes of impacts associated with residual concentrations of hazardous substances under the alternatives.

Because of these limitations, modeling is used only in conjunction with the site scenarios, described above. No statewide modeling is performed. The modeling of site scenarios helps illustrate the range of impacts that could occur at hazardous waste sites after a site has been cleaned up to standards developed under each of the alternative approaches. Modeling of site scenarios was performed using Battelle's Multimedia Environmental Pollutant Assessment System (MEPAS), which is capable of modeling hazardous substance movement through air, surface water, ground water, and soil. The model also predicts individual risks related to a variety of exposure routes.

Site Scenarios

The site scenarios used to illustrate impacts addressed in this EIS were chosen to represent five of the most common types of sites on the hazardous waste sites list. Each of these sites contains different types of hazardous substances, uses different transport pathways, and results in different human and environmental exposures. Together the site scenarios address each of the major classes of hazardous substances, transport pathways, and exposures expected in Washington state. The sites were developed as a composite of many existing sites. Therefore, they are expected to be well within the range of actual sites, but do not represent any particular site. The site scenarios include both large and small businesses. The following sections describe each site scenario.

Landfill

An old municipal solid waste landfill is located on the edge of a large city (Figure 15). The landfill is unlined and has leaked solvents including trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane into the ground water. A water supply well is located 3,500 feet away, and the ground water discharges into a river 4,000 feet away. Exposures modeled by this site scenario include exposures from drinking and showering with ground water, and exposure to river water during recreational activities such as swimming, boating, and shoreline activities. Because this is a common type of site, this scenario was modeled in a variety of soil types and meteorologic conditions representing both eastern and western Washington.

Leaking Underground Storage Tank

Leaking underground storage tanks at a gas station have contaminated soil around the tank with benzene, toluene, and xylene, common gasoline additives (Figure 16). Hazardous substances remaining in the soil after cleanup are leached into a sole-source aquifer and carried to a set of large municipal water supply wells 3,500 feet away. Exposures modeled at this site include drinking and showering with ground water supplied by the municipal water supply wells. Because this is a very common type of site, this scenario was also modeled in a variety of soil types and meteorologic conditions, representative of both eastern and western Washington.

Metal Plating Facility

A metal plating facility is located along a river in a rural area of western Washington (Figure 17). Soil at the site is contaminated with copper, chromium, and zinc to a depth of 10 feet. After cleanup, hazardous substances remaining at the site are leached into ground water and carried to the river, and are also picked up by rainfall and overland runoff leading to the river. In the river is an important tribal steelhead fishery, as well as recreational salmon fishing. Exposures modeled by this site scenario include toxicity

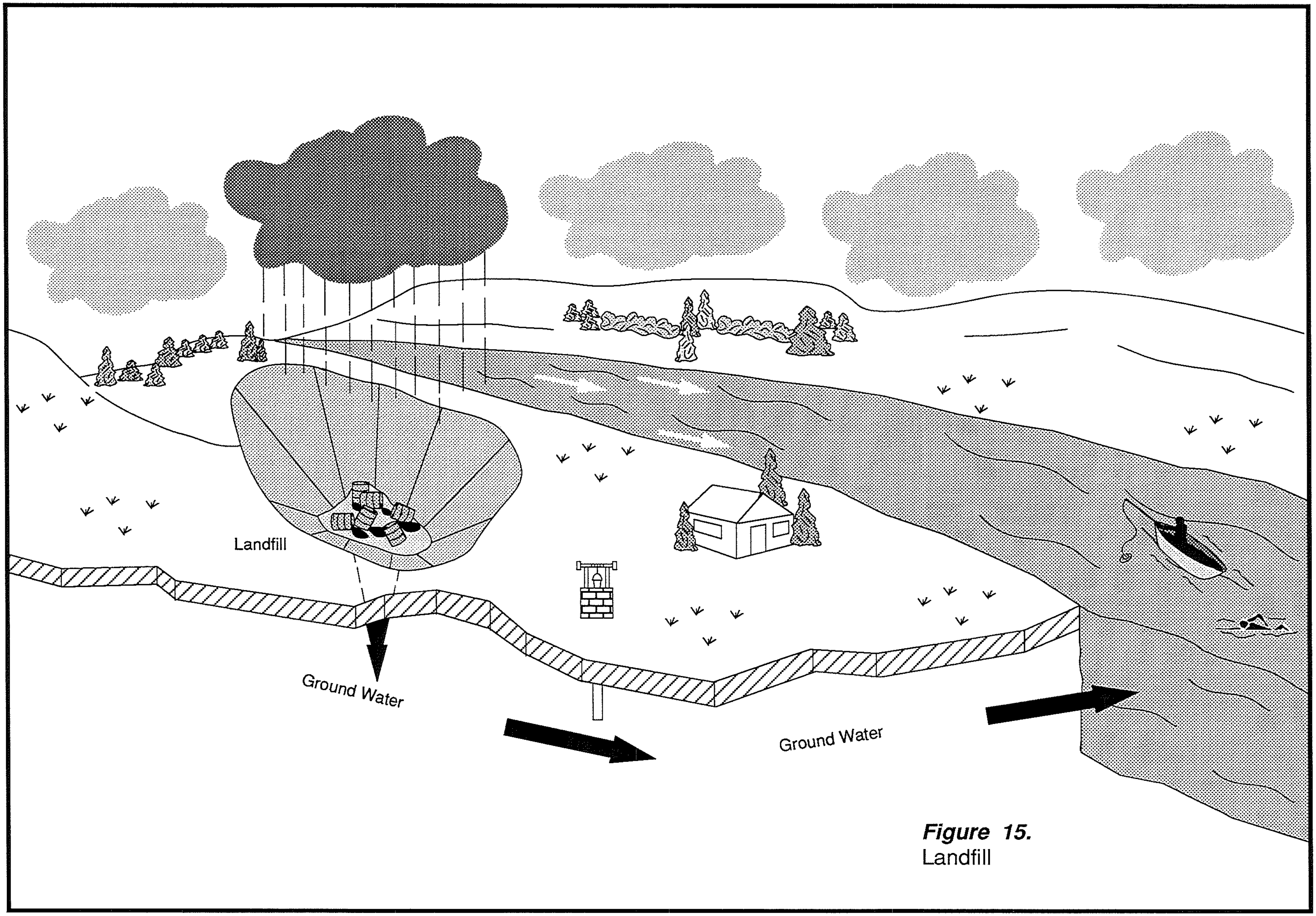


Figure 15.
Landfill

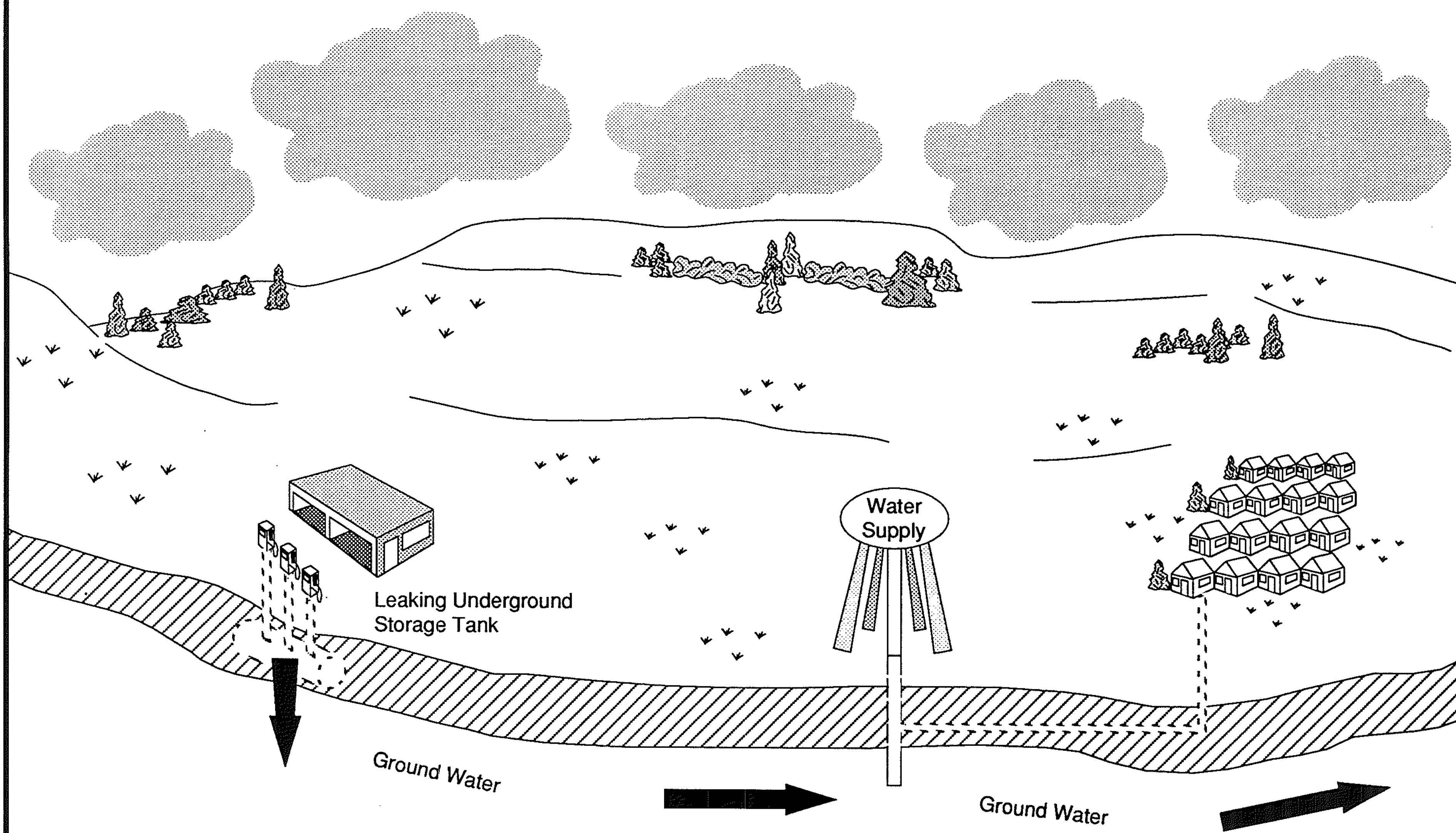


Figure 16.
Leaking underground storage tank

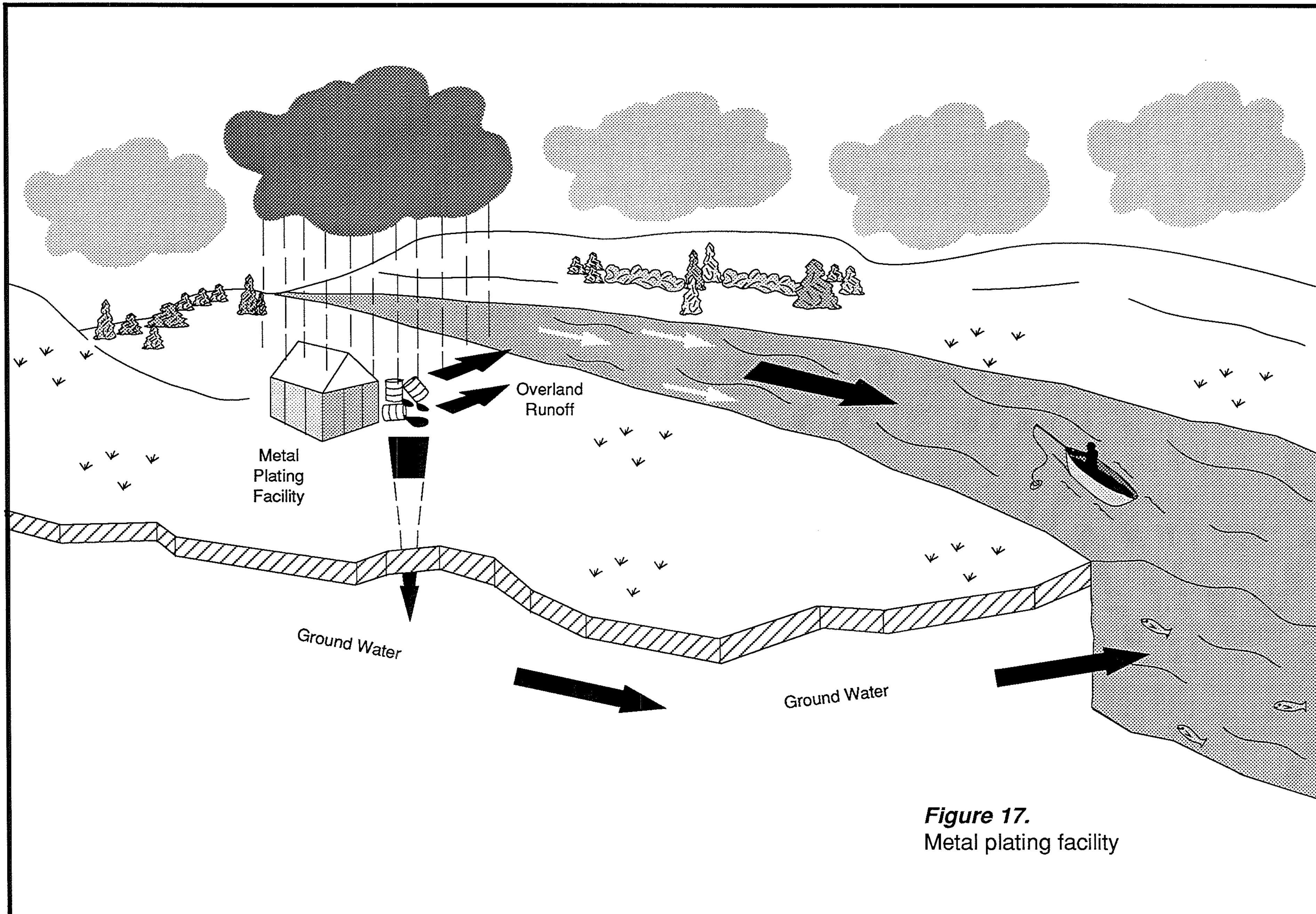


Figure 17.
Metal plating facility

of metals in river water to fish and consumption of the fish by humans.

Wood Treatment Facility

A large wood treatment facility is located on an urban bay in Puget Sound (Figure 18). The soil at this facility has been contaminated with a variety of wood preservatives and hazardous substances of wood preservatives, including pentachlorophenol, 2,3,7,8-TCDD (dioxin), and phenanthrene (a PAH compound common in creosote). After cleanup, site hazardous substances are picked up by rainfall and surface runoff and transported to the bay. Recreational ocean fishing and clam digging are common activities in the bay; this scenario models the risk to aquatic life and the risk to humans from eating the fish and clams. In addition, hazardous substances on dust are carried off the site by wind and deposited onto nearby population centers. Risk from ingestion and inhalation of the dust was modeled.

Agricultural Chemical Facility

A portion of the Yakima River in eastern Washington has been contaminated by agricultural runoff and overland runoff from a pesticide storage and distribution center (Figure 19). Hazardous substances in the river include arsenic, DDT, and lindane (gamma-hexachlorocyclohexane). Water from the river is pumped and used to irrigate farmland on which sweet corn and lettuce are grown. In addition, the water is used for watering of dairy and beef cattle. Risks modeled in this scenario include drinking milk from the cows and eating lettuce, corn, or beef raised in the area. Data from modeling of the five site scenarios described above are presented in detail in Appendix H. These modeling data are used in the following chapters to illustrate impacts resulting from residual hazardous substances remaining after site cleanup.

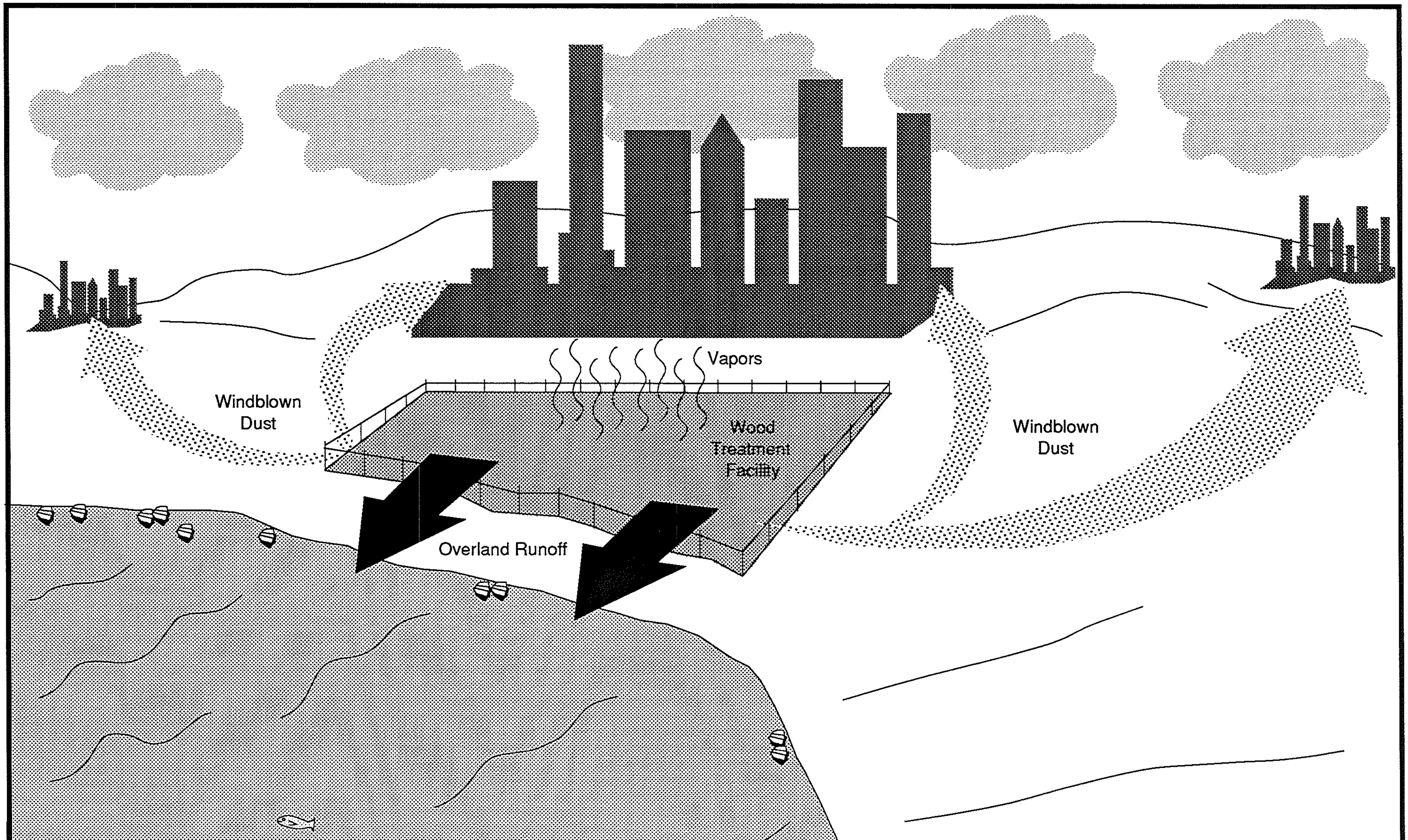


Figure 18.
Wood treatment facility

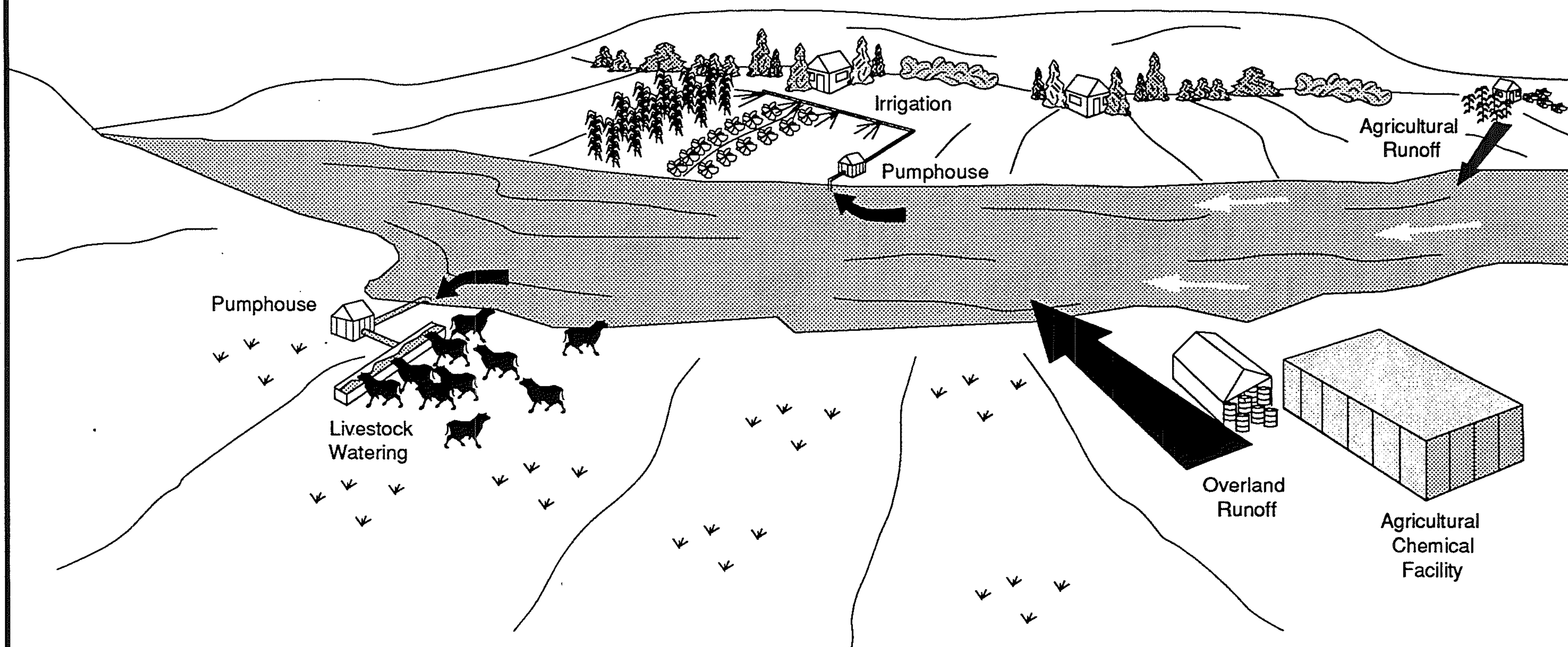


Figure 19.
Agricultural chemical facility

Chapter 7
Impacts During Remedial Actions

Cleanup actions at hazardous waste sites generally involve some combination of hazardous substance removal, treatment, or containment technologies. While removal/excavation activities are generally limited to the cleanup site, treatment and containment may occur at both the cleanup site and off-site locations. The actual combination of technologies used at a particular site will depend upon the hazardous substances present at the site, the environmental setting, and the cleanup standards applicable to the site.

The purpose of this chapter is to evaluate the potential adverse environmental impacts associated with the implementation of various cleanup technologies under the cleanup standard alternatives described in Chapter 4. These impacts are distinct from those impacts associated with residual levels of hazardous substances which remain at a site following the completion of a cleanup action. The potential for such impacts is addressed in Chapters 8 through 11.

The proposed amendments will influence the nature and magnitude of adverse environmental impacts occurring during cleanup actions by specifying criteria for the following:

Selection of cleanup levels

- The environmental impacts associated with the use of particular technologies tend to be inversely related to the cleanup levels selected for the site (that is, the more stringent the cleanup level, the greater the potential for short-term adverse environmental impacts associated with a particular technology). This contrasts with the relationships between cleanup levels and the impacts associated with residual levels of hazardous substances. In those cases, more stringent cleanup levels are generally associated with lower long-term environmental impacts.

Use of permanent solutions

- The Model Toxics Control Act expresses a preference for the use of permanent solutions to the maximum extent practicable. Permanent solutions generally involve the use of some type of treatment (incineration, bioremediation, etc). Treatment technologies frequently have a greater potential for adverse environmental impacts than cleanup actions which rely solely on capping and other containment technologies.

The remaining portions of the chapter are divided into two main sections. In the first section, the technologies most likely to be used for contaminated ground water, surface water, and soils are identified. In the second section, the potential environmental impacts associated with the use of various technologies are identified, potential differences among cleanup standard alternatives evaluated, and potential mitigation measures described. This latter section is divided into four parts which focus on human health, plant and animal, land and water use, and transportation impacts.

Remedial Technologies

Statutory Requirements

The Model Toxics Control Act contains two provisions which guide the selection of cleanup actions. First, RCW 70.105D.030(1)(b) specifies that "[in] conducting, providing for, or requiring remedial action, the department shall give preference to permanent solutions to the maximum extent practicable and shall provide for or require adequate monitoring to ensure the effectiveness of the remedial action...." Second, RCW 70.105D.030(2)(d) specifies that "minimum cleanup standards for remedial actions [shall] be at least as stringent as the federal cleanup standards under section 121 of the federal cleanup law, 42 U.S.C. 9621 and at least as stringent as all applicable state and federal laws...."

Under Section 121(b)(1) of SARA, EPA is required to "select a remedial action that is protective of human health and the environment, that is cost-effective, and that utilizes permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable...." Section 121(d) specifies that protection of human health and the environment is to be achieved, at least in part, through the identification and compliance with "applicable or relevant and appropriate standard, requirement, criteria, or limitation ... for a hazardous substance, pollutant, contaminant, remedial action, or location...." Finally, Section 121(b) identifies a number of factors to be considered in selecting from among alternative remedial actions. Of particular relevance to this evaluation, is the requirement that "the potential threat to human health and the environment associated with excavation, transportation, and redisposal, or containment..." be considered during the selection of remedial actions.

Regulatory Requirements

As part of the proposed amendments, Ecology has developed a number of requirements for cleanup actions. Under the proposed amendments (See WAC 173-340-360(2)), cleanup actions must meet the following general requirements:

All cleanup actions conducted under this chapter shall:

- Be protective of human health and the environment, including complying with cleanup standards;
- Comply with all applicable state and federal laws; and
- Provide for monitoring.

When evaluating alternative cleanup actions that meet these requirements, the cleanup action selected shall:

- Use permanent solutions to the maximum extent practicable;
- Be practicable for the site;
- Provide for a reasonable restoration time frame; and
- Consider public concerns.

Within these general constraints, the proposed amendments provide a great deal of flexibility in selecting a cleanup action for a particular site. Consequently, a wide variety of remedial technologies are available for cleanup of ground water, surface water, and soils at hazardous waste sites. Some of the major technologies are summarized in the following sections, with an emphasis on the technologies that are most likely to be used at sites within Washington. Technologies for reducing air emissions are not addressed separately, but are discussed in the sections which discuss the use of remedial technologies for contaminated soils and water.

The discussion within this chapter is based on certain general assumptions about the levels and types of contamination found at hazardous waste sites. In addition, assumptions have been made regarding the effectiveness and efficiency of the various treatment technologies discussed (see Appendix I). Because of the general nature of the discussion, this section is intended only to provide an overview of the types of remedial technologies that could be used at a site and their possible impacts. For each site, treatment efficiencies, the potential environmental impacts of various remedial actions and initial contaminant concentrations will vary; therefore, this section should not be viewed as a substitute for site-specific feasibility studies.

Ground Water Measures

Ground water contamination problems or potential problems have been identified at 75 percent of the hazardous waste sites in Washington. The steps taken to correct ground water contamination generally involve several common steps:

- Measures to eliminate or minimize ongoing sources of ground water contamination;
- Measures to extract contaminated ground water;
- Measures to treat contaminated ground water; and
- Measures to dispose or discharge treated ground water.

Source Control Measures

Sources of ground water contamination commonly found at hazardous waste sites in Washington include non-aqueous phase liquids, such as creosote or petroleum, contaminated soils or other waste materials, and underground storage tanks. Initial efforts at hazardous waste sites are generally focused on eliminating or minimizing ongoing sources of ground water contamination. For example, removal of non-aqueous phase liquids, or free product, from the ground water surface may be accomplished by installing trenches or wells down gradient of the contaminated material which is then removed by filter separators, skimmers or pumps. In other cases, a ground water gradient can be created by pumping ground water and the floating materials collected from the resulting ground water depression. These types of techniques have been used at Cascade Pole, Wyckoff-Eagle Harbor, and various petroleum-contaminated sites. Proper treatment and disposal of the materials collected, and any contaminated water generated, will be required for this source removal option. Direct removal of dense non-aqueous phase organic liquids may not be technically feasible at some sites. Bioremediation of these sources, or containment of the ground water contaminated by such sources, are among the options to control this source.

Ground Water Extraction

Ground water extraction is often a component of cleanup actions where ground water contamination is being addressed. Ground water extraction systems may be installed to (1) contain contaminated ground water and prevent migration of hazardous substances into uncontaminated aquifers or (2) extract and treat of contaminated ground water. Types of extraction systems include drilled wells, well points, and trenches. Ground water extraction systems have been or are in the process of being installed at several Washington hazardous waste sites, including Western Processing, Ponders Corners, Well 12A, Wyckoff-Eagle Harbor, and the Colbert Landfill.

Treatment of Contaminated Ground Water

Methods used for ground water treatment largely depend on the type of contaminant in the water. Common treatment methods for volatile organics contaminants, other organics contaminants, and metals are described below:

Volatile Organic Compounds

Water treatment for the removal of volatile organics can be accomplished by at least three types of treatment processes; air stripping, aqueous phase carbon adsorption, and chemical oxidation. Each of these treatment processes should be capable of achieving any of the alternative cleanup standards, if they are properly designed and operated. To date, the most common technology for removal of volatile organic compounds has been air stripping. Air stripping has been used at Western processing, Well 12A, Ponder Corners and other smaller cleanup sites in Washington. Air stripping involves contacting the contaminated water with large volumes of air. Transfer of the hazardous substance from the contaminated ground water to the air is fast and effective for volatile compounds. Vapor phase carbon adsorption, catalytic oxidation, and vapor condensation are available emission control technologies used to reduce the amount of hazardous substances being released into the air. Vapor phase carbon adsorption, followed by thermal desorption and incineration of the desorbed organics, is being used at the Western Processing Site. The proposed amendments will probably increase the use of air treatment technologies.

Semivolatile and Nonvolatile Compounds

Treatment with granular activated carbon is the most commonly used technology for removing semivolatile and nonvolatile organic contaminants from water. Additionally, carbon adsorption can be effectively used for mixtures of volatile and semivolatile organic contaminants. Biotreatment may also be used to treat certain semivolatile and nonvolatile organics. Biotreatment generally works well for compounds such as PAHs and PCP, but not for PCB, dioxins, or certain chlorinated organic pesticides. Biotreatment, in combination with carbon adsorption is being used at the Wyckoff-Eagle Harbor site for treatment of PAHs and PCPs.

Metals

Treatment to remove metals in water generally involves generally involves some type of precipitation or coagulation/flocculation process. Both types of processes involve the use of a chemical additive to induce the metal contaminant to settle out of the water. Water treatment using these processes results in the formation of sludges, which must be treated and disposed. Well designed and operated precipitation or coagulation/flocculation processes will be capable of achieving the alternative cleanup standards for most metals in ground water. Further reductions in metal concentrations can be achieved by combining this treatment with ion exchange or other treatment methods. A precipitation method is being used to treat the contaminated ground water being extracted from the Western Processing site. Ion exchange, reverse osmosis, or electrodialysis can also be used alone to remove metals from water.

Water Discharge

The treated or partially treated water resulting from a ground water pump and treat system may be discharged to a nearby surface water body, released to the ground, or discharged to a local publicly owned treatment works (POTW).

Insitu Treatment

Bioremediation of ground water aquifers is an alternative or addition to the pump and treat option when organic contaminants are involved. This usually involves bioremediation, with the same potential for by-product formation as discussed above. In situ containment, involving the injection of grout or installation of slurry walls or other containment structures are potential options. A slurry wall was installed around the Western Processing site to help control and contain the contaminated ground water.

Surface Water Measures

Surface water contamination has been identified as a problem or potential problem at over 50 percent of the hazardous waste sites in Washington. Cleanup measures are generally directed towards eliminating or minimizing the discharge or potential discharge of hazardous substances into surface waters. The steps taken to correct surface water contamination problems generally involve several common steps:

- Measures to collect contaminated surface water runoff;

- Measures to treat contaminated surface water; and
- Measures to discharge treated or partially treated surface water.

Many of the same issues and treatment processes involved with ground water extraction, treatment, and discharge also apply to surface water. In particular, the treatment and ultimate discharge options for contaminated water are often identical. Measures to collect or divert contaminated surface water generally involve the construction of dikes, berms, or other diversions. Capping of contaminated materials may also be performed to prevent contact with surface water runoff.

Soil Measures

Soil contamination has been identified as a problem or potential problem at over 75 percent of the hazardous waste sites in Washington. The measures taken to correct soil contamination problems generally involve the use of one or more of the following technologies:

- Excavation of contaminated soils or waste materials;
- Treatment of contaminated soils or waste materials;
- Containment or contaminated soils or waste materials; and
- Transport/off-site disposal of contaminated soils or other waste materials.

Excavation

Excavation activities include bulldozing, front-end loading, mixing with chemical adsorbents, and transfer operations (loading and unloading). Environmental impacts associated with the excavation of soil include direct releases of volatile organics to the air, and transport of other organics and metals adsorbed to soil particles that become air borne due to excavation activities.

Off-Site Transport of Contaminated Soils

The off-site transport of contaminated soil can impact local traffic congestion, noise and other aesthetic factors. These impacts may also occur in the areas surrounding off-site treatment or disposal facilities. The potential for spills enroute should be considered and addressed in a site specific accident contingency plan. Air emissions during loading, transportation and off-loading are also potential environmental impacts.

Containment

Containment measure include the installation of caps, covers, and slurry walls. Installation of these involve the mobilization and use of heavy equipment. Depending on the location and setting of the site, these activities may result in short-term local traffic congestion, air emissions, and adverse aesthetic factors relating to visual and noise impacts. Monitoring and maintenance of the site will be required over the long-term.

Soil Treatment

Methods for soil treatment may include immobilization, vapor extraction, incineration, or biodegradation.

Immobilization

Soils may be treated in order to stabilize or solidify the waste matrix (e.g., soil) and reduce the potential for leaching of hazardous substances. Processes involving the addition of cement and various additives are commonly used to immobilize metals in soils. Processes for immobilizing semivolatile organics are currently being tested. Soil immobilization processes have been proposed for Tacoma Tar Pits, PACCAR, and Frontier Hard Chrome. Vitrification is another process that immobilizes metal and semivolatile contaminants in a soil matrix through high-temperature solidification. Vitrification is being proposed at Northwest Transformer.

Vapor Extraction

Vapor extraction is a viable treatment option for many types of soils which are contaminated by volatile organic compounds. This process has been used at Ponders Corners and several petroleum contaminated sites in Washington. Vapor extraction operates by creating a negative pressure within slotted piping (i.e., extraction wells) placed below the ground surface. Volatile contaminants present in the soil migrate toward the extraction wells where they are removed. Removal of volatile organic compounds and some semivolatile organics can be accomplished by steam stripping of the soil using a process similar to conventional vapor extraction. Hot steam is forced through the soil to strip organic contaminants from the soil. Since these processes transfer the contaminants from the soil to the air, some type of air treatment is usually required. Technologies similar to those used to treat emissions from air strippers may be used to treat emissions from these soil treatment systems.

Incineration

Incineration efficiently destroys organic contaminants in soil through high temperature combustion. However, incineration of certain contaminants such as PCBs may create low levels of chlorinated dioxins. In addition, incineration of soils contaminated with metals may result in an increased release of metals into the atmosphere and the generation of an ash containing high levels of metals. Incineration may be performed at the cleanup site or at off-site locations.

Biodegradation

Biodegradation makes use of natural organisms to break down contaminants into less harmful products. This process is not recommended for contaminants such as DDT because they tend to break down into other compounds that are at least as toxic as the original contaminant. Compounds such as PCBs, dioxins, heavily chlorinated solvents and others degrade very slowly using conventional biotreatment methods. Biodegradation has been shown to be particularly useful for removing petroleum hydrocarbons, PAH compounds and pentachlorophenol from soils. As discussed earlier, the potential for formation of toxic by-products is a major potential environmental impact of bioremediation. High levels of metals in the soil can be toxic to the organisms.

Impacts to Elements of the Environment

The purpose of this section is to provide a qualitative evaluation of the potential adverse environmental impacts associated with performing cleanup actions under the various alternative approaches described in Chapter 4. In performing this evaluation, the following assumptions were made:

- The Model Toxic Control Act's preference for cleanup actions that involve "permanent solutions to the maximum extent practicable" will lead to increased use of treatment technologies. For purposes of evaluating incremental impacts, it was assumed that 80 percent of the cleanup actions performed under MTCA will utilize treatment technologies, as opposed to 30 percent in the "no action" alternative. The assumptions of 80 percent treatment-based cleanup actions performed under MTCA and 30 percent under existing requirements are similar to the assumptions used by EPA in evaluating the regulatory impacts of the proposed National Contingency Plan (ICF, 1988). Given the development of federal cleanup rules, it is likely that the use of a 30 percent figure will result in a conservative overestimate of the incremental impacts attributable to the proposed rules.

- The land disposal restrictions being implemented as a result of the Hazardous and Solid Waste Amendments (HSWA) of 1984 will reduce the reliance on off-site disposal of untreated materials.

- Sufficient treatment capacity is available to handle wastes from sites being cleaned up under the Model Toxics Control Act. As discussed in Chapter 12, it appears that sufficient treatment capacity is available to handle wastes from MTCA cleanup actions.

- The proposed amendments will not impact the number of sites undergoing cleanup under the Model Toxics Control Act.

Although the statute expresses a preference for permanent solutions, not all sites are conducive to treatment. For example, it appears that for certain classes of hazardous substances, current treatment technologies will be unable to routinely achieve likely cleanup standards under one or more of the alternative approaches (See Appendix I). In these situations, additional measures, such as site use restrictions or other institutional controls, containment, or removal of the contaminated media for off-site treatment of disposal, may be required to assure protection of human health and the environment (The potential adverse impacts associated with residual levels of hazardous substances are addressed in Chapters 8 through 11). In other situations, the use of treatment-based cleanup actions at sites with large quantities of waste materials, such as municipal landfills and mining sites, may result in considerable environmental impacts. Finally, there may be situations where the application of currently available treatment technologies may foreclose future opportunities for the beneficial reuse of hazardous materials.

Human Health

Site cleanup activities are likely to result in impacts on human health. Impacts may occur among on-site workers, off-site populations, or as a result of transportation-related accidents. Potential impacts of the cleanup standard alternatives on human health, the potential significance of those impacts, and possible mitigation measures that could reduce the impacts are discussed below.

On-site Workers

Construction and operation of cleanup measures often involves extensive physical disturbance of hazardous substances in soils, tanks, and other containers. This increases the potential for (1) inhalation of volatile substances or particulate matter generated during construction, (2) direct contact with hazardous substances, and (3) fires and explosion. These risk factors, in combination with the fact that construction workers may lack specialized health and safety training, increases the risk of a serious accident during construction activities. Other possible health effects include heat or cold stress, physical hazards, and fatigue.

In general, regulatory requirements which result in more stringent cleanup levels and greater use of treatment technologies will increase the potential for adverse health effects among on-site workers. Over the last several years, cleanup levels have generally been established at concentrations equivalent to those under the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action, although the requirements under those alternatives may vary from site to site. Consequently, it is expected that the background alternative is the only alternative that will significantly increase the potential for adverse health effects among on-site workers.

Increased use of treatment technologies may also increase the potential for adverse health effects among workers. For example, formation of toxic by-products during chemical and biological oxidation processes is a potential problem associated with the use of those technologies. In addition, as more complex technologies are utilized, the potential for releases due to human error (resulting from mismatches between people and the equipment they are responsible for) may increase.

Worker exposures and adverse health effects during cleanup activities can, to a large degree, be mitigated by occupational health and safety practices and the implementation of site-specific health and safety plans. The proposed rule also provides the flexibility to consider "net environmental impacts" (including worker health and safety) when selecting cleanup actions (See WAC 173-340-360(7)(a)(ii)) and establishing cleanup levels (See WAC 173-340-700(5)(d)(ii)) for individual sites. For example, worker health and safety concerns might lead to the selection of a cleanup action involving treatment of highly contaminated soils and in-place capping of soils with low to moderate levels of contamination.

Off-site Populations

Adverse health effects in off-site populations may result from exposure to contaminants released during a cleanup action. Of particular concern are the inhalation of vapors and other particulates released during soil excavation, ingestion of dust deposited in nearby areas, inhalation of hazardous substances released during air stripping or other treatment processes, or exposure to contaminated wastewater discharged to surface waters or local POTWs. Although these exposures tend to be temporal in nature, significant short term exposures may occur.

Off-site impacts may be limited to areas adjacent to the cleanup sites. This is generally the case with releases of vapors or particulates. In other instances, the impacts may occur some distance from the cleanup site. For example, the discharge of wastewaters containing high concentrations of volatile hazardous substances to publicly owned treatment works (POTWs) may lead to adverse health effects among plant workers. Similarly, the discharge of wastewater containing high levels of metals to a local POTW may result in increased metal concentrations in the POTW sludge. This may result in increased human health and environmental concerns at the sludge treatment or disposal site.

In situations involving contamination of drinking water supplies, the shift to alternate sources of drinking water may result in adverse impacts on human health. For example, contamination of ground water supplies have often resulted in closure of private wells with subsequent hookup to municipal water supplies. Where municipal water supplies have been chlorinated, the overall cancer risk may exceed the risks associated with marginally contaminated ground water.

As with worker health and safety, regulatory requirements which result in more stringent cleanup levels and greater use of treatment technologies may increase the potential for adverse health effects among nearby residents or off-site workers. Over the last several years, cleanup levels have been established at concentrations equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the requirements under those alternatives may vary from site to site. In particular, ground water cleanup levels for carcinogens under those alternatives may be more stringent than state and federal drinking water standards where the ground water has been contaminated with a number of carcinogens. Consequently, it is expected that the background alternative is the only alternative that will significantly increase the potential for adverse health effects among off-site populations during cleanup actions.

Potential adverse impacts among off-site populations can be mitigated through the use of appropriate pollution control devices. For example, the use of carbon adsorption units for air stripping towers can significantly reduce the amount of hazardous substances released into the atmosphere. In other instances, it may possible to schedule activities to minimize adverse impacts (i.e. avoid excavation of vapor contaminated soils during the summer months). In addition, the proposed amendments provide the flexibility to consider "net environmental impacts" (including short term impacts to nearby communities) when selecting cleanup actions (See WAC 173-340-360(7)(a)(ii)) and establishing cleanup levels (See WAC 173-340-700(5)(d)(ii)) for individual sites. For example, concerns about exposure to nearby communities might lead to the selection of a cleanup action involving treatment of highly contaminated soils and in-place capping of soils with low to moderate levels of contamination instead of using the treatment technology for all site soils.

Transportation Related Injuries

The excavation of contaminated soil and transport to off-site treatment and disposal facilities may result in an increase in the number of transportation-related injuries. In order to estimate the increased risk of accidental deaths associated with the transportation of cleanup wastes, it is necessary to estimate the fatality rate per truck mile and the average haul distance for cleanup wastes. Based on data from the Washington Department of Transportation, it is estimated that fatal accidents involving trucks in Washington state occur at a rate of about 1.8 per 100 million miles traveled (DOT 1989). The number of miles traveled during a typical site cleanup is approximated by the round-trip mileage between Seattle and the nearest hazardous waste disposal facility. Most wastes from Washington have been transported to a disposal site in Arlington, Oregon, which is 300 miles from Seattle, or 600 miles round-trip. Based on this information, each truckload of soil removed from a site would be associated with an increased risk of transportation-related deaths of 1.1×10^5.

Regulatory requirements which result in more stringent cleanup levels may increase the potential for transportation-related injuries. Over the last several years, cleanup levels have been established at concentrations equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the requirements under those alternatives may vary from site to site. Consequently, it is expected that the background alternative is the only alternative that might increase the potential for transportation-related injuries.

The number of truckloads of material that would need to be removed from hazardous waste sites in the future under the various cleanup standard alternatives is not known. However, as noted below, the estimated number of trucks involved with the transport of hazardous wastes represent a small percentage of the overall truck traffic in the state (approximately 1 in 300 to 1 in 400). While the risk of traffic-related deaths may exceed what is considered acceptable in other situations, none of the alternatives are likely to result in a significant incremental increase in transportation-related injuries.

Greater use of treatment technologies will probably reduce the amount of long-distance hauling of cleanup wastes and therefore may serve to mitigate some of the adverse impacts. In addition, the proposed rule provides the flexibility to consider ways to minimize the need for long-distance hauling of cleanup wastes (and the potential for transportation-related injuries) when selecting cleanup actions and establishing cleanup levels. However, once it is determined that off-site transport of cleanup wastes is necessary, mitigation options are limited. Routing trucks through areas with low traffic volume, scheduling trips for off-peak hours, and designing emergency response plans can help to reduce the chances of accidents. However, such measures only deal with part of the problem; the Office of Technology Assessment (OTA, 1986) estimates that more than 50 percent of the risk associated with the transport of hazardous waste is related to "driver error".

Plants and Animals

Site cleanup actions are likely to result in some adverse impacts on plants and animals. These impacts are influenced by the types of hazardous substances, the environmental setting, and the selected cleanup actions. Potential impacts of the alternatives on plants and animals, the potential significance of those impacts, and possible mitigation measures that could reduce the impacts are discussed below.

Plants

Many site cleanup activities involve soil excavation or capping which results in the complete destruction of existing habitat including removal of vegetation and damage or loss of topsoil. Such impacts may occur at the cleanup site or at off-site locations which serve as sources of capping or fill material. In addition, air emissions associated with air stripping and other site cleanup activities may result in vegetation damage in adjacent areas.

Regulatory requirements which result in more stringent cleanup levels may increase the areas to be remediated and, consequently, increase the potential for adverse impacts on plants. Over the last several years, cleanup levels have been established at concentrations equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the requirements under those alternatives may vary from site to site. Consequently, it is expected that the background alternative is the only alternative that might increase the potential for adverse impacts associated with the implementation of cleanup measures.

Greater emphasis on treatment technologies may produce mixed effects. On the one hand, greater use of treatment technologies may increase the need for auxiliary structures such as treatment facilities and access roads. On the other hand, such a shift may also result in a reduced need for capping materials which would reduce off-site impacts on plant habitat.

The overall significance of the proposed amendments with respect to plant damage during cleanup actions is probably minimal. The majority of cleanup sites in the state are industrial in nature and plant life will already have been significantly reduced or eliminated as a result of past practices.

Where there is a potential for adverse environmental impacts on plants during cleanup actions, potential mitigation measures include the relocation of disturbances, such as site access roads, to less critical or previously disturbed areas, and replacement of damaged vegetation and topsoil after site cleanup activities are completed.

Aquatic Organisms

Cleanup actions may result in adverse impacts on a variety of aquatic organisms including fish, shellfish, plankton, and benthic infauna. These impacts may arise as a result of (1) discharge of untreated or partially treated wastewater and surface water runoff; (2) increased or decreased surface water flows; and (3) spills of hazardous substances and other contaminants.

Many soil and ground water cleanup measures result in the generation of contaminated wastewater. In addition, rain water may come into contact with contaminated materials and increase the runoff of hazardous substances. Under current state law, all wastewaters must be treated with "all known, available, and reasonable methods of treatment" (AKART) prior to being released into waters of the state. Where the discharge of wastewater treated with AKART will result in violations of the water quality standards, Ecology may require additional treatment or authorize temporary reductions in water quality through the use of dilution zones. These zones would be specified in the waste discharge permit for a site. Based on a review of currently available water treatment technologies and past experience at cleanup sites, it appears that dilution zones may be needed at some sites.

Impacts associated with these partially treated wastewaters and authorization of dilution zones are related to increases in (1) turbidity and siltation and (2) hazardous substances concentrations. For example, fish species in general, and freshwater fish in particular, have a low tolerance for increases in turbidity. Fish mortality due to asphyxiation is often the result of fine particulates settling on the gills. Gradual reductions in fish population size and even local species elimination have been found as a result of increasing turbidity levels in streams that typically had low background levels of suspended solids. Another possible impact due to turbidity and siltation is through the reduction in spawning ground habitat. Fish may abandon previously used spawning grounds if siltation becomes too great. Finally, most of the hazardous substances found at hazardous waste sites are toxic to freshwater and marine species. Freshwater fish are generally more sensitive to hazardous substances than are marine species and are therefore more susceptible to hazardous substances released from cleanup sites. In addition, metals are generally more bioavailable in freshwater than marine waters.

Cleanup actions may also influence the quantity of water in a stream or water body. For example, remediation of contaminated ground water or surface water via the removal or isolation of the contaminated water may result in reduced water availability in aquifers or streams. Elimination of a ground water resource can also lead to reduction of surface water flows that are fed by the aquifer. These impacts may occur at considerable distances from the cleanup site. Reduced water flow can eliminate habitat for fish and other aquatic species and can reduce long-term or seasonal water availability for streamside vegetation and associated animal communities.

Regulatory requirements which result in more stringent cleanup levels may increase the potential for adverse impacts on aquatic organisms during the construction and operation of the cleanup action. Over the last several years, cleanup levels have been established at concentrations equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the requirements under those alternatives may vary from site to site. Consequently, it is expected that the background alternative is the only alternative that might increase the potential for adverse impacts associated with the implementation of cleanup measures

Terrestrial Organisms

Site cleanup actions may result in the destruction of wildlife habitat and cause significant adverse impacts to terrestrial wildlife. For example, the construction of roads, wells, water-tight enclosures, or treatment facilities, generally results in the physical disruption of wildlife habitat. In addition, releases of hazardous substances during the construction and operation of cleanup technologies may adversely affect animal communities. The types of wildlife and number of species impacted will depend upon the type of habitat being destroyed. For example, cleanup actions performed in open areas will generally impact smaller animals and relatively less diversified communities than actions performed in forested areas.

As with impacts on plant life, regulatory requirements which result in more stringent cleanup levels may increase the potential for adverse impacts on terrestrial wildlife during the construction and operation of cleanup actions. Over the last several years, cleanup levels have been established at concentrations equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the requirements under those alternatives may vary from site to site. Consequently, it is expected that the background alternative is the only alternative that might increase the potential for adverse impacts associated with the implementation of cleanup measures.

The significance of impacts to terrestrial species will depend upon the availability of nearby habitats to assimilate displaced wildlife. However, the overall significance of the proposed amendments with respect to impacts on terrestrial wildlife during cleanup actions is probably minimal. The majority of cleanup sites in the state are industrial in nature and animal communities will already have been significantly reduced or eliminated as a result of past practices.

In those situations where adverse impacts are identified, mitigation may be accomplished by (1) temporary or permanent relocation of species, (2) relocation of disturbances to less critical or previously disturbed habitats, or (3) reconstruction of the damaged habitat after the cleanup action has been completed.

Land and Water Use

Most land uses are incompatible with the contamination problems present a hazardous waste sites. Cleanup actions may increase land use impacts by implementing measures which result in short-term increases in the release of hazardous substances and the physical interferences associated with the use of heavy equipment. Cleanup actions may also adversely affect off-site land uses. For example, cleanup actions involving excavation of contaminated soils may release vapors and particulate matter and impact off-site residential land uses.

In general, the degree to which cleanup actions impact on-site land or resource use is a function of how long it takes to complete the cleanup action. The time frames required for remediation are determined by the cleanup levels for individual substances and the cleanup technologies used to attain those levels. In most cases, more stringent cleanup standards and the use of treatment technologies will result in longer remediation periods, and therefore, greater impacts on land or resource uses. In the extreme, cleanup standards that are below technically achievable levels may require permanent or semipermanent land-use restrictions. With respect to off-site impacts on land use, a similar relationship applies. More stringent cleanup standards and greater use of treatment technologies tend to increase the potential for the release of hazardous substances and associated impacts on off-site land uses.

Drinking Water

In terms of impacts during cleanup actions, the proposed amendments will have two primary effects. First, at cleanup sites where contaminated ground water is considered a current or potential source of drinking water, the ground water will generally be unavailable for this use during the period of active ground water restoration. More stringent cleanup levels will generally increase the length of time required to complete ground water restoration (EPA, 19891).

As note several times above, cleanup levels over the last several years have been established at levels equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the ground water cleanup levels for certain carcinogens under those alternatives may be more stringent than state and federal drinking water standards. Consequently, it is expected that the background alternative and, in some instances, the risk and combination alternatives will increase the duration of cleanup actions.

The increases in time frames may be significant for some contaminants and some geological settings.

The proposed amendments, by creating a shift towards the use of treatment-based technologies, may also reduce the potential for future impacts on drinking water at the cleanup site and/or off-site treatment or disposal facilities. From this perspective, more stringent soil cleanup levels will also provide some prevention benefits in terms of ground water protection beyond the current situation.

During the period of active ground water restoration, ground water will generally be unavailable for use as a source of drinking water. Potential mitigation measures include the use of alternate water supplies and point of use treatment.

Agriculture

Construction and operation of cleanup actions may impact agricultural land uses through the continued loss of property use, reductions in crop yield to loss of topsoil or exposure to hazardous substances, or reductions in the amount of water available for irrigation. These impacts are anticipated to be of minimal significance on a state-wide basis given that (1) the size of most cleanup sites is extremely small in comparison to the total agricultural acreage in the state and (2) the use agricultural sites undergoing cleanup have already been impacted as a result of past practices.

Ranching

Cleanup actions may result in localized impacts on ranching. However, on a statewide basis, these impacts are anticipated to be of minimal significance because (1) few cleanup sites are in close proximity to ranching areas and (2) the size of most cleanup sites is extremely small in comparison to statewide ranching areas.

Hunting

Cleanup actions may result in localized impacts on hunting. However, on a statewide basis, these impacts are anticipated to be of minimal significance because (1) few cleanup sites are in close proximity to hunting areas and (2) the size of most cleanup sites is extremely small in comparison to statewide hunting areas.

Forests and Logging

Cleanup actions may result in impacts on forests and logging. However, on a statewide basis, these impacts are anticipated to be of minimal significance because (1) few cleanup sites are in close proximity to forests and logging areas and (2) the size of most cleanup sites is extremely small in comparison to statewide forests and logging areas.

Urban and Suburban Land Use

Many urban and suburban land uses are incompatible with the construction and operation of cleanup actions. Implementation of short-term cleanup actions, such as tank removals, may necessitate the temporary closure of commercial and industrial businesses. Cleanup actions requiring lengthy treatment or operation and maintenance periods may result in the prohibition of certain activities at the cleanup site. Such prohibitions would be incorporated into a restrictive covenant required under the proposed amendment (See WAC 173-340-440).

Transportation

In this section, the impacts of the alternatives on transportation patterns and volume in Washington and Oregon are described and evaluated. Site cleanup activities are likely to result in some impacts on local transportation. Increased transportation of contaminated soils or liquids from hazardous waste sites may also result in impacts on long-distance trucking and hazardous waste spills. Potential impacts of the alternatives on transportation, the potential significance of these impacts, and possible mitigation measures that could reduce the impacts are discussed below.

Local Transportation Impacts

Local transportation impacts will be generally associated with vehicles entering and leaving the cleanup site. The specific impact on local traffic depends on a variety of site-specific factors including quality of roads, population around the site, existing traffic patterns, degree of congestion, and remedial technologies used at the site. Traffic around a site may also be affected by spills or emergencies at the site. These factors must be addressed and considered on a site-specific basis.

The increase in traffic around treatment and disposal sites may also be impacted by the proposed amendments. Ecology estimates that site cleanup wastes account for 27 percent of the volume of wastes transported by truck from Washington to Oregon, Idaho, and other states (U.S. EPA 1988d). Washington state contributes over 95 percent of the total wastes hauled to Arlington, Oregon (U.S. EPA 1988d). The proposed siting of one or more hazardous waste incinerators in central Washington could result in significant traffic and infrastructure impacts in the immediate area of the proposed incinerators. These traffic impacts are addressed in the EISs prepared for the proposed incinerators.

Traffic impacts near individual sites are expected to be most severe during the period of initial remediation. For example, at a site where 1,000 tons of soil needed to be removed, 45 truckloads would be required over a period of 1 week. Larger sites might require a month or more to remove all site wastes. Following this period, minor impacts may continue to occur, associated with long-term monitoring at the site. These long-term traffic impacts are generally expected to be insignificant.

Regulatory requirements which result in more stringent cleanup levels may increase the potential for localized traffic impacts. Over the last several years, cleanup levels have been established at concentrations equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the requirements under those alternatives may vary from site to site. Consequently, it is expected that the background alternative is the only alternative that might increase the potential for adverse impacts associated with the implementation of cleanup measures.

Various measures may be implemented to mitigate these impacts. One measure that may allow site remediation to occur without imposing undue hardship on local residents is building or improving of roads surrounding hazardous waste sites or treatment and disposal facilities. Traffic may be directed away from the site, and vehicles entering or leaving the site may be scheduled to arrive and depart during nonpeak traffic hours. Emergency response plans should be in place so that spills or other emergencies can be handled in an efficient and safe manner. Finally, adding noise barriers and wetting road surfaces to decrease noise and dust may be required at some sites.

Impacts on Long-Distance Traffic Volume

Impacts on long-distance traffic volume may include an increase in the volume of truck traffic or a change in the patterns of long-distance hauling. Of the approximately 234,000 tons of hazardous waste generated in Washington in 1987, approximately 64,000 tons was considered one-time waste derived largely from site cleanups (Ecology 1989e). Therefore, hazardous waste generated from remedial activities in 1987 accounted for approximately 27 percent of the waste produced in Washington in that year. A few specific sites may account for most of the cleanup-related wastes produced in any given year. Sites such as the ASARCO smelter in Tacoma and Western Processing in Kent contributed most of the site cleanup wastes that were produced in the year those cleanups commenced. If site cleanups generate more wastes, there will be an increased need for hauling wastes off-site and, in turn, increased traffic.

Impacts on traffic volume from long-distance trucking can be estimated by predicting the total volume of waste that is currently hauled as a result of site remediation, determining the number of trucks needed to haul the waste, and comparing the number of these trucks with traffic volume statistics. Ecology estimates that 143,000 tons of hazardous waste was shipped out of state in 1987. Of this amount, approximately 64,000 tons was waste from site cleanups. A typical truck can carry 22 tons of hazardous waste (Cook 1989). Therefore, approximately 2,900 truckloads were needed to haul this waste out of state. Although hazardous waste sites are located throughout the state, 84 percent of the sites are concentrated along the Interstate-5 corridor in western Washington. Therefore, about 2,400 trucks (84 percent of 2,900) carrying site cleanup wastes would use Interstate-5 each year.

Traffic statistics available for the Interstate-5 corridor from Tacoma to Portland are used to evaluate the significance of impacts associated with long-distance hauling. It is estimated that approximately 28,500 vehicles pass any given point on Interstate-5 each day. The total number of vehicles is likely to be significantly larger. Of these, about 2,700 are combination trucks (DOT 1989). Therefore, the total number of vehicles passing any point on Interstate-5 in a year is around 10.4 million, and the total number of combination trucks is 980,000. Of this traffic, only 1 vehicle in 4,300, and 1 truck in 400, would be associated with cleanup of hazardous waste sites based on 1987 data. This number is not considered to have a significant impact on traffic volume.

Traffic statistics are also available for Interstate-84 in Oregon. Average daily traffic in 1987 was approximately 18,000 vehicles, or 6.6 million vehicles per year. Of this number, approximately 2,600 vehicles per day were large trucks (ODOT 1989). Therefore, the total number of large trucks on Interstate-84 in 1987 was approximately 940,000. As discussed above, 2,400 trucks hauling hazardous waste from cleanup sites would be expected to travel east to Arlington. This amounts to about 1 vehicle in 2,800, and 1 truck in 390. Near Arlington, traffic from hazardous waste site cleanups accounted for approximately 1 vehicle in 1,000, and 1 truck in 300. Based on this analysis, traffic impacts in Oregon in 1987 from hazardous waste site cleanups were also not significant.

Hazardous Waste

Spills associated with transporting hazardous wastes may also affect transportation. Spills of hazardous wastes along transportation routes will result in road closures and negative impacts on traffic. The number of spills is expected to increase if more wastes are transported by truck.

It is estimated that in Washington large trucks are involved in 180 accidents per one hundred million vehicle miles (DOT 1989). Some of these accidents may involve spills of hazardous materials. Because the Interstate-5 corridor passes through some of the most congested areas in Washington state and includes sections where construction is ongoing, these statistics may be considered a worst-case analysis for large freeways that pass through level terrain. Hauling routes that include smaller freeways and mountain passes may have higher accident rates. Using the assumptions outlined above (based on 1987 data), the number of accidents due to long-distance hauling of hazardous waste from cleanup sites is approximately three per year. By comparison, there have been an average of seven hazardous materials-related accidents involving large trucks on Interstate-5 each year (DOT 1988).

Regulatory requirements which result in more stringent cleanup levels may increase the potential for adverse impacts associated with transportation-related spills. Over the last several years, cleanup levels have been established at concentrations equivalent to the ARAR alternative. This alternative is more stringent than the technology-based alternative and is probably less stringent than the background alternative. The stringency of the ARAR alternative is similar to the risk-based alternative and the proposed action (the combination alternative), although the requirements under those alternatives may vary from site to site. Consequently, it is expected that the background alternative is the only alternative that might increase the potential for adverse impacts associated with the implementation of cleanup measures.

Mitigation of these impacts can be performed by scheduling long-distance hauling through major urban areas during nonpeak hours, thus avoiding impacts on traffic volume and reducing the chances of accidents. Impacts of spills resulting from highway accidents can be mitigated by efficient implementation of emergency response plans equipped to deal with hazardous waste spills along major hauling routes. Brett et al. (1989) have concluded that the potential human health and environmental risks associated with a transportation-related spill of contaminated materials on land are likely to be small. Their conclusion is based on the assumptions that the total amount of dust and vapors from a single spill pile would be limited and would likely be contained and promptly cleaned up.

Chapter 8
Impacts on the Natural Environment

Ground water, surface water, marine water, soil, and air are important elements of the natural environment. They are valued for their ability to support life, agriculture, fishing, industry, and recreational activities. These uses of the natural environment of the state are addressed in subsequent sections. In addition to benefitting the plants, animals, and human residents of the state, a clean environment is desirable regardless of present or future use. This section describes the relative residual contamination of ground water, surface water, marine water, soil, and air that would result from implementation of the various alternatives.

The impacts on the natural environment addressed in this chapter are primarily concerned with the chemical contamination of the resources. This section addresses the residual contamination allowed under each alternative, recognizing that a clean environment is inherently valuable, regardless of use. The impacts on the uses of land and water are addressed in Chapter 11, and the impacts of contamination of natural resources on human health and the environment are addressed in Chapters 9 and 10. Impacts to natural resources (such as water and air) during remediation are discussed in Chapter 7.

Identification of Impacts on the Natural Environment

The impacts on the natural environment are determined by the relative amount of residual contamination that would be left in place after remediation of the hazardous waste site. Because returning the environment to its natural state is one of Ecology's goals for remediation efforts, any contamination left in place that is above the natural background of the environment at the site is considered an impact.

Assessment of the Significance of Impacts

The extent of contamination in each medium is evaluated using the residual concentrations of hazardous substances (cleanup levels) that could be allowed under the various alternatives. The areas of the state that are most at risk of contamination are determined by comparing the locations of hazardous waste sites with the locations of sensitive elements of the environment. If there is a significant risk of contamination of a medium, the alternatives are evaluated in order to determine which alternatives would result in the least contamination of that medium in the event of a release. Because the impact being evaluated is simply the presence of hazardous substances in various media, the alternatives that would return those media most nearly to their natural state are given a higher rating. Alternatives that would place the concentration of a hazardous substance below its natural background concentration will not be rated more highly than those that reach the background concentration. However, for most synthetic organic compounds, it will be assumed that there is no natural background concentration.

Ground Water

One way to determine the aquifers most at risk of contamination is to compare the locations of known hazardous waste sites with ground water aquifers. This comparison is shown in Figure 20. According to this comparison, aquifers in the Puget Sound region, especially along the Seattle-Olympia corridor, are at risk for contamination, including the sole-source aquifers of Cedar Valley and western Pierce County. Other aquifers at particular risk of contamination include the aquifer underlying Vancouver, Clark County; the aquifer underneath Yakima, Yakima County; and the Spokane aquifer (a sole-source aquifer) in Spokane County. Because most hazardous waste sites are located in or near urban areas, these areas are most at risk.

An additional factor governing risk of contamination is the soil type. Modeling of the landfill and leaking underground storage tank site scenarios showed that the soil type was the single most important factor in determining the spread of ground water contamination. The volatile organic hazardous substances modeled in both site scenarios traveled 1 mile in 15-50 years, assuming a sandy loam soil type, which is common in the Puget Sound area and much of eastern Washington. Fractured basalt, such as is found in the Columbia basin, allows even faster movement of hazardous substances. Soils rich in silt and clay retard the movement of hazardous substances; modeling results show that the same hazardous sub-

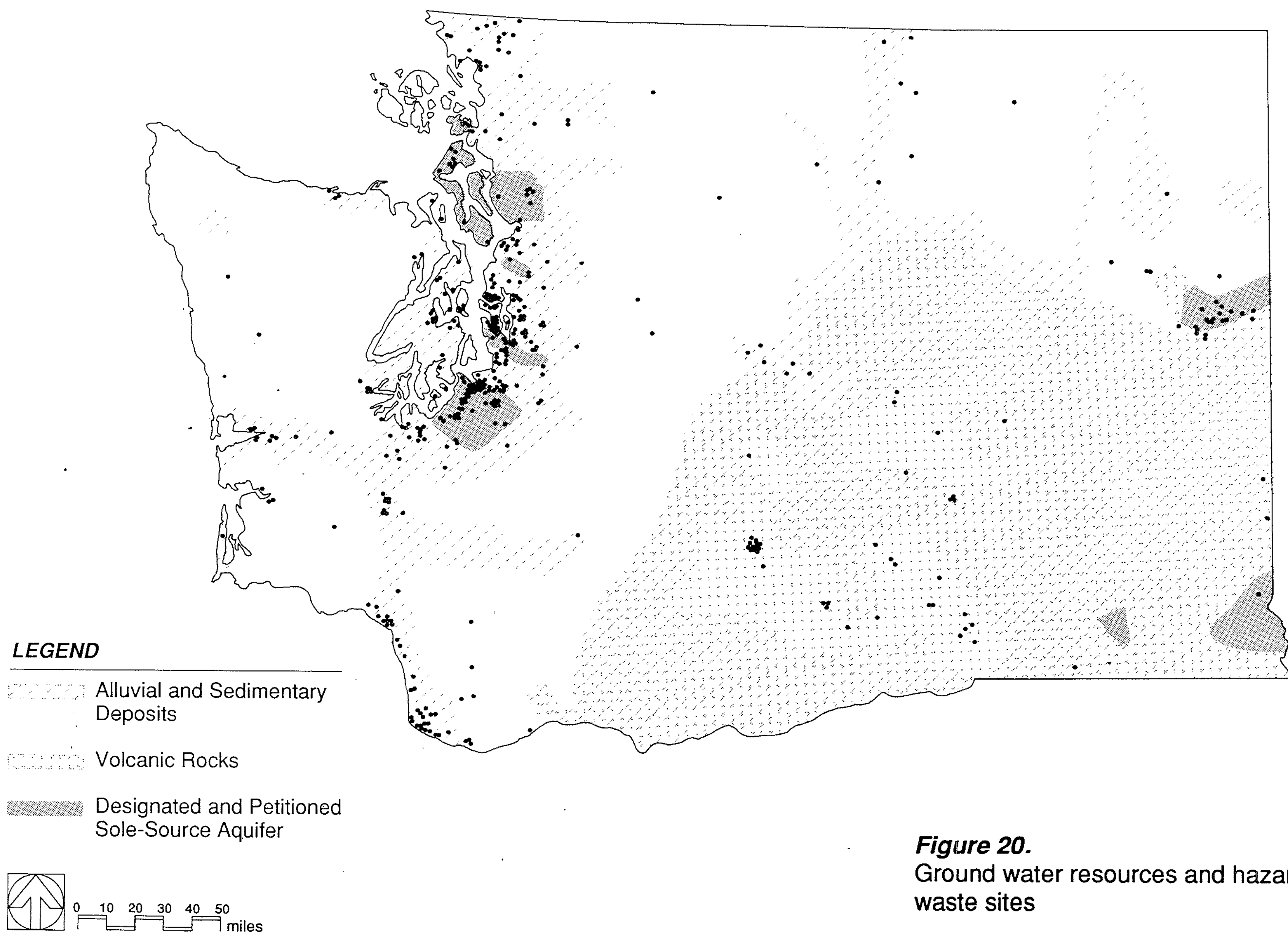


Figure 20.
Ground water resources and hazardous waste sites

stances in a silty clay took from 500 to over 7,000 years to travel 1 mile. However, such soils are not common in Washington; they are primarily restricted to areas around the west side of Puget Sound.

The rate that hazardous substances move is also affected by the climate; more rainfall leaches hazardous substances out of soils faster. Therefore, hazardous substances will not travel as fast in dryer climates such as eastern Washington as they will in western Washington. However, rainfall is not as important a factor as the soil type; hazardous substances in eastern Washington (near Spokane) were found to move about 5 times slower than hazardous substances near Puget Sound.

The background and technology-based standards in ground water would be consistently low; as discussed above, remedial technologies for ground water are capable of removing hazardous substances to the ppb level. Because noncarcinogens are thought to have a threshold below which adverse health effects do not occur, risk-based standards for noncarcinogens would typically be high compared with other alternatives. However, risk-based standards for carcinogens tend to be very low. Analysis of the alternatives shows that the combination, background, and technology-based alternatives would consistently result in low concentrations for all the hazardous substances more often than the other alternatives; the ARAR alternative would be intermediate; and the risk-based alternative would result in the highest concentrations for some hazardous substances, particularly noncarcinogens. Soil standards also affect ground water through infiltration. As discussed in the soil section, the risk-based and technology-based alternatives result in the highest soil concentrations and in the greatest potential for ground water contamination.

Surface Water

The surface water resources at risk of contamination are identified by comparing the locations of known hazardous waste sites with surface water bodies (Figure 21). According to this comparison, the river and lake bodies most at risk of contamination from hazardous waste sites are as follows: surface waters near Bellingham; the mouth of the Snohomish River near Everett; Lake Union and Lake Washington; rivers in King, Pierce, and Thurston counties that pass through the urban corridor from Seattle to Olympia; the Columbia River below Vancouver; the Yakima River below Yakima; and the Spokane River below Spokane.

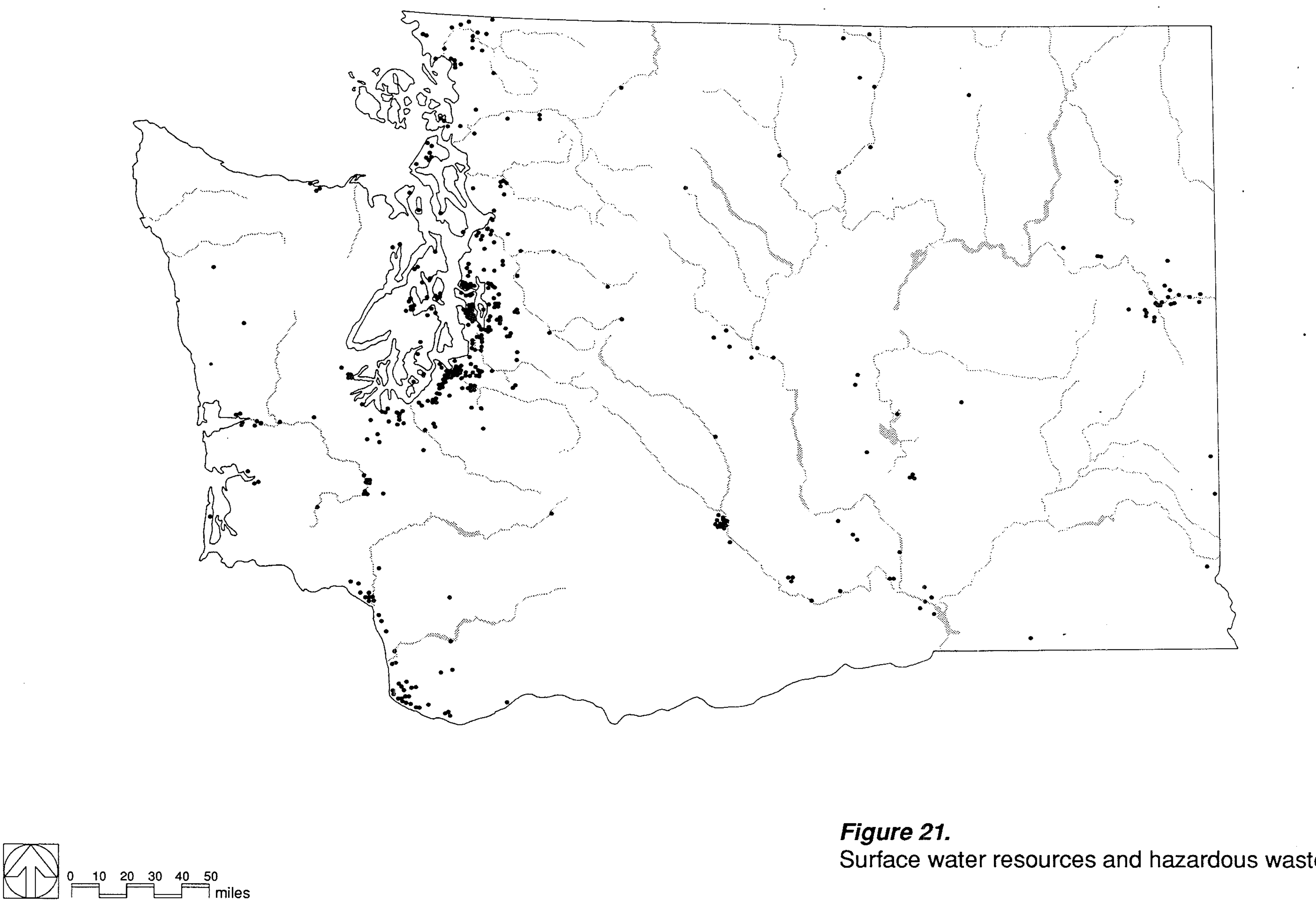


Figure 21.
Surface water resources and hazardous waste sites

When the alternatives for setting cleanup levels for surface water are analyzed, it is seen that each of these alternatives (other than the combination alternative) would result in the lowest concentrations for a different class of chemicals. The background alternative would have the lowest concentrations for metals, the technology-based alternative would attain the lowest concentrations for noncarcinogenic volatile organic compounds, and the risk-based and ARAR alternatives would provide the lowest concentrations for carcinogens. The ARAR alternative would provide lower concentrations in surface water than in ground water because, in addition to human health, toxicity to aquatic life would be considered in setting surface water concentrations. In general, the ARAR and background alternatives would provide the lowest overall concentrations. Soil standards also affect surface water through runoff from a site. As discussed in the soil section, the risk-based and technology-based alternatives would result in the highest concentrations in soil and the greatest potential for surface water contamination.

Marine Water

Figure 21 also shows marine areas and the hazardous waste sites located near them. The marine areas most at risk of contamination include Bellingham Bay, Everett Harbor, Elliott Bay, Commencement Bay, East Passage in Puget Sound, Budd Inlet, Oakland Bay, Dyes Inlet, Sinclair Inlet, and Grays Harbor near Aberdeen.

Analysis of the alternatives for setting cleanup levels shows that the background alternative would likely have the lowest concentrations for most hazardous substances. The combination and technology-based alternatives would be intermediate, except technology-based concentrations for metals would be fairly high. The ARAR and risk-based concentrations would be highest for noncarcinogens, but lowest for carcinogens. The ARAR and risk-based alternatives do not provide concentrations as low as those for surface water because the consideration of drinking water risks is not relevant. In addition, the technology-based alternative would not be able to provide cleanup levels for metals that are as low as those in other water media, because salinity interferes with the treatment process. Therefore, hazardous substance concentrations would likely be lowest under the background alternative. Each of the other alternatives would work well for some hazardous substances but not others. Marine water will also be affected by hazardous substances left in soil or sediments. A discussion of sediment impacts on water quality will be included in the EIS for sediment standards.

Soil

Because contamination of soil is a problem at most hazardous waste sites, the alternatives are evaluated in order to determine which alternatives would be most protective in the event of a release. Soil contamination would be most extensive in urban areas, as these areas have the highest number and density of hazardous waste sites. The background alternative would provide much lower concentrations than any of the other alternatives. The combination and ARAR alternatives, because they take into account protection of ground water, would provide the next lowest concentrations. The risk-based concentrations would be highest. The risk-based concentrations would be highest in soils because most exposures to hazardous substances do not occur through exposure to soil; therefore, it has been calculated that relatively high concentrations of hazardous substances in soil would not result in significant human health risk. Hazardous substance concentrations in soil would be lowest under the background alternative and highest under the risk-based alternative.

Air

The areas in which impacts will be most significant are those at and downwind of hazardous waste sites. These areas are predominantly located along the west side of the Cascades and near major urban centers such as the Seattle-Olympia corridor, Yakima, Vancouver, Spokane, Bellevue, and Everett (Figure 1).

The risk-based alternative for air would likely provide the lowest concentrations, and the technology-based alternative would provide the highest concentrations. The other alternatives would fall indistinguishably in the middle. The technology-based alternative would not provide low concentrations because it is based on concentrations left in soils by the technology-based alternative for soils. If those concentrations were lowered, the technology-based alternative for air would result in lower concentrations. The background alternative would also provide lower concentrations if the background concentrations of rural areas were used as the standard; the background of many hazardous substances in urban areas can be many times higher.

Sediment

Although sediment standards are not addressed in this EIS, the standards for marine water, surface water, and soil may have impacts on sediments. Hazardous substances in marine water may settle out into sediments, and hazardous substances left in onsite soils after cleanup may be carried by surface water runoff (either in dissolved or particulate form) to marine water and sediments. These impacts will be greatest for hazardous substances that do not dissolve easily and that usually bind strongly to soil or sediment. These hazardous substances include most metals and nonvolatile and semivolatile organic hazardous substances. Of the standards for marine water and surface water, the technology-based standards would result in the highest concentrations of these hazardous substances. Of the soil standards, the technology-based and risk-based standards (for noncarcinogens) would be highest.

Summary of Impacts on the Natural Environment

Analysis of the above results for all media shows that the background and combination alternatives have the lowest overall impacts on the natural environment. These alternatives consistently result in relatively low to medium hazardous substance concentrations after remediation. The risk-based and ARAR alternatives result in fairly high relative contamination of the media, primarily because of high allowable concentrations for noncarcinogens. The technology-based alternative falls in the middle because it is effective at reducing hazardous substance concentrations in some media but not in others. Because these impacts are directly tied to the cleanup levels, mitigation can only be achieved by choosing lower cleanup levels for the affected medium. However, cross-media impacts may be mitigated to some extent by preventing migration of hazardous substances from one medium into another. This can be accomplished by capping a site to prevent infiltration of hazardous substances into ground water and resuspension of dust into the air, and by installing surface water or leachate collection systems.

Chapter 9
Human Health

The human health element of the environment addresses diverse threats to human health during a variety of activities. Impacts on human health can occur from exposure to residual concentrations of hazardous substances in environmental media and from concentrations in food and drinking water. The protection of human health is one of the primary goals of the MTCA, and the significance of impacts on human health under each of the alternatives will be a determining factor in the choice of the preferred alternative.

Impacts on Human Health

In general, implementation of the proposed regulations will reduce adverse effects on human health from existing hazardous waste sites in Washington state. However, none of the proposed alternatives includes cleaning up the sites to a pristine state for all hazardous substances, so some residual impacts may be associated with each alternative. Potential impacts from hazardous substances at the sites are described, and the significance of these impacts for each alternative is discussed. Impacts on worker health and the health of nearby populations during remediation and impacts resulting from spills and accidents during transportation of hazardous wastes offsite are discussed in Chapter 7.

Identification of Human Health Impacts

For the purposes of regulatory action and risk assessment, adverse health effects from environmental hazardous substances are typically divided into carcinogenic and noncarcinogenic effects. The scientific basis for this division is the presumption that there is no safe threshold for effects of carcinogens and, therefore, even a very low dose of a carcinogen is associated with some degree of risk. For carcinogens, all residual levels of contamination are believed to have some degree of risk. Establishing cleanup levels for carcinogens requires a decision on what level of risk is acceptable.

For noncarcinogens, however, the presumed existence of a threshold implies that there is no risk associated with exposure to the hazardous substance below the threshold. Therefore, it would theoretically be possible to have safe levels of residual concentrations of noncarcinogens at hazardous waste sites.

Another important factor in determining the significance of human health impacts is the degree of severity associated with them. Although all cancers are typically viewed as having similar impacts, significant differences do exist. For example, lung cancers are usually fatal, while most skin cancers are seldom fatal or disabling. Other cancers such as leukemias may be fatal if untreated but may have a good recovery rate when treated. Fatal or disabling diseases obviously have the greatest impact on individuals.

The range in severity of noncarcinogenic effects is even greater. Effects can range from death to subtle biochemical or physiological changes that are not clearly identifiable as toxic. Some of the most serious effects are impairment of reproduction; effects on development of the fetus, infant, or young child; neurological dysfunction; and immunological effects. These four categories represent effects that are most likely to occur even at low levels of exposure.

A third factor relevant to assessing human health impacts is the prevalence of the effect. Generally, as more people are affected, the impact is considered to be more significant. For example, a small increase in the incidence of a very rare disabling disease may be considered acceptable, whereas exposure to a pollutant that causes discomfort, but not disability, to a large number of people may not be acceptable. Many factors relating to the assessment of human health impacts involve societal judgments rather than medical or scientific judgments.

Exposure Routes of Statewide Importance

Adverse health effects may be caused by hazardous substances released from the site in air, surface water, ground water, or soil. Exposure to hazardous substances in these media may arise from a variety of human activities. These activities may be divided into three categories that affect duration and frequency of exposure:

- Residential activities
- Commercial and industrial activities
- Recreational activities.

Exposure routes of potential importance in each of these categories are presented in Table 14. A subset of these exposure routes would be used to derive statewide risk-based standards (see Chapter 4). Potential exposure to residential populations would be evaluated whenever possible, because these populations typically have the greatest exposure duration and frequency. As noted in Chapter 4, the exposure routes that would be used to develop the risk-based alternative were chosen because they were judged to be the primary exposure routes at most hazardous waste sites. Other exposure routes that were not evaluated may be important at some sites. Two examples are discussed below.

Exposure from Food Sources

Exposure from hazardous substances in food sources is potentially significant in some cases. Fish and shellfish were included in the risk-based alternative because so many sites are located near Puget Sound or the Columbia River. At some sites, however, exposures via meat, vegetables, and dairy products may be more important. Hazardous substances may enter plants either by depositing on the leaves or by uptake from soil and water through the roots. Agriculture is a major industry for the state, particularly east of the Cascades, where large land areas are devoted to fruit and grain production. West of the Cascades, dairy production occurs near a number of sites. Additionally, the long growing season in the west encourages production of fruits and vegetables in household gardens. Nationally, 38 percent of households have vegetable gardens (U.S. EPA 1989i). Food produced in household gardens is likely to be eaten primarily by members of the immediate household. Commercial agricultural products, however, are distributed across the state and beyond. Therefore, the affected population is larger, but the impact of contamination from any single site will be diminished by the relatively small contribution of one area to each person's food supply.

In order to address routes of exposure through food sources, three of the site scenarios included ingestion of potentially contaminated food sources. At the metal plating facility, the effects of surface water runoff and ground water containing metals on fisheries in the river was modeled. No adverse health effects were predicted. At the wood treatment facility, surface water runoff carried hazardous substances (phenanthrene, 2,3,7,8-TCDD, and pentachlorophenol) to a nearby urban bay, containing shellfish and ocean fish that are harvested recreationally by local fishermen. The results predicted significant risk to human health under any of the possible soil standards from consuming the fish and shellfish (illustrating the need for soil standards that are more protective of other media).

TABLE 14. POTENTIAL EXPOSURE ROUTES

Exposure Medium/Exposure Route	Residential Population[a]	Commercial/Industrial Population[a]	Recreational Population[a]
Ground water			
Ingestion[b]	L	A	--
Dermal contact[b]	L	A	--
Surface water			
Ingestion[b]	L	A	L,C
Dermal contact[b]	L	A	L,C
Sediment			
Incidental ingestion	C	A	C
Dermal contact	C	A	L,C
Air			
Inhalation of vapor phase chemicals			
Indoors[b]	L	A	--
Outdoors[b]	L	A	L
Inhalation of particulates			
Indoors	L	A	--
Outdoors[b]	L	A	L
Soil/Dust			
Incidental ingestion[b]	L,C	A	L,C
Dermal contact[b]	L,C	A	L,C
Food			
Ingestion			
Fish and shellfish[b]	L	--	L
Meat and game	L	--	L
Dairy products	L,C	--	L
Eggs	L	--	L
Vegetables	L	--	L

[a] L - Lifetime exposure
C - Exposure in children may be significantly greater than in adults
A - Exposure to adults (highest exposure is likely to occur during occupational activities)
-- - Exposure of this population via this route is not likely to occur.

[b] Routes used in deriving risk-based cleanup levels.

Adapted from U.S. EPA (1989c).

Finally, the agricultural contamination scenario addressed risks to human health from contamination of irrigation or livestock water at the level of the cleanup levels. Risks from arsenic contamination were high, even at background concentrations. The technology-based alternative was the only alternative resulting in significant risk for other pesticides.

Exposure During Recreation

Also of potential significance at some sites is the exposure to hazardous substances during swimming or other water-based recreational activities. This exposure route may be important in areas where a lake, river, or other water body used for recreational activities becomes contaminated above certain levels. Exposure can occur by absorption through the skin or accidental drinking of water during the activity. A historical example of a location where this exposure route might have been important is Lake Union in Seattle, which was contaminated by hazardous materials and bacteria at one time. Hazardous substance levels have since been improved to the point where swimming and other water-based recreational activities no longer pose unacceptable risk. As an illustration, recreational exposure to 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene was modeled in a river less than 1 mile from a leaking landfill. Even assuming very high concentrations of these hazardous substances in the landfill, significant risks to human health were not predicted by the model.

Assessment of Significance of Human Health Impacts

Methods for assessing impacts of hazardous substance releases on human health are discussed in the description of the risk-based alternative. Concentrations for the risk-based alternative would be derived directly from hazardous substance concentrations judged to have minimal or acceptable impacts on human health. Therefore, these concentrations could be used to assess the relative impacts of the various alternatives. The main limitation of this approach is that only the potential exposure routes expected to be significant at most sites are included in the risk equations. Methods for assessing other exposure routes may be found in U.S. EPA (1989c,i). In addition, the modeling results of the site scenarios are available to help place the risks from various exposure routes in perspective.

As noted earlier, the risk-based concentration for noncarcinogens that is protective of human health would usually be higher than the other alternative concentrations. No significant impacts are expected from a concentration lower than that required to prevent adverse effects to human health. Therefore, all of the alternatives are expected to be protective of human health (and will have no significant impacts) for noncarcinogens in the medium for which the standards are set.

However, when cross-media impacts are considered, very high standards for noncarcinogens (such as those that would result from the risk-based alternative in soils) could result in impacts in other media, such as in ground water. For example, risks from benzene in soils were modeled under the leaking underground storage tank scenario. The results of the model showed that the ARAR and risk-based concentrations of benzene that were based on direct contact with soils could result in significant human health risks from contamination of ground water over 1 mile away.

For carcinogens, the opposite relationship generally holds. When there are significant differences among alternatives, the risk-based standard would usually be lower than that of the other alternatives. Because of this relationship, differences among alternative cleanup levels for carcinogens are expected to result in significant differences in human health impacts. One exception to this generalization is for soils, when the background standard (or PQL) could be lower than the risk-based standard for many hazardous substances.

Except in soils, the alternative associated with the highest cancer risks is the technology-based alternative. This alternative would result in particularly high risks for metals, semivolatile organic compounds, and pesticides, because these hazardous substances cannot always be effectively removed from the environment to safe levels. The background and ARAR alternatives would often, but not consistently, be protective of human health. For instance, drinking water MCLs (ARARs), when modeled for volatile organic compounds in the landfill scenario, were found to be inadequately protective of human health. This probably occurs because the MCLs do not protect against potential exposure to hazardous substances in tap water through inhalation and dermal exposure, while the MEPAS model does take these exposure pathways into consideration. The background alternative would not always be protective of human health. The risk-based alternative is generally protective of human health, except when cross-media impacts occur. The combination alternative considers cross-media impacts and is protective of human health.

Mitigation of Human Health Impacts

Human health impacts can generally be mitigated through a combination of land and resource use restrictions. For example, sites that still present health hazards after cleanup can be fenced off and access can be restricted. Industrial or commercial facilities may be allowed on certain sites, but residential use or development would not be permitted. If drinking water or irrigation water remains contaminated after cleanup, either these water uses could be prohibited and alternative water supplies could be developed or the water could be treated before use. Containing surface water runoff and preventing infiltration (by installing surface water collection systems, barriers, and caps) could deter further contamination of ground water and surface water from hazardous substances left in onsite soils.

Summary of Human Health Impacts

Hazardous waste sites in Washington tend to be clustered around population centers. Therefore, if cleanup levels exceed risk-based concentrations, significant local impacts to human health could result. The technology-based alternative would result in the greatest impacts to human health from carcinogenic hazardous substances. Each of the other alternative approaches for setting cleanup levels could result in significant impacts under certain situations, but would be protective much of the time. Based on modeling data, the greatest risks from any of the proposed alternatives are from levels in soil insufficient to protect drinking water or nearby aquatic food supplies. The combination alternative for soils is designed to protect ground water. None of the alternatives would result in significant impacts on human health from residual concentrations of noncarcinogenic hazardous substances.

Chapter 10
Plants and Animals

Under the plants and animals element of the environment, risks to natural plant and animal communities from residual concentrations of hazardous substances left in place after remediation are addressed. Impacts to plants and animals and mitigation measures for those impacts are described in Chapter 7. The protection of ecological communities is a primary goal of the MTCA, and the significance of impacts on plants and animals under each of the alternatives will be a determining factor in the choice of the preferred alternative.

Impacts on Plants and Animals

The effects of hazardous substances on the plants and animals of Washington state not only include individual toxicity and mortality, but also include alterations in population abundance and distribution. Poor health of individual organisms at or before the time of reproduction may lead to population effects. Although ecological effects (changes in populations) are of principal concern, most available data record the impacts of hazardous substances on individuals rather than on populations. Therefore, effects on individuals are presumed to be associated with effects on populations, except when toxic effects are noted only in individuals too old to reproduce.

The proposed regulations will establish cleanup levels for ground water, surface water, marine water, soil, and air. These media include all of the known exposure pathways to terrestrial organisms. Marine and freshwater species may additionally be exposed to hazardous substances via sediments, either directly or through the food chain. The impact of the regulations can therefore be fully addressed for terrestrial species (insofar as available data allow), but not for aquatic species. In the latter case, even if the impacts on aquatic plants and animals from the proposed regulations appear to be minimal, there is no assurance that the health of aquatic populations will be maintained without consideration of cleanup levels for sediments. Sediment standards are being addressed in a separate EIS.

Identification of Impacts on Plants and Animals

The impacts from chronic exposure to residual contamination may be long-term and continuing and may lead to permanent modifications of the biological community in the affected area. For particularly sensitive species, the residual levels of some hazardous substances may even cause acute effects. The possible effects of residual hazardous substances on individuals include:

- Mortality
- Reduced growth, vigor, or size
- Reduced reproductive success (failure to reproduce, induction of birth defects, or alterations in sex ratio)
- Lesions, tumors, demineralization of bones, leukemia, and other body abnormalities
- Behavioral changes
- Mutations and other genetic effects (for example, chromosomal abnormalities).

Widespread effects on individuals are assumed to have effects on the population as a whole. These can be manifested as:

- Reduced abundance or local extinction of the species
- Reduced tolerance to other stresses or environmental extremes
- Loss of effectiveness in certain ecological roles (for example, reduced ability of a predator to capture prey)
- Genetic alterations.

Changes in the population of a sensitive species can affect the distribution and abundance of other species in the biological community, even if those other species are not directly affected by the residual contamination. Severe effects on a single species, as in the case of a food source at the base of the food chain or a predator that controls the abundance of other species at the top of the food chain, can lead to fundamental changes in the biological community near a site.

Assessment of Significance of Impacts on Plants and Animals

The Washington Department of Natural Resources and the Department of Wildlife have performed studies to determine what sensitive, threatened, and endangered species and special habitats are present at or near currently existing hazardous waste sites

(DNR 1990; DOW 1990). Two endangered and five sensitive plant species were documented in areas near hazardous waste sites. Of these 7 species, 6 were found at 12 sites in the Puget Sound region. Only one was documented in the Columbia Basin. Three high-quality wetland areas are located near sites in the Puget Sound region (DNR 1990).

Wildlife species of concern were also concentrated in the Puget Sound region. There have been 29 sightings of 11 species near hazardous waste sites, mostly in King and Pierce Counties. In the Puget Sound region, about 5 percent of the hazardous waste sites may be associated with threatened, endangered, or sensitive species. Most of the species of concern on the list are birds. Seven of the species of concern have been sighted at sites in the Columbia Basin, four have been sighted on the Olympic Peninsula, and four have been sighted in the western Cascades (DOW 1990). A comparison of the locations of sensitive ecosystems and hazardous waste sites is presented in Figure 22.

These data show that a majority of hazardous waste sites are isolated from sensitive terrestrial areas. However, a large proportion of sensitive aquatic areas, such as rivers used by anadromous fish, pass through areas with numerous hazardous waste sites. Therefore, the most significant impacts on plants and animals are expected to occur to aquatic life. In order to address this concern, two of the site scenarios (metal plating facility and wood treatment facility) included exposure pathways to surface water through ground water and surface runoff from the sites. At any of the alternative cleanup concentrations, the risks from chromium, copper, and zinc at the metal plating facility to aquatic life were very small. However, soil standards based on ARARs and technical feasibility at the wood treatment facility resulted in exceedances of marine water quality criteria for phenanthrene (a PAH) and 2,3,7,8-TCDD in a nearby urban bay.

Assessment of long-term impacts in affected areas must be based on an evaluation of the sensitivity of plants and animals to residual levels of hazardous substances. Sensitivity should be established by the demonstration of statistically significant changes in population size, distribution, or genetic composition or by statistically significant changes in mortality rates, growth or size, reproductive success, bodily abnormalities, or behavior. Monitoring data or experimental studies (for example, bioassays) should be used to establish species responses to hazardous substances. When data for a species of concern are not available and are not practical to collect (for example, for endangered species), data for related species must

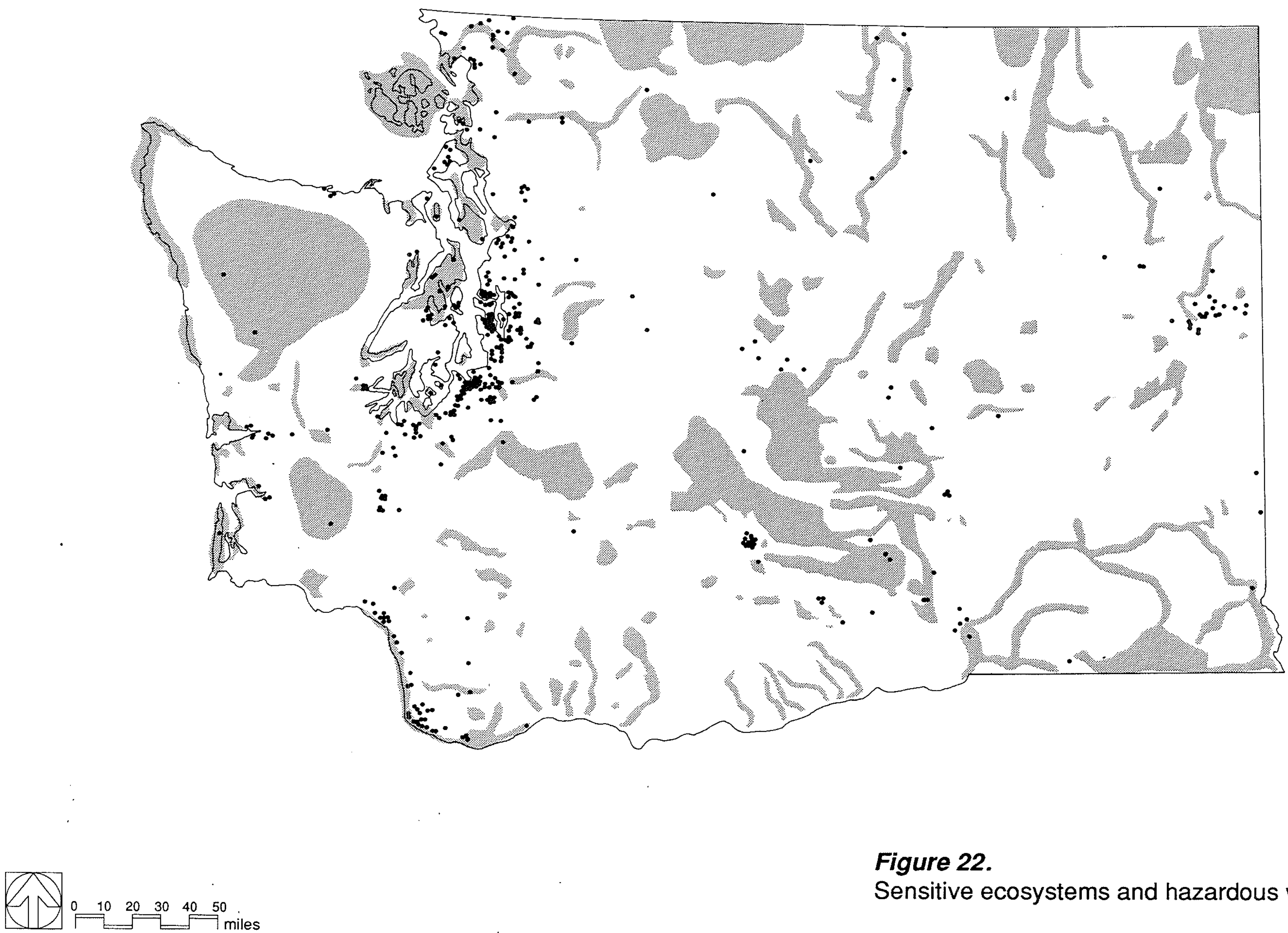


Figure 22.
Sensitive ecosystems and hazardous waste sites

be used. Because bioaccumulation factors may differ between closely related species by 1-2 orders of magnitude, an equivalent safety factor should be applied before using such data.

Available information on hazardous substance effects on plants and wildlife covers a wide variety of species and field or experimental conditions. Evaluations of toxicity for each of the hazardous substances of concern and for species of interest in Washington state are not available. For evaluation of statewide effects, therefore, available data are used in a conservative (protective) manner. For each hazardous substance for which there are sufficient data, the maximum tolerable concentration (MTC; the concentration at which most species will not experience toxic effects) for the most sensitive species in each environmental medium is identified or estimated. In some cases (particularly for aquatic organisms), sensitivities are expressed in terms of environmental concentrations of hazardous substances. In other cases, sensitivity is expressed in terms of the concentration of a hazardous substance in the diet. The scarcity of data on bioaccumulation factors throughout successive steps of food chains often requires assumptions to be made about hazardous substance concentrations in the diet. When toxic effects are recorded only as dietary concentrations, it is presumed that dietary concentrations are equivalent to soil or water concentrations, and a comparison to the example concentration is made on this basis.

Phytotoxicity refers to the poisoning of plants by hazardous substances in soil, resulting in reduced growth, failure to reproduce, or death. Evaluation of the phytotoxicity of hazardous substances in soil to plants is usually made on the basis of the percentage of the hazardous substance that is available to the plant. The proportion of a soil hazardous substance that is available to plants depends on the hazardous substance, the soil pH, and the concentrations of other soil constituents. Because this proportion is often not known, in this document the entire amount of the hazardous substance in soil is assumed to be available to the plant. This provides a conservative measure of the possible total harm to the plant.

The principal exposure route for some plants to hazardous substances is through airborne dust that settles onto the leaves. The amount of a hazardous substance to which a plant will be exposed depends on the rainfall and wind patterns; the number, size, and orientation of leaves on each species; and the length of time during the year that the plant has leaves. Data to support even the most general conclusions about the anticipated exposures and sensitivities of plant species to atmospheric hazardous substances are lacking (one study was found on the toxicity of airborne arsenic to plants). Such information must generally be gathered on a site-by-site basis.

Toxicity effects are often expressed as LC_{50} or LD_{50} values, which are defined as the concentration in the environment or the dose in food at which half of the organisms die in an experimental study. These concentrations are higher than the MTC. When only the lethal concentrations are available, conversions to MTCs are made by dividing the LC_{50} or LD_{50} by 10 for aquatic species and by 5 for terrestrial species, following the procedure established by Urban and Cook (1986). Long-term or chronic LD_{50} values are used instead of acute values where possible, to better reflect the likely effects of long-term exposure to residual contamination in the environment.

The MTCs for selected hazardous substances and sensitive species or groups of species in various media are shown in Table 15. The table includes data for a variety of aquatic and terrestrial species. The data are drawn principally from Eisler (1985, 1986a,b,c, 1987, 1988a,b, 1989), which directly address toxicities to wildlife. This database is not comprehensive; available summaries were used to illustrate the magnitude of impacts that might be expected. Most of the available data are for surface water and marine water. Some data are available for soil, and almost no data are available for air. Because aquatic species in Washington are expected to be most vulnerable to hazardous substances, the water-related data are particularly useful in predicting impacts. In addition to surface and marine water, ground water standards are important to consider because of the potential impacts of residual contamination in ground water on surface water communities to which the ground water may be hydrologically linked.

Data for metals are the most extensive, followed by data for semivolatile organic compounds and pesticides. Data on the toxicity of volatile organic compounds to plants and animals are generally not available due to the difficulty of measuring and maintaining concentrations of these substances under experimental conditions. For quite a few hazardous substances, there are insufficient data to predict potential effects at different concentrations on some wildlife groups, particularly mammals and species at higher levels of the food chain.

Arsenic toxicity data are available for aquatic plants and animals and for terrestrial plants. No arsenic data for terrestrial animals are included. In each case, the MTC is somewhere within the range of

TABLE 15. MAXIMUM TOLERABLE CONCENTRATIONS

Contaminant	Sensitive Group	Exposure Pathway	Maximum Tolerable Concentration	Reference
Arsenic	Crop plants	Surface water	3 mg/L	Eisler 1988a
		Soil	25 mg/kg	Eisler 1988a
	Terrestrial plants	Air	3.9 $\mu g/m^3$	Eisler 1988a
	Freshwater algae	Surface water	19 µg/L	Eisler 1988a
	Cladocera	Surface water	0.52 mg/L	Eisler 1988a
	Rainbow trout embryos	Surface water	54 µg/L (LC_{50}/10)	Eisler 1988a
	Juvenile *Eurytemora affinis*	Marine water	0.1 mg/L	Eisler 1988a
Cadmium	Crop plants	Soil	20 mg/kg	Purves 1985
	Freshwater insects and crustaceans	Surface water	0.7 µg/L	Eisler 1985
	Juvenile salmonids	Surface water	0.17 µg/L (LC_{50}/10)	Eisler 1985
	Fiddler crabs	Marine water	1.0 µg/L	Eisler 1985
	Juvenile striped bass	Marine water	0.5 µg/L	Eisler 1985
	Black ducks; hatchlings of exposed parents	Diet (soil)	4 mg/kg	Eisler 1985
Chromium (6+)	Freshwater crustaceans	Surface water	<10 µg/L	Eisler 1986a
	Freshwater algae, duckweed	Surface water	<10 µg/L	Eisler 1986a

TABLE 15. (Continued)

Contaminant	Sensitive Group	Exposure Pathway	Maximum Tolerable Concentration	Reference
	Marine algae	Marine water	<10 µg/L	Eisler 1986a
	Marine polychaetes	Marine water	17 µg/L	Eisler 1986a
	Young waterfowl	Diet (surface water, soil)	<10 ppm	Eisler 1986a
	Earthworms	Surface water	<10 µg/L	Eisler 1986a
Lead (2+)	Marine algae	Marine water	<5.1 µg/L	Eisler 1988b
	Cladocera	Surface water	<1.0 µg/L	Eisler 1988b
Lead (trimethyl lead)	Rainbow trout	Surface water	0.35 µg/L (LC_{50}/10)	Eisler 1988b
Lead (2+)	Marine diatoms	Marine water	0.51 µg/L (LC_{50}/10)	Eisler 1988b
Lead	Soil decomposers	Soil	12,800 mg/kg	Eisler 1988b
Lead	Sensitive bird species	Diet (soil)	50 mg/kg	Eisler 1988b
Pentachlorophenol	Freshwater algae and macrophytes	Surface water	8 µg/L	Eisler 1989
	Terrestrial plant roots	Surface water	0.3 mg/L	Eisler 1989
	Freshwater snail	Surface water	16 µg/L (LC_{50}/10)	Eisler 1989
	Rainbow trout	Surface water	10 µg/L	Eisler 1989
	Oyster	Marine water	7.7 µg/L (LC_{50}/10)	Eisler 1989
	Razor clam	Marine water	15.8 µg/L	Eisler 1989

TABLE 15. (Continued)

Contaminant	Sensitive Group	Exposure Pathway	Maximum Tolerable Concentration	Reference
	Sockeye salmon, coho salmon, chinook salmon	Marine water	5.5-6.5 µg/L (LC_{50}/10)	Eisler 1989
PAH compounds	Aquatic and terrestrial plants	Atmosphere and soil	Phytotoxicity is rare	
	Marine crustacea (copepod)	Marine water	32 µg/L (LC_{50}/10)	Eisler 1987a
	Salmon fry	Surface water	92 µg/L (LC_{50}/10)	Eisler 1987a
PCB mixtures	Ostrich ferns	Soil	<26 mg/kg	Eisler 1986c
	Freshwater algae	Surface water	<0.1 µg/L	Eisler 1986c
	Brook trout	Surface water	0.94 µg/L	Eisler 1986c
	Cladoceran	Surface water	0.13 µg/L (LC_{50}/10)	Eisler 1986c
	Northern bobwhite	Diet (soil)	1.21 mg/kg (LD_{50}/5)	Heath et al. 1972
	Mink	Diet (soil)	1.3 mg/kg (LD_{50}/5)	Eisler 1986c
DDD	Pheasant	Diet (soil)	116 mg/kg (LC_{50}/5)	Heath et al. 1972
DDE	Bobwhite	Diet (soil)	165 mg/kg (LC_{50}/5)	Heath et al. 1972
DDT	Pheasant	Diet (soil)	62 mg/kg (LC_{50}/5)	Heath et al. 1972
Hexachloro-cyclohexane (lindane)	Pheasant	Diet (soil)	112 mg/kg (LC_{50}/5)	Heath et al. 1972

TABLE 15. (Continued)

Contaminant	Sensitive Group	Exposure Pathway	Maximum Tolerable Concentration	Reference
2,3,7,8-TCDD	Freshwater snail	Surface water	0.2 µg/L	Eisler 1986b
	Northern pike eggs and fry	Surface water	1×10^{-4} µg/L	Eisler 1986b
	Rainbow trout eggs	Surface water	1×10^{-4} µg/L	Eisler 1986b
	Laboratory rats	Diet (soil)	0.2 µg/kg	Eisler 1986b

standards that would be generated by the alternatives. This concentration is expected to be above both risk-based and background standards. In general, the arsenic MTC would also be above ARARs. Arsenic toxicity in soil may vary greatly from site to site and is increased by low soil pH, high moisture content, phosphorous and aluminum deficiency, and iron and phosphorous excess (Eisler 1988a). Body arsenic concentrations of 20.8 mg/kg have been found in dead honeybees, although these concentrations may be caused by aerial spraying of pesticides. The honeybee body arsenic concentrations are within the range of the alternative standards.

Cadmium toxicity data are available for terrestrial plants, freshwater and marine animals, and a waterfowl species. The MTCs of surface water species would typically be at or below the lowest of the alternative standards (background). MTCs for marine species would be above only the background concentration. Plants exposed to cadmium in the soil and ducks exposed to dietary cadmium have MTCs that are much higher than background concentrations in soil. Although cadmium is known to be toxic to humans and other mammals, available data relate toxic effects to the total amount in the body rather than to dietary or environmental concentrations. Freshwater and marine organisms and earthworms are known to accumulate cadmium (Eisler 1985; Chaney 1984), so higher levels of the food chain may be exposed to increased concentrations. Additional data are needed to adequately assess the impact of cadmium on mammals.

Chromium is a necessary nutrient for terrestrial plants, and phytotoxicity has not been observed under natural conditions (Chaney et al. 1984). Marine and freshwater algae and invertebrates have chromium MTCs at concentrations above background concentrations in water. Young waterfowl exhibit toxic responses at dietary concentrations that would be above all of the alternative standards for water and below all of those for soil. Feeding waterfowl are exposed to chromium directly through both of these sources and indirectly through plants. Information on the relative contribution of soil to waterfowl diets is necessary to assess whether the cleanup levels represent a risk to these species.

Lead toxicity data indicate that some freshwater invertebrates and fish may experience some adverse effects at concentrations below those of any of the alternative standards. Marine and terrestrial species have MTCs that are higher than background concentrations in water. Lead is known to be quite toxic to birds, and many experimental studies have been performed on waterfowl (Eisler 1988b). However, in these studies, toxicity is related to the number and type of lead shot eaten or to the total amount of the hazardous substance in the body. Therefore, most of the toxicity data cannot be used to predict the effects of environmental contamination. Although some experiments have been performed with laboratory animals, very few data exist on lead toxicity to mammalian wildlife (Eisler 1988b).

Pentachlorophenol toxicity to domestic and experimental animals and birds has been observed, but toxicity is generally recorded in terms of the total amount of hazardous substance in the body, which cannot be easily related to environmental concentrations (Eisler 1989). Toxicity data for organisms exposed to surface and marine water are shown in Table 15. Background and technology-based standards would typically be below the concentrations at which toxic responses were observed or expected.

PAH compounds are known to have toxic and carcinogenic effects on man and laboratory animals, but dose-response data for vertebrate wildlife are lacking (Eisler 1987). Phytotoxicity is rarely observed, perhaps because many plants produce PAH compounds naturally. Sensitive freshwater and marine species would be affected only at concentrations more than an order of magnitude higher than the highest of the alternative standards.

PCBs generally have toxic effects on sensitive plants and animals at concentrations above ARARs and above or equivalent to background concentrations of PCBs. Based on available data, the mink is the most sensitive mammal; the MTC shown in Table 15 is based on the assumption that the mink's diet reflects soil concentrations. Terrestrial (crop) plants generally accumulate PCB mixtures to a concentration only one-tenth of that in soil, although the skin of carrot roots can magnify PCB concentrations (Chaney 1984). Magnification of PCB concentrations can occur at higher levels in the food chain, however. Invertebrates and fish have bioconcentration factors of tens of thousands (Eisler 1986c), and the concentrations in fat tissue of cattle and pigs reach levels of 5 times higher than those in the feed (Chaney 1984). Although elevated PCB concentrations are associated with lowered reproductive success in some birds (Eisler 1986c), there are insufficient data on bioconcentration factors throughout the food chain to allow these effects to be directly related to soil, water, or atmospheric concentrations of PCB mixtures.

Results of experiments on the toxicity of pesticides to birds indicate that toxic effects begin only at concentrations that exceed the highest alternative standards by several orders of magnitude.

Dioxin toxicity has been evaluated for few wildlife species, and no evaluations of phytotoxicity were found. Freshwater invertebrates and some fish have MTCs that would likely be above all of the alternative standards. Birds have acute LD_{50} values in the range of 1-100 μg/kg of body weight (Eisler 1986b), but these responses cannot be related directly to environmental concentrations or chronic exposures. Toxic effects on mammals have only been reported for laboratory animals, generally in terms of total body concentrations. The most sensitive of these animals is the guinea pig, with an acute LD_{50} of 0.6 μg/kg of body weight (Eisler 1986b). The guinea pig is at least 10 times more sensitive than the rat to acute doses. If this relationship is also true for chronic exposures, then, using the rat's MTC shown in Table 15, the guinea pig's chronic sensitivity would be near the lowest of the alternative standards. Dioxin is probably not introduced to the terrestrial food chain via vegetation, because rooted plants do not usually bioaccumulate such organic compounds (Eisler 1986b). However, storage in fat and liver can lead to biomagnification at higher levels of the food chain.

The significance of the impacts of cleanup levels for water that would be used under the various alternatives can also be assessed by comparison with established water quality criteria for marine and fresh water aquatic life (U.S. EPA 1986g). If all of the alternative standards were above the established criterion for a hazardous substance, a significant impact would be likely to occur. This circumstance occurs, for example, for DDT in ground water. The lowest possible ground water standard for lead is below the EPA criterion, by less than a factor of 2. Cadmium, chromium, and copper standards for ground water would also equal or slightly exceed the EPA criterion. Comparisons of EPA criteria to alternative surface water and marine water standards show that the background, risk-based, and ARAR standards would generally be below the EPA criteria.

Mitigation Measures

Impacts to plants and animals cannot be as easily mitigated as impacts to human health because of the difficulty in restricting the behavior of plants and animals. However, certain measures can be taken. For instance, the impacts of residual soil contamination on plants and animals can be mitigated by capping the site; however, capping the site reduces the amount of habitat available at the site. Larger animals can be prevented from entering a site by fencing the site appropriately. If a stream runs through a contaminated site, it may be possible to divert the stream around the site. In general, many of the same mitigation measures that were applicable during cleanup action (see Chapter 7) may also be applied after the site has been cleaned up.

Summary

For most hazardous substances, one or more of the alternative standards would be below the concentrations at which sensitive species are likely to experience significant toxic effects. Even the use of the background alternative could result in impacts to plants and animals because the alternative, as proposed, does not incorporate pristine background concentrations. Instead, it uses prerelease background concentrations or PQLs as standards. Hazardous substances for which available data suggest that even the lowest of the alternative standards could result in adverse effects to wildlife are listed below:

- **Chromium**—Young waterfowl may be affected if their dietary concentration approaches the alternative standards for soil.
- **Lead**—Freshwater invertebrates and some fish may be affected at the lowest surface water alternative standard. In addition, the surface water standards would all be above the EPA chronic exposure criterion.
- **DDT**—The lowest surface water and ground water alternative standards would be well above the EPA chronic exposure criterion.

None of the five alternatives for setting cleanup levels would result in concentrations consistently below the MTCs for all hazardous substances. However, some alternatives would be equal to or below these concentrations more often than others. It is the goal of Ecology to provide cleanup levels that are protective of at least 95 percent of all species in the environment. Therefore, any alternative that meets or exceeds that goal is considered protective and will likely have no significant impacts on the environment. An alternative that is at or below MTCs 50 percent or less of the time clearly does not meet the requirement that the standards be adequately protective of the environment.

The background alternative would be protective of the environment in almost every case. Therefore, it is expected that the background alternative would have no significant impact on the environment. The technology-based alternative would result in concentrations that are not protective of the environment about 50 percent of the time. This alternative would have the potential for the most significant impacts on the environment. In most cases, the combination, risk-based, and ARAR alternatives are protective of the environment. These alternatives are moderately protective of the environment, but could result in significant impacts at individual sites. However, the combination and risk-based alternatives require site-specific environmental review to determine possible impacts and mitigation measures at each individual site. This review would largely mitigate the impacts from these alternatives.

Chapter 11
Land and Water Use

The land and water use element of the environment addresses the loss of human use of land or water and includes consideration of drinking water, agriculture, ranching, hunting, fishing, logging, urban and suburban land uses, and recreation. The extent to which these resources are affected may vary considerably depending on the alternative cleanup level selected. The protection of these land and water uses is an important goal of the MTCA.

Impacts on Land and Water Use

Many land and water uses may be affected at or near a site by the presence of hazardous substances remaining after remediation (impacts on land use during remediation are addressed in Chapter 7). The degree of post-remediation impacts on land or water use may depend on the cleanup alternative selected. For example, some farming activities may be excluded at one cleanup concentration but not at another. Similarly, the impacts of residual contamination on water uses such as recreational fishing may vary depending on the cleanup concentration selected.

The relative effects of the alternatives for setting cleanup levels on potential land and water use are assessed in this section. Where available and appropriate, information is presented on hazardous substance-specific criteria for land and water uses. Potential impacts are identified for cases in which the criteria may be exceeded, and the impacts are evaluated based on the magnitude of criteria exceedance, the regional or statewide importance of the land use or resource use, the proximity of known sites to the affected use, and the scale and duration of the possible impacts. Impacts are evaluated for drinking water, agriculture, ranching, hunting, fishing, logging, urban areas, and recreational areas.

Drinking Water

In 1988, 19 of the 4,037 public water supply systems that use ground water in Washington were found out of compliance with drinking water MCLs. Of these, 18 were out of compliance due to nitrate contamination, and 1 was out of compliance due to synthetic organic compounds. Most public water supply systems have not been required to test for metals or synthetic organic compounds, and the presence of these hazardous substances may be unrecorded. More representative data may be available in the future (U.S. EPA 1989e).

Contamination of drinking water from releases at hazardous waste sites may result in risks to human health and in loss of use of the drinking water. Human health risks are discussed in Chapter 9. Loss in use of the resource may result if hazardous substances in the drinking water source exceed primary or secondary MCLs or other regulatory limits. Therefore, impacts would be expected only if the standard for a certain hazardous substance exceeded the drinking water regulatory limit. For each of the following alternatives, the types of hazardous substances for which standards would exceed regulatory limits are described:

- **ARAR alternative**—By definition, no standards under this alternative would exceed regulatory limits. However, there are no MCLs for many hazardous substances, such as dichloromethane, PAHs, or 2,3,7,8-TCDD.
- **Background alternative**—All standards under this alternative would be less than or equal to regulatory limits.
- **Risk-based alternative**—The risk-based standards for many noncarcinogens would be higher than regulatory limits (such as secondary MCLs, which are not based on protection of human health).
- **Technology-based alternative**—The technology-based standards for highly toxic metals and nonvolatile hazardous substances would often be higher than regulatory limits.
- **Combination alternative**—The combination alternative standards would be, by design, equal to or lower than all regulatory limits.

Implementation of the risk-based or technology-based alternative for setting standards in water media may result in loss of use of both ground water and surface water for drinking water supplies. Similarly, modeling of several of the site scenarios showed that the alternatives for soil standards, particularly the risk-based standards for noncarcinogens in soil and the technology-based standards for carcinogens in soil, could result in ground water or surface water exceedances of MCLs. The ARAR and combination alternatives have been modified to take into account cross-media impacts from soil to ground water.

The severity of the impacts would depend primarily on the location of hazardous waste sites relative to existing or potential drinking water supplies. In general, the vulnerability of an area would be expected to increase with an increase in the number of hazardous waste sites located near sources of drinking water. In areas where drinking water is derived from groundwater, extraction points are likely to be near population centers (and thus near concentrations of hazardous waste sites). In contrast, the extraction point for surface water used as a drinking water source is often far removed from population centers (and thus likely to be relatively removed from hazardous waste sites) (DOH 1989).

Drinking water sources for Skagit, Cowlitz, Franklin, and Whatcom counties are potentially most affected by hazardous substances in surface water. In these counties, several hazardous waste sites are located near a major watershed used for drinking water. A worst-case scenario may be defined as a loss in use of surface water in these counties if the risk-based or technology-based alternative is implemented for the hazardous substances listed above. Areas where worst-case losses may be significant are:

- **Skagit County**—28,000 gallons/minute (seven sites in the Skagit River drainage)
- **Cowlitz County**—16,000 gallons/minute (6 sites in the Cowlitz, Columbia, and Lewis rivers and Campbell Creek drainage plus more than 30 sites upstream in Clark County)
- **Franklin County**—13,000 gallons/minute (five sites in the Columbia River drainage)
- **Whatcom County**—7,000 gallons/minute (seven sites in the Nooksack River drainage).

The numbers associated with each county indicate current withdrawals for municipal water supplies.

Other counties that derive a large percentage of their drinking water from surface water sources include Snohomish, King, Pierce, San Juan, Skamania, and Wahkiakum counties. Potential losses in use of drinking water in these counties are small for two reasons: either water is extracted from areas that are remotely located and very unlikely to become contaminated from releases of hazardous substances, or there are few (or no) hazardous waste sites in watersheds used as drinking water sources.

The likelihood of impacts on ground water sources used for drinking water depends on the proximity of hazardous waste sites to ground water wells (see Figure 20). Spokane and Pierce counties are the counties most likely to be affected by hazardous substances in ground water. Spokane County derives all of its ground water supplies (444,000 gallons/minute) from a sole-source aquifer, and there are 16 identified hazardous waste sites over that aquifer (14 in the Spokane area). The most likely area for loss in use to occur is the Spokane area, where water is extracted at a rate of 416,000 gallons/minute. Pierce County derives 242,000 gallons/minute of drinking water from a sole-source aquifer, and there are 99 hazardous waste sites within the county. There are two likely areas for loss in use to occur in Pierce County. In the Tacoma-Puyallup area, 144,000 gallons/minute of water is extracted, and there are 66 hazardous waste sites. In the Fort Lewis area, 30,000 gallons/minute of water is extracted, and there are 18 hazardous waste sites. In addition to Spokane and Pierce counties, loss in use of groundwater resources may be significant in the following areas:

- **Clark County**—62,000 gallons/minute is extracted from Vancouver area wells in an area with 26 hazardous waste sites
- **Yakima County**—19,000 gallons/minute is extracted from Yakima area wells in an area with 21 hazardous waste sites
- **Thurston County**—16,000 gallons/minute is extracted from Olympia area wells in an area with 18 hazardous waste sites.

Mitigation of this impact would require treating ground water or surface water before using it for drinking water.

Agriculture

Releases of hazardous substances from hazardous waste sites can result in loss of use to agriculture through crop failure or reduced marketability. The two most likely routes of exposure for crops are through direct contact with contaminated soil or through contact with contaminated irrigation water. As an example, impacts are assessed for Washington's three most valuable cash crops: wheat, apples, and potatoes. These crops are grown almost entirely in eastern Washington, with the heaviest production in Kittitas, Yakima, Klickitat, Benton, Grant, Adams, Chelan, Okanogan, and Walla Walla counties (Figure 23). It is reasonable to assume that current production is not occurring within the boundaries of existing hazardous waste sites; therefore, no additional loss in use due to onsite soil contamination would occur, either during or after remediation, regardless of the cleanup level selected. There are

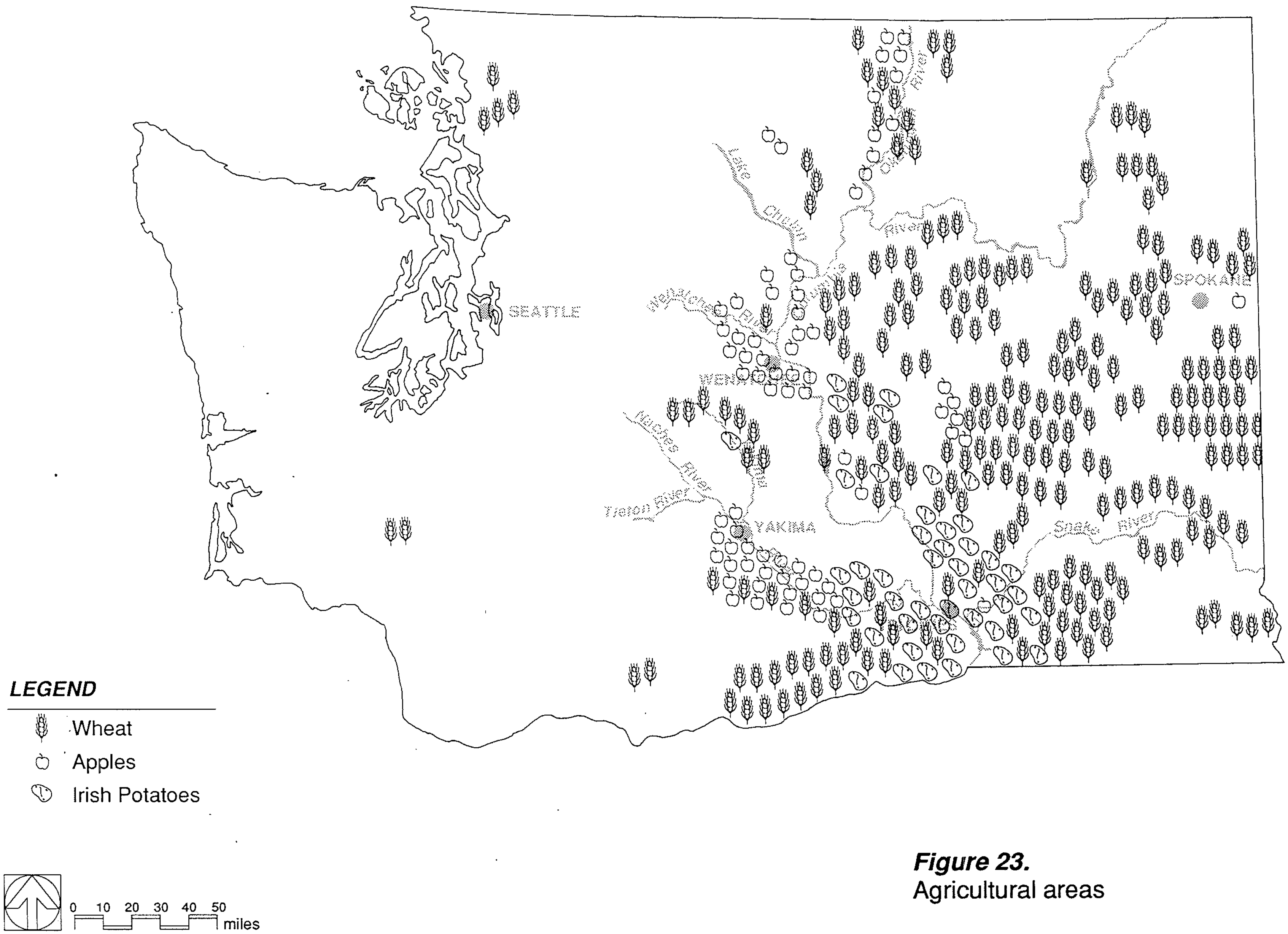


Figure 23.
Agricultural areas

relatively few (approximately 15) sites within the primary areas used for the production of wheat, apples, or potatoes. Based on best professional judgment of patterns of aerial transport and deposition, the areal impact on soil from offsite hazardous substance transport is not likely to result in a significant loss in use to agriculture. The future use of the hazardous waste site land for agriculture could be impaired by higher cleanup levels. However, such land forms a very small percentage of the total land available for agriculture.

The second pathway for hazardous substances to affect agriculture is through irrigation with contaminated water. For example, nearly all of the approximately 130,000 acres of potatoes grown in Washington are irrigated. Most of the potatoes grown in the state are produced in Grant, Adams, Franklin, Walla Walla, and Benton counties. Irrigation water for these areas is taken predominantly from the lower Snake and Yakima rivers and the Columbia River. There are 31 hazardous waste sites between Yakima and Kennewick along the Yakima River; most of these sites are in and around Yakima. Agricultural areas receiving irrigation water from this river segment would be most at risk. However, hazardous substances from these sites may be highly diluted by the large flows in these rivers.

Ten percent (or approximately 250,000 acres) of the wheat crop is irrigated. Water for wheat irrigation also comes from the Columbia basin irrigation project (the Yakima, Naches, and Tieton rivers), the Snake River, and ground water. As stated above, the areas most at risk are those receiving water from the Yakima River near Yakima.

Irrigation is used only as a supplement during dry weather for the production of apples. The three largest apple producing areas of the state are the Yakima basin (with irrigation water from the Naches, Yakima, and Tieton rivers), north central Washington (with irrigation water from the Wenatchee, Chelan, Methow, and Okanogan rivers and Lake Chelan), and the Columbia basin (with irrigation water from the Columbia basin project). Five sites are located along the Okanogan River, five sites are located near the confluence of the Columbia and Wenatchee rivers, and 31 sites are located on the Yakima River.

Information on the toxicity of hazardous substances to crops and other terrestrial plants is presented in Chapter 10. Based on the location of hazardous waste sites with respect to major growing areas and use of irrigation water, the area most at risk of significant impact, if any, is near Yakima. Other impacts from the choice of hazardous waste site cleanup levels are expected to be minimal. To address this area, the agricultural contamination scenario was set in Yakima County. Results from modeling this scenario, discussed in Appendix H, suggest that impacts on land use and water use are possible if large stretches of river become contaminated with agricultural chemicals and must be cleaned up. Although this scenario is considered unlikely at present, such impacts have occurred in other areas of the country. Mitigation of this impact may be accomplished by treating the contaminated water before it is used for irrigation.

Ranching

Contamination from hazardous waste sites can result in loss of land use for ranching through impacts on grazing land, direct toxic impacts on animals, or loss of marketability due to ingestion of hazardous substances from contaminated soil, plants, feed, or water. Transport pathways for hazardous substances vary by type of ranching. The most likely route of exposure for poultry is through feed or water, and the most likely route of exposure for grazing animals is through consumption of contaminated soil or plant matter (such as open range land and irrigated pastures for dairy or meat production). An example of a site-specific evaluation of the danger to ranch animals is presented for poultry, below.

The relationship between feed (for poultry or other animals) and contamination from hazardous waste sites cannot be determined in any reliable manner. For example, processed feed, such as that used for poultry, may originate from various parts of the country and have no relationship with contaminated sites in Washington. Because the vast majority of poultry is raised indoors (and therefore out of possible contact with soil or airborne contamination), the only pathway that can be evaluated for poultry is the ingestion of hazardous substances from water.

Potential toxicity values for poultry are mg/kg trivalent chromium (dietary intake for young waterfowl), 50 mg/kg lead (dietary intake for sensitive bird species), and 4 mg/kg cadmium (dietary intake for black ducks) (Table 15). A comparison of these toxicity values with typical alternative standards shows every alternative except the background alternative has the potential for significant impacts from these hazardous substances. All alternative standards would be below the toxicity value for chromium. The technology-based standard would be between 1 and 2 orders of magnitude above the toxicity value for both lead and cadmium. The risk-based, ARAR, and combination standards would be well above the toxicity values for these hazardous substances. Mitigation of this impact could be accomplished by treating the water before using it to water livestock or poultry.

Grazing animals such as cows and sheep may ingest hazardous substances through contaminated soil or grazing plants, or through the ingestion of contaminated drinking water. No toxicity values are available with which to compare hazardous substance concentrations.

Hunting

Contamination from hazardous waste sites can result in loss of hunting opportunities due to reduced populations or reduction in the quality of a hunting experience. Reductions in populations may occur due to direct toxicity, reproductive effects, or habitat degradation. Reduction in the quality of a hunting experience may occur due to knowledge of contamination in the target species. These impacts could not be easily mitigated.

There are fewer than 10 hazardous waste sites within national forest lands or wildlife refuges in Washington, the primary areas of public lands in which hunting is expected to occur. Because of the lack of data on the toxicity of hazardous substances of concern to game animals, it is not possible to quantify direct toxic effects or other population level effects. Because of the small area affected by these sites, it is highly unlikely that game animals would be adversely affected by loss of habitat under any of the alternative cleanup scenarios (even under a worst-case scenario of total habitat loss within site boundaries). However, ducks and other waterfowl may be particularly at risk from contamination in surface water, especially in wetlands and river deltas. The quality of a hunting experience in these areas may be reduced, or hunting in these areas may be avoided because of knowledge about contamination. Under these conditions, some local loss in use of the resource might be expected. As noted above, the background alternative is the only alternative that is fully protective of waterfowl.

Fishing

Losses in use of fisheries from contamination at hazardous waste sites may result from population decreases, decreased marketability, fishing area closures, or reduction in the quality of the fishing experience (for recreational fisheries). Population decreases may result from direct toxicity, impaired reproduction, loss of habitat, or loss of prey. Decreased marketability may result from contamination or knowledge that the fish product was harvested from a contaminated area. Closures may be imposed in some fishing areas because of human health concerns regarding risks from consumption of contaminated fish. A reduction in the quality of a fishing experience may result from knowledge about contamination of the water or of the target species. The toxicity of various hazardous substances to fish is addressed in the *Plants and Animals* section (Table 15).

Losses in use of fisheries are likely to be highest in areas of high resource use that have the potential for surface water contamination from hazardous waste sites. Sediment contamination may also result in loss (these potential impacts are the subject of a separate EIS and are not discussed in this document). Based on resource characteristics and hazardous waste site distribution, major areas with a potential for loss in use are urban bays in Puget Sound, Grays Harbor, Willapa Bay, and sections of the Columbia, Yakima, and Spokane rivers (Figure 24). Impacts will be highest to fish species living in polluted areas and to anadromous fish that must pass through polluted areas to reach spawning grounds. These impacts cannot be easily mitigated.

As discussed with respect to human health in Chapter 9, two of the site scenarios addressed potential impacts to fisheries. Although the metal plating facility scenario did not result in impacts either to the fish or to human health, the wood treatment facility scenario resulted in slight impacts to fish and shellfish and significant impacts to human health. Because of these concerns, such an area would likely be closed to fishing by the state or the county.

Specific areas of concern in Puget Sound include Oakland Bay near Shelton (6 sites), Budd Inlet (18 sites), Commencement Bay (53 sites), Eagle Harbor (2 sites), Elliott Bay (over 30 sites), Shilshole Bay (over 10 sites), Everett Harbor (8 sites), and Bellingham Bay (10 sites). Commencement Bay, Elliott Bay, Shilshole Bay, Everett Harbor, and Bellingham Bay provide large areas of important habitat for a variety of commercially and recreationally important species such as salmon, steelhead trout, English sole, rock sole, starry flounder, several species of rockfish, and a variety of shellfish. Although Eagle Harbor does not provide an estuarine habitat, it has been used historically for recreational fishing and shellfish harvesting and is near an important commercial bottomfish area. Most fishing activity in the inner bays is recreational or tribal. Commercial harvesting of fish and shellfish occurs predominantly in outer bays or in open water near the bays. Some tribal fishing also occurs within the major river systems of Puget Sound (for example, the Nooksack, Snohomish, Duwamish, and Puyallup rivers and the Lake Washington ship canal).

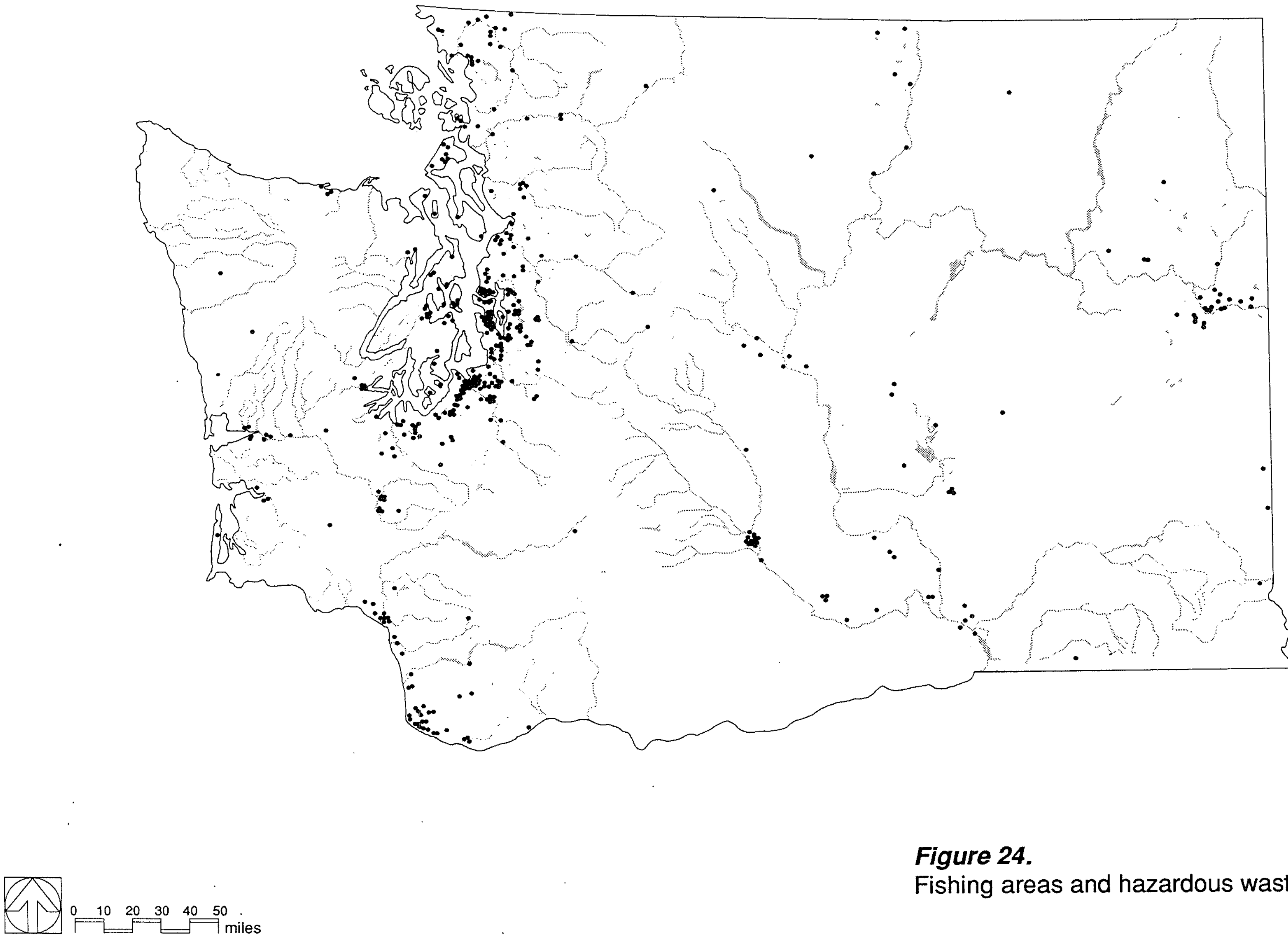


Figure 24.
Fishing areas and hazardous waste sites

Reference: DeLorme Mapping Company (1988)

The Chehalis River (eight sites) in Grays Harbor is a migratory pathway for salmon and steelhead. Salmon and trout in the Willapa River (two sites) also support commercial, tribal, and recreational fisheries. The Columbia River supports commercial, tribal, and recreational fisheries for several species such as salmon, steelhead, sturgeon (in brackish water), bass, catfish, walleye, and whitefish. Sections of the Columbia River with the highest numbers of hazardous waste sites include the area from Longview to Carson (47 sites), the tri-cities area (4 sites), the Hanford area (4 sites), the Wenatchee area (5 sites), and the Oroville to Okanogan area (7 sites). The Yakima River (28 sites, with 21 sites in Yakima) provides important spawning and rearing habitat for bass and trout and supports important tribal and recreational fisheries.

Other areas of concern may include the Lake Sammamish/Lake Washington system (more than 20 nearby sites), the Skagit River (7 sites), the Stillaguamish River (4 sites), the Snohomish River (5 sites), the Green River (more than 10 sites), and the Puyallup River (9 sites). These areas provide important passage for salmonids and support recreational and tribal fisheries for salmon, as well as recreational fisheries for trout and other freshwater game fish.

Several resources in Washington have already experienced losses in resource use. The eastern shoreline of Puget Sound from Commencement Bay to Meadowdale is permanently closed to the commercial harvest of shellfish because of the presence of numerous hazardous substance sources. Fish and shellfish harvested recreationally from Commencement Bay, Elliott Bay, and Eagle Harbor have been significantly affected by toxic contamination. In each of these areas, posted warnings and health advisories have likely affected the recreational harvest of fish and shellfish. Losses in use of the commercial harvest of bottomfish may have occurred in areas where there is an elevated prevalence of hazardous substance-associated fish disease. These areas include Everett Harbor, Port Gardner, Elliott Bay, Puget Sound between Whidbey Island and Eagle Harbor, Sinclair Inlet, Commencement Bay, and Case Inlet. The economic value of these losses has not been estimated.

In addition to losses from contamination by hazardous materials, the recreational and commercial harvest of razor clams from Pacific Ocean beaches has been affected severely during the past 10 years due to a viral epidemic. The viral infestation has severely reduced razor clam populations throughout their range resulting in total closure of the harvest season in 1984 and 1985, and severe restrictions on the season in 1977, 1978, 1982, 1983, 1986, and 1987 (DOF 1987). The Department of Fisheries estimates that the viral epidemic has resulted in monetary damages to commercial fisheries of $2,670,000 for the years from 1978 to 1987 (DOF 1987). Estimates of damages to recreational fisheries are not available. Existing losses in use of commercial harvesting of shellfish are not likely to be exacerbated by releases from hazardous waste sites because the existing losses are caused by ongoing problems of bacterial contamination.

Losses in use of these resources may vary depending on the alternative that is implemented for surface and marine water. For this analysis, it is assumed that a standard higher than the ambient water quality criterion could result in a closure or loss of fisheries due to a reduction in fish populations. Similarly, it is assumed that any standard higher than a human health risk-based concentration (for risks from human consumption) may result in avoidance or restriction of fishing in an area. The toxicity and risk-based values used in this analysis are presented in Table 16.

For marine waters, standards that could exceed toxicity values are listed below (no standards are available for many noncarcinogens):

- **Background alternative**—All background standards would be lower than toxicity values
- **Risk-based alternative**—All risk-based standards would be designed to be lower than or equal to toxicity values
- **ARAR alternative**—Most ARARs for aquatic life, because they are based on risks, would be close to toxicity values
- **Technology-based alternative**—Technology-based standards for many metals and certain other hazardous substances (such as DDT) would be higher than toxicity-based values
- **Combination alternative**—The combination alternative standards would be designed to be lower than or equal to toxicity values.

For fresh waters, the following alternative standards would exceed toxicity values:

- **Background alternative**—Background standards (PQLs) for certain hazardous substances such as PAHs, PCBs, DDT, and hexachlorocyclohexane would be several orders of magnitude higher than toxicity values

TABLE 16. TOXICITY AND RISK-BASED CONCENTRATIONS FOR EVALUATING LOSS IN USE OF FISHERIES

	Surface Water		Marine Water	
	Risk (μg/L)	Toxicity (μg/L)	Risk (μg/L)	Toxicity (μg/L)
Metals				
Arsenic	0.015	54	0.079	54
Cadmium	--[a]	1.1	--	9.3
Chromium	--	11	--	50
Copper	--	12	--	2.9
Lead	--	3.2	--	5.6
Zinc	--	110	--	86
Volatile Organic Compounds				
1,1,1-Trichloroethane	1,500	--	--	31,200
Trichloroethene	1.5	21,900	52	2,000
Tetrachloroethene	0.3	840	3.9	450
Dichloromethane	1.8	--	130	--
Benzene	0.23	5,300	16	700
Toluene	5,000	17,500	--	5,000
Total xylene	32,500	--	--	--
Ethylbenzene	1,400	32,000	--	430
Semivolatile Organic Compounds				
Pentachlorophenol	--	5.5	--	7.9
PAH compounds	0.0029	92	0.0311	--
PCB mixtures	0.000012	0.014	NA	NA
Pesticides				
DDT, DDD, DDE	0.00036	0.001	0.00033	0.001
Hexachlorocyclohexane	0.0043	0.08	--	--
Ethylene dibromide	0.00039	--	NA	NA
Dioxins				
2,3,7,8-TCDD	8×10^{-9}	--	8×10^{-9}	--

[a] Not available.

- **Risk-based alternative**—Risk-based standards would be close to toxicity values
- **ARAR alternative**—Most ARARs are within an order of magnitude of toxicity values
- **Technology-based alternative**—Technology-based standards would be within an order of magnitude of most metals toxicity values, but would exceed toxicity values by several orders of magnitude for hazardous substances such as PAHs, PCBs, DDT, and ethylene dibromide
- **Combination alternative**—By design, all combination alternative standards would be equal to or less than toxicity values.

Based on this analysis, loss of use may occur if the background or technology-based alternative is implemented. The risk-based, ARAR, and combination alternatives would not be expected to result in significant impact on fishing activities.

Forests and Logging

A total of 23,181,000 acres of public and private land in Washington state was forested in 1988 (Hoffman 1989). This land is located primarily in national forests in the western half of the state. It is reasonable to assume that most, if not all, hazardous waste sites are not currently available for logging and are not likely to be available for logging during remediation (regardless of the alternative concentration implemented). Therefore, implementation of cleanup alternatives is not likely to result in any loss in use of logging areas.

Although there is a potential for losses in land use due to residual contamination, these impacts are not likely to be significant. There are fewer than 10 hazardous waste sites in national forests in Washington. Based on the distribution of sites and timber land in the state, there are probably fewer than 15 sites in privately owned forests. The predominant route of exposure of timber crops to hazardous substances is through uptake from contaminated soil (aerial deposition is likely to be a minor exposure route in Washington for these hazardous substances). Information on the toxicity of the hazardous substances to timber species is insufficient to evaluate potential impacts of alternative concentrations. However, a worst-case scenario would be the complete loss of resource use in an area immediately surrounding each site. Even in this scenario, very few acres would be lost to logging because of contamination. Therefore, the potential worst-case losses are not likely to be significant under any of the alternatives.

Urban and Suburban Land Use

The majority of hazardous waste sites in the state are located in urban areas, typically occupying land zoned for either commercial or industrial uses. Use of land on or near hazardous waste sites may be lost both during and after remediation. The degree to which land at or near a hazardous waste site is unavailable for other uses depends on several factors, including the nature of the contamination, the remedial technology used, the period required for remediation, and the residual contamination level.

In general, sites currently in industrial or commercial areas will not be available for residential use (that is, commercial and industrial uses would represent the "highest use" of the land, and the land is probably not desirable for residential use). Therefore, losses in use at hazardous waste sites are most likely to affect the original use of the sites. An exception to this generalization may be a case where a hazardous waste site is located near the boundary of industrial and residential zones. In such a case, residential use would be precluded if the nearby site presented hazards to human health. Human health hazards are assessed in Chapter 9. Based on that evaluation, the technology-based alternative is expected to result in the most significant loss of residential land use, the background and ARAR alternatives may result in some loss of land use, and the combined and risk-based alternatives are not expected to result in loss of commercial or residential land use. These impacts cannot be easily mitigated.

Recreation

Water-related recreational activities have been impaired at numerous locations across the state. Impairment in these and other areas may be exacerbated if surface water cleanup levels are not adequate to protect human health. The most sensitive areas are expected to be bodies of water (predominantly lakes, streams, and rivers) that are used extensively for contact recreation near hazardous waste sites. These areas may include:

- **Lake Sammamish/Lake Washington system**—This area encompasses more than 20 sites and is used extensively for all forms of water recreation, including swimming, boating, and waterskiing
- **Green River**—This area encompasses approximately 10 sites and is used extensively for swimming and rafting

- **Sections of the Columbia River**—The area from Longview to Carson (47 sites), the tri-cities area (4 sites), the Hanford area (4 sites), the Wenatchee area (5 sites), and the Oroville to Okanogan area (7 sites) are variably used for swimming, boating, floating, rafting, and waterskiing
- **Yakima River**—This area contains 28 sites (with 21 sites in Yakima) and is used for swimming, floating, rafting, and boating.

Other areas of potential concern include the Puyallup River (nine sites), the Skagit River (approximately seven sites), the Stillaguamish River (four sites), and the Snohomish River (five sites). These impacts cannot be easily mitigated.

Summary of Impacts on Land Uses and Natural Resources

The impacts of the hazardous waste site cleanup levels on various land uses are summarized below:

- **Drinking water**—Implementation of the risk-based or technology-based alternatives may result in significant impacts on drinking water resources because of exceedances of primary or secondary MCLs. These impacts are most likely to occur because of contamination of surface water in Skagit, Cowlitz, Franklin, and Whatcom counties or because of contamination of ground water in Spokane, Pierce, Yakima, Clark, and Thurston counties.
- **Agriculture**—Based on the location of known hazardous waste sites, the Yakima area is most at risk of contamination. Very limited information is available to characterize the impacts of the alternative concentrations on crops. The alternatives are evaluated in Chapter 10 with respect to protection of plants and animals in general. Under that evaluation, the background alternative would not be expected to have any impact on agriculture; the risk-based, ARAR, and combined alternatives would have minimal impacts on agriculture; and the technology-based alternative would have the greatest impact on agriculture.

- **Ranching**—Evaluation of the effects of hazardous substance levels in soil and water is not feasible because of lack of data on effects of hazardous substances on grazing animals. However, the evaluation of the alternatives with respect to plants and animals described above can also be applied here.

- **Hunting**—No significant impacts on hunting of big game are expected from any of the alternatives. Hunting of waterfowl may be impacted if wetland and river delta areas become contaminated. The background alternative would not result in significant impacts on wetlands. The technology-based alternative would likely result in the greatest impacts on wetlands.

- **Fishing**—Impacts on freshwater and marine fishing resources are expected to be greatest for the technology-based alternative. The background (PQL) concentrations for organic compounds may also result in impacts on fishing. The other alternatives are not expected to result in significant impacts on fishing. Impacts on fishing will be greatest for species that live in urban bays or for anadromous species that pass through polluted bays and rivers to reach spawning grounds. Areas of concern include urban bays in Puget Sound, Grays Harbor, Willapa Bay, and the Columbia, Yakima, and Spokane rivers.

- **Logging**—No impacts on logging are expected from any of the alternatives.

- **Urban and suburban land use**—These impacts will consist largely of losses of use of land for residential purposes. No such impacts are expected from use of the risk-based or combined alternative. Minor impacts may occur from use of the ARAR or background alternatives, and significant impacts may occur from use of the technology-based alternative.

- **Recreation**—Significant impacts on recreational use of surface waters are most likely to occur in Lake Sammamish, Lake Washington, Green River, sections of the Columbia River, and Yakima River. However, the relative magnitude of these impacts under each of the alternatives cannot be evaluated.

Chapter 12
Programmatic Impacts

Programmatic impacts are defined as impacts on state programs, planning, and resources. These programmatic impacts reflect the cumulative impacts of statewide application of the standards. These impacts will depend, in part, on the strictness of the standards (higher vs. lower standards) and how that factor affects the extent and type of cleanup at hazardous waste sites.

Capacity of Treatment, Storage, and Disposal Facilities

The total volumes of contaminated media requiring cleanup will be determined by the strictness of the cleanup levels. Total remediation volumes are expected to increase as cleanup levels are made more strict, because larger volumes of soil and ground water would exceed cleanup concentrations. The strictness of the cleanup levels will also determine the extent to which onsite cleanup technologies can be used. The remaining waste that must be treated or disposed of offsite will affect the available capacity of regional treatment, storage, and disposal (TSD) facilities. Existing TSD facilities have capacity limits; expansion of these facilities or siting and construction of new facilities requires additional time, money, and agency approval.

Capacity issues for TSD facilities have been addressed by Ecology and other agencies. Under CERCLA/SARA [Section 104(k)], each state, in order to remain eligible for federal cleanup action funds, must assure the availability of TSD facilities to handle the volume of hazardous wastes expected to be generated within 20 years. These hazardous wastes include both recurring wastes (those generated as part of ongoing manufacturing operations or by other annual generators) and nonrecurring wastes. Nonrecurring wastes include MTCA and NPL site cleanup wastes, spill cleanups, RCRA site closures and corrective actions, and other one-time waste generation (Ecology 1989e).

The requirement under CERCLA for sufficient TSD capacity can be satisfied using in-state TSD facilities or interstate or regional agreements for the use of out-of-state TSD facilities. EPA Region 10 and the four states within the Pacific Northwest region have recognized that the hazardous waste issues within the region are best addressed through interstate cooperation. Initial coordination efforts after the passage of SARA resulted in the first regional overview in the nation of hazardous waste generation and treatment, storage, and disposal (U.S. EPA 1988b). As a result of this early coordination, the Pacific Northwest Hazardous Waste Advisory Council (PNHWAC) was established. One of the primary purposes of the council is to assess waste generation and capacity issues. The council has issued findings on the regional need for additional TSD capacity, particularly for incineration (DeVries, A., 16 November 1989, personal communication; PNHWAC 1989a,b,c).

In addition, Ecology has compiled annual summaries of hazardous waste activities in Washington since 1982. The volumes of hazardous wastes generated annually from 1982 through 1987 (the most recent year for which data are available) are listed in Table 17. These figures include wastes that are designated as dangerous wastes under Washington regulations or as hazardous wastes under RCRA. Wastewaters that are treated onsite are excluded. Both recurring and nonrecurring wastes are included in the annual totals. The portion of nonrecurring wastes from site cleanup actions that is included in these figures only represents wastes that were generated and shipped offsite to TSD facilities; it does not include waste volumes that may have been treated or disposed of onsite.

Nonrecurring wastes in Washington have been specifically tracked by Ecology only since 1987. For that year, nonrecurring wastes constituted 27 percent (64,258 tons) of the total statewide hazardous waste volume (Ridgley 1989; Ecology 1989c,d). A large proportion of the nonrecurring wastes for 1987 came from site cleanup actions (not spill cleanups, RCRA closures, or other one-time waste sources). A small number of major cleanup actions accounted for much of the total (Ecology 1989e).

Although no comprehensive inventories of nonrecurring wastes are available for years prior to 1987, some information is available that either identifies waste generation for specific cleanup projects or otherwise estimates the volume of nonrecurring wastes (Ecology 1986, 1987, 1988a; U.S. EPA 1988b; PNHWAC 1989a). A review of this information supports the conclusion that from 1984 through 1987, a small number of major site cleanup actions has accounted each year for a large proportion of total site cleanup wastes and

TABLE 17. ANNUAL WASHINGTON GENERATION OF HAZARDOUS WASTES (OTHER THAN WASTEWATERS)

Year	Hazardous Waste Volume (tons)
1982	205,433
1983	186,754
1984	183,128
1985	198,464
1986	233,540
1987	234,539

Reference: Ecology (1988a, 1989d).

nonrecurring wastes. Moreover, annual nonrecurring wastes appear to have contributed a significant part (20 to 25 percent) of the total annual hazardous waste volume generated in the state. The figure of 27 percent from the 1987 data appears to be consistent with experience in prior years.

The volume of future site cleanup wastes and TSD capacity demand is estimated in the Capacity Assurance Plan (Ecology 1989c), based on a survey of agency site managers for both NPL and state sites. However, site managers have been unable to predict site-specific cleanup volumes before the sites were further characterized and potential cleanup technologies had been addressed. The efforts of the interstate coordinating committee (U.S. EPA 1988b) and the PNHWAC (1989a,b,c) have been similarly unsuccessful in predicting site cleanup waste volumes. The private proponents of new commercial TSD facilities in Washington have recognized the potential contribution of nonrecurring wastes to the total waste stream requiring TSD capacity but have not published estimates of the volume of that contribution (ECOS 1989; Smedes, G., 16 November 1989, personal communication; Zaluska, P., 17 November 1989, personal communication).

The existing capacity at TSD facilities can best be reviewed by considering three types of facilities separately: landfills, incineration, and all other physical and chemical treatment methods. A regional, rather than state, perspective is appropriate because commercial hazardous waste landfills exist only in Oregon and Idaho, and because the interstate management of hazardous wastes has been recognized and accepted by the region. TSD capacity has been documented and reviewed by Ecology in the Capacity Assurance Plan (Ecology 1989c). The PNHWAC (1989a,b,c) has also reviewed capacity and demand from a regional perspective. The data from these reviews are presented below.

Summary data for out-of-state shipments of hazardous wastes from Washington for the years 1982 through 1987 are provided in Table 18. These data are for generated wastes other than wastewaters and include both recurring and nonrecurring waste streams. The majority of out-of-state shipments have been to the commercial hazardous waste landfill at Arlington, Oregon. The amount of waste going to the Idaho landfill has been far smaller. Shipments to other states include relatively small waste volumes sent to hazardous waste incinerators, other landfills, or other treatment facilities.

TABLE 18. ANNUAL OUT-OF-STATE HAZARDOUS WASTE SHIPMENTS FOR WASTES GENERATED IN WASHINGTON (OTHER THAN WASTEWATERS)

Year	Total Volumes		Destination			
	Generated (tons)	Shipped (tons)	Oregon	Idaho	California	All Other States
1982	205,433	23,846	22,441	404	266	735
1983	186,754	29,430	26,262	2,042	977	149
1984	183,128	86,561	84,218	90	2,126	127
1985	198,464	70,171	62,449	2,692	4,251	779
1986	233,540	106,749	96,223	5,050	3,772	1,704
1987	234,539	143,120	125,159	3,893	2,720	11,348

Sources: Ecology (1986, 1987, 1988a, 1989d); Misko (14 November 1989, personal communication).

At projected annual rates, the two commercial hazardous waste landfills in the region are estimated to be filled in 1996 and 2007 (U.S. EPA 1988b). Fluctuations in actual annual waste volumes could change those projected dates by at least several years in either direction. Room for expansion of existing landfills is available and is reasonably expected to be permitted at appropriate times to meet developing capacity demands. Therefore, an adequate regional capacity for hazardous waste landfills is assumed, including the existing demand for capacity from site cleanups (DeVries, A., 16 November 1989, personal communication; Ecology 1989b).

There are currently no hazardous waste incinerators in the Pacific Northwest region. Incineration of site cleanup wastes has been accomplished either by using mobile onsite incinerators or by shipping wastes to relatively distant facilities (for example, in Texas and Arkansas). The lack of an incinerator in the region has been identified as the primary deficiency in TSD regional planning (DeVries, A., 16 November 1989, personal communication; Ecology 1989b; PNHWAC 1989b,c). The PNHWAC has reviewed the potential demand for hazardous waste incineration and has concluded that there is sufficient regional demand for incineration to support the siting of one or more facilities. The council's conclusion was based on a conservative, minimum estimate of waste volumes for incineration. That estimate did not specifically address possible site cleanup wastes for incineration (DeVries, A., 16 November 1989, personal communication). Some, perhaps most, of the site cleanup wastes for which incineration is an appropriate remedial technology will be low-energy materials such as contaminated soils. It may not be possible to directly incinerate such low-energy materials without adding other high-energy wastes or fuels. Low-energy wastes would also generate a large amount of residual ash or soils, requiring landfilling or other disposal after incineration.

Commercial hazardous waste incinerators in Washington have been proposed by two private applicants. One of these sites would likely include additional landfill and hazardous waste treatment facilities (Smedes, G., 16 November 1989, personal communication; Zaluska, P., 17 November 1989, personal communication). Either or both of these facilities could be constructed and in operation by the mid-1990s. Permit applications and facility development may be affected by the adoption of TSD facility siting criteria (Ecology 1989b), currently proposed by Ecology. Neither project is yet assured of successful completion of the permitting process.

The availability of other physical and chemical methods for treating hazardous wastes, such as stabilization and solidification, aqueous treatment, and solvent or metals recovery, has been reviewed by Ecology in the Capacity Assurance Plan (Ecology 1989c). Existing commercial facilities for such hazardous waste treatment generally have adequate capacity for expected demand. If the selection of cleanup actions at one or more sites produces a short-term surge in demand for capacity, temporary storage for site cleanup wastes or delays in site cleanup could become necessary. Expansion of commercial TSD facilities beyond the permitted facilities would require permit modification, which could be a lengthy process.

It is reasonable to assume that as site cleanup levels under the MTCA become more strict, the total volume of wastes subject to remediation will increase. The preferences in state and federal statutes for hazardous waste treatment over landfilling and for permanent reduction in waste volume, toxicity, and mobility are expected to increase the frequency of selection of permanent remedies. The adoption of land bans for disposal of certain wastes may further support the selection of permanent remedies.

However, if available and feasible technologies for hazardous waste treatment cannot meet strict cleanup levels, onsite options for containment or isolation of contaminated media would have to be evaluated along with offsite disposal options. Strict cleanup levels that are beyond the capabilities of treatment technologies could result in rather large capacity demands for offsite disposal facilities (especially for contaminated soils) if onsite containment or isolation with institutional controls is not considered acceptable. As discussed in Chapter 7, the background alternative is expected to result in standards that would require removal or containment for many more sites than the combination, risk-based, ARAR, or technology-based alternatives. Therefore, the background alternative would be expected to diminish landfill capacity more quickly than the other alternatives.

Based on all of the above considerations, most of the alternatives would not be expected to exceed the existing or planned capacity of TSD facilities in the region. The capacity of these facilities has been studied and is generally considered to be adequate for the current demand. The only alternative that would significantly increase annual demand for TSD facility capacity is the background alternative, which could require removal or containment of soil at a greater number of sites.

Property Transfers

Placing a site on the hazardous waste site list generally poses a significant barrier to purchase or development. Concerns over legal liability for cleanup, cleanup costs, or the constraints on site development posed by future site remediation may significantly impede property purchase or development decisions. The effects of placing a site on the hazardous sites list could extend to adjacent, unlisted properties to a somewhat lesser degree, especially where the full extent and severity of contamination from the site is unknown, as it often is at the time of initial site listing.

Such effects are not absolute; in some instances, the listing of a site may be evaluated and determined not to pose undue risks or impediments to the sale or use of the property. However, site use or development that would impede site investigation or the implementation of a cleanup action, or that would increase the costs of site cleanup, could create significant liabilities for property owners or operators. Ecology can take action to prevent the creation of imminent hazards to human health or the environment, including restrictions on new site development before cleanup actions are completed. Site activities can be prohibited if they promote the release or migration of hazardous substances or lead to potentially threatening exposures to human populations or the environment.

At listed sites, the obstacles to site purchase or development are expected to last throughout site investigations, until a site has been taken off of the list, or until cleanup actions (selection and implementation of a remedy for site contamination problems) are sufficiently advanced to allow reasonable projections of their success and consistency with planned site development. Therefore, impacts on property transfers and development at listed sites are expected to depend on the time required to select and implement a remedy. Partial mitigation of these impacts would be achieved by cleaning sites up as promptly as possible, as long as remedies are selected that are protective of human health and the environment.

The cleanup levels under different alternatives would differ substantially for some constituents in some media. It is conceivable that for the most strict alternatives with the lowest standards, the process of selecting and implementing a remedy may be more difficult and may require more time. For example, limitations in the effectiveness of treatment technologies may make very strict cleanup levels difficult to achieve.

Cleanup levels adopted under the MTCA may be considered by the parties involved in property transfers at unlisted sites. There is no specific requirement that properties be investigated for the presence of hazardous substances, either at the time of purchase or at any other time. However, many site screening investigations are now performed voluntarily as part of a prudent approach to define and limit potential owners' liabilities for contamination problems. In addition, many banks and insurance companies are now requiring such investigations before approval of loans or insurance coverage. Unlisted sites at which significant contamination is found must be reported to Ecology (WAC 173-340-300). Purchase or development of such sites may be delayed until Ecology can make a determination of whether the extent of contamination at the site warrants listing. If Ecology declines to list such a site, even though hazardous substances have been detected, decisions on purchase or development of the site may take into account the possibility that the site may be listed at some later time.

The detection of hazardous substances at levels above the cleanup levels will always be a factor to consider in property transfer or development decisions at unlisted sites. The degree of potential risk to human health or the environment, the likelihood of site listing, the likelihood of cleanup actions being required if a site is listed, the type and duration of probable cleanup actions, and the consistency of planned site developments with cleanup actions will need to be taken into account. The exact magnitude of these impacts cannot be determined. However, the impacts are expected to be greater under those alternatives that set more stringent cleanup levels. Judgments about the significance of such site contamination may improve with experience in the implementation of site cleanups under the MTCA; uncertainties about how to proceed will be diminished and precedents will be available to guide decision-making.

State Resources

The strictness of the cleanup levels may affect the timing of site remediations due to demands on state resources. More strict standards may lengthen the time and increase the resources needed to investigate and remediate each site. Because Ecology must pursue site cleanups within the limitations imposed by its available resources, this would result in fewer sites actively remediated each year. Ecology could choose to limit its cleanup of sites to those sites that rank highest in potential risks to human health or the environment, or to those that are quickest and easiest to remediate.

Encouraging and expediting voluntary remediation of such sites would help reduce impacts from sites at which remediation would otherwise be deferred. However, to avoid the most significant potential impacts from deferred sites, the state may need to take some interim actions. Interim actions such as source removal, control or prevention of hazardous substance movement, or management of potential exposures through restricted access may be appropriate. Interim actions and partial site remedies could also reduce potential impacts from delays in implementation of final cleanup actions (for example, when disputes arise between Ecology and PLPs over the selection of a final remedy).

The strictness of cleanup levels can also affect how readily liable parties accept or participate in site cleanup. Cleanup levels that are perceived by responsible parties as unnecessarily strict could result in resistance by responsible parties to voluntary site cleanup. Site cleanup negotiations, enforcement orders issued by Ecology, and litigation would be used more often to resolve any disputes over the cleanup levels. The necessity of using such procedures greatly increases the cost and time required for cleanup action.

Any deferral of cleanup actions at contaminated sites would result in continuing impacts from uncontrolled hazardous substance release, migration, and exposure. Impacts from such uncontrolled sites may be much greater than those resulting from residual concentrations from even the least stringent of the cleanup alternatives.

Finally, as cleanup levels become more strict, cleanup technologies will be less able to meet the cleanup levels and more sites will require the use of additional remedies that are not permanent. Therefore, Ecology will expend more resources in periodic review of sites if more stringent cleanup levels are chosen.

Summary of Programmatic Impacts

Three types of programmatic impacts have been identified. Although the magnitude of these impacts cannot generally be predicted in advance, each impact increases in severity if more stringent cleanup levels are chosen.

- **Capacity of Treatment, Storage, and Disposal Facilities**—More strict cleanup levels may increase the annual volume of site cleanup wastes and the demand for available landfill capacity. Regional capacity and planning for landfills and waste treatment appear adequate under the current cleanup policy. Adoption of the background alternative may significantly increase demand for landfill capacity.

- **Property Transfers**—The listing of a site by Ecology is expected to pose significant obstacles to purchase or development of that site. These obstacles will be reduced once the site is removed from the list or when cleanup actions are sufficiently advanced that the likely success and consistency of cleanup actions with planned development actions can be evaluated. The cleanup levels are also likely to be considered by private parties involved in property transfers at unlisted sites.

- **State Resources**—Ecology's resources for managing site investigations and implementing cleanup actions are limited. Action at some sites may be deferred because of these resource limitations. More strict cleanup levels will result in more comprehensive cleanups at each site and more sites requiring periodic review, potentially limiting the number of sites that can be addressed each year. The willingness of PLPs to perform voluntary site cleanups may also decrease as the cleanup levels become more strict. Therefore, negotiations, enforcement actions, and appeals may be required to enforce cleanup requirements, which will further defer action at a site. Deferral of site cleanup actions, particularly at highly contaminated sites, may result in significant impacts from continuing uncontrolled release, migration, and exposure to hazardous substances at relatively high concentrations.

Chapter 13
Summary of Environmental Impacts

The potential impacts identified in the previous chapters are summarized and discussed below for each alternative. Under each alternative, significant impacts and mitigation measures are identified. The chapter in which each impact is discussed in greater detail is indicated. Certain impacts are common to all alternatives; although these impacts do not affect the choice of alternatives for setting cleanup levels, they are briefly summarized here.

Certain hazardous substances are particularly difficult to regulate. Examples discussed in previous chapters include the following:

- **Arsenic**—Modeling results for arsenic show that concentrations even as low as natural background may be associated with risk in certain situations (Chapter 9). Arsenic in soil is naturally high in the Pacific Northwest. In addition, historical sources of arsenic, such as the ASARCO smelter in Tacoma, have contributed to area-wide elevation of arsenic concentrations in the Puget Sound area. EPA and other agencies are currently reviewing risk assessment procedures for arsenic.
- **2,3,7,8-TCDD**—Historically, 2,3,7,8-TCDD has been considered a highly carcinogenic hazardous substance; as a result, risk-based cleanup levels that have been proposed are lower than for almost any other hazardous substance. To complicate the issue, there is no technically feasible method of reducing levels in soil to cleanup levels that would be used under any of the alternatives (Chapter 7). Because of these factors, some impact on human health and the environment would be expected under any of the alternatives. However, recent research suggests that 2,3,7,8-TCDD may not be as carcinogenic as originally thought (Keenan, R., 9 April 1990, personal communication).
- **Chromium, lead, and DDT**—None of the cleanup levels for the various alternatives would be below the threshold of toxic effects to plants and animals for these hazardous substances (Chapter 10). This circumstance exists because not enough is known about the effects of these hazardous

substances on most plants and animals to set standards; however, there is evidence that the alternative standards may not be protective enough.

Certain impacts during remediation of hazardous waste sites are unavoidable. Plant and animal communities at and around hazardous waste sites will be affected by particular remedial technologies. For instance, excavation of soil for incineration displaces plants and animals living at the site, and steam stripping of volatile organic compounds may kill microorganisms in the soil that require a certain temperature range to live. These remedial technologies may be the only methods available for use at certain sites.

The following impacts have been identified for particular alternatives. These impacts will be used to evaluate the alternatives and to identify a preferred alternative.

Background Alternative

The following significant impacts associated with the background alternative were identified.

Impacts During Site Cleanup

Several impacts during cleanup action result because the background alternative is generally the most strict alternative, requiring the lowest cleanup levels overall. For instance, the background alternative is the only alternative for which there is no technically feasible method of removing metals from soils to the cleanup level (Chapter 7). The impacts during remediation are mainly caused by the necessity of capping or excavating and hauling large amounts of soil to a landfill or other treatment facility.

Either excavation or capping of soil is expected to have a significant impact on plant and animal communities at or near the site (Chapter 7). However, impacts on human health will be greater from excavation of contaminated soil than from capping the site with clean soil, because excavation and transportation of contaminated soil could potentially expose more people to hazardous substances on dust from the site or during a spill. In addition, the background alternative would significantly increase the amount of soil required to be hauled long distances (Chapter 7). Such an increase in the long-distance hauling of site wastes could result in increased injuries or spills of hazardous material due to traffic accidents.

Natural Resource Availability

More stringent cleanup levels and standards that are not technically feasible could result in land and water use restrictions for long periods of time. For example, if a low cleanup level resulted in a long pump-and-treat period for ground water or surface water, that water would be unavailable for use as drinking water or to support wildlife (Chapter 7). Similarly, if a soil standard could not be met, a site would be capped and/or restricted from certain kinds of uses, such as residential use.

Practical Quantitation Limits

The background alternative includes the use of PQLs for synthetic organic hazardous substances. These PQLs are not always protective of the full range of uses in the media being evaluated. In Chapters 9 and 11, it was determined that the background alternative could have minor impacts on human health from synthetic carcinogens, and minor impacts on the use of certain areas for fishing, due to human health concerns over the possible bioaccumulation of synthetic organic hazardous substances in fish and shellfish. In addition, the use of PQLs for synthetic organic hazardous substances could allow more contamination of surface water and air than would other alternatives (Chapter 8).

Programmatic Impacts

The excavation of greater amounts of soil might result in a need for increased landfill or incinerator capacity (Chapter 12). Such impacts could be significant, depending on the number of sites remediated each year and the passage of various laws regulating the landfilling of hazardous wastes. In addition, strict cleanup levels such as those under the background alternative would require greater use of Ecology's resources at each site, limiting the number of sites that could be addressed each year and potentially postponing action at some sites (Chapter 12). Deferral of action at sites could result in significant environmental impacts from uncontrolled releases of hazardous substances to the environment. These impacts would likely be greater than impacts remaining after cleanup using any of the cleanup levels alternatives.

Risk-Based Alternative

The following significant impacts associated with the risk-based alternative have been identified.

Impacts During Site Cleanup

The risk-based alternative would result in very low standards for a number of carcinogens. For these hazardous substances, cleanup actions would take longer and would be more costly. Therefore, the impacts described under *Impacts During Site Cleanup* in Chapter 7 would be expected at sites where these hazardous substances were a problem.

Contamination of the Natural Environment

Application of the risk-based approach often results in concentrations for noncarcinogens that are quite high relative to other alternatives, and these concentrations often exceed ARARs for these hazardous substances. Because secondary MCLs for drinking water are exceeded for some hazardous substances, there could be loss of use of drinking water resources in the vicinity of some hazardous waste sites (Chapter 11). In addition, compared to other alternatives, the risk-based alternative would allow the most contamination by noncarcinogens of marine water and soil, and would allow minor contamination of ground water and surface water by noncarcinogens (Chapter 8). In particular, risk-based standards in soil could result in significant ground water contamination and associated risks to human health (Chapter 9). Additional impacts would be predicted if PQLs were used to determine compliance with these standards.

ARAR Alternative

The following significant impacts associated with the ARAR alternative have been identified.

Contamination of the Natural Environment

Standards based on ARARs for certain media would be higher than those for other alternatives. For instance, ARARs for hazardous substances in air and for volatile organic compounds in marine water would be high relative to alternative standards. ARARs also would be higher than some of the other alternatives in ground water. ARARs in soil would be particularly high because very few health-based ARARs exist for soil (Chapter 8).

Impacts Due to Residual Contamination

Minor impacts on human health could be expected from the ARAR alternative, because in many cases, the ARAR alternative is not as stringent as the risk-based alternative for carcinogens. Even when corrected for the protection of ground water, the ARAR alternative for soil could result in some human health risk from ground water contaminated by leachate from soil (Chapter 9). Minor impacts on plants and animals are also expected because of the lack of ARARs for plants and animals in several environmental media, and because studies reviewed in Chapter 10 suggest that the MTCs for some species would be somewhat lower than the available ARARs.

Technology-Based Alternative

The following impacts associated with the technology-based alternative were identified.

Impacts During Site Cleanup

In general, the technology-based alternative results in the least impacts during remedial alternatives, in part because the cleanup levels are less stringent, and in part because excavation of soil would be required less often than for other alternatives. However, one impact of the technology-based alternative during remediation does affect the environment disproportionately. Because the technology-based standards are often higher than those of other alternatives, waste streams from remedial technologies at a site might contain higher concentrations of hazardous substances than they would under the other alternatives. These hazardous substances in the waste stream, if released to the environment, could cause toxic effects in wildlife near the site, particularly aquatic life (Chapter 7).

Contamination of the Natural Environment

Compared with other alternatives, the technology-based alternative would allow the greatest contamination of air and surface water and minor contamination of marine water. Technology-based standards would be particularly high relative to those for other alternatives for metals in marine water and soil and for volatile organic compounds in air.

Human and Ecological Health

Compared with all of the other alternatives, the technology-based alternative would likely result in the most significant impacts on human and ecological health and land and natural resource use (Chapters 9, 10, and 11). Significant impacts on human health and plants and animals are expected because for metals and carcinogens, the technology-based alternative often could not provide concentrations that are as protective as risk-based concentrations. The technology-based concentrations would often be 3-5 orders of magnitude above risk-based levels. It is estimated that the technology-based alternative would result in standards that would not be protective of plants and animals for approximately half of the hazardous substances for which toxicity data exist (Chapter 10).

Land and Water Use

Because of these risks to human health and the environment, many land uses are expected to be impaired, including agriculture and ranching (from contamination of water and soil), hunting of waterfowl and fishing (from contamination of marine water and fresh water), and residential uses (from contamination of all media) (Chapter 11). Ground water could be restricted from use as drinking water because of exceedance of MCLs. Fisheries could be closed because of concerns about accumulation of organic hazardous substances in fish and shellfish (Chapter 11).

Combination Alternative

The following impacts associated with the combination alternative were identified.

Contamination of the Natural Environment

Few significant impacts on human health, the environment, or land and natural resource use were identified. However, because the combination alternative does not require the use of a concentration lower than the risk-based or ARAR concentrations, and because standards are not used that would be below PQLs, the combination alternative allows minor contamination by noncarcinogens of marine water, soil, and air, compared with the other alternatives.

Human Health and Water Use

The combination alternative includes the use of PQLs to determine compliance with the cleanup levels. These PQLs are not always protective of the full range of uses in the media being evaluated. In Chapters 9 and 11, it was determined that the use of PQLs as standards could have minor impacts on human health from synthetic carcinogens and on the use of certain areas for fishing, due to human health concerns over the possible bioaccumulation of synthetic organic hazardous substances in fish and shellfish.

Mitigation Measures

This section presents a summary of mitigation measures for the impacts identified above. Because many of the alternatives have similar impacts, the mitigation measures are presented according to the type of impact.

The Natural Environment

Impacts to the natural environment from residual contamination at the level of the cleanup levels for those resources cannot be mitigated. However, cross-media impacts, such as those that occur when hazardous substances in soil leach into ground water, can be mitigated to some extent. Mitigation measures for cross-media impacts include a variety of barriers to hazardous substance migration, such as capping of soil to prevent resuspension of contaminated dust and infiltration, installation of surface water collection systems, and isolation of ground water aquifers by pumping or underground containment.

Human Health

Human health impacts during remediation may be mitigated by using site health and safety plans for the remedial work and by controlling emissions from remedial technologies. Protection of human health during cleanup actions will be an important consideration in choosing cleanup technologies for a site. Injuries from accidents during transportation of site wastes can partially be mitigated by routing trucks through areas with less traffic during off-peak hours. Emergency response plans are also important in preventing injury from spills and accidents.

Human health impacts from hazardous substances remaining in ground water or surface water after site cleanup can be mitigated by restricting the use of the water or by treating the water further before use. Impacts from direct contact with hazardous substances remaining in soil or water can be mitigated by restricting access to the site.

Plants and Animals

Impacts to plants and animals during remediation are unavoidable, but can be mitigated to some extent. Successful mitigation requires a careful assessment of species present at the site, identification of critical habitats or seasons of the year, and identification of the types of disturbances that remediation at the site will cause. Mitigation measures could include relocation of disturbances at the site to noncritical areas, choice of a cleanup technology with lesser impacts on plants and animals, relocation of plants and animals from the site, creation of replacement habitats adjacent to the site, and restoration of the site once remediation is complete.

Long-term impacts to plants and animals from residual concentrations at the site are more difficult to mitigate. Fences and other restrictive measures may be able to keep large animals out of the contaminated area. Streams that run through the site could be diverted to run around the site. Other mitigative measures may be available on a site-specific basis.

Land and Water Use

Most impacts on land use cannot be mitigated, because the land cannot be made available for its original set of uses. However, some potential losses of water use (for example, drinking water, irrigation, and livestock watering) can be mitigated by treating the water before use.

Chapter 14
Evaluation of the Alternatives

In this chapter, the five alternatives (background, risk-based, ARAR, technology-based, and combination) are evaluated and one alternative is selected as the preferred alternative. The no-action alternative is not evaluated separately because it is essentially the same as the ARAR alternative.

The alternatives are evaluated according to several criteria that reflect statutory requirements of the MTCA, such as protection of human health and the environment and compliance with ARARs, as well as some practical goals, such as technical feasibility and ease of use. Each alternative is discussed under each criterion in a narrative section and is given a low, medium, high, or unpredictable score based on the narrative evaluation and the environmental impacts discussed in the previous chapters. This type of evaluation allows the strengths and weaknesses of each alternative to be documented, providing a basis for the selection of the preferred alternative. A summary table of the scores is provided at the end of the discussion.

Finally, a process is described for identifying the preferred alternative from among the five alternatives. The criteria used to evaluate the alternatives are weighted, and a screening process is used to find the alternative that best meets the diverse goals and requirements of the MTCA.

Evaluation Criteria

In this section, each of the five alternatives is evaluated according to several different criteria. Each criterion is described, along with the basis for evaluation under the criterion. The alternatives are then evaluated according to the criteria, and their strengths and weaknesses under each criterion are discussed. Where applicable, information on environmental impacts developed in Chapters 7-13 is included. Finally, Table 19 summarizes the results of the evaluation.

TABLE 19. EVALUATION CRITERIA SUMMARY MATRIX[a]

Alternative	Threshold Criteria					Balancing Criteria				Modifying Criteria		
	Protection of Human Health		Protection of the Environment		Compliance with ARARs	Technical Feasibility	Cross-Media Impacts	Contaminant Interactions	Applicability to All Contaminants	Regulatory Precedence	Understandability	Consistency
	by Design	by Default	by Design	by Default								
Background	L	M	L	H	U	M	U	L	H	H	M	L
Risk-based	H	H	H	H	U	U	H	H	L	H	M	M
ARAR	M	M	M	M	H	H	U	L	L	H	H	L
Technology-based	L	U	L	U	L	H	U	L	H	M	M	M
Combination	H	M	H	H	H	H	H	H	H	M	M	L

[a] H - High
M - Medium
L - Low
U - Unpredictable.

Description of the Criteria

The criteria are divided into three classes:

- **Threshold criteria** represent the direct goals of the MTCA: protection of human health and the environment, and compliance of the standards with all ARARs. An alternative must meet these primary goals before being considered further.
- **Balancing criteria** represent practical considerations that affect how easily an alternative can be implemented as a process for developing standards. Some of these criteria also reflect goals and priorities of the MTCA and Ecology.
- **Modifying criteria** reflect issues of public acceptance and perceptions that do not directly reflect the goals and priorities of the MTCA and Ecology. These criteria are given less weight, but may affect the outcome of the evaluation if the alternatives are ranked similarly under the preceding sets of criteria.

The criteria are as follows:

Threshold Criteria

- Protection of human health
- Protection of the environment
- Compliance with ARARs.

Balancing Criteria

- Technical feasibility and enforceability
- Preference for permanent solutions
- Cross-media impacts
- Incorporation of hazardous substance interactions
- Applicability to all hazardous substances
- Scientific uncertainty.

Modifying Criteria

- Regulatory precedence
- Understandability
- Consistency.

Threshold Criteria

Threshold criteria directly reflect the statutory requirements of the MTCA: protection of human health and the environment and compliance of the standards with all ARARs. Each of these requirements is discussed separately below, and the alternatives are evaluated.

Protection of Human Health

This criterion is used to evaluate whether the alternative takes into account the protection of human health by design; that is, whether the alternative is protective of human health for any and all hazardous substances, including those currently not regulated or used. The criterion is also used to evaluate whether the alternative is protective of human health by default (whether the alternative approach consistently provides concentrations that are protective of human health). This latter evaluation gives an indication of how well an alternative protects human health in practice, whether or not it was designed to do so. The alternatives are evaluated separately below for each of the two parts.

By Design—This part of the criterion is used to evaluate whether the alternative addresses by design acute and chronic health threats. The ranking system is described below:

- **Low**: The approach used under the alternative does not consider human health when developing cleanup levels
- **Medium**: The approach used under the alternative considers human health, but the cleanup levels may also be affected by other factors
- **High**: Protection of human health is the primary factor in the approach used to develop cleanup levels under the alternative.

The background alternative and the technology-based alternative were assigned low scores under this evaluation. Although the background alternative might, in many cases, be protective of human health in practice, it would not directly consider protectiveness of human health when developing cleanup levels. There is at least one case (arsenic in soils) in which the background concentrations of hazardous substances may not be protective of human health. In other cases, the environmental medium may have been contaminated prior to the release of hazardous substances at a site to concentrations not protective of human health. An example is the presence of many volatile organic chemicals in urban air. The technology-based alternative would consider only what is technically feasible, which may or may not be protective of human health.

The ARAR alternative was assigned a medium score. Although most ARARs are developed to be protective of human health, some ARAR concentrations (for example, MCLs for carcinogens) have been modified upward to take into account technical feasibility. In addition, some ARARs, such as levels used to designate wastes as dangerous, were not designed as cleanup levels.

The risk-based alternative and the combination alternative were assigned high scores. The risk-based alternative is solely concerned with the protection of human and environmental health. The combination alternative would employ several alternatives in the development of the standard. However, the final standard would be no higher than a level that is protective of human health.

By Default—This part of the criterion is used to evaluate whether the alternative provides concentrations that, by default, are consistently protective of human health. To evaluate the alternatives under this part of the criterion, standards that would be used under each alternative are compared with concentrations based solely on human health. The ranking system is described below:

- **Low**: The standards for a majority of hazardous substances would be higher than human health risk-based concentrations and higher than human health-based ARARs.
- **Medium**: The standards for a majority of hazardous substances would be close to human health risk-based concentrations and human health-based ARARs.
- **High**: The standards for a majority of hazardous substances would be equal to or lower than human health risk-based concentrations and human health-based ARARs.
- **Unpredictable**: The alternative would result in standards that are highly variable with respect to protectiveness of human health.

The background, ARAR, and combination alternatives were assigned medium scores. During remediation, the background alternative could result in an increase in injuries from transportation of soil and hazardous wastes (see Chapter 7). The background concentrations of metals would generally be protective of human health. One exception is air, where ambient concentrations of arsenic and lead exceed risk-based concentrations. Background concentrations of volatile organic compounds are protective of human health, except in air, where urban ambient concentrations of some of these compounds are higher than risk-based numbers and ARARs. Some surface water standards would also be exceeded under the background alternative because of the use of PQLs as standards. PQLs, when used as standards for pesticides and semivolatile organic compounds, may not be protective of human health; however, the actual background concentrations for these hazardous substances may be protective. The ARAR alternative received a medium score, because in many instances ARARs are somewhat higher than risk-based concentrations due to consideration of technical feasibility. In addition, the ARARs available for soils, which have been developed for a separate regulatory purpose, are generally not protective of human health. The ARAR alternative was found to have minor impacts on human health, both during and after remediation (see Chapter 13). The combination alternative, although designed to protect human health, also requires that cleanup levels be enforceable. As a result, PQLs are used for hazardous substances such as pesticides and semivolatile organic hazardous substances when the risk-based standards for these hazardous substances would be very low.

The risk-based alternative was assigned a high score. The risk-based alternative was designed with the protection of human health in mind; therefore, standards developed under this alternative would be protective of human health in nearly all cases.

The technology-based alternative would be unpredictable in its protectiveness of human health. Technologies available for the remediation of metals and volatile organic compounds in all media except air are protective of human health (see Chapter 7). However, technologies used for the remediation of semivolatile organic compounds and pesticides were not protective of human health. Because of these variations, the technology-based alternative was found to have the greatest potential for impacts on human health (see Chapter 9). This alternative might become more protective as technologies improve. However, it currently cannot be considered protective of human health, except when applied to treatment of metals and volatile organic compounds in soil and water.

Protection of the Environment

This criterion is also divided into two parts. As with human health, the two parts reflect whether the alternative is protective of the environment by design or default. The two parts to this criterion are described below.

By Design—This part of the criterion is used to evaluate whether the approach addresses acute and chronic ecological risks by design. The ranking system is described below:

- **Low:** The approach used under the alternative incorporates no consideration of ecological risks when developing standards
- **Medium:** Ecological risks are considered in the approach used under the alternative, but the standards may be adjusted by other factors
- **High:** Protection against ecological risks is the primary factor in the approach used under the alternative.

The background and technology-based alternatives were assigned low scores, for the same reasons given above in the section on protection of human health. The ARAR alternative received a medium score. Although the ARARs that are available (for example, water quality criteria) are designed solely for the protection of ecological health, they are only available for fresh and salt water. No ARARs for protection of ecological health are available for soil or air.

The combination alternative was assigned a medium score. Although the combination alternative is designed to protect ecological health, the alternative would also take into account enforceability by requiring that cleanup levels be greater than or equal to PQLs.

The risk-based alternative was assigned a high score because this approach is specifically designed to protect ecological health. Because of the complex and site-specific nature of risk assessments for plants and animals, the risk-based standards cited in the regulations are based on ARARs. However, under the actual risk-based alternative, risk assessments would be performed to determine standards that would be protective of plants and animals at risk on a site-specific basis.

By Default—This part of the criterion is used to evaluate whether the alternative provides concentrations that are consistently protective of the environment by default. The ranking system is described below:

- **Low:** Standards for a majority of hazardous substances would be more than 1 order of magnitude greater than ecological health-based ARARs
- **Medium:** Standards for a majority of hazardous substances would be near ecological health-based ARARs

- **High:** Standards for a majority of hazardous substances would be less than or equal to ecological health-based ARARs

- **Unpredictable:** Use of the alternative would result in standards that are highly variable with respect to protectiveness of ecological health.

Because the method for evaluating ecological health risk to diverse plant and animal species is not yet well developed, ARARs were used to evaluate whether an alternative is protective of ecological health. The ecological health-based ARARs used in this evaluation are generally protective of ecological health, because they do not incorporate factors such as cost and technical feasibility. This part of the criterion can only be evaluated for surface water and marine water because no ARARs are available with which to compare the potential standards in other media. However, as discussed in Chapter 10, some toxicity values are available for soil. These values were used in place of ARARs in this analysis. Because no toxicity values for air were identified, the following scores may not be representative for air.

The ARAR alternative was assigned a medium score. This alternative is designed to meet all ARARs in surface water and marine water. However, the comparison (see Chapter 10) of ARARs with soil and water concentrations necessary to protect the environment showed that ARARs alone would not be protective for some species.

The background, risk-based, and combination alternatives were assigned high scores. Although background concentrations would exceed surface water ARARs for a few hazardous substances, the analysis in Chapter 10 showed that the background alternative would be protective in nearly all cases. The risk-based and combination standards would meet all ARARs. However, the above analysis showed that these alternatives are not protective of the environment all of the time, because the standards for these alternatives would be based only on freshwater and marine water ARARs. However, the risk-based and combination standards at a particular site would take into account any information known about the toxicity of site hazardous substances to the plants and animals at the site. The risk-based or combination standard would then be lowered to be protective of the species present at the site.

The technology-based alternative would be unpredictable with respect to protection of the environment. Again, the technology-based alternative would be fully protective for volatile organic compounds, but often unprotective for metals, semivolatile organic compounds, and pesticides. The technology-based alternative was found to be protective of only half of the species reviewed in Chapter 10.

Compliance with ARARs

This criterion is used to evaluate whether the alternative would result in standards that are at least as stringent as all ARARs, as required by the MTCA. The ranking system is described below:

- **Low**: Standards for a majority of hazardous substances would be less stringent than all available ARARs
- **Medium**: Standards for a majority of hazardous substances would be at least as stringent as all available ARARs
- **High**: Standards for all hazardous substances would be at least as stringent as all available ARARs.
- **Unpredictable**: Standards for hazardous substances in some media would meet most available ARARs, but standards for other media would not.

The technology-based alternative was assigned a low score. The technology-based alternative would consistently produce concentrations that are above ARARs for surface water, marine water, and air, with the exception of volatile organic compounds in water. Technology-based concentrations of hazardous substances in ground water would be below ARARs for some metals and pesticides. Standards for hazardous substances in soil would generally be above ARARs but would fall below ARARs for some metals (ICF 1990).

The ARAR and combination alternatives were assigned high scores. The ARAR standards must be equal to ARARs in every case. The combination alternative would result in concentrations that are less than or equal to ARARs in every case. The combination alternative would not meet an ARAR that was below the natural background at the site. However, an ARAR that was below the natural background at a site would not be considered applicable to that site.

The background and risk-based alternatives are unpredictable with respect to providing standards that meet ARARs. Background standards would meet all ARARs for ground water and soil. Most ARARs would also be met for volatile organic compounds in other media. However, because of the use of PQLs, background standards may meet ARARs for other organic hazardous substances in surface water, marine water, and air. Risk-based standards would meet most ARARs for soil and air. However, risk-based standards would not meet many ARARs for ground water, surface water, and marine water. Although most risk-based standards for carcinogens would be below ARARs, most risk-based concentrations for noncarcinogens would be above ARARs, because some ARARs for noncarcinogens are based on prevention of effects not related to human health (for example, secondary MCLs).

Balancing Criteria

Balancing criteria address essential practical considerations that affect the ease of development and implementation of the standards. Some of these criteria also reflect preferential goals of the MTCA and Ecology. The criteria and their ranking systems are described below.

Technical Feasibility and Enforceability

This criterion is used to evaluate whether the alternative would result in standards that are technically feasible and measurable using best available treatment technologies, best management practices, and available analytical techniques. Standards that are not measurable or technically feasible would be more difficult to enforce than those that can be implemented and measured. The scoring system is described below:

- **Low:** The alternative would result in standards that are lower than technically feasible concentrations and PQLs for a majority of hazardous substances
- **Medium:** The alternative would result in standards that are near technically feasible concentrations and PQLs for a majority of hazardous substances
- **High:** The alternative results in concentrations that are above technically feasible concentrations and PQLs for the majority of the hazardous substances in the hazardous substance classes
- **Unpredictable:** The alternative would result in standards that are highly variable with respect to technical feasibility.

The background alternative was assigned a medium score. Background standards would always be greater than or equal to PQLs. They would also be technically achievable for approximately one-half of the hazardous substances for which cleanup levels are provided in the proposed regulations (ICF 1990).

The technology-based, ARAR, and combination alternatives were assigned a high score. The standards provided by the technology-based alternative would usually be above PQLs and are, by design, technically feasible. Compliance with standards provided by the combination alternative would be determined by comparison with PQLs and, as a result, implementation of this alternative would generally be technically feasible (ICF 1990). ARARs, having been developed by regulatory agencies, are generally feasible and enforceable for a majority of hazardous substances.

The risk-based alternative would be unpredictable with respect to technical feasibility. The risk-based alternative would generally be infeasible for air, feasible for soil, and highly variable for surface, ground, and marine water (ICF 1990).

Preference for Permanent Solutions

This criterion is used to evaluate whether the alternative approach facilitates the use of permanent solutions to the maximum extent practicable. The measures that determine whether an alternative facilitates the use of permanent solutions are the same as the measures that evaluate whether an alternative is technically feasible, under the definition of the technology-based alternative used in this EIS. Because this criterion is so similar to technical feasibility, scores are not assigned separately. The technologies that would be considered in setting a standard under the technology-based alternative would result in removal or destruction of the hazardous substances in the media. Therefore, any concentration below technology-based standards would require additional containment, isolation, or removal technologies that are not permanent.

Cleanup levels below those that are technically feasible may result in a deterrent for using permanent solutions. Standards provided by the background alternative would be technically infeasible most often. Additionally, cleanup levels below background may not result in permanent solutions because hazardous substances from offsite sources may eventually enter and recontaminate a site to local background concentrations. Risk-based standards would most often be below background.

Cross-Media Impacts

Two types of cross-media impacts may occur at a hazardous waste site. Short-term cross-media impacts are a direct result of the remediation process at a site. For instance, treatment of volatile organic compounds in ground water may result in the release of the volatile compounds into the air. The higher the cleanup concentrations, the less remediation will be required, resulting in fewer short-term cross-media impacts.

Long-term cross-media impacts result when the residual concentrations left in the medium after cleanup are not low enough to protect other media with which the hazardous substances may come into contact. For instance, residual soil concentrations may or may not be protective of ground water that comes into contact with the soil. Long-term cross-media impacts are lessened when the residual concentrations of hazardous substances are lowered. The two types of cross-media impacts are discussed separately below.

Short-Term Cross-Media Impacts—This part of the criterion is used to evaluate whether the alternative implemented in one medium results in adverse impacts in other media during remediation. Short-term cross-media impacts will depend heavily on the type of remedial technology that is employed. Because cleanup actions must meet all cleanup levels during remediation, it is assumed that most releases during remediation will be controlled. For instance, volatile organic emissions from air-stripping towers can be controlled by passing the emissions through activated carbon. Any short-term cross-media impacts that occur from the use of this technology will be from unplanned releases during remediation and, therefore, cannot be predicted. However, less stringent cleanup levels will generally result in fewer short-term cross-media impacts, because a lesser remedial effort will be needed.

Long-Term Cross-Media Impacts—This part of the criterion is used to evaluate whether the alternative implemented in one medium results in adverse impacts to other media after completion of onsite treatment or redisposal of treated material. The ranking system is described below:

- **Low**: The alternative would result in residual concentrations for a majority of hazardous substances that exceed ARARs for other media as a result of hazardous substance migration from the original environmental medium
- **Medium**: The alternative would result in residual concentrations that are below ARARs for other media for a majority of hazardous substances after they migrate from the original environmental medium

- **High:** The alternative would result in residual concentrations that are below ARARs for other media for nearly all hazardous substances after migration from the original environmental medium.

The actual transfer of hazardous substances between media at any given site will strongly depend on site-specific factors such as the level of contamination, type of contamination, soil type, depth to ground water, and wind velocity. Therefore, the cleanup levels that will need to be attained will be based on site-specific modeling of hazardous substance transfers between media.

For this evaluation, simple models and the results of more complex MEPAS modeling (see Appendix H) are used to predict the migration of hazardous substances between media. Six categories of cross-media migrations take place most often: soil to air, soil to surface water, soil to ground water, surface water to ground water, surface water to marine water, and ground water to surface water. To provide a conservative model, the movement of hazardous substances between water media was assumed to take place without dilution, allowing direct comparison of water ARARs. A simple particle transport model (ICF 1989) was used to evaluate the movement of hazardous substances from soil to air on particulates. Capping and wetting of the soil to prevent movement of hazardous substances was assumed to be 90 percent effective.

Transfers of hazardous substances from soil to ground water and from soil to surface water were modeled extensively (using the MEPAS model) for the site scenarios described in Chapter 6. Details of the model are provided in Appendix H. For hazardous substances not modeled in the site scenarios, the concentration of a hazardous substance entering ground water from soil was assumed to be 100 times less than the concentration of that hazardous substance in the overlying soil. The factor of 100, which is based on elutriate tests, generally overestimates the amount of a hazardous substance that will enter ground water from soil (Tetra Tech 1982) and is therefore considered protective. This factor of 100 is used in the proposed regulations and by the state of California to set standards in soil that are protective of ground water (DHS 1986).

The models described above were used to determine whether standards in the primary medium would be protective of uses of the secondary medium. For instance, the soil-to-ground water model was applied to the residual soil concentrations used in the site scenarios for the various alternative standards. In this manner, the ground water concentrations that would result from the movement of those hazardous substances from soil to ground water were determined. These concentrations were then compared with ground water ARARs to determine whether the example standards in soil were protective of all uses of ground water.

For each alternative, some transfers of hazardous substances between media would be protective of all uses in the receiving media, while others would not. In general, the standards would be moderately protective against migrations from surface water to ground water and to marine water but not protective against all migrations from ground water to surface water. Surface water standards are generally stricter than ground water standards because they are intended to protect aquatic life.

Migrations from soil to ground water were determined to cause the greatest environmental impacts for all alternatives (see Chapter 8). To protect against these impacts, soil standards for the combination alternative would be modified to take into account protection of ground water. In addition, under the risk-based or combination alternatives, all standards would be modified downward if necessary to protect other media. Therefore, these alternatives received a high score. The other alternatives would be unpredictable with respect to cross-media impacts.

Incorporation of Hazardous Substance Interactions

This criterion evaluates whether the approach used under the alternative would incorporate the interaction among hazardous substances at a site. Multiple hazardous substances at a site may increase risks in an additive or multiplicative manner. A hazardous substance may also interact with another hazardous substance to lessen the toxicity of one or both of the hazardous substances. Only additive interactions are addressed in this EIS because of a lack of consensus in the scientific community on methods to address the other types of effects. The alternatives were evaluated as follows:

- **Low**: The approach used under the alternative is not able to incorporate interactions between hazardous substances that affect ecological and human health risk
- **Medium**: The approach used under the alternative is able, in some cases, to incorporate interactions between hazardous substances that affect ecological and human health risk
- **High**: The approach used under the alternative is able to incorporate interactions between hazardous substances that affect ecological and human health risk.

The background, ARAR, and technology-based alternatives were assigned low scores. Each of these alternatives would set standards solely based on hazardous substance-specific factors, without considering the effects that multiple hazardous substances may have on health risk. The background alternative would rely on separate and direct measurement of each hazardous substance concentration. The presence of multiple hazardous substances was not considered in the derivation of available ARARs. Instead, the ARARs were derived based on exposure of humans, plants, or animals to only a single hazardous substance of concern. Technology-based standards would reflect the limits of technical feasibility for remediation of each hazardous substance or group of hazardous substances, but would not address health risk.

The risk-based and combination alternatives were assigned a high score. The equations used to derive the risk-based standards would be modified to take into account the presence of multiple hazardous substances on a site-specific basis. For example, the risk-based standards for each hazardous substance might simply be divided by the total number of hazardous substances at the site. This approach assumes that the risks from the individual hazardous substances can be added together, an assumption that is most appropriate when the hazardous substances in question affect the same parts of the body. Similarly, standards under the combination alternative would be lowered until the risk associated with all contaminants and exposure pathways at a site reached an acceptable level.

Applicability to All Hazardous Substances

This criterion evaluates whether the alternative can be easily used for all new and existing hazardous substances. The ranking system is described below:

- **Low**: The approach under the alternative requires data that are currently unavailable for many hazardous substances or that cannot easily be obtained for new hazardous substances
- **Medium**: The approach under the alternative requires data that are currently unavailable but can easily be measured
- **High**: The approach under the alternative requires data for new hazardous substances that can be obtained from the literature or estimated from data for chemically similar substances.

The ARAR and risk-based approaches were assigned low scores. These alternatives require data that are currently unavailable for some hazardous substances and would be time-consuming and costly to develop. ARARs for protection of the environment are not available for three out of the five media, and the development of such ARARs would require costly, time-consuming studies. In addition, ARARs that are protective of human health are not available for some hazardous substances (particularly in soil). New ARARs are not anticipated to be available for many hazardous substances in the near future. The risk-based alternative makes use of CPFs and RfDs that are not available for some hazardous substances of concern. This poses a particular problem for air, as most CPFs and RfDs that have been developed so far are for oral, rather than inhalation, routes of exposure. However, other methods of risk assessment are available that do not require CPFs and RfDs. These methods could be used where such data are unavailable.

The background alternative was assigned a high score. Although data on the background concentrations of many hazardous substances are missing, the background concentrations of these hazardous substances could be measured on a site-specific basis. When the background concentration is too low to be measured, a PQL could be used in its place.

The technology-based and combination alternatives were also assigned high scores. Methods of treatment are available for each of the hazardous substance classes known to be present at contaminated sites. New hazardous substances within hazardous substance classes can be treated using the technologies available for those classes. Although the combination alternative is made up of the ARAR, risk-based, and background alternatives, it is more flexible than any of these alternatives alone, allowing any one of the concentrations to be used when others are not available. Using this approach, Ecology was able to derive a standard for every hazardous substance of concern listed in the proposed regulations. Furthermore, the combination alternative allows for the incorporation of site-specific, health-based data in the absence of other information.

Scientific Uncertainty

This criterion evaluates whether the approach used under the alternative results in standards that have an acceptable degree of scientific uncertainty. Because an acceptable degree of scientific uncertainty is difficult to define, the uncertainty associated with each of the alternatives is discussed in a narrative fashion, and scores are not assigned.

The uncertainty associated with background concentrations is related to the use of a single number to represent background for an entire state. Background concentrations in Washington generally range within 3 orders of magnitude, with isolated exceptions (such as PAHs in air or lead in soils) (PTI 1989). Because metals occur naturally in the environment, their concentrations vary more than the background concentrations of most organic compounds (which are often undetected). In order to determine appropriate cleanup levels for an individual site, a site-specific measurement should be made to determine the prerelease background concentrations of each hazardous substance in each medium at each site.

The risk-based alternative contains the greatest degree of uncertainty, particularly associated with risk assessments of carcinogens. The regression equations and various assumptions used in risk assessment for carcinogens can result in a number with uncertainty ranging up to 10 orders of magnitude (Food Safety Council 1980; Eaton 1989). However, risk assessments are performed in such a way that the concentrations derived are likely to be protective. In other words, the true risk from carcinogens is not likely to be greater than the calculated risk and may be as low as zero. Risk assessments for noncarcinogens result in concentrations with at least 3 orders of magnitude uncertainty. This uncertainty is associated with uncertainty in the data set, variation among species and individuals, and the short duration of the studies.

The ARAR alternative is not subject to statistical uncertainty because each ARAR is a defined concentration that has been promulgated. Although there may be some uncertainty in the original method used to derive the individual ARAR, there is no uncertainty about the number to be applied under each ARAR. However, there may be some judgment involved in determining which standards and criteria are applicable for use as ARARs at a particular site.

The technology-based alternative is subject to some uncertainty because of the variation in the response of remedial technologies to the types of contamination encountered at hazardous waste sites. Cleanup efficiencies vary because of differences in initial concentrations of hazardous substances, the effects of mixtures of hazardous substances, and variation in the media containing the hazardous substances. The uncertainty in standards under the technology-based alternative has been estimated to fall within 2 orders of magnitude (ICF 1989).

The uncertainty associated with the combination alternative would be the same as the uncertainty associated with the risk-based, ARAR, or background alternatives, depending on which alternative was chosen for each hazardous substance.

Modifying Criteria

Modifying criteria primarily reflect community welfare and perception issues that do not directly reflect the goals of the MTCA or the programmatic priorities of Ecology. The criteria described below may modify the choice of the preferred alternative, especially if two or more alternatives rank similarly under all of the preceding criteria.

Regulatory Precedence

This criterion is used to evaluate whether the standard-setting process used under the alternative has been incorporated into major environmental legislation that has goals similar to those of the MTCA. The ranking system is described below:

- **Low:** The process used to set standards under the alternative is innovative
- **Medium:** The process used to set standards under the alternative has been incorporated into major environmental legislation whose goals may be somewhat different from those of the MTCA
- **High:** The process used to set standards under the alternative has been incorporated into major environmental legislation whose goals are similar to those of the MTCA.

The technology-based and combination alternatives were assigned medium scores. The technology-based approach is an integral part of the federal Clean Air Act and the Clean Water Act, which have been in effect since 1970 and 1972, respectively. This approach is used to set standards for emissions into air and water from stationary and mobile sources. Because these acts are intended to regulate emissions from industry, technical feasibility was an important factor in setting the standards. The purpose and goals of these acts are somewhat different from those of the MTCA, because the MTCA regulates the cleanup of hazardous waste sites. Under the MTCA, considerations other than the protection of human health and the environment are secondary. Therefore, the process used to set standards under the Clean Air Act and the Clean Water Act is not necessarily appropriate to the MTCA. The combination alternative incorporates elements of the CERCLA and RCRA approaches to setting cleanup levels (for example, the use of risk-based, ARAR, and background standards). Although the combination alternative is similar to the approach used in practice under CERCLA, such an approach has not been promulgated as major environmental legislation.

The ARAR, risk-based, and background alternatives were assigned high scores. The ARAR and risk-based approaches specified for use in establishing cleanup levels for hazardous waste sites under CERCLA. The goals of CERCLA are the most similar to those of the MTCA: clean up hazardous waste sites and protect human health and the environment. Therefore, the processes used in CERCLA may be considered to have a legal precedent for use under the MTCA. RCRA is another statute intended to regulate hazardous substances. In cleaning up contaminated sites and spills under RCRA, the risk-based and background approaches are most commonly used. Therefore, the background approach may also be considered to have a legal precedent for use in the MTCA.

Understandability

This criterion is used to evaluate whether the alternative can be easily understood and applied by the regulated community and the general public. The ranking system is described below:

- **Low**: The alternative incorporates complex technical concepts and requires substantial technical knowledge for application at a site
- **Medium**: The alternative incorporates complex technical concepts but can be easily applied in the manner defined by Ecology
- **High**: The alternative is conceptually simple and can be easily applied at a site.

The background, risk-based, technology-based, and combination alternatives were assigned medium scores. None of these alternatives uses a strict numerical standard and will therefore require some effort on the part of the site operator. All of these alternatives contain complex concepts. Under the background alternative, the site-specific background that reflects the history of the site and the surrounding area must be determined in each case. Background measurements may need to be performed. However, finding an appropriate reference area in contaminated areas may be difficult. The risk-based alternative requires identification of the pathways and routes of exposure at each site, the hazardous substances of concern for each pathway, and hazardous substance-specific variables needed for the risk-assessment equations. The technology-based alternative requires an analysis of the technologies that could be used at the site, along with an identification of any site-specific factors that may modify the technically feasible cleanup level. Under the combination alternative, the performance of a site-specific risk assessment would be required and some background concentrations would need to be measured. In addition, ARARs would need to be considered.

The ARAR alternative was assigned a high score. This alternative is simple in concept, the standard is predominantly numerical, and development costs have already been incurred prior to promulgation of these ARARs under the MTCA. The same numbers would be applied at all sites with few exceptions or modifications for site-specific factors.

Consistency

This criterion is used to evaluate whether the approach used under the alternative can be applied consistently in all circumstances, for different hazardous substances and different geographic areas. The ranking system is described below:

- **Low**: The approach used under the alternative incorporates hazardous substance-specific considerations during the development of the standards, resulting in standards for different hazardous substances that have inconsistent methods of derivation
- **Medium**: The approach used under the alternative produces standards that must be modified according to site-specific characteristics, and the modification process incorporates the use of professional judgment
- **High**: The approach used under the alternative produces standards that are consistently derived and can be applied consistently in all circumstances, regardless of site-specific factors.

The background, ARAR, and combination alternatives were assigned low scores. Each of these alternatives would result in standards that have inconsistent methods of derivation. Under the background alternative, if the true background concentration of a hazardous substance is not measurable, the PQL would be used. Therefore, in some cases, a measured background concentration would be used, and in others, the PQL would be used. The ARAR alternative would incorporate a wide variety of ARARs, each of which was developed to protect against different effects and considered different factors in the setting of the standards. For instance, the standard for one hazardous substance might be set using a secondary MCL (an ARAR that protects against taste, odor, and color changes in drinking water), while the standard for another hazardous substance might be set using chronic ambient water quality criteria for the protection of freshwater fish. These standards would have inconsistent premises. Finally, under the combination alternative, either a risk-based, ARAR, or background-based standard could be used for each hazardous substance, depending on the outcome of the decision-making flow chart.

The risk-based and technology-based alternatives were assigned medium scores. These standards would be based on consistent premises, the protection of human health at a specified level or the level that is technically feasible. Additionally, the risk-based alternative requires evaluation of the number of hazardous substances and exposure pathways at each site, and it may require a site-specific ecological risk evaluation. The technology-based alternative requires a determination of the achievable concentration at each site, which depends on the initial level of contamination at the site and media-specific properties such as the salinity of water and the type of soil. Evaluation of these factors requires sound professional judgment.

Selection of the Preferred Alternative

In this section, a process is described for identifying a preferred alternative. Each alternative is evaluated according to the process, and the preferred alternative is selected. The process used in this EIS for identifying the preferred alternative is patterned after the process outlined in Superfund guidance documents (U.S. EPA 1989d).

Description of the Process for Identifying the Preferred Alternative

The process used to identify the preferred alternative relies on the evaluation of the environmental impacts of the alternatives (presented in Chapters 7-13) and on the hierarchy of criteria developed in the preceding evaluation of the alternatives. The threshold criteria address protectiveness of human health and the environment and compliance with ARARs. The balancing criteria address issues of long- and short-term effectiveness; reduction of toxicity, mobility, and volume through permanent solutions; and implementability. The modifying criteria address agency and community acceptance.

Each alternative has strengths and weaknesses under the various criteria; the following process provides a method of weighing the relative importance of these strengths and weaknesses. First, the alternatives are evaluated according to how well they meet the goals of the threshold criteria. At this stage, those alternatives that clearly do not meet the threshold criteria are considered unsuitable and are not evaluated further. As the next step, the remaining alternatives are compared according to their scores under the balancing criteria. At this step, additional alternatives may be removed from consideration if they do not perform as well as other alternatives under threshold and balancing criteria. Finally, the scores under the modifying criteria are considered, and the final identification of the preferred alternative is made. Throughout this process, the significant impacts associated with the alternatives are considered when assigning scores under the evaluation criteria.

Application of the Process for Identifying the Preferred Alternative

In this section, the alternatives are ranked according to their performance under the three categories of criteria. A summary of the scores assigned to the alternatives under the evaluation criteria is presented in Table 19 for reference in the following discussion.

Threshold Criteria

The three threshold criteria are: protection of human health, protection of the environment, and compliance with ARARs. The risk-based alternative performs very well in the protection of human health and the environment categories, but is unpredictable in its compliance with ARARs. The combination alternative was partially designed to correct this shortcoming in the risk-based alternative by requiring compliance with ARARs when the ARARs are lower than the risk-based concentrations (this is particularly important for noncarcinogens). Standards under the combination alternative would be fully protective of human health and the environment and would comply with all ARARs. The use of PQLs as a measure of compliance with the combination alternative standards increases enforceability of the standards, while still being moderately protective of human health. The ARAR alternative performed moderately well, receiving a medium score for all of the threshold criteria. These three alternatives are all retained for evaluation under the following criteria.

The background and technology-based alternatives were assigned low, medium, or unpredictable scores for most criteria in this category. Because prerelease background concentrations and PQLs are used as standards, the background alternative is not as protective of human health or the environment as it would be if it solely used natural background concentrations as standards. In addition, the background alternative would be likely to have significant impacts during remediation on plants and animals, transportation, and state planning. The technology-based alternative would have the greatest impacts on human health, the environment, and land and natural resource use. These alternatives are therefore considered unsuitable for further consideration because they do not meet the primary goals of the MTCA.

Balancing Criteria

The balancing criteria include considerations of technical feasibility and enforceability, preference for permanent solutions, cross-media impacts, hazardous substance interactions, and applicability to all chemicals. The remaining alternatives evaluated at this stage are the risk-based, ARAR, and combination alternatives.

The risk-based alternative scored variably under these criteria, receiving one score of unpredictable, two high scores, and one low score. These scores reflect the shortcomings of this alternative: it would not be consistently technically feasible or enforceable, and toxicity values for many hazardous substances are either not available or are controversial. The risk-based alternative performed well in its ability to protect against cross-media impacts and take into account hazardous substance interactions. The ARAR alternative also performed variably under these criteria, receiving one high score, a medium score, and two low scores. These scores illustrate the strengths and weaknesses of this alternative. Although most ARARs are technically feasible and enforceable, they often do not protect against cross-media impacts and are not available for many hazardous substances. They also do not take into account the interactions between hazardous substances. The combination alternative incorporates the strengths of these other two alternatives and therefore performed better than the other two alternatives, receiving all high scores. These scores reflect the ability of this alternative to provide standards for a wide variety of hazardous substances that are technically feasible and enforceable, while taking into account cross-media impacts and hazardous substance interactions.

Based on these considerations, the ARAR alternative is dropped from further consideration, having received lower scores than both of the other alternatives under the threshold and balancing criteria. In addition, the ARAR alternative would have more significant impacts on human health, plants and animals, and environmental media than would the risk-based or combination alternatives (see Chapter 13).

Modifying Criteria

Modifying criteria address the issues of regulatory precedence, understandability, and consistency. The risk-based alternative performed somewhat better than the combination alternative under these criteria because it would be a more consistent and widely used approach for developing cleanup levels for various hazardous substances.

Recommendation of the Preferred Alternative

Based on the analysis described above, the combination alternative is recommended as the preferred alternative for setting cleanup levels at hazardous waste sites. Because the technology-based and background alternatives would have significant environmental impacts and often would not comply with ARARs, they are excluded from further consideration. The ARAR alternative would not be as protective of human health or the environment as the risk-based or combination alternatives and could not easily address as many hazardous substances or the interactions between them. Therefore, it was also excluded from further consideration.

The choice between the risk-based and combination alternatives is made on the basis of the relative strengths and weaknesses of each alternative, and the relative importance of the balancing and modifying criteria. Both of the alternatives meet nearly all of the goals of the MTCA and perform quite well under the threshold criteria. The risk-based alternative is somewhat stronger on the modifying criteria, which relate to community and agency perception. This relative strength results from the fact that the alternative is a well-known and more consistent method of setting standards. The combination alternative is a flexible approach that takes into account hazardous substance-specific factors.

However, the combination alternative is much stronger in the balancing criteria, which reflect the effectiveness and implementability of this approach to setting cleanup levels. The combination alternative would be effective at providing standards that are protective of human health and the environment, while still being achievable and enforceable. In addition, the combination alternative is the only alternative with few significant impacts to human health, the environment, or land and water use. These relative strengths under the balancing criteria outweigh consideration of the modifying criteria. Therefore, the combination alternative is considered a stronger alternative overall and is recommended as the preferred alternative for use in setting standards at hazardous waste sites in Washington.

Chapter 15
Opportunities for Public Involvement

Ecology encourages the public to become involved during the development of all rules and regulations. Given the controversial nature of the MTCA cleanup levels, the department has taken extra measures to increase public awareness and facilitate public comments on the draft requirements. These include:

- Public meetings
- Work groups/advisory panels
- Fact sheets
- Presentations
- Coordination with other departments at Ecology.

Public Involvement During Development of the EIS and Cleanup Levels

The following opportunities for public involvement were available during development of the cleanup levels and the draft EIS.

Public Meetings

The public was notified of the intent to complete an EIS on the alternatives for setting cleanup levels and was encouraged to participate in this process. Early involvement of the public in developing regulations is called scoping. The purpose of scoping is to determine, with input from the public and various groups, including agency staff, significant issues related to the proposed actions analyzed in the EIS. A declaration of significance was published in the SEPA Register, and public EIS scoping meetings were held in Seattle, Olympia, and Spokane during March 1989.

A preliminary draft of the cleanup levels dated 9 March 1990 was available for comment by the general public. Printed notice of the public comment period and workshop dates was mailed to approximately 1,800 people. Public workshops were held in locations throughout the state to provide the public with an opportunity to informally discuss the proposed regulations and related issues with Ecology staff. Workshops were held in the following cities: Olympia, Seattle, Tacoma, Vancouver, Spokane, Ellensburg, and Richland.

Public comments were reviewed and considered for incorporation into the cleanup levels regulation and were reported and commented on in the Responsiveness Summary made available by the Toxics Cleanup Program (formerly the Hazardous Waste Investigations Cleanup Program) of Ecology on 18 July 1990.

Work Groups and Advisory Panels

During the development of the cleanup levels, Ecology attempted to address the concerns and opinions of a wide range of interest groups. To facilitate these efforts, Ecology formed the Cleanup Standards Work Group in March 1989. The work group, comprised of representatives from federal, state, and government agencies; tribal governments; environmental groups; businesses; and environmental consultants met on 18 occasions over a period of 18 months. These working sessions allowed the participants the opportunity to make recommendations on concepts and proposed regulatory language. Additionally, the Underground Storage Tank Advisory Committee has been considering issues and regulatory language associated with leaking underground storage tanks since November 1989.

The MTCA specifically directed Ecology to form a Science Advisory Board to advise the department with respect to the scientific and technical aspects of the cleanup levels and other regulatory issues, such as the Washington Ranking Method. The Science Advisory Board consists of five independent members who have been meeting every 6 weeks over the past year to provide advice and comment. These meetings were open to the public. In addition, the Science Advisory Board, along with the Cleanup Standards Work Group, hosted a meeting that focused on quantitative risk assessment and its use by Ecology.

Fact Sheets

The Toxics Cleanup Program maintains a mailing list of over 1,600 interested citizens, environmental organizations, tribal governments, business groups, and government agencies. Over the past year, the Toxics Cleanup Program has periodically mailed updates on the status of the cleanup levels. The updates included information on the rule development plan, updates on the development of the cleanup levels, availability of the preliminary draft cleanup levels, availability of the site register, the development of the hazard ranking system for hazardous waste sites, and updates on the development and adoption of the administrative portions of Chapter 173-341 WAC.

Presentations

Throughout the rule development process, Ecology staff have made numerous presentations to interested groups. These groups include the Association of Engineering Geologists, Environment and Land Use Section of the Washington State Bar Association, Environmental Hazards Conference, Petroleum Contaminated Soils Work Group, Seattle Chamber of Commerce, Seattle-King County Bar Association, state and county appraisers, Western Petroleum Marketers Association, and Weyerhaeuser.

Coordination

Ecology recognizes the importance of close coordination among the various programs it manages. Therefore, Ecology has attempted to minimize inconsistencies among programs in the requirements for MTCA hazardous waste cleanup and the requirements being developed by the ground water, surface water, air pollution, sediment management, and hazardous waste management programs.

Throughout the rulemaking process, the department has also coordinated with the following groups:

- Federal agencies
  - U.S. Environmental Protection Agency
  - Agency for Toxic Substances and Disease Registry
- State agencies
  - Department of Community Development
  - Department of Health
  - Department of Corrections
  - Department of Ecology
  - Department of Fisheries
  - Department of General Administration
  - Department of Natural Resources
  - Department of Transportation
  - Department of Wildlife
- Tribal governments

- Local governments
  - Association of Washington Cities
  - Association of Washington Counties
  - Spokane Department of Solid Waste Management
  - King County Solid Waste Division
  - Seattle Solid Waste Utility
  - Tacoma Public Works Department
- Ports
  - Washington Public Ports Association
  - Port of Tacoma
- Business groups
  - Northwest Pulp and Paper Association
  - Western States Petroleum Association
  - Association of Washington Business
  - Independent Business Association
- Environmental groups
  - Sierra Club
  - Washington Environmental Council
  - Puget Sound Alliance
  - League of Women Voters
- Environmental consultants.

Future Opportunities for Public Involvement

Public review of the draft EIS is an important part of the SEPA process. The purpose of the draft EIS is to provide information to the public on the environmental impacts of the proposed regulations and on the alternatives for developing cleanup levels. Before development of the final regulations for setting cleanup levels, all comments by the public and other interested parties will be reviewed and considered. A summary of the comments received by Ecology and Ecology's responses to the comments will be included in the final EIS, which will accompany the final regulations in December 1990.

Comments may be provided to Ecology either at a public hearing or by mail. Public hearings, followed by informational meetings, will be held at the following locations and times:

- **Seattle** - Thursday, 6 September 1990, at 7 p.m. in the Moutaineers Club Skagit Room, 300 Third Avenue West

- **Richland** - Monday, 10 September 1990, at 7 p.m. in the Federal Building Auditorium, 825 Jawdin Avenue

- **Spokane** - Tuesday, 11 September 1990, at 7 p.m. in the Spokane County Health District Building, Conference Room 140, West 1101 College Street.

For interested parties in other areas, additional informational meetings will be held. At these meetings information on the proposed cleanup levels will be provided, but comments regarding the cleanup levels will not be taken. These meetings include the following:

- **Tacoma** - Monday, 13 August 1990, at ~~7~~ 1 p.m. in the World Trade Center Conference Room, 3600 Port of Tacoma Road

- **Vancouver** - Tuesday, 14 August 1990, 7 p.m. in the Clark County Public Utilities Department Community Room, 1200 Fort Vancouver Way

- **Seattle** - Wednesday, 15 September 1990, 7 p.m. in the Moutaineers Club Tahoma Room, 300 3rd Avenue West

- **Lacey** - Thursday, 16 August 1990, 1 p.m. in the Energy Facility Site Evaluation Council Hearing Room, Rowe 6, Building 1, 4224 Sixth Avenue South.

Written comments can be mailed to:

Elena Guilfoil
Toxics Cleanup Program
Washington State Department of Ecology
Mail Stop PV - 11
Olympia, WA 98504-8711

Written comments should be mailed so that they are received by Ecology no later than 5 p.m. on 17 September 1990.

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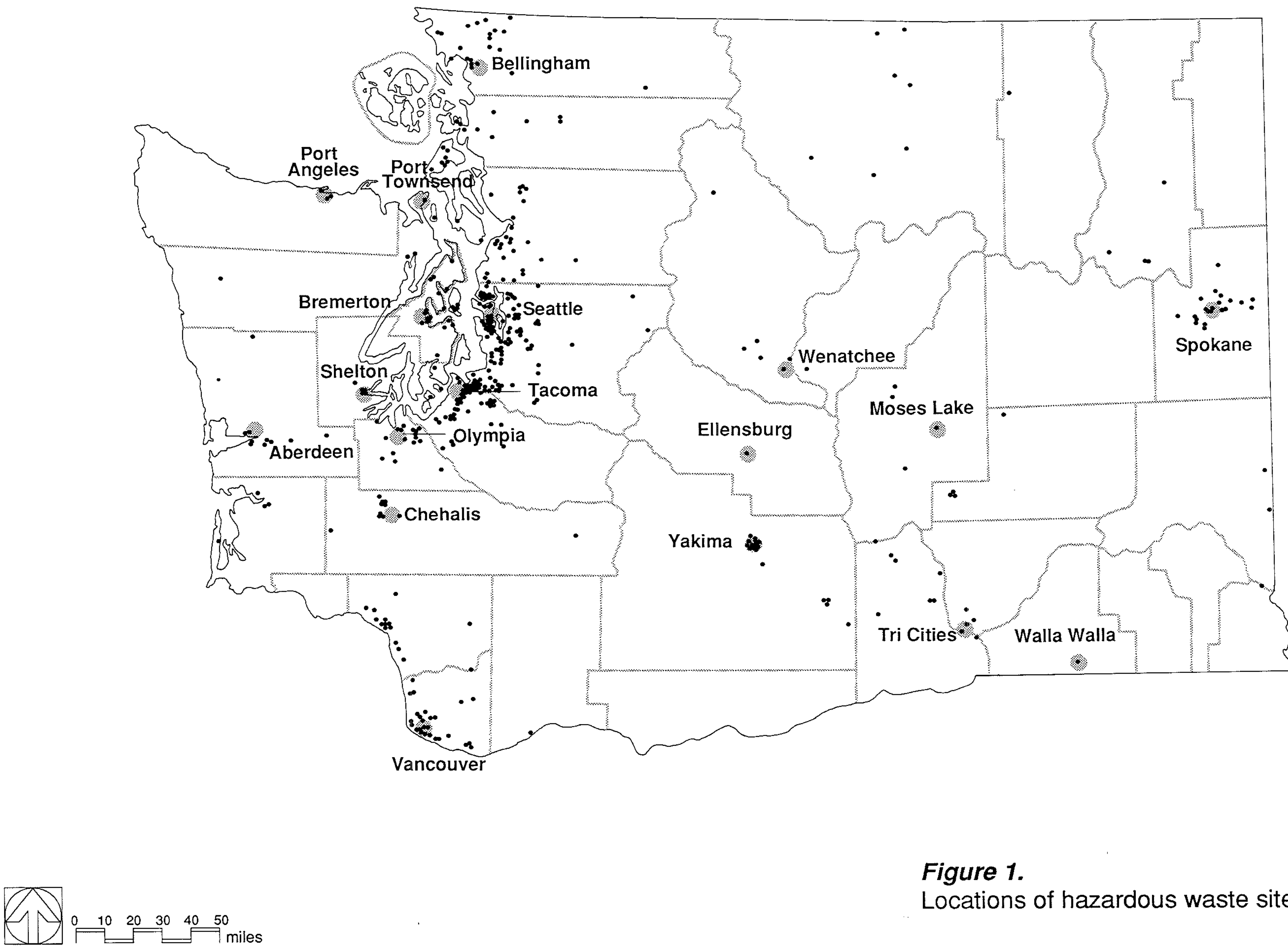


Figure 1.
Locations of hazardous waste sites

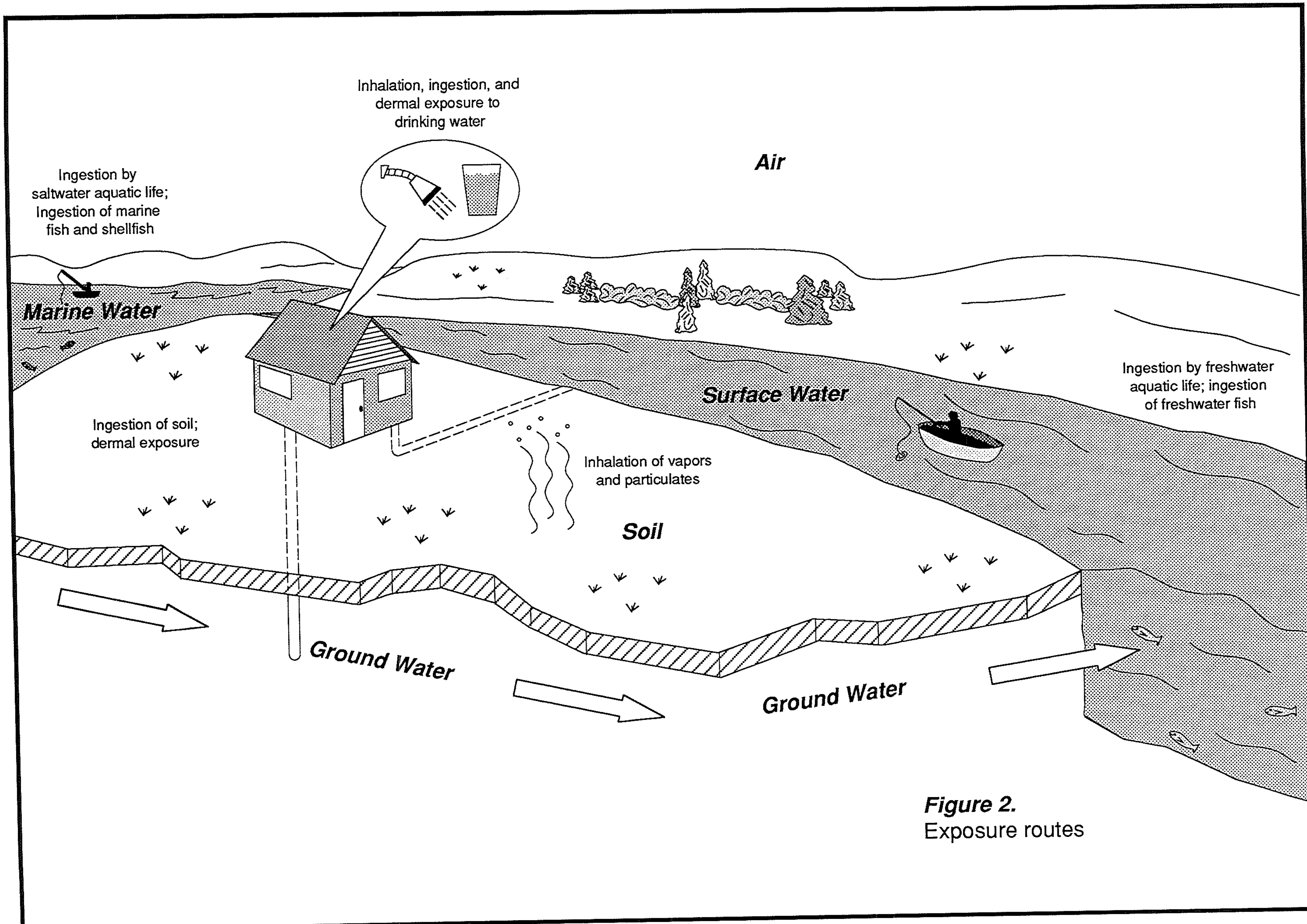


Figure 2.
Exposure routes

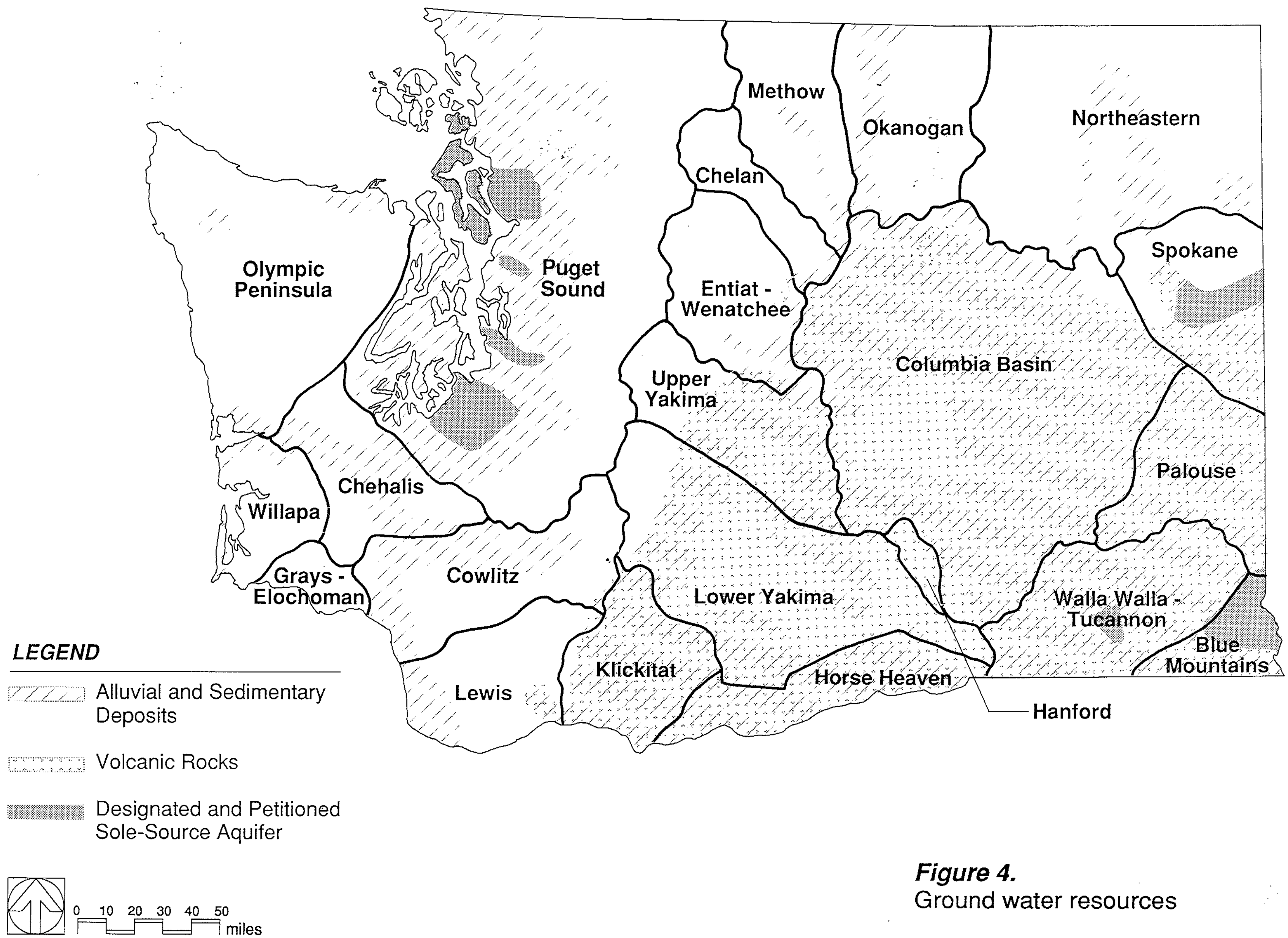


Figure 4.
Ground water resources

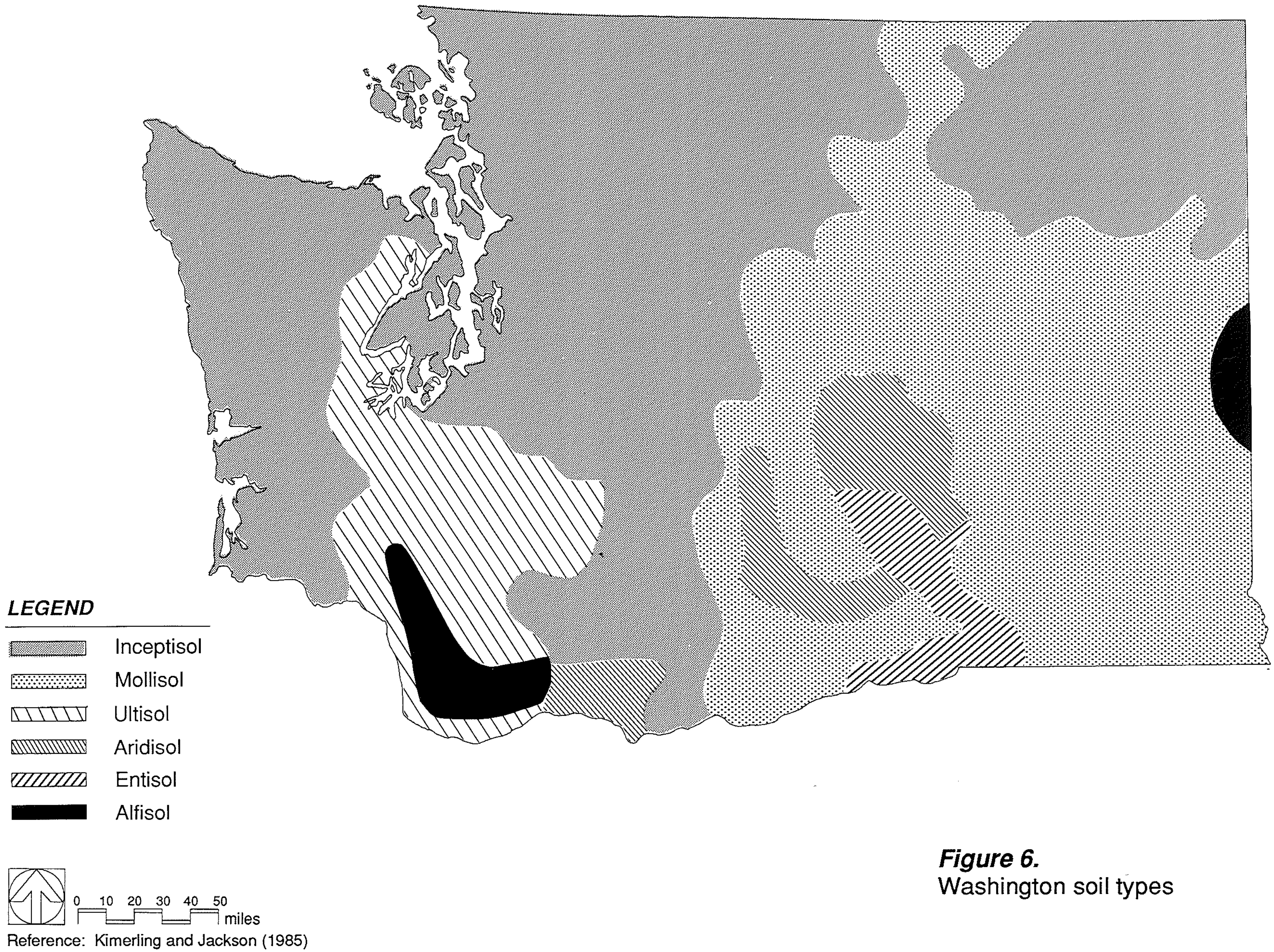
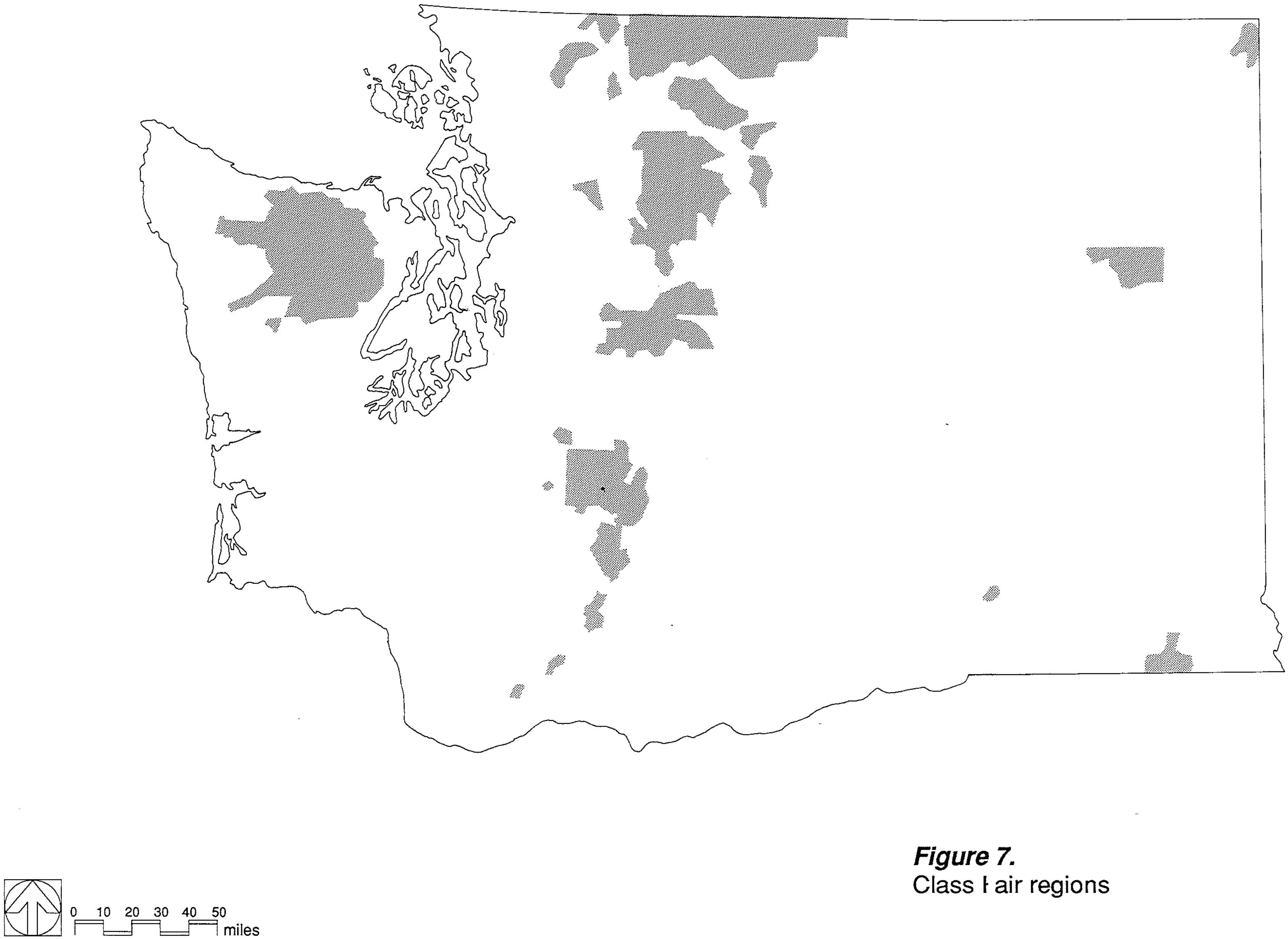
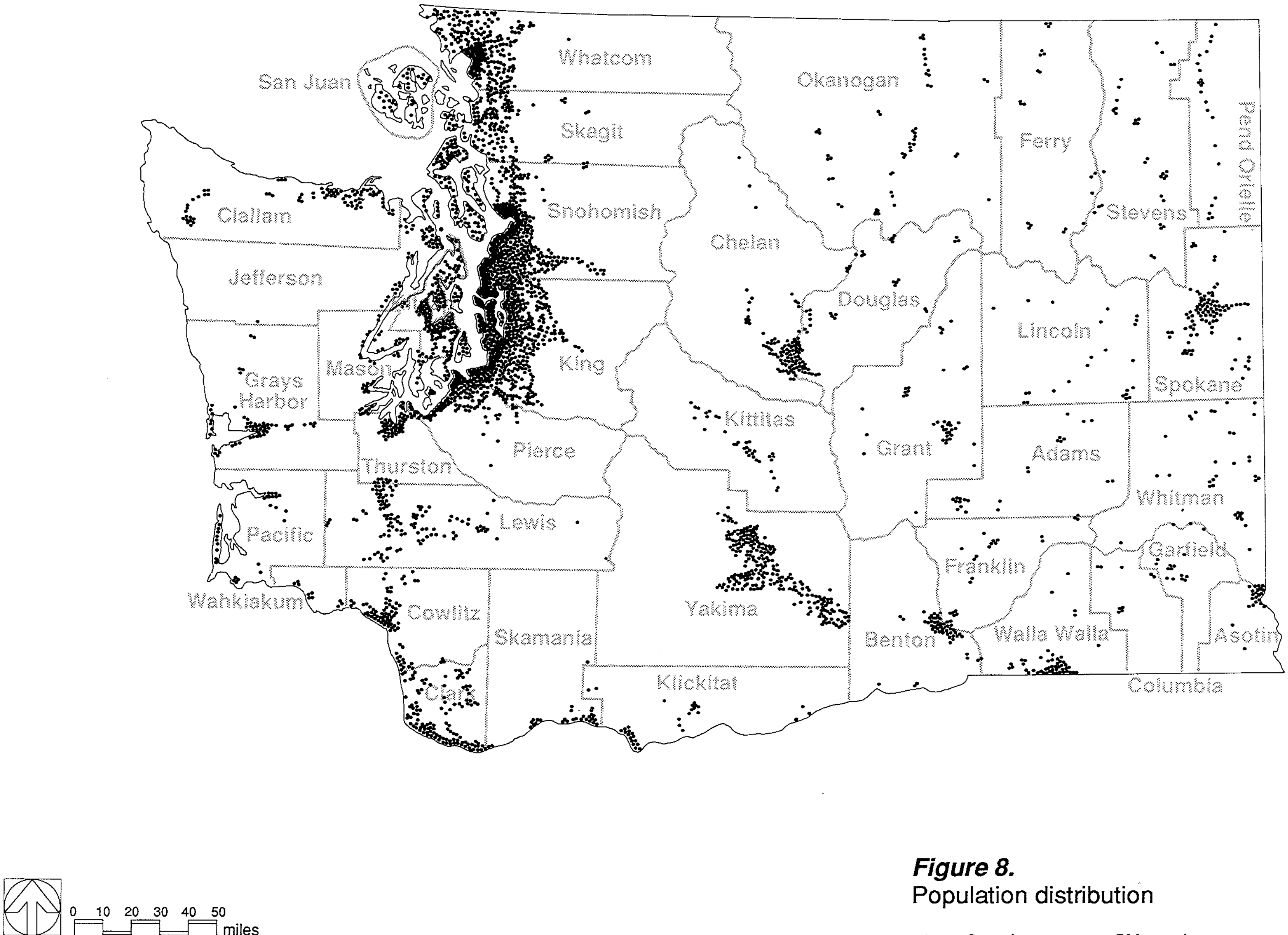


Figure 6.
Washington soil types



Source: U.S. EPA Region 10

Figure 7.
Class I air regions



Source: U.S. Census (1980)

Figure 8.
Population distribution

Note: One dot represents 500 people

highest numbers of these species are found in the Olympics and the Cascades, reflecting the specialized nature of many species inhabiting these temperate rain forests. Threatened and endangered plants and animals of Washington are listed in Tables 10 and 11.

Additional sensitive species occurring in Washington state are listed in the nongame data system of the Washington Department of Wildlife. The distribution of sensitive ecosystems has been mapped by the U.S. Army Corps of Engineers and is shown in Figure 10. Species may be identified as sensitive based on limited habitat, low abundance, or special exposures or sensitivities to harmful influences. Sensitive ecosystems include unique or critical habitats, as well as wildlife refuges, game parks, and wildlife recreation areas.

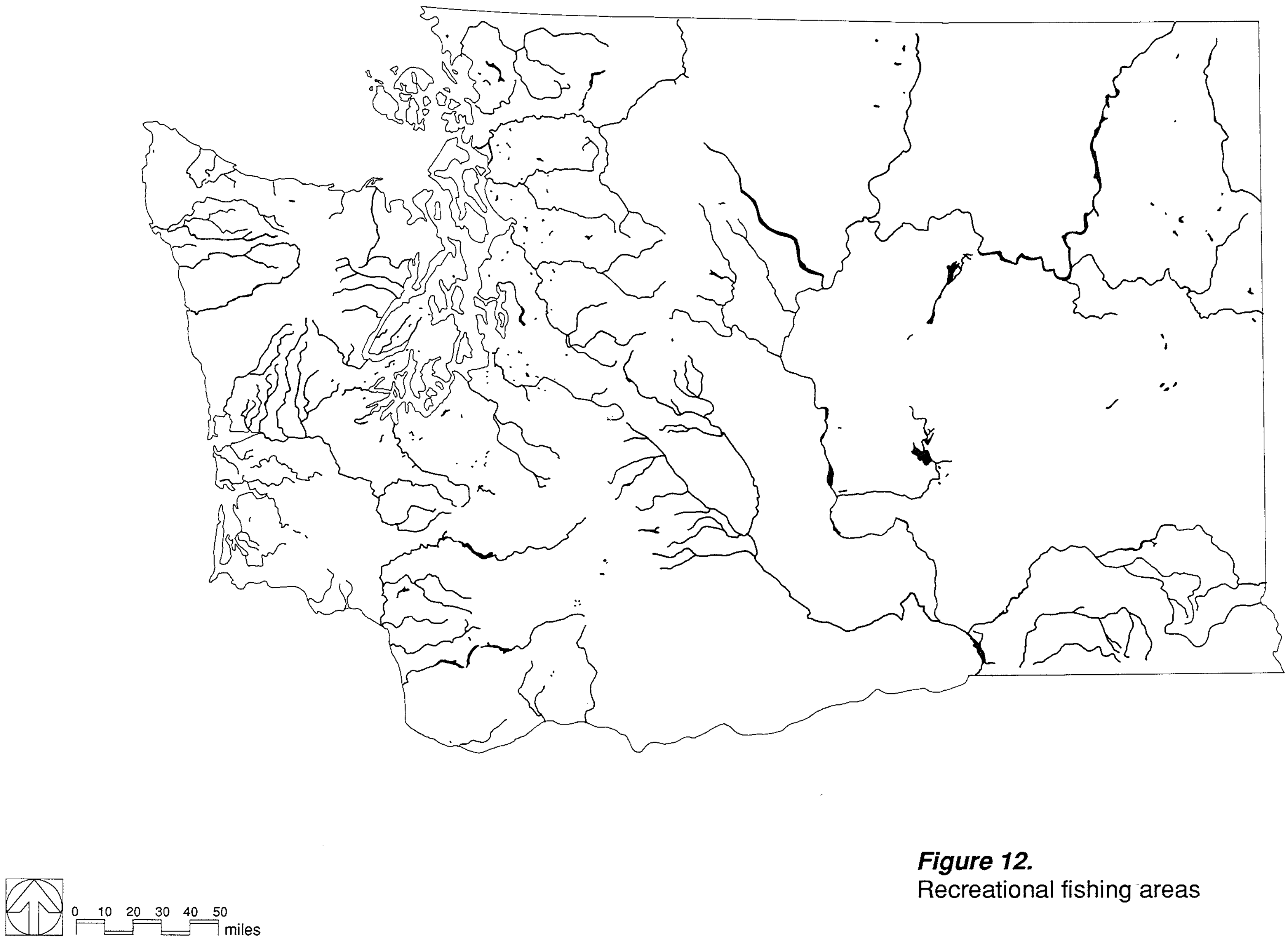
Land and Water Use

The distribution and intensity of land and water uses in the state of Washington are defined primarily by the distribution of natural resources and the population. The varied and rich natural resource base of Washington supports a wide variety of land and water uses ranging from consumptive uses such as drinking water, fisheries, forestry, and agriculture to nonconsumptive uses such as recreation and tourism.

The uses of water and land that may be affected by these regulations have been organized into the following sections:

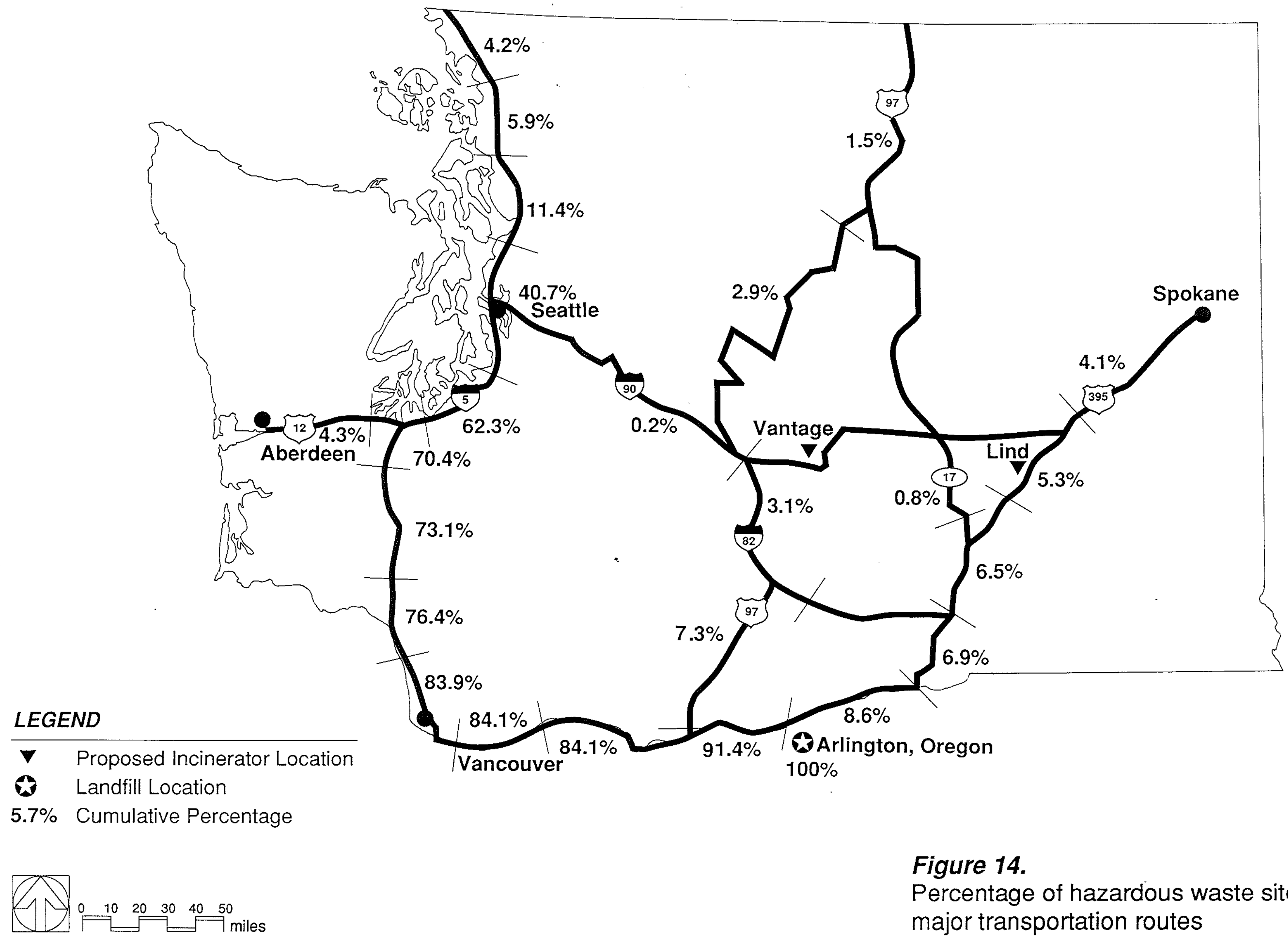
- Drinking water
- Fisheries
- Agriculture
- Ranching
- Recreation
- Hunting
- Forests and logging
- Residential, commercial, and industrial areas.

Figure 10.
Sensitive ecosystems



Reference: DeLorme Mapping Company (1988)

Figure 12.
Recreational fishing areas



Reference: DeLorme Mapping Company (1988)

Figure 14.
Percentage of hazardous waste sites along major transportation routes

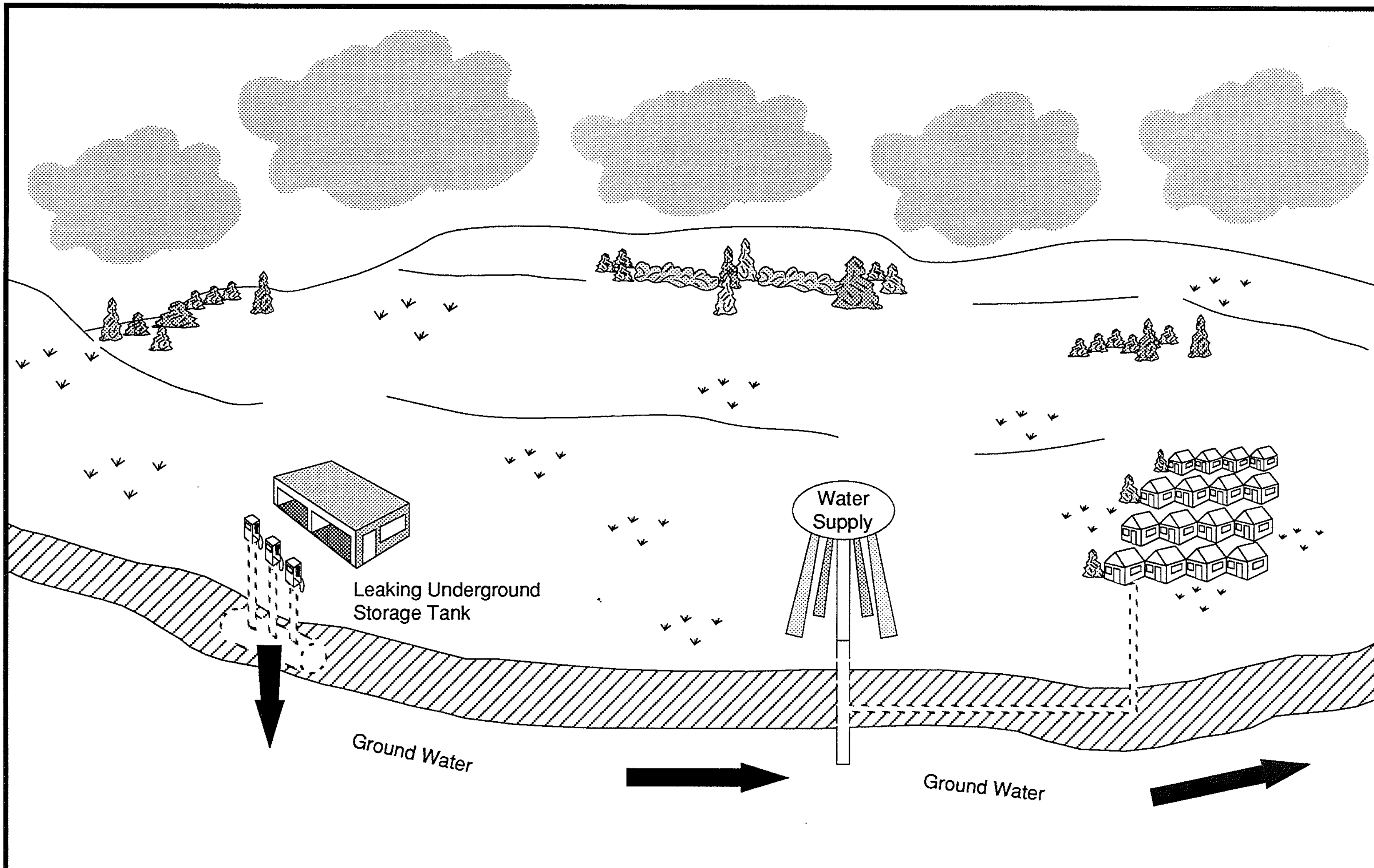


Figure 16.
Leaking underground storage tank

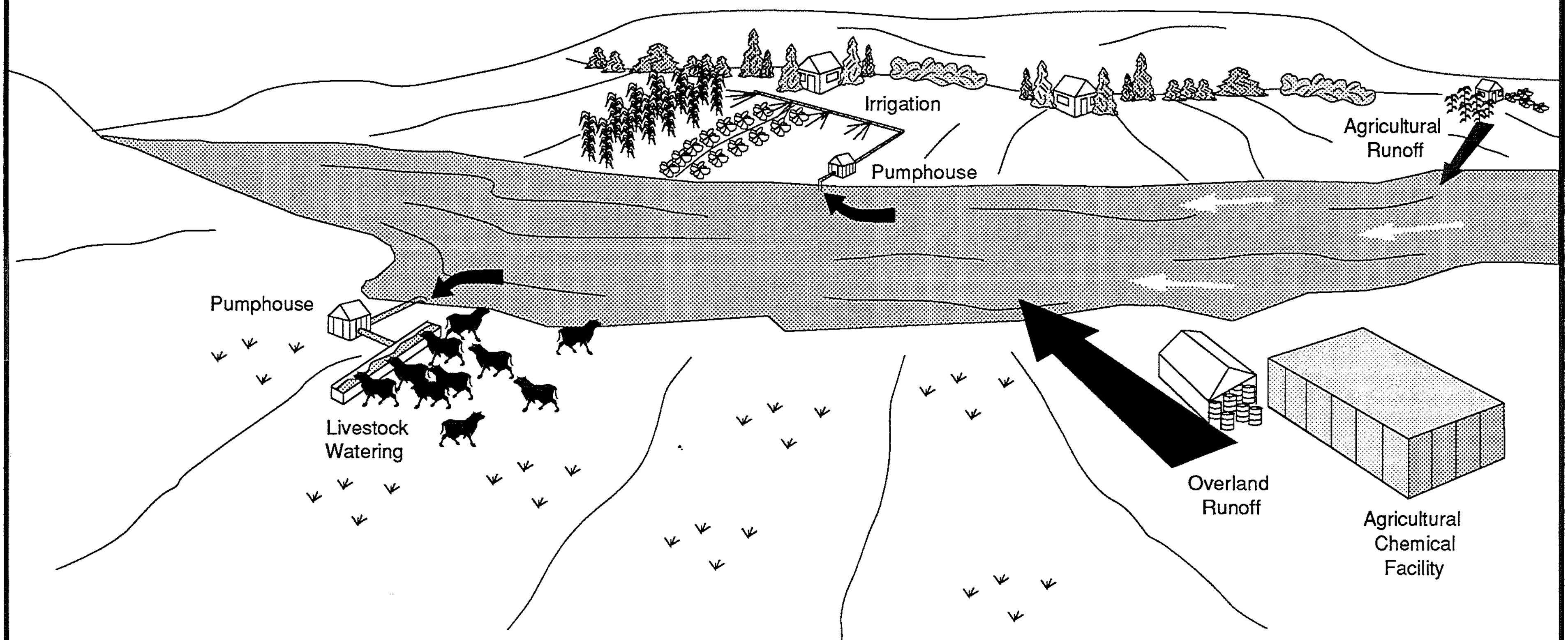


Figure 19.
Agricultural chemical facility

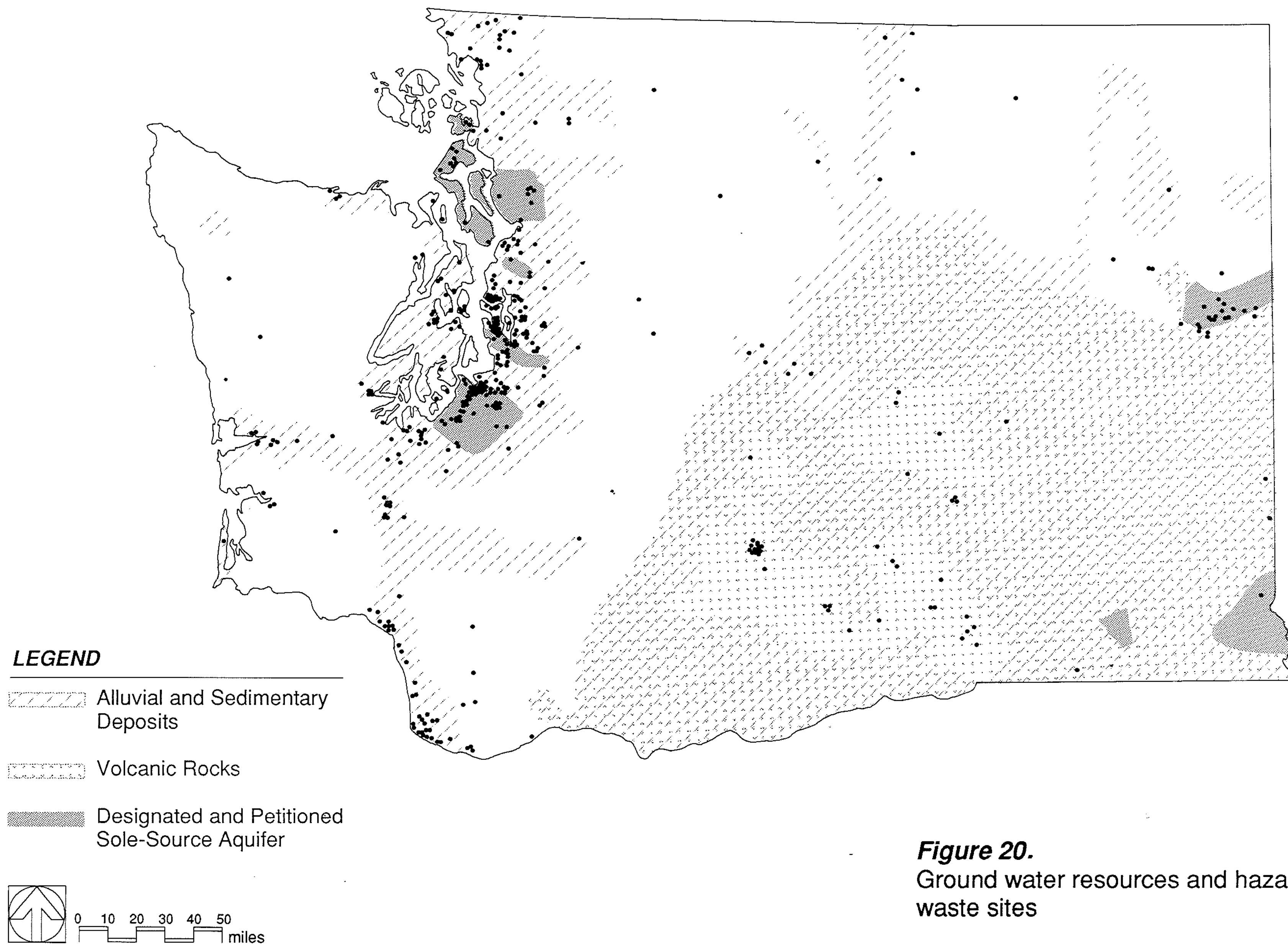


Figure 20.
Ground water resources and hazardous waste sites

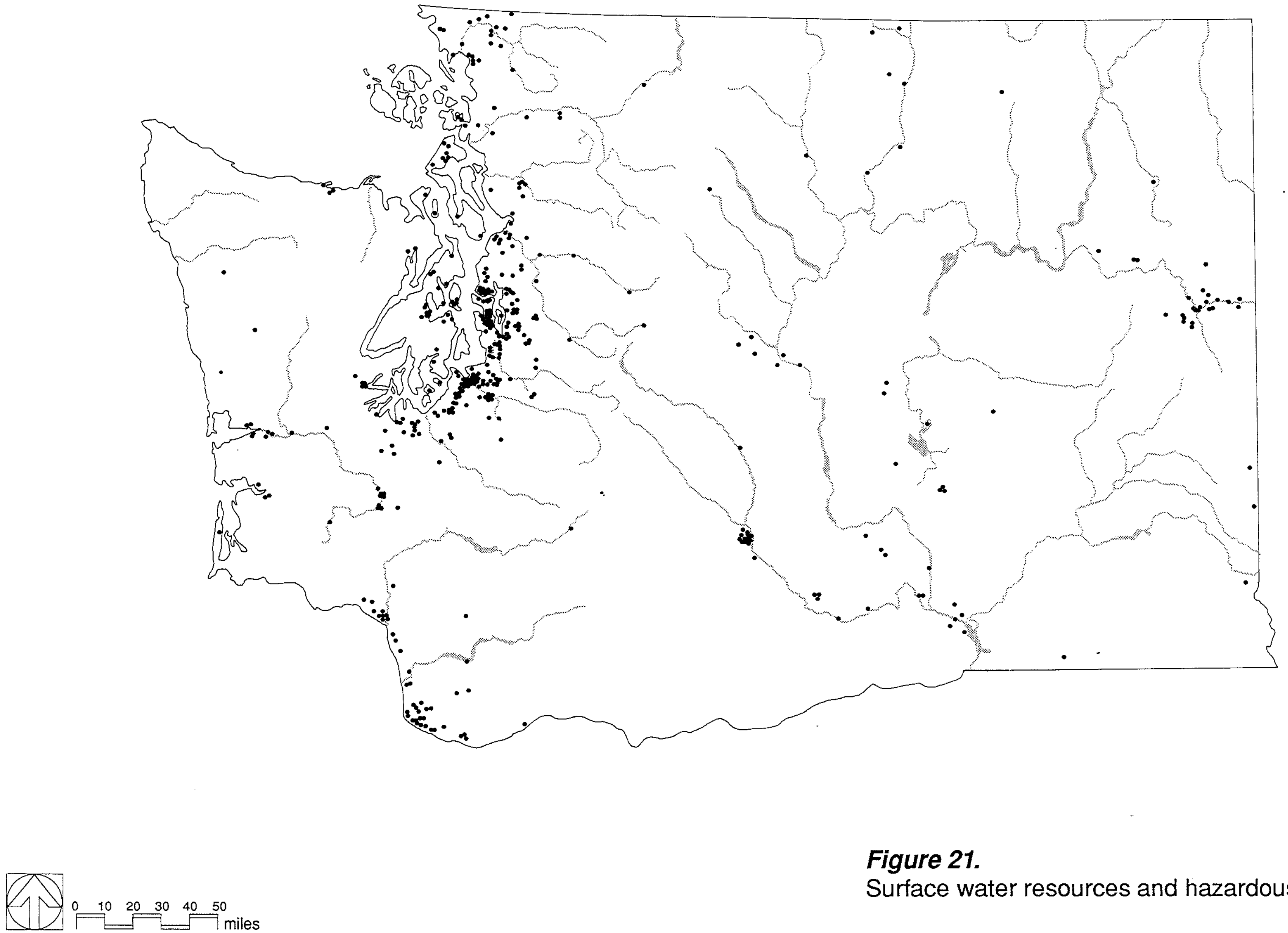


Figure 21.
Surface water resources and hazardous waste sites

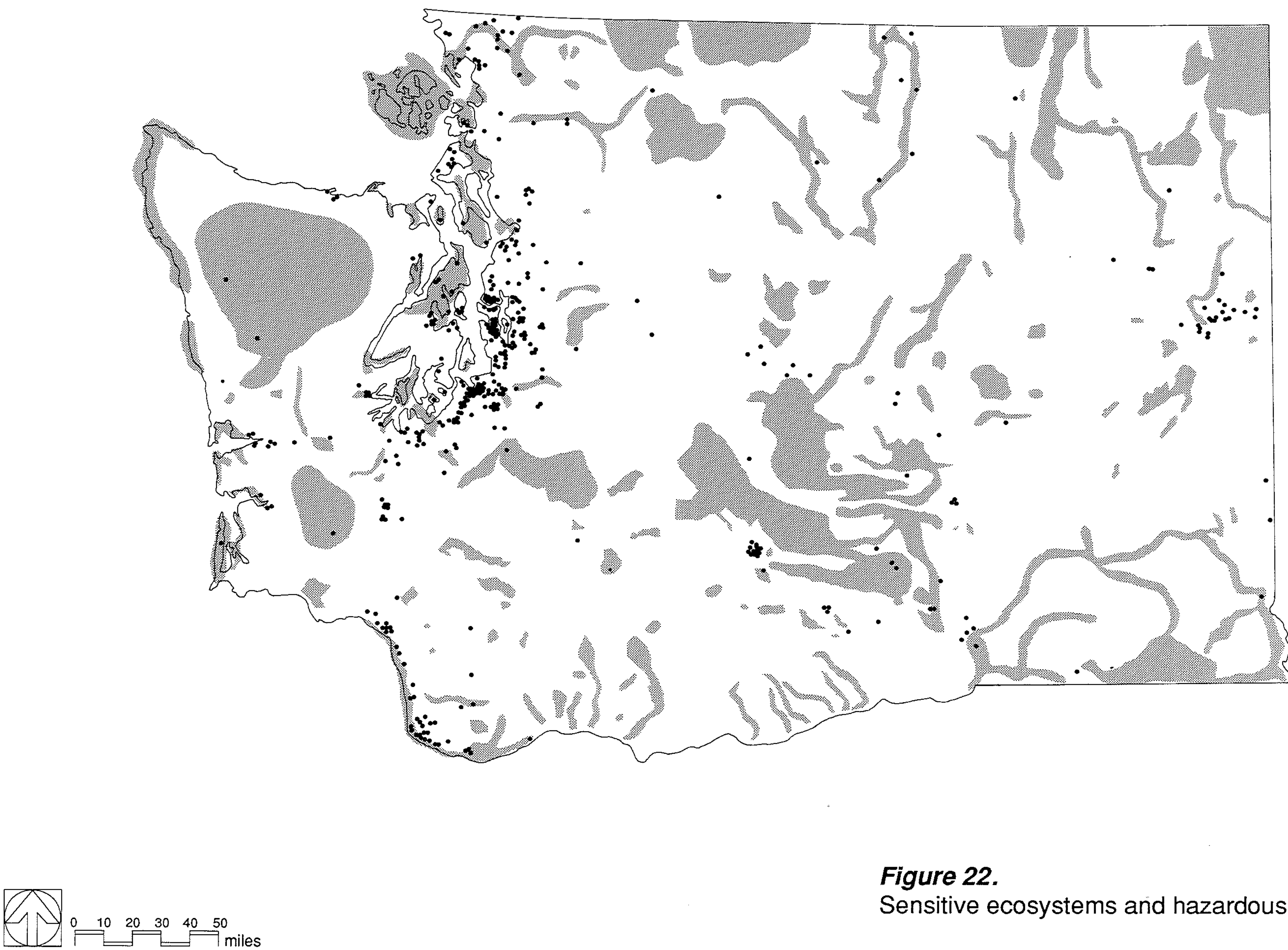


Figure 22.
Sensitive ecosystems and hazardous waste sites

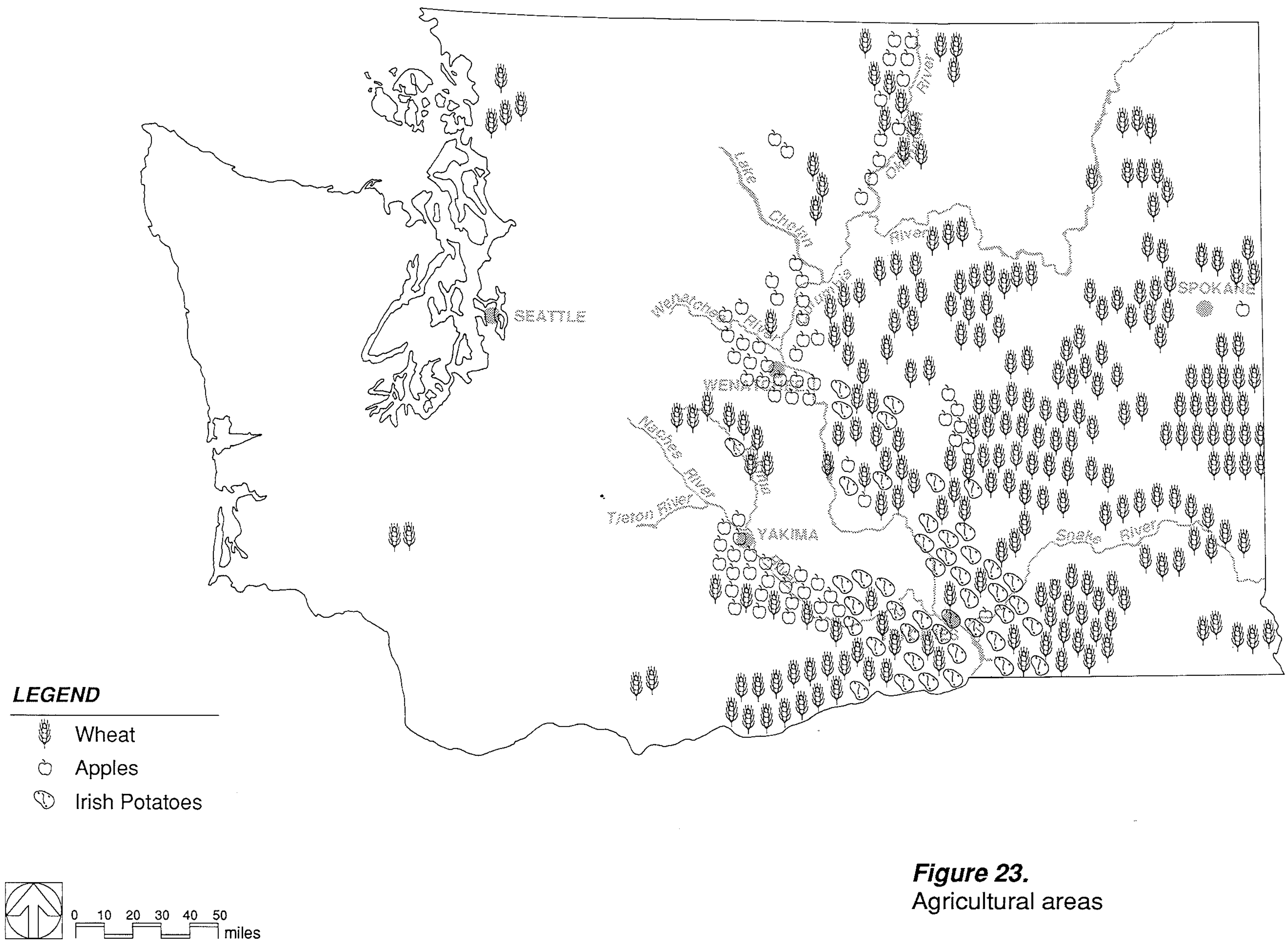
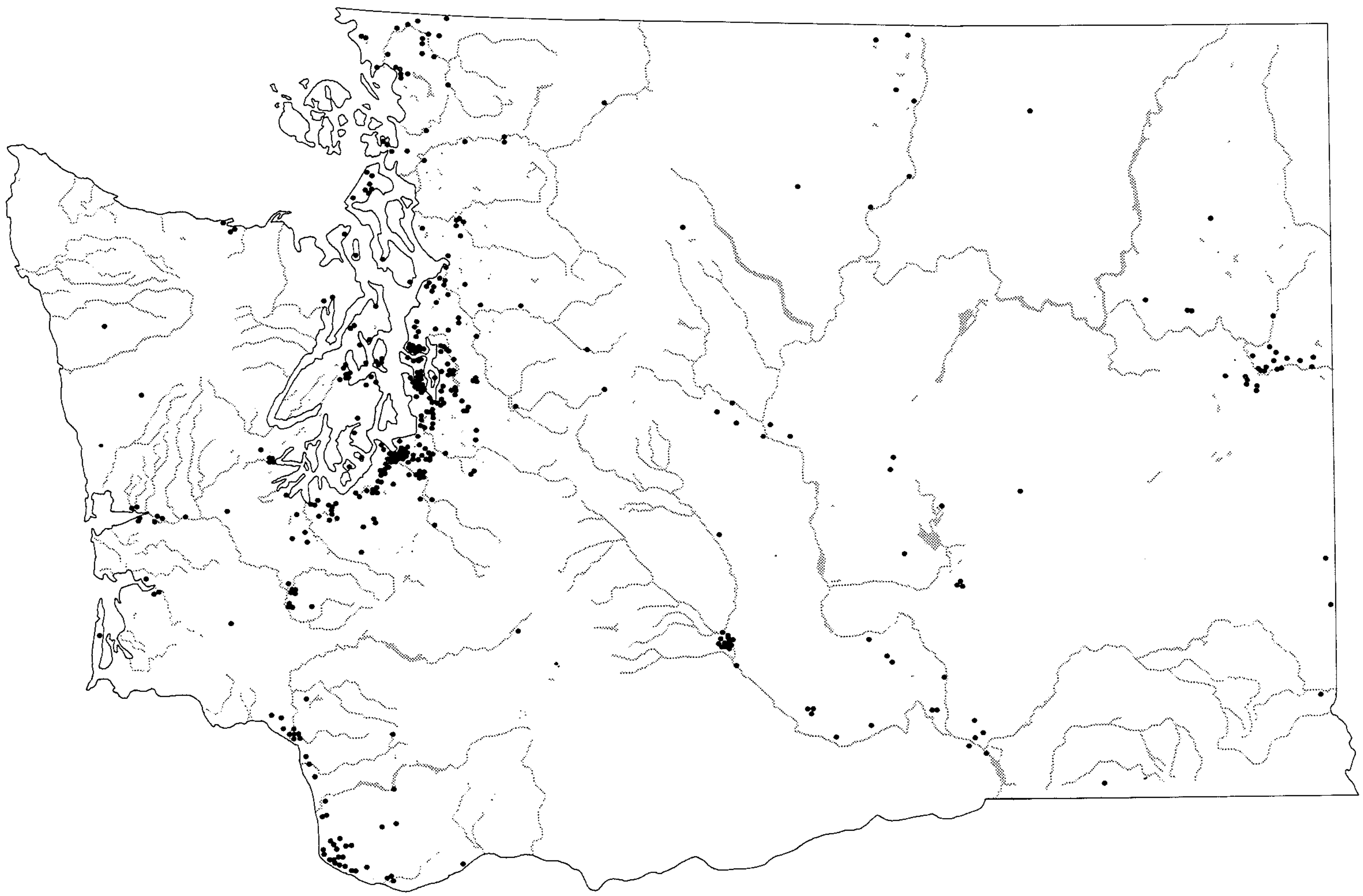


Figure 23.
Agricultural areas



0 10 20 30 40 50 miles

Reference: DeLorme Mapping Company (1988)

Figure 24.
Fishing areas and hazardous waste sites