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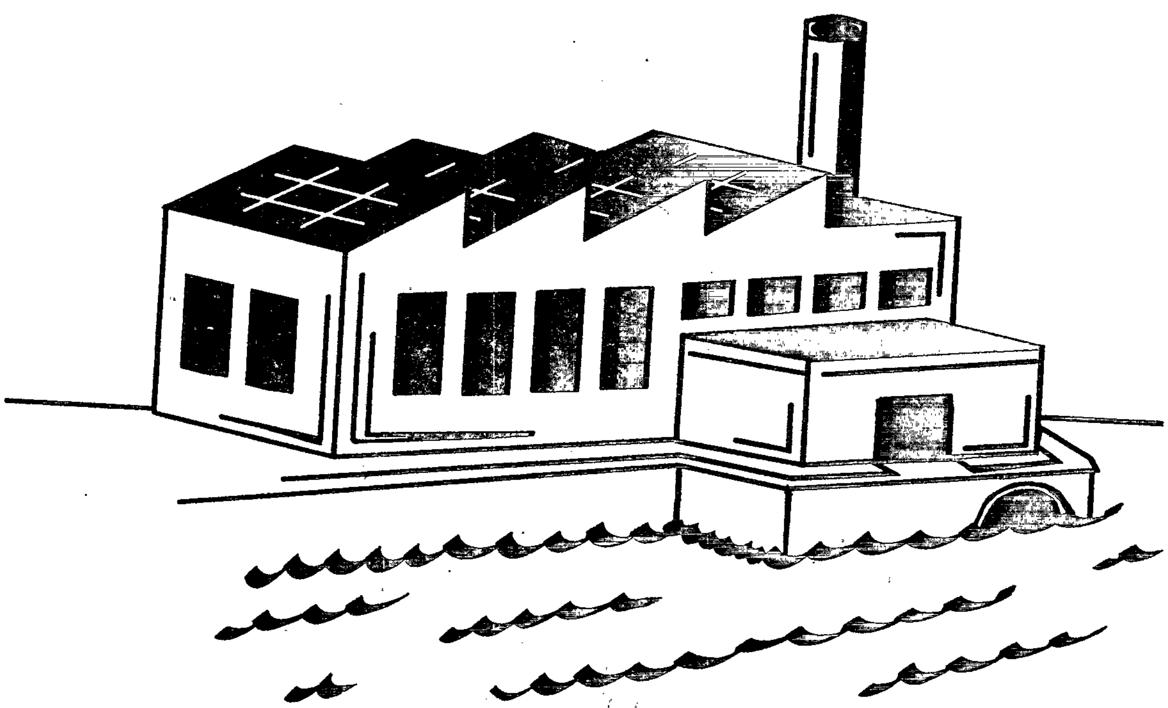

REGULATORY IMPACT ASSESSMENT OF PROPOSED EFFLUENT GUIDELINES AND NESHAP FOR THE PULP, PAPER, AND PAPERBOARD INDUSTRY

Final Report

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REGULATORY IMPACT ASSESSMENT OF THE PROPOSED EFFLUENT GUIDELINES AND NESHAP FOR THE PULP, PAPER, AND PAPERBOARD INDUSTRY

EXECUTIVE SUMMARY

BACKGROUND

This report has been prepared to comply with Executive Order 12866, which requires that federal agencies assess costs and benefits of each significant rule they propose or promulgate. The regulations for the pulp and paper industry, which are proposed by the U.S. Environmental Protection Agency (EPA, or the Agency), meet the Order's definition of a significant rule. In this Regulatory Impact Assessment (RIA), the Agency has assessed both the costs and benefits of the proposed rule. The integrated proposed rules include effluent guidelines and emission standards. The production of pulp, paper, and paperboard generates releases to all three media--air, water, and land, via sludge. The proposed rulemaking will specifically address releases to two media--air and water--reducing the releases of hazardous air pollutants (HAPs), volatile organic compounds (VOCs), and total reduced sulfur to air; and reducing toxic and other pollutant discharges to the nation's waters.

The pulp and paper industry is the eighth largest manufacturing industry in the U.S. in terms of the value of goods shipped and third among the nondurables sector in sales. It is also a dominant industry in the international market (ERG, 1993a). The products of this industry are used every day and involve many aspects of our lives. Approximately 200 companies are engaged in the manufacture of pulp, paper, and paperboard in the United States. These companies own and operate 565 facilities in 42 states.

The pulp, paper, and paperboard industry is one of the largest users of water in the U.S.; because large quantities of water are used in making pulp and paper products, these mills recycle, treat and discharge large quantities of effluent water. The 1991 Toxic Release Inventory (TRI) report indicates this industry to be the second largest discharger of TRI pollutants to surface water (U.S. EPA, 1993a). The main categories of aquatic pollutants found in pulp and paper mill effluent are conventional pollutants, such as biochemical oxygen demand (BOD), and toxic pollutants such as chlorinated compounds. Conventional pollution abatement in the U.S. paper industry has focused on reducing solids and BOD. Recent investigations have found toxic contaminants, including dioxin, in bleach mill effluents; additionally, effluent color is becoming a concern in some areas of the country.

Chlorinated organic compounds represent the major toxic constituents in pulp mill effluent. They are generated almost exclusively at bleach plant operations that use elemental chlorine or chlorine-containing bleaching chemicals. Minuscule quantities of these toxics also are produced at paper mills (or papermaking operations at integrated pulp and paper mills) that use chlorine-bleached pulps. Many individual chlorinated organic compounds have been identified in bleach plant effluents, representing about two-thirds of all compounds that have been isolated in these effluents. Among these compounds are various dioxins and furans, chloroform, and chlorinated phenolics.

The major air pollutants from pulp operations include reduced sulfur compounds, particulates (PM), volatile organic compounds (VOCs), and various hazardous air pollutants (HAPs). Air emissions of 1-butanone (MEK), 2-propanone, chloroform, hexane, methanol, and toluene comprise the majority of HAP emissions. Some of these pollutants, including chloroform, are known or probable human carcinogens, while others have been linked to causing respiratory and other health problems in humans or causing cancer in animals. Reduced sulfur compounds are associated with the kraft pulping process, and cause the rotten egg or rotten cabbage odor in areas near pulp mills. In addition to odor problems, reduced sulfur compounds have been linked to causing shortness of breath, nasal irritation and headaches. VOC emissions are of concern because they chemically react with nitrogen oxide in the atmosphere to form ground-level ozone, or smog. Studies of the effects of ozone have shown that it is responsible for health problems such as respiratory problems and premature aging of the lungs. Ozone has also been linked with contributing to damage of crops and other plants.

The integrated regulation is expected to decrease emissions of HAPs by approximately 121,200 Megagrams (Mg) annually. Additionally, the regulation is expected to decrease air emissions of volatile organic compounds by approximately 716,000 Mg annually and emissions of total reduced sulfur compounds by approximately 295,000 Mg annually.

The integrated regulation is also expected to decrease mass loadings of toxic pollutants in effluents currently discharged by this source category. The total toxic pollutant reduction expected to result from this regulation is 2,798 metric tons annually. The Agency also expects BOD discharges to be reduced by 94,500 metric tons annually and total suspended solids (TSS) discharges to be reduced by 128,000 metric tons annually.

COST ESTIMATES

The Agency evaluates the costs and economic impacts of pollution control standards in order to assess the potential impact of the standards on our nation's economy in terms of facility closures, job losses, and market disruptions. These impacts can be translated into measures of the social cost of the regulation, which is the monetary value of these disturbances. This information, compared to the potential benefits of the proposed standards, is useful for policy decisions concerning the stringency of the standard.

To assess the economic impact of compliance with the proposed rule, mill-specific private costs were developed. For the proposed standard, the total annual compliance cost was estimated at $599.5 million ($1992) for the entire industry.

Economic Impact Analysis Results

A financial impact model and a market impact model were developed to estimate mill closures, job losses and gains, output changes, product price changes, product export and import changes, and the potential impacts on small and large entities. The following results were obtained:

- The Agency estimates that from 11 to 13 mills may face closure as the result of the costs of the proposed standards. The mills that are projected to close are projected across industry subcategories.

- The Agency estimates that from 2,800 to 10,700 jobs could be eliminated as a result of the increase in production costs attributable to the proposed standards. The job losses are associated with both mill closures and reductions in output at mills that continue to operate. Up to 875 new production jobs may be created due to increases in output at mills that are not directly affected, or only mildly affected by the rule. These mills may benefit by being able to supply the void left in the market by competitors who close.

- The Agency predicts that market prices for most products will not increase by more than 1 or 2%. The most significant price increase is nearly 3% for uncoated free sheet.

- The market impact model predicts that the overall quantity of imports will increase by less than 1%, and the overall value of exports will decrease by less than 1%. However, individual product groups may experience significant declines in export value. The most notable declines in export value for significant individual product groups are 20.5% for uncoated free sheet, 7.6% for recycled paperboard, 6.5% for newsprint, and 3.8% for bleached sulfite market pulp. The most notable increases in significant imports are 1.4% for clay coated printing paper, 1.5% for recycled paperboard, and 6.1% for folding carton board.

- The analyses indicate that between 1 and 6 estimated mill closures are mills employing less than 125 workers, and between 9 and 10 are mills employing less than 750 workers. Examination of the impact of the proposed rules on relevant financial ratios of both large and small facilities indicates that small entities will experience less deterioration in financial health than larger facilities. The results also indicate small facilities will have a smaller decline in earnings before interest, taxes, and depreciation than large facilities. Finally, the analysis indicates that small companies are not any more likely than large companies to face bankruptcy after regulation.

Social Costs

The social costs of regulation are the opportunity costs to our society of employing scarce resources in pursuit of pollution control, and include both monetary and nonmonetary outlays made by society. Monetary outlays include private-sector compliance costs, government administrative costs, and the costs of relocating displaced workers. Nonmonetary outlays that are often assigned a monetary value include losses in consumers' or producers' surpluses, discomfort or inconvenience, loss of time, and slowing the rate of innovation. Table ES-1 shows the estimates of social cost derived from the market impact model for the various integrated regulatory alternatives.

Table ES-1
Annual Social Cost Estimates (Millions of 1992 Dollars)

Social Cost Category	Alt. 3	Alt. 16	Alt. 23	Alt. 24	Alt. 25	Alt. 26*
Consumer Surplus Loss	$166.2	$508.0	$512.7	$514.0	$514.3	$491.6
Producer Surplus Loss	$118.4	$310.0	$415.8	$440.9	$498.1	$428.3
Worker Displacement Costs	$4.9	$25.0	$25.3	$25.3	$25.5	$25.3
Government Administrative Costs (MACT only)	$2.6	$2.6	$2.6	$2.6	$2.6	$2.6
Total Social Cost	$292.1	$845.6	$956.4	$982.8	$1,040.5	$947.8

* Selected option

QUALITATIVE ASSESSMENT OF BENEFITS

Reductions in air emissions of individual hazardous air pollutants (HAPs) are expected to reduce carcinogenic risks as well as other human health impacts. Health benefits are also expected from emission reductions of volatile organic compounds (VOCs), which are a precursor to the formation of ozone. VOC reductions will also produce welfare benefits associated with reductions in crop losses and plant damages. Additionally, the proposed regulation is expected to significantly decrease emissions of total reduced sulfur compounds, which are responsible for the odor problem often associated with pulp and paper production. Finally, limited negative benefits will result from small increases in carbon monoxide, nitrogen oxide, sulfur dioxide, and particulate matter.

Water-related benefits to aquatic life include reduction of toxic, conventional, and nonconventional pollutants to levels below those considered to impact the biota of receiving waters. Such impacts include acute and chronic toxicity, as well as sublethal effects on metabolic or reproductive functions, physical destruction of spawning habitat, and loss of prey organisms. Chemical contamination of aquatic biota may also directly and indirectly impact local terrestrial wildlife and birds. Water quality improvements beneficial to human health concerns are the reduction in ambient water contaminant concentrations to levels protective of human health for drinking water or ingestion of chemically-contaminated fish. Human health benefits of particular concern include reduction in both carcinogenic risks and noncarcinogenic hazards for recreational and subsistence anglers. Other potential benefits include the effects of proposed BAT on streams presently affected by state fish consumption advisories.

QUANTITATIVE ASSESSMENT OF BENEFITS

National Benefits

Data and other limitations preclude development of a fully quantified and monetized benefits analysis. Although several benefit categories cannot be fully quantified or valued, benefit information has been developed to the extent feasible.

Air-Related Benefits. Air-related benefits include human health risk reductions due to reductions in HAP emissions, health and agricultural benefits due to VOC emission reductions, and the alleviation of odor problems (not monetized in this RIA). Increases in some pollutants (most notably, sulfur dioxide and PM) will reduce total air-related benefits levels somewhat.

To value the reductions in annual cancer incidences expected to result from the proposed regulation, a cancer risk assessment was performed. The risk assessment showed that the proposed regulation is expected to reduce the annual cancer incidence rate by 0.4 cases. The total monetized benefit for reducing cancer risk for the proposed regulatory alternative ranges from $0.8 - $4.2 million annually (1992 dollars).

Reductions in VOC emissions result in the largest category of benefits. The value of VOC emission reductions was estimated through the use of an average dollar per Megagram estimate extrapolated from a previous study that assessed the nationwide benefits of reducing ambient ozone concentrations (the control of VOC emissions is important because these emissions transform into ozone). For the proposed regulatory alternative, estimates of benefits using this approach range from $88.1 - $552.0 million annually (1992 dollars).

Another large category of benefits, the benefits of reducing total reduced sulfur (TRS) emissions, will be left unquantified and therefore, unmonetized. The control of TRS emissions is expected to lead to the alleviation of the odor problem often associated with pulp and paper production. Although odor problems have been linked to causing adverse health symptoms to the respiratory and cardiovascular systems, these symptoms are not readily quantified.

Water-Related Benefits. Two different models, Simple Dilution (SD) and Dioxin Reassessment Evaluation (DRE), were used to determine instream TCDD and TCDF[1] concentrations, the potential accumulation of these contaminants in fish, and the resulting impacts to human health. Evaluation of these impacts indicates that implementation of process changes would eliminate between 5 (DRE approach) and 35 (SD approach) cancer cases per year resulting from the consumption of contaminated fish tissue. These risk reductions result in a range of annual benefits of between $10.0 million and $350.0 million. Additionally, under the proposed rules, the individual lifetime cancer risk from some facilities would be reduced to 0, based on eliminating the formation and subsequent discharge of chlorinated organics. Implementation of the process changes could eliminate 14 dioxin-related fish advisories using the SD modeling approach, and 19 advisories using the DRE modeling approach. Water quality benefits associated with the lifting of fish consumption advisories and the elimination of water quality criteria exceedences were also examined. In addition, the regulation is expected to lower TCDD concentrations in sludge, resulting in avoided sludge disposal costs of $56.3 million annually.

Combined Summary of National-Level Benefits. The combined range of national-level air and water benefits from the proposed regulation is shown in Table ES-2. Water-related benefits include human health risk reductions, benefits to recreational anglers, and avoided costs of sludge disposal. Air-related benefits incorporate human health risk reductions and welfare benefits associated with VOC reductions. The total benefits from the regulation are estimated to range from $160.4 million to $986.6 million per year.

Case Study Benefits

Because benefits are often highly site-specific, a portion of the benefits analysis was based on a case study approach, using benefits transfer where feasible, and relying on qualitative discussion of how benefits may be generated where confidentiality agreements preclude calculation of quantitative results. The case studies include segments of: 1) the Penobscot River in Maine; 2) the Wisconsin River, located in central Wisconsin; 3) the lower Columbia River in Washington and Oregon. A qualitative analysis of the Leaf River in Mississippi was also conducted. An analysis of the representativeness of the case study sites with respect to the universe of sites affected by the regulation is also presented.

[1] TCDD is used as an abbreviation for 2,3,7,8-TCDD (the most toxic dioxin congener). TCDF is used as an abbreviation for 2,3,7,8-TCDF (the most toxic furan congener).

Table ES-2
Potential National Level Air- and Water-Related Benefits of the Pulp and Paper Regulation

Benefit Category	Millions of 1992 Dollars per Year
Air	
·Cancer Risk Reduction	$0.8 - $4.2
·VOC Benefits[1]	$88.1 - $552.0
Air Benefits Range	$88.9 - $556.2
Water	
·Human Health[2]	$10.0 - $350.0
·Recreational Angling	$5.2 - $24.1
·Avoided Costs of Sludge Disposal	$56.3
Water Benefits Range	$71.5 - $430.4
Combined Air and Water Benefits Range	$160.4 - $986.6

1 The method used to value VOC emission reductions ignores the chronic health effects associated with repeated exposure to ozone. This omission results in an underestimate of the total value of reduced ambient ozone levels.

2 Lower bound uses DRE approach health benefit estimate. Upper bound based on SD approach health benefit estimate.

Penobscot River Case Study. The Penobscot River is the site of a sensitive Atlantic Salmon run and, as a result of a major restoration effort, the state's most active salmon sport fishery. The river is also important to the Penobscot Indian Nation, whose territory includes 146 islands located in the river. Consumption of any species of fish from the Penobscot is cautioned by a fish consumption advisory, however. The Penobscot receives discharges from five pulp and paper mills, two of which are bleached kraft facilities. Analyses conducted for the RIA indicate that process changes for these mills could generate dioxin reductions sufficient to lift the fish consumption advisory.

The lifting of the fish consumption advisory implies the potential for several types of benefits. First, there is a reduction in human health risk associated with the lower dioxin concentrations. Both subsistence and recreational angler populations would receive benefits in the form of reduced excess cancer risk. Second, benefits may accrue to anglers from the knowledge of the reduced contaminant levels signaled by the lifting of the advisory and/or from an increase in angling use of the river. Third, the reduced levels of dioxins in fish will generate ecologic benefits, notably for piscivorous birds and mammals.

Valuing the reduced incidence of cancer attributable to the regulation results in a benefits range of between $0.04 million to $0.4 million per year. For the Atlantic salmon fishery, benefits from the knowledge of reduced contaminant levels in fish are estimated to be between $0.2 million and $0.6 million ($1992) per year. Applying the analysis to other fisheries implies additional angler benefits of from $0.1 million to $0.3 million per year.

The Penobscot Nation possesses sustenance fishing rights; these special rights, and the traditional outlook of the Penobscot Nation toward the health of the river and fishery, suggest that the Penobscots place a high value on these resources. Assuming the baseline resource value were increased by 10-20% as a result of reducing dioxin contamination to levels allowing fish consumption advisories to be rescinded, the benefits to Penobscot tribal members would be in the range of $0.2 - $0.5 million per year. Additionally, a nonuse value estimate of the regulation of between $0.1 and $0.7 million per year was included. In summary, the regulation is expected to generate water-related benefits on the order of $0.6 to $2.5 million annually in the Penobscot River basin. Air benefits were estimated to be $0.4 to $2.3 million annually. Addition of the air-related benefits to the water results produces a total benefits range of $1.0 million to $4.8 million per year.

Wisconsin River Case Study. In the northcentral U.S., five pulp and paper facilities in relative close proximity to one another are located on the Wisconsin River. This section of the river runs through a five county area in central Wisconsin. The Wisconsin River provides both recreational opportunities as well as habitat for wildlife, including important endangered species.

The use and nonuse values associated with the river are currently limited by water quality, with significant impacts from dioxin contamination. These impacts are seen most concretely in a dioxin-related fish consumption advisory designed to protect against excess cancer risk in humans. Consumption of dioxin-contaminated fish also has the potential for impacting fishing-eating birds and mammals, such as bald eagles and mink. Analyses conducted for the RIA indicate the regulation may result in an elimination of the consumption advisory for the Wisconsin River. Thus, the rulemaking can enhance the use and nonuse values associated with the river to the extent that it contributes to lowered concentrations of dioxin in the ecosystem.

Human health benefits attributable to the regulation are evaluated in terms of reduced incidence of cancer from ingestion of dioxin-contaminated fish. These benefits are estimated to range from $0.4 million to $2.1 million per year. Recreational angling benefits of approximately $0.1 million per year are estimated as a result of an increase in the consumer surplus associated with the activity and/or an increase in use of the resources. Individuals may also value reduced toxic concentrations in the nation's waters apart from any values associated with their direct or indirect use of the resource. These nonuse values are estimated to range from $0.02 million to $1.3 million per year for the case study site. In total, the regulation is expected to generate water-related benefits of between $0.5 to $3.4 million per year. Air benefits were estimated to be $0.9 to $5.4 million per year. The combined air and water benefits range is between $1.4 million and $8.8 million per year.

Columbia River Case Study. The Columbia River and its tributaries comprise the dominant water system in the northwest United States. The system supports many industries, such as fishing, transportation, agriculture, forestry, manufacturing, hydroelectric power, and recreation. Numerous industries use the river to transport products and raw materials and to carry away effluent and discharges from manufacturing processes, including eight pulp and paper manufacturers of which six are located in the stretch below Bonneville referred to as the lower Columbia.

In the case study, benefits are estimated for improvements in human health, recreational fishing, commercial fishing, and nonconsumptive uses attributable to reductions in dioxins and other contaminants as a result of the proposed regulations. Benefits in the form of reduced health risks from the consumption of contaminated fish are calculated for both recreational anglers and subsistence anglers. Depending on the assumed value for a statistical life, these benefits range in value from $0.3 million to $4.7 million. Improved reproductive success and productivity of the fishery are expected to lead to benefits for both recreational and commercial fishing. Estimated values range from $0.8 million to $2.4 million for recreational fishing, and from $0.1 million to $0.8 million for commercial fishing. Nonconsumptive uses as well as ecological and nonuse values are also an important component of value for the lower Columbia river. Nonconsumptive benefits estimates range from $0.1 million to $0.2 million per year, while nonuse values range from $0.4 million to $4.5 million per year. Total water-related benefits for this case study area range from $1.8 million to $12.5 million annually. Air benefits were estimated to be $4.2 to $26.5 million annually. The combined air and water benefits range from $6.0 million to $39.0 million per year.

Representativeness Analysis. Case study benefits comprise slightly less than 5% of the total national benefits, while case study costs comprise approximately 10% of total national costs. Thus, the case studies tend to underrepresent potential benefits and overrepresent potential costs. Most of the sites affected by the regulations, therefore, would be expected to have greater net benefits than those found for the case study sites.

COMPARISON OF BENEFITS TO COSTS

National Level Results

A comparison of the total annualized costs of the regulation to the total monetized annual benefits at the national level is presented in Table ES-3. The results indicate that the annual costs of the regulation are commensurate with the annual monetized benefits at the national level.

Table ES-3
Comparison of National Level Annual Benefits to Costs for the Pulp and Paper Rulemaking

Benefits	Millions of 1992 Dollars per Year
Air Benefits[1]	$88.9 - $556.2
Water Benefits[2]	$71.5 - $430.4
Combined Air and Water Benefits Range	$160.4 - $986.6
Combined Air and Water Compliance Cost	$599.5
Social Costs	$947.8

1 Benefits include cancer risk reductions associated with HAP emission reductions and acute health and agricultural benefits associated with VOC emission reductions. Refer to Chapter 8.0 for a complete explanation of the benefit categories that were left unmonetized due to a lack of data.

2 Benefits include human health risk reductions, benefits to recreational anglers, and avoided costs for sludge disposal.

Case Study Results

Comparison of total monetized benefits to annualized costs for the case studies is presented in Table ES-4. Those benefits that could be quantified and monetized, although less than the costs of the regulation, are of the same order of magnitude. An analysis of the representativeness of the case study sites revealed that the case study benefits comprise slightly less than 5% of the total national benefits, while case study costs comprise approximately 10% of total national costs. Because the case studies tend to underrepresent potential benefits and overrepresent potential costs, other sites affected by the regulations are expected, on average, to have greater net benefits than found for the case studies.

Table ES-4
Comparison of Potential Annual Air- and Water-Related Benefits to the Potential Costs of the Pulp and Paper Regulation for the Case Study Sites
(Millions of 1992 Dollars per Year)

Benefits	Penobscot River	Wisconsin River	Columbia River
Water-Related Benefits	$0.6 - $2.5	$0.5 - $3.4	$1.8 - $12.5
Air-Related Benefits[1]	$0.4 - $2.3	$0.9 - $5.4	$4.2 - $26.5
Total Benefits	$1.0 - $4.8	$1.4 - $8.8	$6.0 - $39.0
Combined Air and Water Compliance Cost	A	$15.5	$46.0
Total Social Costs[2]	A	$24.9	$67.5

A Confidentiality agreements preclude disclosure of total costs for this site.
1 The calculation of monetized air-related benefits includes benefits from reductions in annual cancer incidences attributable to HAP emission reductions as well as acute health and agricultural benefits attributable to VOC emission reductions. Refer to Chapter 8.0 for a complete explanation of the benefit categories that were left unmonetized due to a lack of data.
2 Social cost estimates do not include worker dislocation and government administrative costs.

1.0 INTRODUCTION

1.1 PURPOSE

This report has been prepared to comply with Executive Order 12866, which requires federal agencies to assess costs and benefits of each significant rule they propose or promulgate. The regulations for the pulp and paper industry, which are proposed by the U.S. Environmental Protection Agency (EPA, or the Agency), meet the Order's definition of a significant rule. The Agency has assessed both costs and benefits of the proposed rule, as presented in this Regulatory Impact Assessment (RIA). The integrated proposed rules include effluent guidelines and emission standards.

1.2 ORGANIZATION OF REPORT

The principal requirements of the Executive Order are that the Agency perform an analysis comparing the benefits of the regulation to the costs that the regulation imposes, that the Agency analyze alternative approaches to the rule, and that the need for the regulation be identified. Wherever possible, the costs and benefits of the rule are to be expressed in monetary terms. To address the analytical requirements of the Executive Order, this RIA is organized into nine major sections:

- Background
- Need for the Regulation
- Technology Options and Regulatory Alternatives
- Economic Impacts and Social Costs
- Pollutant Reduction
- Qualitative Assessment of Benefits
- Quantitative Assessment of Benefits
- Quantitative Case Study Benefits Assessments
- Comparison of Benefits to Costs.

Chapter 2.0 ("Background") presents an overview of the pulp and paper industry and describes the history of this integrated rulemaking process.

Chapter 3.0 ("Need for the Regulation") briefly explains marketplace failures that water pollution control regulations are intended to correct. In addition, this section discusses the environmental factors necessitating the development of the integrated rulemaking. Finally, the Agency's legal mandate for developing the regulation is summarized.

Chapter 4.0 ("Technology Options and Regulatory Alternatives") describes the options considered in the development of the proposed effluent guidelines and emissions standards.

Chapter 5.0 ("Economic Impacts and Social Costs") presents: (1) the costs of compliance with the proposed regulation, (2) results of the economic impact analysis, and (3) estimates of the social costs associated with the proposed effluent guidelines and emissions standards.

Chapter 6.0 ("Pollutant Reduction") presents pollutant reduction results for toxic water pollutants, conventional water pollutants, hazardous air pollutants, and other air quality effects.

Chapter 7.0 ("Qualitative Assessment of Benefits") discusses the types of benefits included in the analysis, describes the chain of events that must be understood in order to link a regulatory actions with beneficial outcomes, and presents results of qualitative analyses of air- and water-related benefits.

Chapter 8.0 ("Quantitative Assessment of Benefits") describes the methodologies used in the quantitative benefits analyses and limitations of these assessments, and summarizes quantified benefits findings at a national level.

Chapter 9.0 ("Quantified Case Study Benefits Assessments") presents results of case studies of air- and water-related benefits.

Chapter 10.0 ("Comparison of Benefits to Costs") compares annualized benefits and costs and discusses the context within which these results should be interpreted.

References are provided in Chapter 11.0.

2.0 BACKGROUND

2.1 INDUSTRY OVERVIEW

The pulp and paper industry is the eighth largest manufacturing industry in the U.S. in terms of the value of goods shipped and third among the nondurables sector in sales. It is also a dominant industry in the international market (ERG, 1993a). The products of this industry are used every day and involve many aspects of our lives.

2.1.1 Facilities Profile

Approximately 200 companies are engaged in the manufacture of pulp, paper, and paperboard in the United States. These companies own and operate 565 facilities in 42 states. Figure 2-1 is a presentation of the 537 facilities that are included in the economic analysis data base. Most of these facilities are located in the eastern region. New York has the most facilities at 49, followed closely by Wisconsin with 46 mills. Pennsylvania, Michigan, Ohio, California, and Massachusetts each have approximately 30 mills. Georgia and Washington each have approximately 24 mills. The remaining states have fewer than 20 mills each. In 1989, this industry employed over 220,000 people, of whom about 73% were in production.

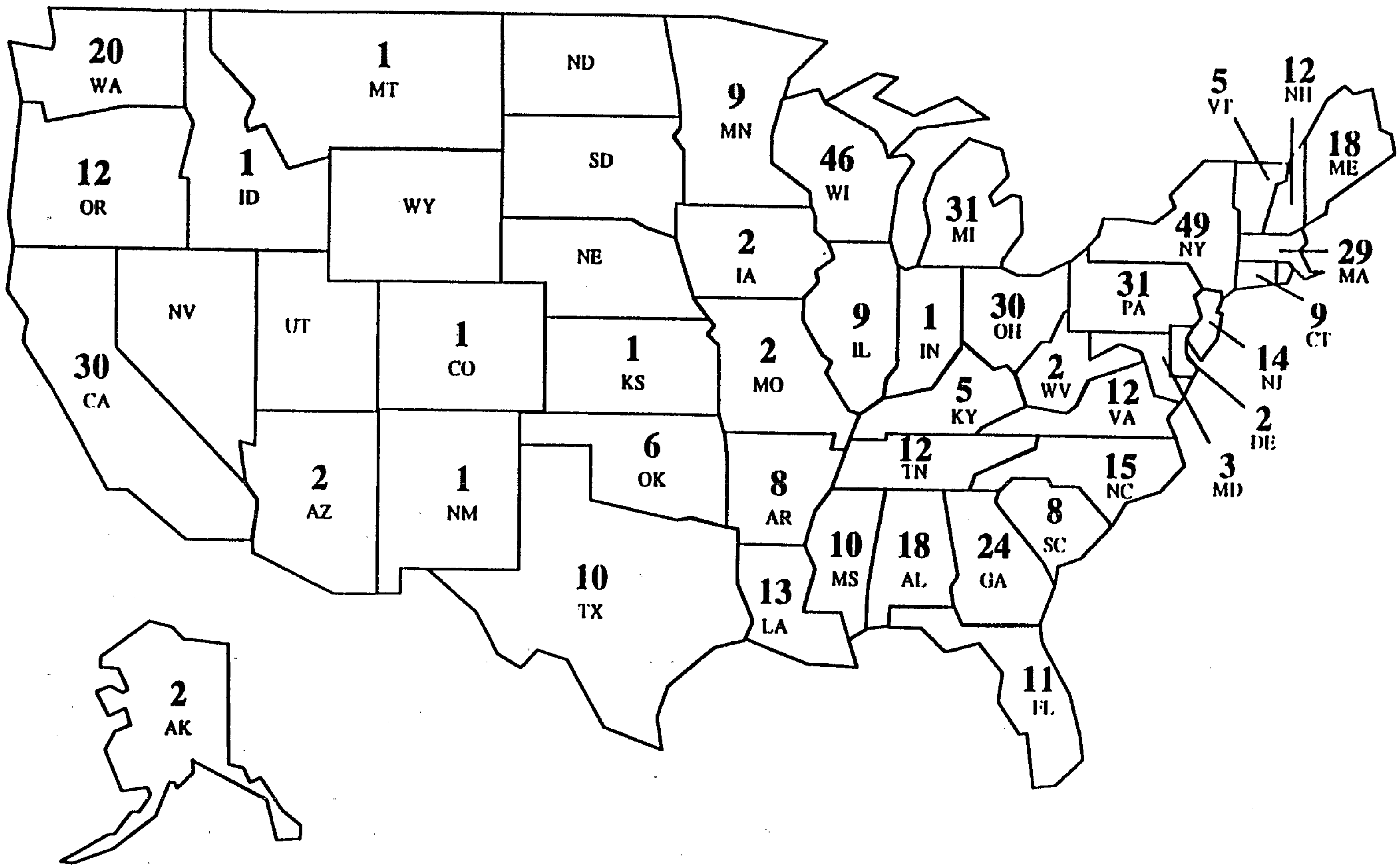
A facility that both produces pulp and uses it to manufacture paper and/or paperboard products is considered an integrated mill. There are approximately 290 integrated mills. In 1989, 209 facilities sold only paper, 177 sold only paperboard, 15 sold molded paper products, and 11 sold other products such as photographic paper and other specialty items.

The average facility had assets of $81 million in 1985 that have grown to $107 million in 1989. Assets for the whole industry totaled $36 billion in 1985 and have risen to $55 billion in 1989. The average asset base for an independently-owned facility is about one-third to one-half the assets of a multifacility organization's facility. The median assets for an independently-owned facility in 1985 were $11 million. The difference between the median and mean assets for a comparable group indicate that the distribution is skewed by a smaller number of large facilities. The asset numbers indicate the industry's capital-intensive nature.

In 1989 the industry shipped pulp valued at $7.7 billion, paper valued at $34 billion, and paperboard valued at $16 billion. Independent mills account for about 5% of the value of pulp shipments and 3% of the paper and paperboard shipments.

For the purpose of establishing effluent limitations guidelines, an industry might be subcategorized based on manufacturing process and/or other distinguishing characteristics. The pulp, paper, and paperboard industry is categorized into 13 subcategories (see Development Document for details (U.S. EPA, 1993b)). The subcategories are listed in the

Figure 2-1



Note: Distribution of 537 facilities included in the economic analysis database.
Source: ERG, 1993a

left column of Table 2-1. The table's right columns summarize the regulations applicable to each subcategory (e.g., all subcategories are subject to revised BPT requirements, while only the top six subcategories are subject to revised BAT/PSES requirements). A mill with production in two different subcategories would be counted in each of these two subcategories. No total is given at the bottom of the column due to this overlap.

2.1.2 Effluent Characterization

Making pulp, paper, and paperboard generates releases to three media--air releases, wastewater discharges, and sludge. The proposed rulemaking will specifically address releases to two media--air and water. Improvements to sludge quality are expected as a result of reduced releases from wastewater. The proposed regulatory requirements will reduce the releases of chloroform to air and reduce the toxic and other pollutants in wastewater discharges.

Effluent Discharges

The pulp, paper, and paperboard industry is one of the largest users of water in the U.S. The 1991 TRI report indicates this industry to be the second largest discharger of TRI pollutants to surface water (U.S. EPA, 1993a). Because large quantities of water are used in making pulp and paper products, these mills recycle, treat and discharge large quantities of effluent water. Major categories of aquatic pollutants found in pulp and paper mill effluent include total suspended solids (TSS), biochemical oxygen demand (BOD), color, and toxics. Conventional pollution abatement in the U.S. paper industry has focused on reducing solids and oxygen demand. In the 1980's, investigations found toxic contaminants, including dioxin, in bleach mill effluents, and effluent color is becoming a concern in some areas of the country.

Suspended solids include dirt, grit, and fiber from wood preparation; fiber and dissolved lignin solids from the pulp bleaching stages; and fiber and additives washed from the early stages of papermaking. Solids have the potential to coat the bottom of receiving water bodies and could destroy or impair the habitat of bottom-living organisms. As the blanket of solids decomposes, anoxic conditions could develop, releasing methane, hydrogen sulfide, and other noxious and/or toxic gases.

Biochemical oxygen demand (BOD) measures the tendency of an effluent to consume oxygen from receiving waters during biological degradation. High levels of BOD can deprive fish, fungi, bacteria, and other nonplant matter of needed oxygen. BOD, which is comprised primarily of organic material, is produced during several pulping and bleach stages.

Chlorinated organic compounds represent the major toxic constituents in pulp mill effluent. They are generated almost exclusively at bleach plant operations that use elemental chlorine or chlorine-containing bleaching chemicals. Minuscule quantities of these toxics also are

Table 2-1
Subcategories and Regulatory Coverage

Effluent Subcategory	Number of Mills in this Subcategory	Clean Air Act MACT	Clean Water Act		
			BAT & PSES	BPT/ BCT	BMP
Dissolving Kraft*	3	X	X	X	X
Bleached Papergrade Kraft*	88	X	X	X	X
Unbleached Kraft*	58	X	X	X	X
Semichemical*	21	X	X	X	X
Dissolving Sulfite*	5	X	X	X	X
Papergrade Sulfite*	11	X	X	X	X
Groundwood CMP, CTMP	56			X	
Nonwood Chemical	12			X	X
Deink Secondary	43			X	
Nondeink Secondary	342			X	
Nonintegrated Fine and Lightweight	115			X	
Nonintegrated Tissue, Filter, Nonwoven, Paperboard	168			X	
Total	--	161	160	325	172

* Mills that will be covered by both Clean Water Act effluent guidelines and Clean Air Act MACT standards in the October '93 proposed rule. All other mills will have only effluent standards proposed.

Source: ERG, 1993a.

produced at paper mills (or papermaking operations at integrated pulp and paper mills) that use chlorine-bleached pulps. Many individual chlorinated organic compounds have been identified in bleach plant effluents, representing about two-thirds of all compounds that have been isolated in these effluents. Among these compounds are various dioxins and furans, chloroform, and chlorated phenolics.

Dioxin and furans are a byproduct generated by the complex reactions occurring during bleaching. The concentrations of these toxics are usually in parts per billion or parts per quadrillion in uncontrolled effluents, but due to their high toxicity and capacity to bioaccumulate, dioxins and furans have become a prime environmental concern. Secondary wastewater treatment transfers dioxins and furans from effluents to treatment sludges. Therefore, much scientific and regulatory attention has been concentrated on technologies to prevent the formation of dioxins and furans during bleaching, not on biological or chemical effluent treatment.

Chloroform is a byproduct primarily of the hypochlorite bleaching stage. Because of this compound's volatility, most chloroform escapes the pulp mill as fugitive emissions, with more vaporizing from secondary wastewater treatment systems. While it is an important consideration in air pollution control, chloroform in pulp and paper water effluents is not considered as significant an environmental hazard because its aquatic toxicity and bioaccumulation potential are low. Chlorates are a potential concern because some compounds harm plant life. At concentrations present in pulp and paper effluent, chlorate damage to marine algae populations has been documented in Scandinavia (Sodergren, 1988). Secondary wastewater treatment, however, normally is effective in removing chlorates from effluents (U.S. EPA, 1991a).

Air Emissions

The major air pollutants from pulp operations include reduced sulfur compounds, particulates, volatile organic compounds (VOCs), and various hazardous air pollutants (HAP). According to baseline emission estimates, noncombustion processes in the pulp and paper industry emit approximately 170,000 Mg of hazardous air pollutants annually. Air emissions of 1-butanone (MEK), 2-propanone, chloroform, hexane, methanol, and toluene comprise the majority of HAP emissions. Some of these pollutants, including chloroform, are known or probable human carcinogens while others have been linked to causing respiratory and other health problems in humans or causing cancer in animals.

Reduced sulfur compounds are associated with the kraft pulping process, and are generated from chemical reactions of sodium sulfide that occur during the initial kraft cook. The presence of reduced sulfur compounds causes the rotten egg of rotten cabbage odor in areas near pulp mills. In addition to odor problems, reduced sulfur compounds have been linked to causing shortness of breath, nasal irritation and headaches.

VOCs are a broad class of organic gasses such as vapors from solvents and gasoline. In the pulp and paper industry, VOCs are generated from the complex reactions of lignin, carbohydrates, and extractives in the pulp furnish. VOC emissions are of concern because they chemically react with nitrogen oxide in the atmosphere to form ground-level ozone, or smog. Studies of the effects of ozone have shown that it is responsible for health problems such as respiratory problems and premature aging of the lungs. Ozone has also been linked with contributing to damage of crops and other plants.

The major source of particulates are fly ash and bottom ash from power boilers and chemical recovery furnaces. Fine particulates are a particular concern because they tend to settle from the atmosphere and might be associated with more significant health impacts than large particulates. The major effects of concern include effects on breathing and respiratory symptoms, damage to lung tissue, and aggravation of existing respiratory and cardiovascular disease. Particulate matter also causes material soiling and is often responsible for substantial visibility impairments.

2.2 REGULATORY HISTORY

2.2.1 Clean Water Act

Effluent limitations for the pulp and paper industry have an intricate history, beginning in May 1974 when the EPA promulgated BPT, BAT, NSPS, and PSNS for the builders' paper and roofing felt subcategory of the builders' paper and board mills category (39 FR 16578). Also in May 1974, the EPA promulgated BPT, BAT, NSPS, and PSNS for the unbleached kraft, sodium-based neutral sulfite semi-chemical, ammonia-based neutral sulfite semi-chemical, unbleached kraft neutral-sulfite semi-chemical (cross recovery), and paperboard category (39 FR 18742). In January 1977, the Agency promulgated BPT for the dissolving kraft, market bleached kraft, BCT (board, coarse, and tissue) bleached kraft, fine bleached kraft, papergrade sulfite (blow pit wash), dissolving sulfite pulp, groundwood-thermo-mechanical, groundwood-fine papers, soda, deink, nonintegrated-fine papers, nonintegrated-tissue papers, tissue from wastepaper, and papergrade sulfite (drum wash) subcategories of the pulp, paper and paperboard industry (42 FR 1398).

Challenges to the regulations promulgated in May 1974 and January 1977 were heard in the District of Columbia Circuit Court of Appeals and were upheld in their entirety with one exception. The Court ordered EPA to reconsider the BPT BOD_5 limitation for acetate grade pulp production in the dissolving sulfite pulp subcategory. In response, the Agency proposed BPT regulations for acetate grade pulp production in the dissolving sulfite pulp subcategory in March 1980.

In January 1981, the EPA proposed effluent limitations guidelines and standards for BAT, BCT, NSPS, PSES, and PSNS for 24 subcategories of the pulp, paper, and paperboard industry (46 FR 1430). These regulations were promulgated in November 1982 (47 FR

52006) with the exception of BCT, which was reserved. In December 1986, the EPA promulgated BCT effluent limitations for 24 subcategories (51 FR 45232).

In March 1985, the Environmental Defense Fund (EDF) and the National Wildlife Federation (NWF) filed suit against the Agency concerning the regulation of dioxins and furans. To settle this lawsuit, the EPA entered into a consent decree which requires the EPA to undertake a variety of regulatory activities, including the adoption of a schedule to address the contamination of effluent from bleached pulp mills that contain certain dioxins and furans. The consent decree requires the Agency to propose regulations addressing these discharges on or before October 31, 1993.

The consent decree also requires the EPA to conduct a multiple pathway risk assessment considering sludges, water effluent, and products made from pulp produced at chemical-bleaching mills.

2.2.2 Clean Air Act

In February 1978, the EPA promulgated new source performance standards (NSPS) to limit emissions of particulate matter (PM) and total reduced sulfur (TRS) from new, modified, and reconstructed kraft pulp mills under Section 111. These standards also applied, in some circumstances, to existing sources under Section 111(d). The standards limited TRS and PM emissions from recovery furnaces, smelt dissolving tanks, lime kilns, digester systems, multiple effect evaporator systems, black liquor oxidation systems, brown stock washer systems, and condensate stripper systems that were constructed, modified, or reconstructed after September 24, 1976. These standards reflected the application of best technological system of continuous emission reduction that the Administrator determined had been adequately demonstrated, taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements.

Minor revisions and corrections to these standards were promulgated in May 1986 (51 FR 18538). The revisions exempted black liquor oxidation systems from the standards; revised the existing TRS standard and its units for smelt dissolving tanks; deleted the requirement to monitor the combustion temperature in lime kilns, power boilers, or recovery furnaces; changed the frequency of excess emission reports from quarterly to semi-annual; and exempted diffusion washers from the TRS standard for brown stock washer systems. The revisions also required that monitored emissions be recorded, and corrected the reference for reporting excess emissions.

2.2.3 Sludge Regulatory Development

The consent decree that EPA signed with EDF required that the Agency take one of four possible actions by April 30, 1990: (i) commit to propose regulations in the Federal Register by April 30, 1991; (ii) commit to refer under the Toxic Substances Control Act (TSCA) Section 9 some or all matters under consideration to another federal agency or agencies by October 30, 1990; (iii) determine the regulations or referrals are unnecessary; and (iv) determine that EPA does not have sufficient information to make one of the above choices, establish a schedule to obtain the required information by April 30, 1991, and then exercise one of the above three options within 180 days.

Land Application: In May 1991, the EPA exercised option (i) and published proposed rules under Section 6 of TSCA to regulate the use of sludge produced from the treatment of wastewater effluent of pulp and paper mills using chlorine and chlorine-derivative bleaching processes (56 FR 21802). The proposed regulations sought to establish a final maximum dioxin/furan soil concentration of 10 ppt TEQ and site management practices for the land application of bleached kraft and sulfite mill sludge. In December 1992, EPA informed the plaintiffs that the decision on the promulgation was deferred pending the promulgation in 1995 of the integrated rulemaking for effluent guidelines and national emission standards.

Landfills and Surface Impoundments: In November 1991, the EPA, exercising option (iii), informed the plaintiffs of its decision not to promulgate additional regulations under Subtitle D of the Resource Conservation and Recovery Act (RCRA) for landfills and surface impoundments receiving sludge from bleached kraft and sulfite mills. The EPA concluded that, under current conditions, dioxin contained in pulp and paper mill sludges does not impose an unreasonable risk to human health and the environment when disposed in landfills and surface impoundments.

Land Disposal Restrictions: RCRA land disposal restrictions (LDRs) are applicable to the pulp and paper industry because the industry has ignitable or corrosive wastes at the point of generation, and at some facilities the waste is subsequently land disposed (discharged into a surface impoundment). Based on a September 25, 1992 court decision (dilution is not acceptable as treatment for ignitable and corrosive wastes), RCRA must control underlying hazardous constituents, such as chloroform, from these facilities with surface impoundments. On January 19, 1993, EPA published a Notice of Data Availability to solicit comments on all issues included in the court opinion (58 FR 4972). On May 24, 1993, EPA published an Interim Final Emergency Rule to address those issues that required immediate attention (58 FR 29860). The CWA systems are not immediately affected by the court ruling--the deactivation standard was remanded to the Agency and will remain in effect until the Agency modifies RCRA regulations.

2.3 NATURE OF INTEGRATED RULEMAKING

In 1990, the EPA established the Pulp and Paper Regulatory Cluster. One role of the cluster is to identify optimal approaches to solving environmental problems associated with the pulp and paper industry through regulatory coordination. Pursuant to the Cluster initiative, the Agency developed the joint proposal for effluent limitations guidelines under CWA and National Emissions Standards for Hazardous Air Pollutants (NESHAP) under CAA. A third effort under the Cluster initiative--regulation of land application of pulp and paper mill sludge--was also included in the Agency's coordinated regulatory strategy.

The EPA has several technical and policy goals for coordinating the development of the effluent guidelines and the NESHAP. These goals include greater protection of human health and the environment by attaining significant reductions in pulp and paper industry pollutant releases to all media; reducing the cost of complying with both sets of regulations; promoting and facilitating coordinated compliance planning by the industry; promoting and facilitating pollution prevention; and emphasizing the multimedia nature of pollution control.

In developing these proposed integrated regulations, the EPA first collected information about the industry and developed a mill-specific database of all facilities subject to both sets of standards. Next, the EPA developed control technology bases for effluent limitations and air emission standards to meet separate statutory requirements of the CWA and the CAA. The technology options that addressed pollution prevention, air emissions and wastewater discharges separately were then combined to develop integrated regulatory options. Third, control costs and other environmental and economic impacts for each alternative above the baseline were estimated. These analyses were used to determine the combined effect of the process changes, air controls, improvements to wastewater treatment, and best management practices. These alternatives were designed to evaluate the most efficient application of control technologies and to minimize the cross-media transfer of pollutants between water and air.

The EPA selected control options for the BAT, PSES, and BPT limitations and the NESHAP based on the statutory factor, and considered many factors including pollutant reductions, costs, cost-effectiveness, and economic, environmental, and energy impacts.

3.0 NEED FOR THE REGULATION

The Executive Order requires that the Agency identify the need for the regulation being proposed. The emission of air pollutants and the discharge of pollutants into the effluent pose a threat to human health and the environment. Risks from these emissions and discharges include increases in cancer risk, other adverse noncancer health effects on humans, and degradation of the environment. This section will discuss: (1) the reasons the marketplace does not provide for adequate pollution control absent appropriate incentives or standards; (2) the environmental factors that indicate the need for additional pollution controls for this source category; and (3) the legal requirements that dictate the necessity for and timing of this regulation.

3.1 MARKET FAILURES

The need for effluent guidelines and emission limitations for this source category arises from the failure of the marketplace to provide the optimal level of pollution control desired by society. Correction of such a market failure may require federal regulation. The Office of Management and Budget defines market failures as the presence of externalities, natural monopolies, and inadequate information (U.S. Office of Management and Budget, 1989). This section addresses the category of externalities, the category of market failure most relevant to the general case of environmental pollution.

The concept of externalities partially explains the discrepancy between the supply of pollution control provided by owners and operators of pollution sources and the level of environmental quality desired by the general population. The case of environmental pollution can be classified as a negative externality because it is an unintended by-product of production that creates undesirable effects on human health and the environment.

In making production decisions, owners and operators will only consider those costs and benefits that accrue to them personally, i.e., internalized costs and benefits. However, the cost of environmental pollution is not borne solely by the creators of the pollution because all individuals in the polluted area must share the social cost of exposure to the pollution, even if they had no part in creating the pollution. Therefore, although owners and operators may be the creators of pollution, they do not necessarily bear the costs of the pollution. Government regulation is an attempt to internalize the costs of pollution.

If the people affected by a particular pollution source could negotiate with the party responsible for that source, the parties could negotiate among themselves to reach an economically efficient solution. The solution would be efficient because it would involve only those individuals who are affected by the pollution. In effect, the solution would involve trading of pollution and compensation among the owner or operator and the people affected by the pollution.

Individual negotiation often does not occur in an unregulated market, however, because of high transactions costs, even if trade among the affected parties would be beneficial to all parties involved. For the majority of environmental pollution cases, the costs of identifying all the affected individuals and negotiating an agreement among those individuals are prohibitively high. Another problem preventing negotiations from taking place is that our current market system does not clearly define liability for the effects of pollution.

In the case of environmental quality, an additional problem is the public nature of this "good". Environmental quality is a public good because it is predominantly nonexcludable and nonrival. Individuals who willingly pay for reduced pollution cannot exclude others who have not paid from also enjoying the benefits of a less polluted environment. Because many environmental amenities are nonexcludable, individuals utilize but do not assume ownership of these goods, and therefore, will not invest adequate resources in their protection. The result is that in the absence of government intervention, the free market will not provide public goods, such as clean air, at the optimal quantity and quality desired by the general public.

3.2 ENVIRONMENTAL FACTORS

In the case of the pulp and paper industry, the result of the market's failure to promote air and water pollution control is that pollution of the nation's air, rivers, and streams is not controlled to the optimal level. This industry releases significant amounts of pollutants to ambient air, surface waters, wastewater treatment plants, and wastewater treatment sludges. Despite state and local regulatory programs, many areas are still adversely affected by pollutant emissions and discharges by this industry. Chapter 6.0 discusses in detail the air and water quality impacts of the integrated regulations.

The integrated regulations are expected to decrease emissions of air toxics by approximately 121,200 Mg annually. Additionally, the regulations are expected to decrease air emissions of volatile organic compounds by approximately 716,000 Mg annually and emissions of total reduced sulfur compounds by approximately 295,000 Mg annually.

The integrated regulations are also expected to decrease mass loadings of toxic pollutants in effluents currently discharged by this source category. The total toxic pollutant reduction expected to result from this regulation is 2,798 metric tons annually. The Agency also expects biochemical oxygen demand discharges to be reduced by 94,500 metric tons annually and total suspended solids discharges to be reduced by 128,000 metric tons annually.

3.3 LEGAL REQUIREMENTS

The integrated regulations are proposed under the authorities of Sections 301, 304, 306, 307, and 501 of the Clean Water Act (the Federal Water Pollution control Act Amendment of 1972, 33 U.S.C. 1251 et seq., as amended by the Clean Water Act of 1987, Pub. L. 100-4, also referred to as "the Act") and under the authority of Section 112 of the Clean Air Act Amendments of 1990.

4.0 TECHNOLOGY OPTIONS AND REGULATORY ALTERNATIVES

There are a number of technologies and work practices available to pulp and paper mills that will enable them to reduce the amount of pollution in effluent discharges and air emissions. For this industry, these technologies take the form of process changes, add-on control devices, and wastewater treatment techniques. The following sections briefly describe the control options considered by the EPA for developing the pulp and paper effluent guidelines and national emission standards. The control options are combined to form an integrated regulatory alternative that addresses both the water and the air pollution problems (for more information on control technologies and techniques see the Background Information Document and Development Document).

4.1 TECHNOLOGY COMPONENTS

4.1.1 Process Changes

Process changes are at the heart of the integrated regulatory alternatives because they act to reduce dioxin and furan formation in the wastewater, and to reduce chlorinated hazardous air pollutant (HAP) emissions. The process changes selected by the Agency form the technology basis for the Best Available Technology (BAT) standards. The process change technologies vary by industry subcategory, and the effluent limitations that are demonstrated by the technology also may vary by subcategory.

All process change options have the following components in common unless otherwise noted: adequate woodchip size control, elimination of dioxin precursor defoamers, improved pulp washing efficiency, elimination of hypochlorite, high shear mixing of pulp, and oxygen and peroxide enhanced extraction in bleaching. Also, depending on the option and site specific factors, a recovery boiler upgrade may be included.

Papergrade Kraft Options

The EPA considered five increasingly stringent process change options for this mill subcategory. The options are listed in Table 4-1. Chlorine dioxide is substituted for elemental chlorine to reduce dioxin formation, and extended cooking and oxygen delignification reduce the demand for bleaching chemicals by removing greater amounts of lignin from the pulp before it is bleached. The selected option for the papergrade kraft subcategory is option 4 which uses oxygen delignification or extended cooking and 100% chlorine dioxide substitution.

Table 4-1 Process Change Options for the Papergrade Kraft Subcategory		
Option	**Short Description**	**Technology Description**
1	Split Cl_2	Split addition of chlorine
2	70% ClO_2	Substitution of chlorine dioxide for chlorine at a rate of 70%
3	OD OR Ext. Cook + 70% ClO_2	Oxygen delignification or extended cooking, substitution of chlorine dioxide for chlorine at a rate of 70%, and COD control
4*	OD OR Ext. Cook + 100% ClO_2	Oxygen delignification or extended cooking, complete substitution of chlorine dioxide for chlorine, and COD control
5	OD AND Ext. Cook + 100% ClO_2	Oxygen delignification and extended cooking, complete substitution of chlorine dioxide for chlorine, and COD control

* Selected option

Note: All options include: adequate wood chip size control; eliminating dioxin precursor defoamers; improving pulp washing; eliminating hypochlorite; high shear mixing pulp; and enhancing extraction in bleaching (with oxygen or peroxide).

Dissolving Kraft Options

The EPA considered three increasingly stringent process change options for this mill subcategory. The options, which were transferred from the papergrade kraft subcategory, are listed in Table 4-2. The selected option for this subcategory is option 2 which uses oxygen delignification and 70% chlorine dioxide substitution.

Table 4-2 Process Change Options for the Dissolving Kraft Subcategory		
Option	**Short Description**	**Technology Description**
1	70% ClO_2	Substitution of chlorine dioxide for chlorine at a rate of 70%
2*	OD + 70% ClO_2	Oxygen delignification, substitution of chlorine dioxide for chlorine at a rate of 70%, and COD control
3	OD + 100% ClO_2	Oxygen delignification, complete substitution of chlorine dioxide for chlorine, and COD control

* Selected option

Note: All options include: adequate wood chip size control; eliminating dioxin precursor defoamers; improving pulp washing; eliminating hypochlorite; and high shear mixing pulp.

Papergrade Sulfite Options

The EPA considered two increasingly stringent options for this mill subcategory. The options, listed in Table 4-3, include process modifications involving enhanced extraction in the bleaching sequence, and modifications that involve removing chlorine from the bleaching sequence altogether. The selected option for this subcategory is option 2, a totally chlorine-free process.

Table 4-3
Process Change Options for the Papergrade Sulfite Subcategory

Option	Short Description	Technology Description
1	OD AND 100% ClO_2	Oxygen delignification, complete substitution of chlorine dioxide for chlorine, and COD control
2*	TCF	Totally chlorine-free bleaching using oxygen delignification or extraction followed by peroxide, and COD control

* Selected option
Note: Both options include: adequate wood chip size control; eliminating dioxin precursor defoamers; and eliminating hypochlorite.

Dissolving Sulfite Options

The EPA considered two increasingly stringent process change options for this subcategory. Like the papergrade sulfite subcategory, the options include process changes involving low chlorine dioxide substitution, and process changes that eliminate chlorine use. The selected option for this subcategory is option 1, which uses oxygen delignification and 100% chlorine dioxide substitution. The options are listed in Table 4-4.

Table 4-4
Process Change Options for the Dissolving Sulfite Subcategory

Option	Short Description	Technology Description
1*	OD AND 100% ClO_2	Oxygen delignification and complete substitution of chlorine dioxide for chlorine
2	TCF	Totally chlorine-free bleaching using oxygen delignification, ozone, and/or peroxide

* Selected option
Note: Both options include: adequate wood chip size control and eliminating dioxin precursor defoamers.

4.1.2 Air Pollution Control Options

Air emission controls are primarily add-on controls designed to control process vents, open processes, and condensate wastewaters located in either the pulping or bleaching areas of the mill. Air pollution control options include adding hoods and vents in open process areas, routing process vents to scrubbers and/or combustion devices (either stand-alone incinerators or recovery boilers), and steam stripping of condensate wastewaters. The least stringent option, termed the MACT "floor," applies to the following emission points: digester relief vents, digester blow vents, evaporator vents, foam breaker tank vents, brown stock washer vents, first C and H-stage vents, first and second D and E-stage vents, digester blow condensates, evaporator "foul" condensates, evaporator "clean" condensates, turpentine decanter condensates, and oxygen delignification vents. More stringent options consider controlling the following additional emission points: weak black liquor storage vents, knotter vents, and decker vents.

The selected air pollution control options are listed in Table 4-5.

4.1.3 Secondary Wastewater Treatment

Secondary wastewater treatment practices are designed to reduce the effluent load of conventional water pollutants, which include biochemical oxygen demand (BOD) and total suspended solids (TSS). The two options for setting the BPT standard were:

- Performance level achieved the average of the best performing 90% of facilities
- Performance level achieved the average of the best performing 50% of facilities.

The selected option is the treatment used by the best performing 50% of facilities.

4.1.4 Other Pollution Prevention Practices

In addition to process changes, the Agency considered requirements called Best Management Practices (BMP) as part of the technology options for BAT. BMPs focus on the prevention and control of process-fluid spills from pulping and chemical recovery areas at mills that chemically pulp wood. Pulping liquor spills increase the organic and toxic load sent to the secondary wastewater treatment facility, thereby reducing the treatment facility's effectiveness and efficiency. BMPs require that spill prevention, containment, and control procedures and equipment be put in place at the mill.

Table 4-5
Description of Integrated Regulatory Alternatives[1]

Reg. Alt.	OW Process Changes				Add-On Air Pollution Control			Secondary Wastewater Treatment	Best Management Process
	Papergrade Kraft	Papergrade Sulfite	Dissolving Sulfite	Dissolving Kraft	Pulp Area Vents to be Controlled	Bleach Area Vents to be Controlled	Condensate Wastewater Cut-off		
1	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
2	Baseline	Baseline	Baseline	Baseline	Digester, evaporator, WBL storage, washer, knotter, and foam tank	Scrub C, D1, D2, Scrub, C, D1, D2, E1, E2, H stage	100 ppmw	Baseline	Baseline
3	Baseline	Baseline	Baseline	Baseline	Reg. alt. 2 points plus OD	E1, E2, H stage, Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Baseline	Baseline
4	Baseline	Baseline	Baseline	Baseline	Reg. alt. 3 points plus decker	Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Baseline	Baseline
5	Baseline	Baseline	Baseline	Baseline	Reg. Alt. 3 points plus decker	Duct scrubber to combustion device	100 ppmw	Treatment used by average of best 50%	Yes
11	OD or EC + 70% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 + E_{op}	Digester, evaporator, WBL storage, washer, knotter, and foam tank	Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Treatment used by average of best 50%	Yes
16	OD or EC + 70% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 + E_{op}	Reg. alt. 11 points plus OD	Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Treatment used by average of best 50%	Yes
17	OD or EC + 70% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 + E_{op}	Reg. alt. 16 points plus decker	Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Treatment used by average of best 50%	Yes
18	OD or EC + 100% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 + E_{op}	Reg. alt. 16 points plus decker	Duct scrubber to combustion device	100 ppmw	Treatment used by average of best 50%	Yes
22	OD or EC + 100% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 + E_{op}	Digester, evaporator, WBL storage, washer, knotter, and foam tank	Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Treatment used by average of best 50%	Yes
23	OD or EC + 100% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 + E_{op}	Reg. alt. 22 points plus OD	Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Treatment used by average of best 50%	Yes
24	OD or EC + 100% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 + E_{op}	Reg. alt. 23 points plus decker	Scrub C, D1, D2, E1, E2, H stage	100 ppmw	Treatment used by average of best 50%	Yes
25	OD or EC + 100% ClO_2 + E_{op}	TCF	TCF	OD + 70% ClO_2 +E_{op}	Reg. alt. 23 points plus decker	Duct scrubber to combustion device	100 ppmw	Treatment used by average of best 50%	Yes
26*	OD or EC + 100% ClO_2 + E_{op}	TCF	OD + 100% ClO_2	OD + 70% ClO_2 + E_{op}	Reg. alt. 22 points plus OD	Scrub C, D1, D2, E1, E2, H stage	500 ppmw	Treatment used by average of best 50%	Yes

[1] Baseline = No additional controls; OD = Oxygen delignification; EC = Extended cook; E_{op} = Extraction with oxygen and peroxide; TCF = Totally chorine-free; ClO_2 = Chlorine dioxide substitution; WBL = Weak black liquor; C = Chlorination; E = Extraction; H = Hypochlorite; D = Chlorine dioxide; * = Selected regulatory alternative

4.2 SUMMARY OF INTEGRATED REGULATORY ALTERNATIVES

The control technologies described in the previous sections were combined by the Agency to form integrated regulatory alternatives. An integrated regulatory alternative involves seven regulatory control stringency decisions--one in each of the areas listed across the top of Table 4-5 (the three areas for air controls are evaluated together).

The Agency evaluated several combinations of these seven decisions, which are presented in Table 4-5. The alternative selected as the basis for the proposed standard is Alternative 26.

5.0 ECONOMIC IMPACTS AND SOCIAL COSTS

The Agency evaluates the costs and economic impacts of pollution control standards in order to assess the potential impact of the standards on our nation's economy in terms of facility closures, job losses, and market disruptions. These impacts can be translated into measures of the social cost of the regulation, which is the monetary value of these disturbances. This information, compared to the potential benefits of the proposed standards, is useful for policy decisions concerning the stringency of the standard.

5.1 REGULATORY COMPLIANCE COSTS

Estimates of regulatory compliance costs are prepared for the EPA by environmental engineers. These engineers examine the control technologies and techniques and determine what the cost of installing the controls or instituting the techniques might be for each regulated entity. For the integrated pulp and paper standard, the engineers used mill-specific information from the 1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities and other sources, to determine each mill's cost to comply with the proposed standards. These mill-specific costs are often referred to as the *private cost* of the rule, because they are an estimate of the amount of money the private sector will spend on pollution control.

The key components of private cost estimates are *total capital investment (TCI)*, and *annual operating and maintenance cost (O&M)*. The TCI is an estimate of the purchase and installation cost of capital equipment needed to meet the proposed effluent and air emission standards. For the proposed regulatory option, this cost was estimated at $4.0 billion ($1992) for the entire industry. The O&M component is an estimate of the annual cost of operating and maintaining the pollution control equipment, the cost of such items as local property taxes and insurance, plus the annual cost of implementing the proposed work practice standards and noncapital pollution control techniques. For the proposed standard, this cost was estimated at $401 million ($1992) for the entire industry.

These costs are used to assess the economic impact of the proposed rule on the affected industry, but before they used in an economic impact model, the TCI is annualized, or spread out over a number of years. TCI annualization is used to estimate the annual expenditure stream associated with the capital portion of pollution control expenditures. The length of the stream is the expected depreciable life of the pollution control equipment, for this rule an average of 15 years. The annualized TCI (TCI_A) is calculated as:

$$TCI_A = TCI * \frac{i * (1 + i)^n}{(1 + i)^{n-1}}$$

where:

i	=	discount rate for capital expenditures
n	=	depreciable life of control equipment.

Here, the discount rate is interpreted as the cost of obtaining the TCI, which could correspond to the rate paid on a bank loan, the cost of debt or equity financing, or the opportunity cost associated with forgoing alternative investments. The sum of the annualized TCI, the O&M costs, and the reductions in annual tax liability that result from increases in operating and depreciation expenses is often referred to as the *total annual cost (TAC)* of the standard. The TAC estimate for the proposed standard is $599.5 million ($1992).

5.2 ECONOMIC IMPACT ANALYSIS METHODOLOGY

The EPA developed two economic impact analysis models to assess the economic impact of the proposed standards. Each model employs a distinct methodology for assessing impacts. The results of each, when considered as a whole, offer a comprehensive view of the potential impacts of the proposed standards (for more information on the models and analysis methodologies see Economic Impact and Regulatory Flexibility Analysis of Proposed Effluent Guidelines and NESHAP for the Pulp, Paper, and Paperboard Industry (ERG, 1993a)).

5.2.1 Financial Impact Analysis

The financial impact analysis estimates the incidence of mill closures, the potential employment, output, and export impacts associated with mill closures, and the change in key financial health ratios due to the imposition of regulation. To estimate mill closure, the analysis compares several estimates of the present discounted value of future earnings after control to a couple of estimates of mill salvage value. The comparison is made to determine whether, after imposing regulatory compliance costs, the mill would be more valuable to the current owner if it were shut-down and liquidated rather than in continued operation. The analysis also estimates the changes in key financial ratios after imposing regulatory compliance costs, and compares the changes to fluctuations that have historically occurred in the business cycle.

5.2.2 Market Impact Analysis

The market impact analysis estimates mill supply responses and end-use demand responses to regulatory compliance costs for suppliers and demanders in 31 defined product markets. This analysis indicates the potential changes in pulp, paper, and paperboard product prices, mill production and employment levels, foreign imports and domestic exports, mill production costs and revenues. The market impact model also provides estimates of the social costs of regulations that include producer and consumer surplus changes and worker dislocation costs.

5.3 ECONOMIC IMPACT ANALYSIS RESULTS

The financial impact model and the market impact model combine to produce estimates of mill closures, job losses and gains, output changes, product price changes, product export and import changes, and the potential differential impacts or small and large entities (for more information on the analysis results see Economic Impact and Regulatory Flexibility Analysis of Proposed Effluent Guidelines and NESHAP for the Pulp, Paper, and Paperboard Industry (ERG, 1993a)).

5.3.1 Mill Closure Estimates

The Agency estimates that from 11 to 13 mills may face closure as the result of the costs of the proposed standards, and are scattered across industry subcategories. These projections are based on quantitative estimates of several economic factors, but the ultimate decision to close an industrial facility depends on many judgements outside the scope of the Agency's analysis.

5.3.2 Employment Impacts

The Agency estimates that from 2,800 to 10,700 jobs could be eliminated as a result of the increase in production costs attributable to the proposed standards. The job losses are associated with both mill closures and reductions in output at mills that continue to operate. Up to 875 new production jobs may be created due to increases in output at mills that are not directly affected, or only mildly affected by the rule. These mills may benefit by being able to supply the void left in the market by competitors who close.

5.3.3 Market Price and Production Impacts

The Agency predicts that market prices for most of the product classes identified in the 1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities will not increase significantly, that is by more than 1 or 2%. The largest price increase, nearly 3%, is predicted for uncoated free sheet, which includes paper used for copiers and writing tablets. The availability of imports serves to limit the rise in market prices in most product categories affected by the proposed standards.

Increases in domestic production costs, without significant increases in market prices and together with mill closures, leads to lower output by domestic producers. The market model predicts that at the market level, most of these domestic output declines are small. The largest declines are estimated for bleached sulfite market pulp (3.1%). The financial model, which does not take into account potential changes in product prices or imports, or the market interactions among domestic suppliers, estimates the mills that close due to the proposed standards accounted for up to $2.4 billion in product shipments in 1989.

5.3.4 International Trade Impacts

All else being equal, higher domestic production costs will reduce U.S. competitiveness on world markets and therefore reduce exports. Higher domestic market prices will make U.S. markets more attractive to foreign producers and therefore encourage imports. The market impact model predicts that the overall quantity of imports will increase by less than 1%, and the overall value of exports will decrease by less than 1%. However, individual product groups may experience significant declines in export value. The most notable declines in export value for significant individual product groups are 20.5% for uncoated free sheet, 7.6% for recycled paperboard, 6.5% for newsprint, and 3.8% for bleached sulfite market pulp. The most notable increases in significant imports are 1.4% for clay coated printing paper, 1.5% for recycled paperboard, and 6.1% for folding carton board.

The financial model, which does not take into account potential changes in product prices or imports, or the market interactions among domestic suppliers, estimates the mills that close due to the proposed standards accounted for up to $198 million in product exports in 1989.

5.3.5 Summary of Small Entity Impacts

Complying with the Regulatory Flexibility Act (Public Law 96-354-Sept. 19, 1980) requires the Agency to examine the potential economic impact of regulatory actions on small entities. Several definitions of "small entity" were considered in evaluating impacts. The definitions include:

- Facilities with less than or equal to 750 employees (small facilities)
- Facilities with less than or equal to 125 employees (very small facilities)
- Independent companies with less than 750 employees (small companies).

The impacts for the small group under each definition were compared to the impact for the large group under each definition. The results of the financial impact analysis were used to estimate changes in facility-level and company-level financial ratios, as well as the number of companies affected by facility closures.

The Agency estimates that 35% of the mills in the industry employ less than 125 workers and 84% employ less than 750 workers. Of the nearly 215 companies, about 150 meet the definition of small. The analyses performed indicate that between 1 and 6 estimated mill closures are mills employing less than 125 workers, and between 9 and 10 mills are employing less than 750 workers. This indicates that a small majority of the facility closures are small mills. Also, roughly one half of all estimated closures are mills owned by small companies.

The Agency examined the impact of the proposed rules on relevant financial ratios of both large and small facilities. The results showed that facilities employing less than 125 workers experience less deterioration in financial health than larger facilities. The results were similar for facilities employing less than 750 employees. The company-level ratio analysis generally indicates less deterioration in financial health for small companies as well. The exceptions to this conclusion are the results for net working capital and the net working capital to total assets ratio. Here, small companies experienced larger declines than large companies, presumably due to the smaller baseline net working capital that smaller companies experience.

The Agency also examined potential changes in facility earnings before interest, taxes, and depreciation (EBITD). The results indicate the facilities employing less than 125 workers had a smaller decline in EBITD than large facilities. The same holds true for facilities employing less than 750 employees.

Finally, the Agency also employed the Altman Z-score method to estimate the likelihood of bankruptcy for companies, and assess potential differences between large and small company impacts of the proposed standards. This analysis indicates that small companies are not any more likely to face bankruptcy after regulation than large companies.

Overall, there is no consistent evidence that the regulations will have a disproportionate impact on the economic viability of either small facilities, or small companies, regardless of the definition used to define "small".

5.4 SOCIAL COSTS OF REGULATION

One way of evaluating the merit and efficiency of social decisions, like the one to internalize the ill effects of pollution on human health and the environment through regulation, is to compare the social costs of regulation to the social benefits. The social costs of regulation are the opportunity costs borne by society for employing our scarce resources in pursuit of pollution control.

5.4.1 Social Cost Estimates

The social costs of regulation include both monetary and nonmonetary outlays made by society. Monetary outlays include private-sector compliance costs, government administrative costs and the costs of reallocating displaced workers. Nonmonetary outlays that are often assigned a monetary value include losses in consumers' or producers' surpluses in product markets, discomfort or inconvenience, loss of time, and slowing the rate of innovation. Table 5-1 shows the estimates of social cost derived from the market impact model for the integrated regulatory alternatives 3, 16, 23, 24, 25, and 26. Alternatives 3, 16, 23 and 26 contain the MACT floor level of air add-on control with increasingly stringent process modification requirements. Alternatives 24 and 25 contain increasingly stringent air add-on controls on top of the process modification options selected for Alternative 23. The estimates include producer surplus loss, consumer surplus loss, annualized worker dislocation costs, and government administrative costs.

Table 5-1
Annual Social Cost Estimates (Millions of 1992 Dollars)

Social Cost Category	Alt. 3	Alt. 16	Alt. 23	Alt. 24	Alt. 25	Alt. 26*
Consumer Surplus Loss	$166.2	$508.0	$512.7	$514.0	$514.3	$491.6
Producer Surplus Loss	$118.4	$310.0	$415.8	$440.9	$498.1	$428.3
Worker Displacement Costs	$4.9	$25.0	$25.3	$25.3	$25.5	$25.3
Government Administrative Costs (MACT only)	$2.6	$2.6	$2.6	$2.6	$2.6	$2.6
Total Social Cost	$292.1	$845.6	$956.4	$982.8	$1,040.5	$947.8

* Alternative selected for proposed rulemaking.

In a market environment, consumers and producers of pulp and paper products derive welfare from market transactions. The difference between the maximum price consumers are willing to pay for pulp and paper products and the price they actually pay is referred to as consumer surplus. Similarly, the difference between the minimum price producers are willing to accept for pulp and paper products and the price they actually receive is referred to as producer surplus. Because equilibrium prices and quantities change in each market affected by pulp and paper regulations, there are corresponding changes in consumer and producer surplus.

Worker dislocation costs are estimated based on incremental willingness-to-pay measures for job dislocations in a hedonic wage framework. This estimate conceptually approximates the one-time willingness to pay to avoid an involuntary unemployment episode. Theoretically, the estimate includes all worker-borne costs net of any off-setting pecuniary or nonpecuniary "benefits" of unemployment (e.g., unemployment compensation, leisure time enjoyment). The hedonic displacement cost estimate is a net present value valuation. For the paper and allied products sector, the implied one time statistical cost of an involuntary layoff is $67,323. This value is multiplied by the total number of displaced workers estimated by the market impact model to calculate net present discounted value of the worker displacement cost of the regulation. This cost is then annualized and included in social cost.

Government administrative costs include the cost to private companies, and federal and state governments to prepare and review facility compliance reports and otherwise ensure and oversee compliance with the proposed standards. The costs in Table 5-1 reflect only the private and government administrative costs for MACT standard compliance. In some instances, the EPA believes that compliance with the proposed regulation will result in increases in productivity, enhanced product quality, and improved plant and equipment throughout the chemical pulping and bleaching segments of the industry. These considerations, which have a positive social value, have not been included in the estimates of the social cost of the proposed rule.

6.0 POLLUTANT REDUCTION

This chapter summarizes the approach and results for effluent discharges and air emissions. First, the chapter summarizes the approach used to estimate the mass loadings of pollutants in final effluents currently discharged from pulp and paper mills under baseline conditions and the predicted removals of such pollutants under the regulatory options. Much of this information was obtained from Methodology for Determining BAT Pollutant Loadings for the Revision of Pulp and Paper Effluent Limitations Guidelines (Radian, Inc., 1993). Then, the chapter summarizes approaches used in estimating reductions in air emissions and the estimated changes in air emissions.

6.1 APPROACH TO ESTIMATING WATER POLLUTANT REDUCTIONS

The Agency estimates the reduction in the mass of pollutants that would be discharged from pulp and paper mills after the implementation of the regulations it is proposing. The reduction in pollutant mass is attributable both to process changes and improved end-of-pipe treatment. Process changes that form the technology bases of BAT and PSES reduce the formation of certain pollutants. Other process changes, including wastewater recycle practices that form a part of the BPT technology basis and the pulping liquor management practices that comprise BMP's, reduce pollutant discharges by diverting certain waste streams from wastewater treatment. The pollutants contained in these diverted waste streams may be captured in the product, recovered for reuse, routed to on-site combustion where they are destroyed while their heating value is recovered, or eventually discharged to wastewater treatment in other wastewater streams. When wastewater discharge volumes are reduced by recycle and reuse, pollutants are typically concentrated in the remaining waste streams. This is advantageous, from a treatment standpoint, because more concentrated pollutants can be removed more efficiently in wastewater treatment.

Additional information on the methodology used to estimate the pollutant reductions resulting from the implementation of effluent limitations may be found in Section 9 of the Development Document (U.S. EPA, 1993b).

6.1.1 Approach and Assumptions Used for Estimating Loadings After Implementation of Regulatory Options

Data characterizing each technology option were used to determine the production normalized pollutant loadings for all of the pollutants of concern investigated for the bleach plant and final effluent. Pollutant reductions were estimated by comparing these loadings to the mill's baseline loadings. Mill-by-mill baseline loadings and pollutant reductions in kg/year were calculated. More details about the loadings for each subcategory are provided in the Development Document (U.S. EPA, 1993b).

6.2 TOXIC WATER POLLUTANT REMOVALS

The percent of baseline and mass of each pollutant removed by the process options for each subcategory are presented in the Development Document. For the papergrade kraft/soda subcategory, only data for process option 4 (oxygen delignification (OD) or extended cook and 100% substitution) are presented. Option 3 for this subcategory (OD and 70% substitution) would result in slightly smaller removals. The total toxic pollutant reduction for all bleaching subcategories combined is 2,798 kkg/yr.

6.3 CONVENTIONAL WATER POLLUTANT REMOVALS

For all subcategories, the Agency developed an estimate of the long-term average (LTA) production normalized mass loading of BOD_5 and TSS that would be discharged after the implementation of BPT. The reduction in the mass of BOD_5 and TSS achieved by BPT was estimated on a mill-specific basis. The BPT LTA was multiplied by each mill's 1989 production, for all subcategories present at the mill. The total mill BPT mass was subtracted from its 1989 discharge of BOD_5 and TSS (as reported in the questionnaire), to estimate the mill's BPT pollutant reduction. To calculate a total subcategory pollutant reduction, the pollutant reduction achieved by each multi-subcategory mill was apportioned to each subcategory present at the mill on the basis of production. The Agency estimates that the proposed regulations will reduce BOD_5 discharges by approximately 94,500 metric tons per year. Of the total BOD_5 pollutant reduction, approximately 12,300 metric tons per year (13%) results from implementation of BAT; approximately 12,500 metric tons per year (13%) results from implementation of NESHAP; approximately 5,090 metric tons per year (5%) results from implementation of BMP; and approximately 64,700 metric tons per year (69%) results from implementation of BPT. TSS discharges will be reduced by approximately 128,000 metric tons per year. All TSS pollutant reductions result from implementation of BPT. More details are provided in the Development Document (U.S. EPA, 1993b).

6.4 APPROACH TO ESTIMATING AIR EMISSION REDUCTIONS

A mill-specific industry profile and model process units were used to estimate the air emission impacts of the integrated regulatory alternative. The mill-specific industry profile included information on the 160 mills to be regulated under the NESHAP portion of the integrated regulation. The model process units were assigned to the mills in the mill-specific industry based upon capacity and process type.

The Agency used outputs generated by assigning these model processes to specific mills to calculate the pollutant reductions attributable to this regulation. For example, uncontrolled air emissions were calculated by multiplying model process emission factors by mill-specific process capacities.

Baseline air emissions were calculated from the uncontrolled air emissions by assigning appropriate control efficiencies to the control devices (if any) known to be present at each facility. The baseline emissions calculated by emission point, were then summed for each process and mill. National baseline emissions were estimated by summing emissions from all individual mills.

Air emission impacts were calculated for each mill. To calculate controlled air emissions, the control efficiency required by each control option was assigned to each emission point not already controlled to this level at baseline. Emission reductions were calculated as the difference between baseline emissions and controlled emissions.

The emission reductions achieved by the integrated regulatory alternative were summed for each process line, for each mill, and then for all mills combined to generate national air emission reduction impacts.

6.5 HAZARDOUS AIR POLLUTANT EMISSION REDUCTIONS

Emissions from pulping, bleaching, and wastewater processes typically include a mixture of hazardous air pollutants (HAPs). The HAPs that are emitted from these processes and would be controlled by the integrated regulatory alternative include (but are not limited to) acetaldehyde, acrolein, chlorine, chloroform, formaldehyde, hexane, methanol, methyl ethyl ketone, and toluene. The total HAP emission reduction expected to be achieved by the integrated regulatory alternative is approximately 121,000 Mg annually.

Although the above list of HAPs are not the complete list of HAPs for which emission reductions will be achieved, the listed HAPs comprise approximately 97% of the expected HAP emission reductions. The Background Information Document contains a complete list of the pollutants that were identified and estimates of individual HAP emission reductions.

6.6 OTHER AIR QUALITY CHANGES

6.6.1 Volatile Organic Compound Emission Reductions

Many of the HAPs emitted from this source category are also volatile organic compounds (VOCs). VOC is defined as a criteria pollutant in the Clean Air Act. Although the air emission standards do not require control of VOC, the control technologies upon which these standards are based will also reduce significant amounts of VOC emissions. The integrated regulatory alternative will reduce VOC emissions by approximately 715,900 Mg annually.

6.6.2 Total Reduced Sulfur Compound Emission Reductions

Another benefit of the integrated regulatory alternative is the reduction of total reduced sulfur compounds (TRS). Once again, although the air emission standards do not require control of total reduced sulfur compounds, the implementation of the integrated regulatory alternative will reduce TRS emissions by approximately 295,400 Mg annually.

6.6.3 Other Criteria Pollutant Emission Increases

In addition to examining the impacts of the integrated regulation on HAP, VOC, and TRS emissions, the Agency examined the impacts of this regulation on emissions of several other air pollutants regulated under the Clean Air Act. The analysis shows that this regulation will result in the generation of relatively small amounts of several criteria pollutants (mostly from combustion controls but to a lesser extent, also from noncombustion controls).

The criteria pollutants generated by the implementation of the integrated regulatory alternative include carbon monoxide, nitrogen oxide, particulate matter, and sulfur dioxide. Emission increases of sulfur dioxide are larger than other criteria pollutants; however, they are estimated to be less than 15% of total sulfur dioxide emissions currently generated by this source category.

Criteria pollutant emission decreases and increases generated by the integrated regulatory alternative are shown in Table 6-1.

Table 6-1
Pollutant Emission Decreases and Increases

Pollutant	Emission Decrease (Mg/yr)
Hazardous Air Pollutants	121,000
Volatile Organic Compounds	715,900
Total Reduced Sulfur Compounds	295,400
	Emission Increase (Mg/yr)
Carbon Monoxide	300
Nitrogen Oxide	1,300
Sulfur Dioxide	168,200
Particulate Matter	100

7.0 QUALITATIVE ASSESSMENT OF BENEFITS

7.1 INTRODUCTION

One rationale for environmental regulation, such as this integrated rulemaking for pulp and paper, is to provide benefits to society by enhancing (improving and protecting) environmental quality. In this chapter, and the two that follow, information is provided on the types and levels of social benefits anticipated from the proposed rulemaking. In this chapter, the focus is on (1) providing background information on benefits assessment, by describing benefit categories and issues in benefits estimation; and (2) developing qualitative descriptions of the types of benefits associated with the proposed pulp and paper rulemaking.

This chapter is organized as follows. Section 7.2 describes the economic concepts and benefit categories applicable to the regulation. Section 7.3 provides a qualitative description of the anticipated air-related benefits and Section 7.4 qualitatively discusses the anticipated water-related benefits. Section 7.5 describes the Agency's preliminary assessments of the ecologic benefits associated with the regulation. Finally, a summary of the anticipated benefits is given in Section 7.6.

7.2 CONCEPTS APPLICABLE TO THE BENEFITS ANALYSIS

7.2.1 Benefit Categories Applicable to the Regulation

To implement a benefits analysis, the types or categories of benefits that apply need to be defined. The benefits typology shown in Figure 7-1 summarizes, as an example, benefits typically observed as a result of changes in the water resource environment; a similar benefits typology for air-related environmental improvements would show similar use and nonuse benefit categories resulting from changes in air quality. As reflected in Figure 7-1, benefits typically are categorized according to whether or not they involve some form of direct use of, or contact with, the resource. Although there are important embellishments and appreciable semantic distinctions that can be made to enhance this figure, it can be used as a convenient starting point.

Use Benefits

Use benefit categories can embody both direct and indirect uses of affected waters and ambient air, and the direct use category embraces both consumptive and nonconsumptive activities. In most applications to pollutant reduction scenarios, the most prominent use benefit categories for water are those related to human health risk reductions, recreational fishing, boating and/or swimming; the most prominent use benefits for air are those related to human health risk reductions, effects on crops and plant life, visibility, and materials damage.

Figure 7-1

The Benefits of Environmental Quality Improvements
Example: Water-Related Benefits

USE BENEFITS	
In-Stream	• Human Health Risk Reductions • Commercial Fisheries and Navigation • Recreation (fishing, boating, swimming, etc.) • Subsistence fishing (including human health risks)
Near Stream	• Water enhanced, noncontact recreation (picnicking, photography, jogging, camping, etc.) • Nonconsumptive use (e.g. wildlife observation)
Option Value	• Premium for uncertain future demand • Premium for uncertain future supply
Diversionary	• Industry/Commercial (process and cooling waters) • Agriculture/Irrigation • Municipal drinking water (treatment cost savings and/or human health risk reductions)

NONUSE (INTRINSIC) BENEFITS	
Aesthetic	• Residing, working, traveling and/or owning property near water, etc.
Bequest	• Intergenerational Equity
Existence	• Stewardship/Preservation • Ecologic • Vicarious Consumption

Because recreational activities are amenable to various nonmarket valuation techniques (e.g., travel cost models), they have received considerable empirical attention from economic researchers over the past two decades. Thus, there is a considerable body of knowledge relating to recreational fishing and associated activities, and these generally indicate that water-based recreation is a highly valued activity in today's society. Accordingly, many benefits analyses focus on recreational values because they are well understood, there is a large body of empirical research to draw upon, and the associated benefits tend to be quite large. In part, the benefits assessment of the pulp and paper rulemaking follows in this tradition.

Nonuse (Intrinsic) Benefits

Improved environmental quality can be valued by individuals apart from any past, present or anticipated future use of the resource in question. Such nonuse values may be of a highly significant magnitude; however, the benefit value to assign to these motivations often is a matter of considerable debate. Whereas human uses of a resource can be observed directly and valued with a range of technical economic techniques, nonuse values can only be ascertained from directly asking survey respondents to reveal their values. The inability to rely on revealed behavior to ascertain nonuse values has led to considerable debate as to whether they exist for applicable changes in environmental quality and, if so, whether they are of an appreciable magnitude relative to use values.

Among the more relevant nonuse values associated with the rulemaking are "ecologic benefits" likely to embody reduced risks of direct mortality, and increased reproductive success, in a range of important fish and wildlife species. Whether such "ecologic benefits" fall within the traditional economic rubric of nonuse values is an unresolved semantic issue. Some ecologic benefits will have positive impacts on use values (e.g., recreational angling, bird watching, etc.). But of greater relevance is the applicability of "ecologic benefits" under the traditional nonuse categories of existence (stewardship or preservation) and bequest values. The key distinction may be that nonuse values remain anthropocentric, whereas "ecologic" benefits are viewed by some as completely distinct from human valuation — making them additive to nonuse values (though the removal of these benefits from the anthropocentric realm begs the question of how we assign values to ecologic benefits for the purpose of setting priorities in policy making). For the purposes of this analysis, ecologic benefits are considered as being inclusive within nonuse values.

7.2.2 The Economic Concept of Benefits

The general term "benefits" refers to any and all outcomes of the regulation that are considered positive; that is, that contribute to an enhanced level of social welfare. The term "economic benefits" refers to the dollar value associated with all the expected positive impacts of the regulation; that is, all regulatory outcomes that lead to higher social welfare. Conceptually, the monetary value of benefits is embodied by the sum of the predicted changes in "consumer (and producer) surplus." These "surplus" measures are standard and widely accepted terms of applied welfare economics, and reflect the degree of well-being enjoyed by people given different levels of goods and prices (including those associated with environmental quality).

This conceptual economic foundation raises several relevant issues and potential limitations for the benefits analysis of the regulation. First, the standard economic approach to estimating environmental benefits is anthropocentric — all benefit values arise from how environmental changes are perceived and valued by humans. A related second point is that the benefits of all future outcomes are valued in present day values. Thus, all near-term as well as temporally distant future physical outcomes associated with reduced pollutant loadings need to be predicted and then translated into the framework of present day human activities and concerns.

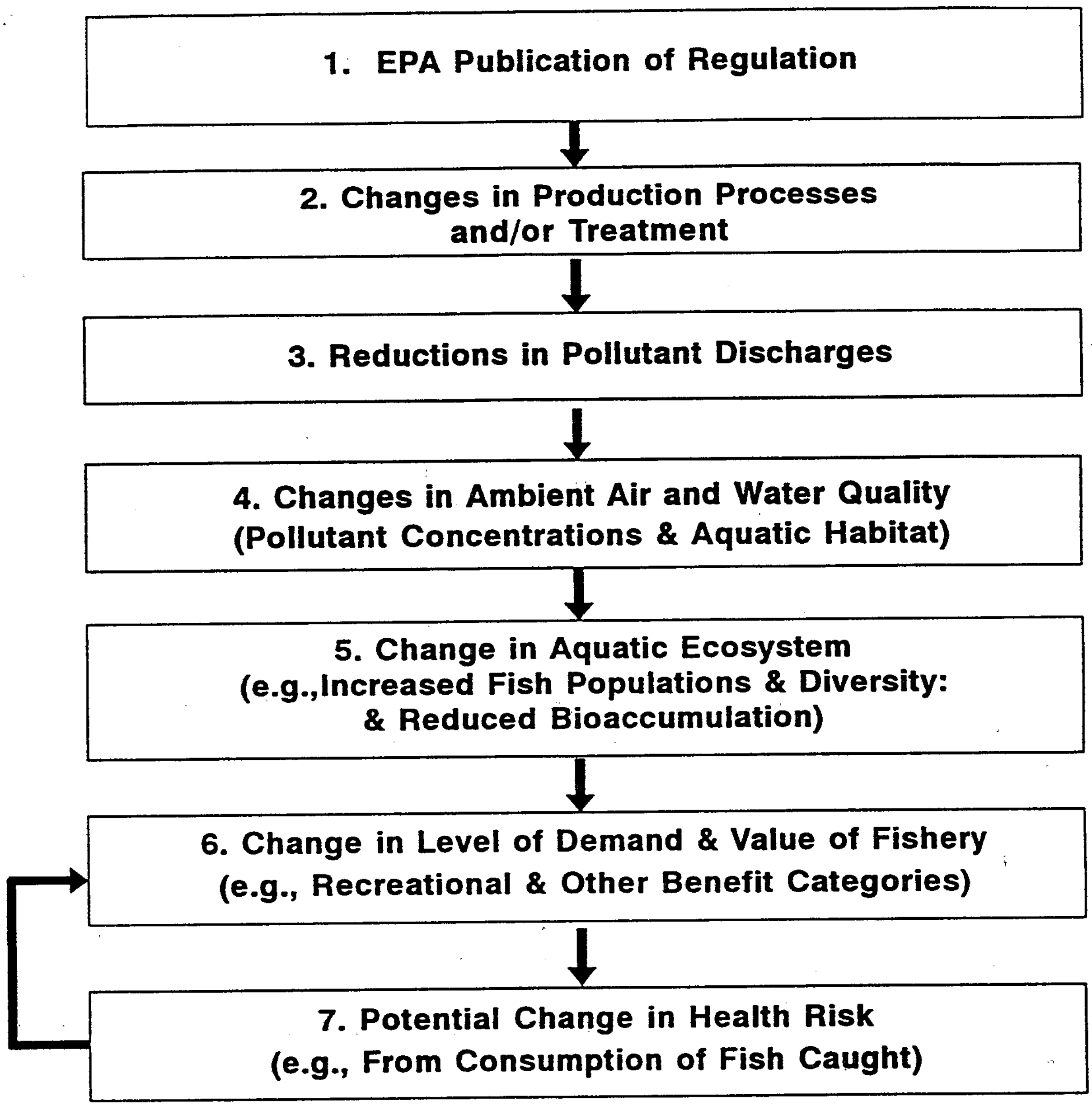
7.2.3 Causality: Linking the Regulation to Beneficial Outcomes

Conducting a benefits analysis for anticipated changes in pollutant loadings to downstream waters and in air emissions is a challenging exercise. This is because the benefits of the regulation require that a chain of events be specified and understood. As shown in Figure 7-1, which illustrates the causality for water-related benefits, these relationships span the spectrum of: (1) institutional relationships and policy-making; (2) the technical feasibility of pollution abatement, and facility-level decision-making; (3) the physical-chemical properties of receiving air and water and their consequent linkages to biologic/ecologic responses in the environment and, finally, (4) human responses and values associated with these changes.

The first two steps of Figure 7-2 reflect the institutional and technical aspects of implementing the regulation (the improved wastewater treatment or process changes). In this benefit-cost analysis of the regulation, we start at step 3, relying in part on pollutant loading reduction estimates (and associated compliance costs) derived in conjunction with the Agency's cost analysis.

Next, as shown in steps 4 and 5 of Figure 7-2, pollutant loading reductions need to be converted into changes in environmental conditions — such as physical chemical parameters (e.g., in-stream pollutant concentrations) and the consequent improvement in biota (e.g., increased diversity and size of fishery population). Finally, in steps 6 and 7 in Figure 7-2, the analysis reaches the stage at which anthropocentric benefit concepts begin to apply, such as illustrated by the link between improved fisheries and the enhanced enjoyment realized by recreational anglers. These final steps reflect the focal point of this benefits analysis, and are defined by the benefits categories described above. Below, relevant air and water benefits are described qualitatively. The potential magnitude of these benefits is quantified and monetized in Chapters 8.0 and 9.0.

Figure 7-2
Chain of Events in a Benefits Analysis
Example: Water-Related Benefits



7.3 QUALITATIVE DESCRIPTION OF AIR-RELATED BENEFITS

This section qualitatively discusses the potential health and welfare benefits associated with air emission reductions resulting from the proposed regulation. The proposed regulation is expected to reduce emissions of a wide range of hazardous air pollutants, volatile organic compounds, and total reduced sulfur. The discussion will focus on adverse health effects resulting from inhalation of the above pollutants as well as welfare effects such as effects on crops and other plant life, materials damage, soiling, and visibility. Also mentioned will be the adverse health and welfare effects resulting from the increase in emissions of several criteria pollutants.

Hazardous Air Pollutants

Inhalation of hazardous air pollutants can cause a variety of adverse health effects. Some hazardous air pollutants are known human carcinogens. The health effects of pollutants that fall into this category will be discussed in terms of cancer risk believed to be caused by inhalation of their emissions. The benefits of reducing emissions of these pollutants will focus on reductions in cancer mortality.

Other hazardous air pollutants are not proven human carcinogens but are nevertheless linked with causing adverse health effects such as lesions or abnormal cell growth (which may eventually lead to cancer). Health benchmark concentrations have been established for many of the pollutants in this category and the benefits discussion will focus on reducing human exposure to these pollutants below the benchmark concentrations.

Volatile Organic Compounds

Emissions of volatile organic compounds are responsible for causing both health and welfare effects. Volatile organic compound emissions are precursors to the formation of ozone. The reduction in adverse health effects expected to result from volatile organic compound emission reductions will be discussed in terms of reducing ambient ozone concentrations. Reducing ozone concentrations is also expected to affect crop yields and other plant life.

Sulfur and Criteria Air Pollutants

An additional category of benefits expected from the proposed regulation is the reduction of total reduced sulfur emissions. Total reduced sulfur emissions are responsible for the rotten egg smell often associated with pulp and paper production. The benefits of reducing total reduced sulfur emissions will be discussed in terms of reducing the malodor problem and the potential health benefits that may result.

Although the proposed regulation will reduce emissions of a wide range of pollutants, increases in emissions of several criteria pollutants must be mentioned. The proposed regulation is expected to slightly increase emissions of carbon monoxide, nitrogen oxide, sulfur dioxide, and particulate matter. Increases in the emissions of these pollutants are by far outweighed by decreases in the emissions of hazardous air pollutants, volatile organic compounds, and total reduced sulfur. Therefore, the benefits of reducing emissions of hazardous air pollutants, volatile organic compounds, and total reduced sulfur exceeded the costs of increasing the emissions of the other criteria pollutants. Nevertheless, the adverse health and welfare effects associated with the emissions of these criteria pollutants will be briefly discussed below.

7.3.1 Health Benefits of Reducing Hazardous Air Pollutant Emissions

According to baseline emission estimates, this source category currently emits approximately 170,000 Mg of hazardous air pollutants (HAPs) annually. The list of 189 HAPs is detailed in Section 112(b) of the Clean Air Act. Although this source category emits a wide variety of the 189 HAPs, only a small portion of the HAPs are emitted in enough quantities to pose a threat to human health and the environment. Therefore, the quantitative benefits assessment will focus on the health benefits that will result from the reduction in emissions of the significant HAPs. (The Background Information Document contains a more complete list of the HAP emissions that will be affected by the proposed regulation. This document also explains the methods used to calculate pollutant emissions and emission reductions.) The proposed regulation will reduce HAP emissions by 121,200 Mg annually.

Carcinogens

For the purposes of this analysis, a HAP was classified as significant if its emission and toxicologic data indicated that it would adversely affect human health. Of the HAPs that are emitted that are known carcinogens, five belong in this category. Based on toxicity and emissions information, chloroform, carbon tetrachloride, formaldehyde, methylene chloride, and acetaldehyde were evaluated for the cancer risk they posed. Studies have shown that these HAPs can cause cancer in animal livers and degeneration of animal olfactory epithelium.

Noncarcinogens

HAPs that are not proven human carcinogens but are linked with adversely affecting human health were also evaluated. Based on toxicity and emission information, an exposure assessment was performed for acrolein, acetaldehyde, toluene, 2-butanone, methanol, hydrochloric acid, and hexane. For noncarcinogens, the dose-response is expressed in terms of an inhalation reference-dose concentration (RfC). Using the RfC methodology, a benchmark concentration is calculated below which adverse effects are not expected to occur.

Exposure to acrolein has been linked with causing abnormal cell changes and acute bronchopneumonia in rats. Other animal studies have shown a relationship between acrolein inhalation and upper respiratory tract lesions, inflammation and necrosis in the respiratory epithelium, ulceration and necrosis of the olfactory epithelium, depressed body weight, and suppressed pulmonary antibacterial defenses. The significance of the RfC benchmark is that exposures to levels below the RfC are considered "safe" because exposures to concentrations of the chemical at or below the RfC have not been linked with any observable health effects.

7.3.2 Benefits of Reducing Volatile Organic Compound Emissions

In addition to health benefits that are expected from HAP emission reductions, health benefits are also expected from emission reductions of volatile organic compounds (VOCs). Baseline emission estimates indicate that pulp and paper mills currently emit approximately 830,000 Mg of VOCs annually. The proposed regulation is expected to reduce these emissions by approximately 716,000 Mg annually.

VOCs are a broad class of organic gases such as vapors from solvents and gasoline. Along with manmade sources, trees and other plants also produce VOCs, with especially high emissions in hot weather. The control of VOC emissions is important because the presence of VOC is a precursor to the formation of ozone. Ozone is produced in the atmosphere through the chemical reactions of VOC and nitrogen oxides (NO_x). Individual VOCs differ substantially in how quickly they react in the atmosphere. In summer, the atmospheric lifetimes of common organic gases range from less than an hour to several days. Also, VOCs are able to transport from a few miles to hundreds of miles. The fastest reacting VOCs tend to produce the most ozone, however, so VOCs from distant sources tend to be less important than "fresh" emissions (U.S. Congress, 1989).

Health Benefits of Reducing Ozone

The following discussion on health and environmental benefits will focus on benefits expected from lower ambient ozone concentrations. Lower ozone levels are expected due to decreased emissions of VOCs. The benefits of reducing ozone will be extrapolated to be the benefits of reducing VOCs.

Human exposure to ozone primarily affects the lungs. Ozone's most perceptible effects on human health are respiratory symptoms such as coughing and painful deep breathing. These immediate or acute effects appear to be reversible, usually disappearing in a few hours (U.S. Congress, 1989).

Although the short-term effects are important, many health professionals are more concerned that repeated exposure to ozone over a lifetime may result in permanent impairment of the lungs. Animal studies have shown that ozone exposure can cause biochemical and structural changes in the lung. Some of these changes are suspected of playing a role in the development of chronic lung diseases (e.g., pulmonary fibrosis), although there is no scientific consensus regarding the significance of these observed effects.

One type of structural change in the lungs that some scientists believe may be linked to the development of lung fibrosis is the deposition of collagen—a structural protein that contributes to "stiffening" of the lungs. This stiffening contributes to premature aging of the lungs (U.S. Congress, 1989).

Epidemiologic studies have been used to investigate the potential link between exposure and respiratory disease. These studies involve large groups of people who are exposed to oxidant air pollution (mostly ozone) in their daily life and who may experience a variety of adverse responses from this exposure. One epidemiologic study of populations living in southern California suggests that respiratory function is affected by chronic exposure to ozone. The study showed an association between loss of lung function over an extended period of time (5 years) and residing in a high oxidant community (U.S. Congress, 1989).

Some scientists are concerned that ozone and acid particulates and vapors may interact to affect human health. This concern has been prompted by research indicating that these chemicals affect a similar target in the lungs and reach peak concentrations the same time of year. Some laboratory findings suggest that the response of subjects exposed to ozone in conjunction with aerosols is greater than when exposed to ozone alone (U.S Congress, 1989).

There is evidence to suggest that two types of acid, ammonium bisulfate and sulfuric acid, are respiratory irritants and that their "target zone" is the periphery of the lungs, similar to that for ozone. In addition, exercise seems to exacerbate the effects of inhaled sulfuric acid, as has been shown to be the case with the impact of ozone exposure. Moreover, on the east coast, airborne sulfates are most acidic in the summertime, the time of year when peak ozone levels tend to occur (U.S. Congress, 1989).

Possible interaction between ozone and some acidic aerosols is believed by some scientists to affect lung clearance mechanisms, lung function, and acute respiratory hospital admissions. Studies of animals exposed to sulfuric acid show persistent impairment of lung clearance, as does research with ozone. Disturbance of lung clearance mechanisms is believed by some scientists to promote the inception or progression of chronic respiratory disease (U.S. Congress, 1989).

In addition to the above adverse health effects the general population is thought to suffer due to exposure to ozone, there are also subpopulations that are more at risk of experiencing adverse health effects. These groups may include people with the following conditions:

- Chronic Bronchitis (3.5% of the U.S. population)
- Asthma (3.5 - 5% of the U.S. population)
- Allergies (7% of the U.S. population)
- Emphysema (1% of the U.S. population)
- Any individual working or exercising heavily during ozone exposure.

The subgroup of the population with a preexisting disease is more susceptible to ozone because their respiratory systems are already compromised, placing them at greater risk than individuals without preexisting disease exposed at the same ozone dose. The subgroup of the population that works or exercises heavily during ozone exposure is at greater risk than the general population because heavy exercise increases breathing frequency and depth of breathing resulting in a larger ozone dose to lungs and deeper penetration of ozone to the most sensitive lung tissue (U.S. Congress, 1989).

Studies have also shown that there is a subpopulation of otherwise healthy individuals who consistently respond more significantly to the same dose of ozone than do their cohorts. These ozone-sensitive individuals are called "responders." Scientists estimate that from five to 20% of the healthy population may represent a subgroup of responders who are at abnormally high risk for the acute effects of ozone exposure (U.S. Congress, 1989).

Welfare Benefits of Reducing Ozone

Elevated concentrations of ambient ozone are also associated with adverse welfare (nonhealth) effects. In addition to humans, crops and other plant life are also adversely affected by exposure to ozone. Plant life have exhibited higher sensitivity to ozone than the health benchmarks for humans.

Crop losses have been linked with increases in ozone concentrations. At ozone concentrations found in rural areas throughout the United States, ozone is thought to depress yields of cash crops such as soybeans and cotton. Visible injury caused by ozone include light flecks, dark stipples, yellow spots, premature aging, and leaf loss. Reduced growth rates and yields may also occur - even without visible injury (U.S. Congress, 1989).

Severe damage to ponderosa and Jeffrey pines in southern California forests and foliar damage and growth reductions in sensitive strains of eastern white pine have been clearly linked to exposure to ozone (U.S. Congress, 1989). Ozone has been hypothesized as partially responsible for decline of other tree species that have been observed in the eastern United States, Southern Canada, and Europe. In several cases, the location and timing of the declines suggest that air pollutants might have played a role. In controlled experiments, ozone has been shown to produce foliar injury and/or reduce growth rates in young trees of numerous species (U.S. Congress, 1989).

Ozone-induced injury in trees shows up primarily as foliar injury, including leaf or needle discoloration, and premature loss. In advanced cases, needles or leaves and then branches of injured trees die back. For example, ozone injury to eastern white pine needles appears as yellow mottle, with needles ultimately dying back from the tips. Reduced growth rates may precede or follow foliar injury. Increased susceptibility to diseases and other stresses may result from reduced photosynthesis and decreased allocation of carbohydrates to tree roots. Ultimately, trees may die prematurely. All of these effects have been observed in forests of the San Bernadino Mountains as a result of exposure to high concentrations of ozone originating from VOC and NO_x emissions in the Los Angeles basin (U.S. Congress, 1989).

7.3.3 Benefits of Reducing Total Reduced Sulfur Emissions

The proposed regulation is also expected to significantly reduce emissions of total reduced sulfur (TRS) by approximately 295,400 Mg annually. TRS emissions are responsible for the rotten egg smell often associated with areas near pulp and paper mills. The reduction of TRS emissions is expected to alleviate some of the odor problems associated with the production of pulp and paper. The alleviation of some of the odor problems may also lead to other health benefits.

Little is known about the effects of prolonged exposure to environmental odorants on the function of the olfactory system. Studies have shown, however, that atrophic changes can occur in the morphology of some cell types in the olfactory bulbs of rats in association with exposure to a constant flow of a single odorant (National Research Council, 1979).

Odorant stimulants of receptors in the nasal mucosa can elicit marked respiratory and cardiovascular responses. The reported effects, documented in various species, include reduction in breathing, sneezing, bronchodilation, lowering of heart rate (bradycardia), increase in arterial blood pressure, reduction in cardiac output, and vasoconstriction in skin, muscle, splanchnic, and renal vascular beds (National Research Council, 1979).

Virtually all information regarding adverse human reactions to environmental odors arises from self-reports, either spontaneous or solicited, rather than from objective measures of physiologic responses. For example, residents of Lewiston, Idaho exposed to the malodors of a pulp mill signed a petition that stated that "this contamination of our air and its odors affects us from headaches, watery eyes, runny noses, and breathing difficulties..." It is likely that these symptoms resulted in part from odorant stimulation of trigeminal receptors - the same receptors that caused the respiratory and cardiovascular reactions cited in the laboratory studies above (National Research Council, 1979).

Systematic surveys of odor pollution caused by pulp mills have supported the link between odor and the above listed symptoms. In Swedish and American surveys described by Jonsson, 5-10% of respondents experienced shortness of breath, nasal irritation and headache. Fifteen percent of the respondents experienced nausea and sinus congestion (National Research Council, 1979).

Self reports of adverse reactions to odorous pollutants should not automatically be categorized as "annoyance." Undoubtedly, many complaints regarding environmental odors fall neatly into this category, which has been defined as "an effect which has not been demonstrably pathogenic but which involves a negative factor for an individual's comfort and well-being." Odorants from pulp and paper production produce health symptoms that transcend beyond annoyance. Unfortunately, symptoms such as headaches and nasal irritation are not readily measured or verified objectively. Therefore, individuals exposed to odor pollution, particularly those exposed only briefly, are often medically ignored.

7.3.4 Negative Benefits from Air Emission Increases

The above discussion focused on the health and welfare benefits expected to be achieved through air emission reductions of HAPs and VOCs (as related to ozone). However, the proposed regulation is also expected to cause a slight increase in the emissions of a few of criteria pollutants. These pollutants include carbon monoxide (CO), nitrogen oxide (NO_x), sulfur dioxide (SO_2), and particulate matter (PM). Table 7-1 presents the annual emission increases expected to result from the proposed regulation. Although the emission data indicate that the proposed regulation will cause emissions of these pollutants to increase, note that these increases in emissions are a fraction of the decreases in VOC emissions discussed earlier.

Table 7-1
Criteria Pollutant Emission Increases

Criteria Pollutant[1]	Emission Increase (Mg/yr)
CO	300
NO_x	1,300
SO_2	168,200
PM	100

1 For comparison, note that VOC emission decreases are projected to be 715,900 Mg/yr.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless gas that is toxic to mammals because of its strong tendency to combine with hemoglobin to form carboxyhemoglobin (COHb). Thus, the oxygen-carrying capacity of the blood is reduced since hemoglobin that has combined with CO in this manner is not available to transport oxygen. The resultant hypoxemia (deficient oxygenation of the blood) can have detrimental effects on the cardiovascular, central nervous, pulmonary, and other body systems. Low-level CO exposures have been shown to cause aggravation of cardiovascular disease. The proposed regulation is not expected to significantly contribute to these problems because it is expected to cause emissions of CO to increase by only approximately 300 Mg annually.

Nitrogen Oxide

The threat to human health and the environment posed by nitrogen oxide (NO_x) emissions was briefly mentioned in the ozone discussion. NO_x emissions are products of fossil fuel combustion. Once in the atmosphere, NO_x may chemically react with VOC to produce ozone. The health effects of ozone were discussed previously.

The relationship between NO_x and VOC reactions is complicated. Some studies have shown that decreases in either NO_x or VOC emissions do not necessarily lead to decreases in ozone formation. These studies have found that under some conditions found in urban areas, reducing NO_x emissions could lead to increased ozone concentrations. The reactions between NO_x and VOC depend on the balance in concentrations of each pollutant found in the ambient air. When the concentration of NO_x is relatively high to the concentration of VOCs, VOC reductions will be effective but NO_x reductions ineffective in limiting ozone formation. Under the above conditions, reducing NO_x can actually increase ozone concentrations. Conversely, NO_x reductions are most effective and VOC reductions least effective at limiting ozone formation when the concentration of VOCs is relatively high compared to the concentration of NO_x (U.S. Congress, 1989). The uncertainty of the above conditions as they relate to this source category make it difficult to assess the impact of the expected increase in NO_x emissions. The proposed regulation is expected at increase NO_x emissions by 1,300 Mg annually. This increase is not expected to cause significant adverse health or environmental impacts because the magnitude of this increase is much less than the magnitude of the VOC emission reductions.

Sulfur Dioxide

For the criteria pollutants, the increase in the emissions of sulfur dioxide (SO_2) by far outweighs all other increases. The proposed regulation is expected to increase SO_2 emissions by 168,000 Mg annually.

SO_2 emissions are created when fossil fuels (oil and coal) are burned to produce energy. The SO_2 chemically reacts with water molecules in the atmosphere and increases the acidity of rain, snow, and fog. SO_2 transformed into acid rain causes undesirable effects on the environment. Acidic precipitation damages the ecosystems of our lakes, rivers, and streams. Acid rain has also been linked to causing decreases in yields of crops such as oats, soybeans, and wheat.

Acid rain is also linked to causing materials damage and household soiling. Acid rain is partly responsible for corroding construction materials such as statues, buildings, and monuments. Soiling induced by air pollution is also linked to SO_2 emissions.

SO_2 emissions can also be transformed into ammonium bisulfate, ammonium sulfate, and acid sulfate aerosols. The interaction of these chemicals and ozone to adversely affect human health was discussed previously. Both human and animal studies of exposure to acid sulfate aerosols show in changes in pulmonary mechanics, after single brief exposures, altered clearance of particles from the lung after single exposures, persistent shifts in clearance after repeated peak exposures, and lung morphological damages after long-term continued exposures.

Particulate Matter

Particulate matter are very small particles that float in the air or settle very slowly. Particulate matter emissions are associated with adverse health as well as welfare effects. Depending on their size, the particles can move through or collect in the upper or middle part of the respiratory region or collect in the most remote portion of the lungs. One study (Mathtech, Inc., 1988) has documented the link between particulate matter emissions and increased incidences of mortality. The mortality is a result of respiratory or cardiac disease brought on by inhalation of particulate matter. Another study (Ostro, 1987), has evaluated other adverse health effects associated with particulate matter exposure. These effects may include increased incidences of bronchitis and increases in the frequency of lower respiratory illness.

Particulate matter emissions can also result in adverse welfare effects. These emissions can be responsible for increased soiling of household items. Particulate matter may also absorb, scatter, or reflect sunlight, causing a reduction in the amount of light available for photosynthesis and heating. This reaction may also decrease visibility.

7.4 QUALITATIVE DESCRIPTION OF WATER-RELATED BENEFITS

This section provides a qualitative description of the water-related benefits expected to be attained under the proposed regulatory options. The benefit categories examined were divided into aquatic life and human health for the water-related benefits. Aquatic life includes those organisms, primarily freshwater fish, that may be found in effluent receiving waters. Human health concerns include potential carcinogenic and noncarcinogenic risks resulting from consumption of chemically-contaminated fish downstream of pulp and paper effluent, or drinking contaminated water.

Water-related benefits to aquatic life include reduction of toxic, conventional, and nonconventional pollutants to levels below those considered to impact receiving water's biota. Such impacts include acute and chronic toxicity, as well as sublethal effects on metabolic or reproductive functions, physical destruction of spawning habitat, and loss of prey organisms.

Water quality improvements beneficial to human health concerns are the reduction in ambient water contaminant concentrations to levels protective of human health for drinking water or ingestion of chemically-contaminated fish. These human health benefits of particular concern include reduction in both carcinogenic risks and noncarcinogenic hazards for recreational and subsistence anglers. Impacts of proposed BAT on streams presently affected by state fish consumption advisories and bans established in response to concerns about chemical contaminants in pulp and paper mill effluent were also evaluated. An evaluation of potential carcinogenic risks and noncarcinogenic hazards associated with the ingestion of surface water was not specifically conducted because there were no municipal public water intakes within the same river reach or 10 miles downstream from any pulp and paper mill effluent discharges (whichever was greater); however, potential impacts on human health from drinking water consumption were evaluated by comparing modeled instream contaminant concentrations to water quality criteria that are protective of human health (from consumption of water and organisms values).

7.4.1 Background

Pulp and paper mill effluent discharges contain toxic chemical compounds (including toxic contaminants on EPA's list of priority pollutants and nonconventional pollutants), as well as conventional pollutants such as biological oxygen demand (BOD) and total suspended solids (TSS). These contaminants may alter aquatic habitats, impact aquatic life, and subsequently adversely affect human health through the consumption of contaminated fish and water.

Toxic and nonconventional pollutants of concern in pulp and paper mill effluent include acetone, ketones, catechols, guaiacols, aldehydes, chloroform, methylene chloride, chlorinated phenols, polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), adsorbable organic halogens (AOX), chemical oxygen demand (COD), and color. Of particular concern are the organochlorides, a class of compounds known for their resistance to biodegradation, toxicity to aquatic life, and long-range environmental transport, as well as the level at which they concentrate in the fatty tissues of organisms through either bioaccumulation or biomagnification (via the food chain). The effects of toxic and nonconventional pollutants on aquatic life vary with the species, concentration of the chemical, and duration of exposure. However, a number of studies have linked toxic or other biological effects in fish, wildlife, and humans to exposure to these contaminants from pulp and paper mill effluents.

Conventional pollutants (e.g., TSS) can also cause site-specific environmental impacts. For example, habitat degradation can result from increased suspended particulate matter that reduces light penetration and, thus, primary productivity or from accumulation of fibers that can alter benthic spawning grounds and feeding habitat. Another conventional pollutant discharged in pulp and paper mill effluents is BOD, which may alter ecosystem structural complexity and functional relationships as populations of planktonic and macrobenthic organisms decrease or die out while pollution- or anoxia-tolerant bacteria flourish.

The following discussion presents a summary of the pollutants of concern found in pulp and paper mill effluents and a review of their chemical characteristics and their potential effects on aquatic life and human health. The issuance of dioxin-related fish advisories is also discussed.

7.4.2 Pollutants of Concern

From 1989 through 1993 EPA conducted short-term sampling episodes at several pulp and paper mills located nationwide. These mills were selected because of their particular pulping or bleaching technologies or their wastewater treatment systems, or because of particular fiber furnishes used or products produced. The samples were analyzed for chlorinated dioxins and furans; chlorinated phenolics; volatile organics; semivolatile organics; pesticides/herbicides; metals; conventional pollutants (BOD_5 and TSS); and nonconventional pollutants (COD, AOX, and total organic halogens (TOX)). A total of 159 analytes were detected in samples from 11 mills. Of the 159 compounds identified, 36 are priority pollutants, 28 exhibit high to moderate acute toxicity in aquatic life, 37 are systemic toxicants in humans, 55 have been identified as carcinogens/mutagens, and 38 have drinking water criteria values (U.S. EPA, 1992a). Fifty-seven of the contaminants do not have aquatic toxicity data, and the effects on humans are unknown for a majority of the analytes. During the last several years, many mills have made process technology and/or operating changes in the bleach plant to reduce the formation of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), 2,3,7,8-tetrachlorodibenzofuran (TCDF), and other chlorinated pollutants. These changes have resulted in much-improved effluents.

A cooperative long-term sampling effort involving both the industry and EPA was undertaken from 1991 to 1992. The cooperative agreement provided for the sampling of eight bleaching mills that were chosen because of their particular pulping or bleaching technologies or their wastewater treatment systems, or because of particular fiber furnishes used or products produced. Samples were collected to characterize the bleach plant effluent, plant exports (final effluent, pulp, and sludge), and wastewater treatment system performance. This sampling effort detected 49 unique analytes in the mills' wastewater during any point in the production process. Of the 49 contaminants detected, 13 are priority pollutants, 11 exhibit high to moderate toxicity to aquatic life, 14 are systemic toxicants in humans, 13 have been identified as carcinogens/mutagens, and 11 have drinking water criteria values (U.S. EPA, 1992b). The effects on humans are unknown for 50% of the contaminants.

The short-term and long-term sampling studies support previous data indicating that most of the priority pollutants are not present in bleached kraft mill effluents. However, among the priority pollutants that were detected in bleached kraft mill wastewater during these studies are TCDD, chloroform, and methylene chloride, as well as pentachlorophenol and trichlorophenols.

Based on an evaluation of the short-term and long-term sampling data, EPA has identified 26 organic compounds of particular concern (U.S. EPA, 1993b) belonging to three chemical groups—(1) dioxins and furans, (2) volatile organic compounds, and (3) chlorinated phenolics. Of these 26 contaminants, 6 are priority pollutants, 11 are systemic human toxicants, 6 are human carcinogens, 24 are aquatic life acute toxicants, and 26 are aquatic life chronic toxicants. Ambient water quality concentrations (for the ingestion of *organisms* and *water and organisms*) for the protection of human health have been established for 12 and 13 of the contaminants, respectively (Table 7-2).

Examples of observed effects of some of the systematic human toxicants include reproductive and developmental effects, liver toxicity, and fetotoxicity (Table 7-3). All of the human carcinogens evaluated are classified as probable, or B2, carcinogens (indicating an agent for which there is sufficient evidence of carcinogenicity based on animal studies but inadequate data regarding its carcinogenicity from human epidemiological studies) (Table 7-4).

The primary focus of this aquatic life and human health risk assessment is on the 26 organic compounds of particular concern that are produced as a result of the pulp bleaching process (Table 7-2). All 26 organic compounds are evaluated in the assessment for their chronic aquatic life impacts, and 24 are evaluated for their acute aquatic life impacts. Acute aquatic life toxicity values are unavailable for TCDD and TCDF. Due to a lack of information on human health toxicity, only the following 13 pollutants are evaluated for their potential human health impacts:

- Acetone
- 2-Butanone
- Chloroform
- 4-Chlorophenol
- 2,4-Dichlorophenol
- 2,6-Dichlorophenol
- Methylene chloride
- Pentachlorophenol
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,4,6-Tetrachlorophenol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol

A review of potential impacts on aquatic life and human health from exposure to 2,3,7,8-TCDD and TCDF, as well as other toxic pollutants (i.e., priority pollutants and nonconventional pollutants) and conventional pollutants, is presented below.

TCDD and TCDF

TCDD and TCDF were found to occur at every bleaching mill sampled in EPA's 104-Mill Study (U.S. EPA, 1990a). The identification of these highly toxic chemicals, and other PCDDs and PCDFs, in pulp and paper mill effluents where chlorine bleaching is used has led to numerous research efforts on the effects of these chemicals on aquatic life.

Table 7-2
Toxicity Values for the Contaminants Analyzed in the Pulp and Paper Assessment

Contaminant	Human Health AWQC (μg/l) Water & Organisms	Human Health AWQC (μg/l) Organisms	Aquatic Life AWQC (μg/l) Acute	Aquatic Life AWQC (μg/l) Chronic	BCF	RfD (mg/kg/day)	Cancer Slope Factor (q1*)
Acetone	$3.5 \times 10^{+3}$	$2.8 \times 10^{+6}$	$1.0 \times 10^{+4}$	$5.0 \times 10^{+2}$	3.9×10^{-1}	1.0×10^{-1}	
2-Butanone	$1.7 \times 10^{+3}$	$5.4 \times 10^{+5}$	$5.2 \times 10^{+5}$	$7.0 \times 10^{+4}$	1.0×10^{0}	5.0×10^{-2}	
4-Chlorocatechol			$1.58 \times 10^{+3}$	$7.9 \times 10^{+1}$	$1.4 \times 10^{+1}$		
Chloroform	5.7×10^{0}	$4.7 \times 10^{+2}$	$1.33 \times 10^{+4}$	$1.24 \times 10^{+3}$	3.75×10^{0}	1.0×10^{-2}	6.1×10^{-3}
4-Chlorophenol	$2.4 \times 10^{+1}$	$7.7 \times 10^{+2}$	$3.8 \times 10^{+3}$	$1.1 \times 10^{+3}$	$1.0 \times 10^{+1}$	7.1×10^{-4}	
6-Chlorovanillin			$2.13 \times 10^{+3}$	$1.07 \times 10^{+2}$	$2.2 \times 10^{+1}$		
4,5-Dichlorocatechol			$8.9 \times 10^{+2}$	$4.45 \times 10^{+1}$	$7.8 \times 10^{+1}$		
2,4-Dichlorophenol	$9.3 \times 10^{+1}$	$7.9 \times 10^{+2}$	$2.02 \times 10^{+3}$	$7.0 \times 10^{+1}$	$4.07 \times 10^{+1}$	3.0×10^{-3}	
2,6-Dichlorophenol	2.0×10^{-1}		$3.24 \times 10^{+3}$	$1.62 \times 10^{+2}$	$9.3 \times 10^{+1}$		
2,6-Dichlorosyringaldehyde			$2.95 \times 10^{+3}$	$1.475 \times 10^{+2}$	$2.1 \times 10^{+1}$		
5,6-Dichlorovanillin			$1.72 \times 10^{+3}$	$8.75 \times 10^{+1}$	$5.7 \times 10^{+1}$		
Methylene Chloride	4.7×10^{0}	$1.6 \times 10^{+3}$	$1.93 \times 10^{+5}$	$9.65 \times 10^{+3}$	9.1×10^{-1}	6.0×10^{-2}	7.5×10^{-3}
Pentachlorophenol	2.8×10^{-1}	8.2×10^{0}	$2.0 \times 10^{+1}$	$1.3 \times 10^{+1}$	$1.1 \times 10^{+1}$	3.0×10^{-2}	1.2×10^{-1}
2,3,7,8-TCDD	1.34×10^{-9}	1.34×10^{-9}		1.0×10^{-6}	$5.0 \times 10^{+4}$	1.0×10^{-9}	$1.6 \times 10^{+5}$
2,3,7,8-TCDF	8.10×10^{-8}	8.41×10^{-8}		1.9×10^{-4}	8.0×10^{3}	1.0×10^{-8}	$1.6 \times 10^{+4}$
3,4,5,6-Tetrachlorocatechol			$7.26 \times 10^{+2}$	7.3×10^{0}	$9.66 \times 10^{+2}$		
3,4,5,6-Tetrachloroguaiacol			$3.2 \times 10^{+2}$	3.2×10^{0}	$1.9 \times 10^{+3}$		
2,3,4,6-Tetrachlorophenol	$8.1 \times 10^{+2}$	$3.5 \times 10^{+3}$	$8.5 \times 10^{+1}$	$1.0 \times 10^{+1}$	$9.3 \times 10^{+1}$	3.0×10^{-2}	
3,4,5-Trichlorocatechol			$1.8 \times 10^{+3}$	$1.8 \times 10^{+1}$	$4.17 \times 10^{+2}$		
3,4,6-Trichlorocatechol			$3.82 \times 10^{+3}$	$3.82 \times 10^{+1}$	$3.44 \times 10^{+2}$		
3,4,5-Trichloroquaiacol			$7.5 \times 10^{+2}$	7.5×10^{0}	$8.39 \times 10^{+2}$		
3,4,6-Trichloroguaiacol			$3.02 \times 10^{+3}$	$3.02 \times 10^{+1}$	$1.79 \times 10^{+2}$		
4,5,6-Trichloroguaiacol			$3.07 \times 10^{+2}$	3.1×10^{0}	$4.8 \times 10^{+2}$		
2,4,5-Trichlorophenol	$4.9 \times 10^{+2}$	$5.65 \times 10^{+2}$	$4.5 \times 10^{+2}$	4.5×10^{0}	$1.905 \times 10^{+3}$	1.0×10^{-1}	

Table 7-2 (Continued)
Toxicity Values for the Contaminants Analyzed in the Pulp and Paper Assessment

Contaminant	Human Health AWQC (μg/l) Water & Organisms	Human Health AWQC (μg/l) Organisms	Aquatic Life AWQC (μg/l) Acute	Aquatic Life AWQC (μg/l) Chronic	BCF	RfD (mg/kg/day)	Cancer Slope Factor (q1*)
2,4,6-Trichlorophenol	1.6×10^{0}	3.2×10^{0}	$3.2 \times 10^{+2}$	3.2×10^{0}	$3.1 \times 10^{+2}$		1.1×10^{-2}
3,4,5-Trichlorosyringol			$5.28 \times 10^{+3}$	$5.28 \times 10^{+1}$	$1.08 \times 10^{+2}$		

Source: Versar, Inc., 1993.

Table 7-3
Systemic Human Toxicants Evaluated and Their Target Organ Endpoints

Systemic Toxicant	Reference Dose Target Organ and Effects
Acetone	Increased liver and kidney weights; neurotoxicity
2-Butanone	Fetotoxicity
Chloroform	Fatty cysts in liver; fetotoxicity
2,4-Dichlorophenol	Decreased delayed hypersensitivity response
2,3,7,8-TCDD	Reproductive and developmental effects
2,3,7,8-TCDF	Reproductive and developmental effects
Methylene Chloride	Liver toxicity
Pentachlorophenol	Liver and kidney pathology
2,3,4,6-Tetrachlorophenol	Increased liver weights and centrilobular hypertrophy
2,4,5-Trichlorophenol	Liver and kidney pathology
4-Chlorophenol	Unknown

Table 7-4
Human Carcinogens Evaluated, Weight-of-Evidence Classifications, and Target Organs

Carcinogen	Weight-of-Evidence Classification	Target Organs
Chloroform	B2	Kidney
Methylene Chloride	B2	Liver
Pentachlorophenol	B2	Liver
2,3,7,8-TCDD	B2	Liver and Other Organs
2,3,7,8-TCDF	B2	Liver and Other Organs
2,4,6-Trichorophenol	B2	Kidney and Blood

Although much of the research has focused on the effects of TCDD and TCDF on the physiology, life history, and community structure of fish populations, many of the same impacts have been observed in other aquatic species, as well as in terrestrial species that rely on aquatic species as a food source (e.g., fish, crustacea, birds, humans, and other mammals) (Table 7-5). Both TCDD and TCDF have the same toxic endpoints. However, the toxicity of TCDD to aquatic life is estimated to be two orders of magnitude greater than that of TCDF, and the toxicity of TCDD to humans is estimated to be one order of magnitude greater than that of TCDF. Therefore, the following discussion is primarily focused on the nature and properties of TCDD.

Gross signs of TCDD toxicity in laboratory-exposed fish are species-dependent but may include decreased growth rate, fin necrosis, cutaneous hemorrhage, hyperpigmentation, and edema. Fish in the early life stages are more sensitive than adults to TCDD toxicity; thus, environmental levels of TCDD may affect fish populations through reduced hatchability and the development of hemorrhages and subcutaneous yolk sac edema (accumulation of fluid in the membrane sac attached to the embryo) similar to blue-sac disease (Cook et al., 1991). Other impacts on fish exposed to TCDD have also been observed in laboratory studies (Table 7-6). TCDF has been shown to adversely affect survival, growth, and behavior of fish.

The degree of toxicity of the contaminants found in pulp and paper mill effluents is directly related to the bioavailability of these compounds and the potential of organisms to accumulate (absorb) the contaminants in their tissues. Analyses of the tissues of invertebrates and fish downstream from mill effluents have revealed a variety of xenobiotics (foreign compounds not produced by an organism) compared to organisms from upstream sites (Owens, 1991; U.S. EPA, 1992c). The highly hydrophobic organic chemicals, such as TCDD and TCDF, become tightly bound to organic carbon in the water column and in sediment particulates and may not be detected in water. Significant quantities, however, may be taken up by organisms from ingestion of sediments or contaminated organisms. Body burdens of these compounds may reach toxic levels.

Other PCDD and PCDF congeners may be more rapidly metabolized in animals, resulting in lower accumulations and relatively low toxicities. Examination of representatives from simple food chain/web organisms have revealed biomagnification of TCDD and TCDF from phytoplankton and zooplankton through mussels or fish to waterfowl (Broman et al., 1992). Terrestrial wildlife that feed on organisms exposed to pulp and paper mill effluents are also at risk for toxic and reproductive effects (Gilbertson, 1989; Rabert, 1990).

Because TCDD and TCDF are lipophilic, or readily absorbable by fatty tissues, they may be concentrated in aquatic organisms that have consumed contaminated food or water. Broman et al. (1992) noted that the wet weight bioconcentration factor (BCF) for 2,3,7,8-TCDD in fish had experimentally been determined to be in the range of 7,000 to 29,000, lower than that expected based on estimates of the water solubility and

Table 7-5
Affected Organisms and the Physiological and Community Impacts That Have Been Linked to the Presence of 2,3,7,8-TCDD

Effect/Impact	Affected Organisms: Fish	Mollusca	Crustacea (e.g., crabs)	Sea Urchins	Birds	Aquatic Inverts	Plants	Humans	Other Mammals
1. Enzyme Induction	+				+			+	+
2. Immunological	+							+	+
3. Wasting Syndrome	+								
4. Hepatic (liver)	+				+			+	+
5. Growth	+				+		+	+	
6. Developmental (skeletal, organs)	+	+	+		+		+		
7. Dermatological (lesions, fin necrosis)	+				+			+	+
8. Reproductive (fecundity, sperm/oocyte development, spawning)	+		+	+	+				+
9. Early Life History (eggs, embryo, larvae)	+	+	+	+	+		+	+	
10. Gill Function (fused lamellae)	+								
11. Hematological	+							+	+
12. Bioaccumulation	+	+	+		+	+	+	+	+
13. Toxicity (lethal/sublethal)	+	+	+	+	+	+	+	+	+
14. Mutagenicity	+		+			+		+	+
15. Carcinogenicity (risk assessment)	+							+	+
16. Behavioral	+								
17. Community Structure	+					+	+		
18. Species Diversity	+	+				+	+		+
19. Biomass	+	+	+			+	+		+
20. Distribution	+	+	+			+	+		

Source: Adapted from Cooper, 1989.

Table 7-6
Target Organs/Tissues, Effects, and Species-Specific Toxicity Values for TCDD

Organ/Tissue[1]	Lesion	LOAEL[2]	Species[3]	Reference
HEMATOLOGIC - CC				
Leukocytes	Leukopenia	1 µg/kg	RBT	Spitsbergen et al., 1986
Thrombocytes	Thrombocytopenia	1 µg/kg	RBT	Spitsbergen et al., 1986
LYMPHOMYELOID				
Thymus - H	Involution	10 µg/kg	RBT	Spitsbergen et al., 1986
		25 µg/kg	YP	Spitsbergen et al., 1988
Spleen - H, CC	Lymphoid depletion	10 µg/kg	RBT	Spitsbergen et al., 1986
		5 µg/kg	YP	Spitsbergen et al., 1988
Head kidney - H	Hypoplasia	10 µg/kg	RBT	Spitsbergen et al., 1986
		25 µg/kg	YP	Spitsbergen et al., 1988
EPITHELIAL				
Skin - GV, H	Fin necrosis	10 µg/kg	RBT	Spitsbergen et al., 1986
	Fin necrosis, hemorrhage, and ascites	5 µg/kg	YP	Spitsbergen et al., 1988
	Fin necrosis			
	Hyperpigmentation	25 µg/kg	RBT, YP, C,	Kleeman et al., 1988
		1µg/kg	LMB, CF, BG	Kleeman et al., 1988
		13.1 ng/g (food)	C, LMB, CS	Miller et al., 1979
Gill - H	Lamellar fusion	10 µg/kg	RBT	Spitsbergen et al., 1986
	Hypertrophy and hyperplasia	25 µg/kg	YP	Spitsbergen et al., 1988
Stomach - H	Necrosis, atrophy, and hyperplasia	10 µg/kg	RBT	Spitsbergen et al., 1986
	Submucosal edema	26 µg/kg	YP	Spitsbergen et al., 1988
Liver - H	Vacuolization, necrosis	10 µg/kg	RBT	Spitsbergen et al., 1986
		2.3 mg/kg (food)	RBT	Hawkes and Norris, 1977
		10 ng/l		
		25 µg/kg	FHM	Adams et al., 1986
	Bile duct hyperplasia	1 µg/kg	RBT	Spitsbergen et al., 1986
	Lipidosis	25 µg/kg	YP	Spitsbergen et al., 1988
	Glycogen depletion	25 µg/kg	YP	Spitsbergen et al., 1988
	Hypertrophy	10 ng/l	YP	Spitsbergen et al., 1988
	Intracytoplasmic inclusions	2.3 mg/kg (food)	YP	Spitsbergen et al., 1988
		10 ng/l	RBT	Hawkes and Norris, 1977
			FHM	Tietge et al., 1986
CARDIOVASCULAR				
Cardiac	Myocyte necrosis	25 µg/kg	YP	Spitsbergen et al., 1988
	Pericarditis-fibrinous	25 µg/kg	YP	Spitsbergen et al., 1988
	Hypertrophy and hyperplasia	25 µg/kg	YP	Spitsbergen et al., 1988

1 Grossly visible (GV), histological (H), cellular count (CC).
2 LOAEL = lowest observed adverse effect level.
3 Rainbow trout (RBT), yellow perch (YP), bluegill sunfish (BG), carp (C), largemouth bass (LMB), catfish bullhead (CF), coho salmon (CS), fathead minnow (FHM).
Source: Cooper, 1989.

octanol/water partition coefficient (K_{ow}). Thomann (1989) observed that the efficiency of uptake from water increases with increasing log K_{ow} to a maximum when log K_{ow} approximately equals 3 to 6, then decreases with increasing log K_{ow} above 6. He concluded that food chain biomagnification would be significant for substances with log K_{ow} approximately equal to 5 to 6.5 and that this process explains virtually all of the top predator contaminant concentrations. Complexities in natural food webs—including mechanisms that control the uptake, metabolism, and clearance rates—and difficulties in assessing the availability of different toxic compounds as the result of sampling and analytical chemistry problems and natural variability make extrapolations from BCFs obtained in laboratory studies to contaminant flux in food webs under field situations difficult (Broman et al., 1992). Nevertheless, a number of studies have examined bioaccumulation and biomagnification of these compounds in aquatic environments. For example, in the northern Baltic Sea, biomagnification of the three most toxic 2,3,7,8-substituted polychlorinated dibenzo-p-dioxins and dibenzofurans decreased in total 2,3,7,8-PCDDs/PCDFs with increasing trophic level in both the littoral and pelagic food chains. The most toxic 2,3,7,8-substituted isomers accumulated in the tissue of eider duck, but 80% of the consumed total PCDDs/PCDFs were metabolized or excreted (Broman et al., 1992).

BCF values are dependent on the characteristics of the individual chemicals. Bioconcentration is a partitioning process between the lipids of the organisms and the surrounding water, and it is dependent on the amount of freely dissolved chemical available to fish through bioconcentration across the gills. BCFs, however, may be affected not only by variations in the lipid content of different fish species but also by the age of the fish; exposure level; how the concentration of the compound in water was measured (freely dissolved or total chemical); low bioavailability (the dioxins are highly hydrophobic); dissolved organic carbon content of the water (the higher the organic carbon content, the lower the bioavailability of hydrophobic chemicals); organic carbon in sediments; slow uptake rates; migration patterns of fish; and other factors, leading to measured BCFs that are lower than those predicted.

The BCF of 50,000 for TCDD used in this assessment is based on a measured value from laboratory research on rainbow trout, a pelagic freshwater species having a lipid content of approximately 7% (Cook et al., 1991). Relative BCFs measured by Mehrle et al. (1988) for TCDD (39,000) and TCDF (6,049) for the same lowest exposure concentration of TCDD, where fish were least affected, in the same species of fish, yielded a TCDD-to-TCDF BCF ratio of 6.45. Therefore, for this environmental assessment, the BCF for TCDD (50,000) is divided by 6.45, resulting in a TCDF BCF of 7,752 (which was rounded to 8,000).

The persistent and lipophilic nature of TCDD facilitates its bioaccumulation in the fatty tissues of aquatic organisms, particularly fish. In spite of its relative insolubility, TCDD will achieve a steady-state equilibrium between the water column and the sediments (U.S. EPA, 1993a). Concentrations of TCDD in the water column can become elevated relative to the concentrations in the sediments because of the redistribution of contaminated sediments resulting from bioturbation and scouring.

TCDD is known to be extremely toxic to aquatic life, with concentrations as low as 0.038 ng/L producing 45% mortality in rainbow trout over a period of 28 days (Mehrle et al., 1988). Although fewer studies have been conducted on TCDF, it is less toxic than TCDD (Mehrle et al., 1988). With respect to human health, TCDD is listed as a *probable* carcinogen and is known to have adverse effects on reproductive capacity and liver function; TCDF has also been identified as a probable carcinogen. More than 99% of the human health-based risk and noncarcinogenic hazard from bleached kraft pulp and paper mill effluent estimated in this assessment is directly related to TCDD and TCDF.

Other Toxic and Nonconventional Contaminants

Of the 57 volatile organic compounds sampled in the short- and long-term sampling studies, chloroform, methylene chloride, methyl ethyl ketone (2-butanone), and acetone were detected at all of the mills (U.S. EPA, 1992a, 1992b). Chloroform and methylene chloride are toxic (priority) pollutants; methyl ethyl ketone and acetone are nonconventional pollutants. Twelve of the 20 chlorinated phenolics that were found in bleach plant and final effluents are associated with the formation and presence of TCDD and TCDF:

- Pentachlorophenol
- Tetrachlorocatechol
- Tetrachloroguaiacol
- Trichlorosyringol
- 2,3,4,6 Tetrachlorophenol
- 3,4,5-Trichlorocatechol
- 3,4,6-Trichlorocatechol
- 3,4,5-Trichloroguaiacol
- 3,4,6-Trichloroguaiacol
- 4,5,6-Trichloroguaiacol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol.

2,4,6-Trichlorophenol and pentachlorophenol are toxic (priority) pollutants, and the remaining pollutants are nonconventionals.

<u>AOX.</u> Chlorinated compounds can also be measured collectively as AOX, TOX, or TOCl (total organic chlorine). The preferred test measure analyzes AOX concentrations. Previous EPA studies (i.e., the Five Mill Study (U.S. EPA, 1988) and the Integrated Risk Assessment (U.S. EPA, 1990b)) indicate that although the AOX concentrations can be used to determine the removal of chlorinated organics to assess loading reductions, they do not provide information on the potential toxicity of the effluent and therefore are not appropriate to evaluate the potential impacts on the environment. Although no statistical relationship has been established between the level of AOX and specific chlorinated organic compounds, AOX analysis can be an inexpensive method for obtaining the "bulk" measure of the total mass of chlorinated organic compounds.

Historically, the use of AOX as a universal parameter was based on past environmental studies conducted in Sweden. Observations from studies in the Gulf of Bothnia off the coast of Sweden indicated decreases in the density and diversity of fish populations located near the discharges of bleached kraft mills, as compared to fish populations that were located near discharges of unbleached kraft mills (Neuman and Karas, 1988). In addition, fish populations near bleached kraft mill effluents exhibited higher incidences of skin diseases, skeletal deformities, fungal infections, fin erosion, smaller reproductive organs, enlarged livers, higher levels of liver detoxification enzymes, and alterations in blood chemistry and blood cell ratios (Andersson et al., 1988).

Several objections have been raised regarding the use of AOX as a regulatory parameter and the conclusion that the abnormalities found in the Swedish studies could be attributed to the discharge of organochlorines (Carey et al., 1993). These objections are based on the following:

- A correlation between AOX and the effects on the ecosystem had never been demonstrated.
- The Gulf of Bothnia has long been a source of various pollutants that might have contributed to the results of the Swedish studies.
- The bleached kraft mill that was examined had operations that are atypical of well-operated and modern North American mills.
- Site-specific factors made the unbleached kraft mill unsuitable as a control for comparative purposes.

The Canadian government initiated some independent studies to address these objections. Fish collected from Canadian study sites were compared to fish collected from reference sites located away from the mills. Fish collected near the mills were found to have smaller reproductive organs, enlarged livers, higher levels of liver detoxification enzymes, and lower levels of sexual hormones in the blood, and they took longer to reach maturity and had fewer secondary sexual characteristics (McMaster et al., 1991). From this evidence, the Canadian government concluded that the findings of the Gulf of Bothnia study were not unique and that similar effects occurred in the fish communities located near Canadian bleached kraft mills (Carey et al., 1993).

The distribution of the effects in the study did not correlate with AOX, and the major component of AOX (>90%) failed to induce effects in laboratory studies. This information raised questions as to the applicability of AOX for judging impacts on the environment and its use as a regulatory parameter. Because of the lack of data to support the use of AOX in evaluating toxicity, it is not one of the parameters included in this assessment.

Color. Color is also a nonconventional pollutant of concern associated with pulp and paper mill effluent discharges. The intense brown color associated with pulp mill effluents is caused by lignin and its derivatives, which are relatively stable compounds that degrade very slowly in biological treatment systems and in receiving waters. These compounds absorb light at wavelengths between 400 and 500 nanometers, the same spectral band that contains the two most important wavelength peaks for chlorophyll *a* and a majority of the other accessory pigments in algae (Thut and Schmiege, 1991). The absorption of these important wavelengths can inhibit photosynthesis and, consequently, primary production and can diminish the visual cues necessary for organisms to feed or to reproduce (Owens, 1991; Thut and Schmiege, 1991). The effect of color on primary productivity is dependent on the concentration of the effluent in the receiving stream, seasonal variations, depth distributions, and distance from the discharge site.

The overall impact of color on aquatic algae is difficult to determine. Algae are capable of adapting over time to shifts in light levels, or they may become metabolically inactive until they are dispersed out of the effluent plume. Primary production losses in phytoplankton as the result of color in pulping effluents reducing light levels have been measured in the Baltic Sea and in freshwater streams. However, total plankton biomass may remain at the same level as species shift from autotropic (photosynthetic) organisms to heterotropic organisms that use organic carbon inputs (Owens, 1991).

Conventional Pollutants

Prior to the focus on toxic contaminants found in bleaching pulp and paper mill effluents and their effects on the aquatic environment, the regulatory community required mills to comply with BPT criteria. As efforts have shifted to the priority pollutants, the efforts to define the chemical compounds in pulp mill effluents responsible for causing environmental impacts at the community and population levels have been greatly complicated by the presence of conventional pollutants such as organic and nutrient loadings, and fiber and suspended solids (Owens, 1991). Such pollutants, in addition to the pulping and bleaching chemicals, can alter the quantity of oxygen in the water column and sediments through biological oxidative reactions (Poole et al., 1978) and may be assessed by measuring the parameters biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) in the water column. BOD is the amount of oxygen required by aerobic (oxygen-requiring) organisms to carry out normal oxidative metabolism or the amount required by oxidation of metabolic by-products from anaerobic organisms in water containing organic matter. COD is the amount of oxidizable compounds (composed of carbon and hydrogen) present in the water. Another water quality parameter affected by these pollutants is turbidity.

Suspended solids such as bark, wood fiber, dirt, grit, and other debris can cause long-term damage to benthic habitats in freshwater, estuarine, or marine ecosystems. Solids increase water turbidity and reduce the amount and quality of light present, reducing the growth of phytoplankton, algae, and submerged aquatic vegetation. Their presence in the water column can interfere with respiration and feeding by clogging and abrading delicate gill lamellae in organisms such as bivalve mollusks and fishes (Hart and Fuller, 1974, 1979; Rand and Petrocelli, 1984). As solids settle out of the water column, they physically cover and smother stationary or immobile benthic flora and fauna. Freshwater mussels are sensitive to sedimentation stress, and a number of species in the United States are considered endangered and threatened (Williams et al., 1993). Feeding and reproductive habitat of more mobile species, such as crustaceans and fishes, may also be eliminated as the result of solids settling on the bottom. Sediment in the water column or deposited on the bottom can also increase the oxygen demand on the water column as the result of microbial respiration and chemical oxidation of compounds. The resulting reduced oxygen levels (hypoxia) can cause lethal and sublethal effects on sedentary benthic invertebrate populations or lead to the replacement of sensitive species by species more tolerant of reduced oxygen.

Fiber mats are a particular problem associated with pulping effluents (Owens, 1991; Thut and Schmiege, 1991). Decomposition of organic matter in the debris reduces dissolved oxygen levels in the water column and may lead to anoxic conditions in the sediment with accompanying buildup of methane, hydrogen sulfide, and other toxic gases. In the Gulf of Bothnia study off Sweden, oxygen levels in the water column were reduced nearest the effluent, particularly during the summer, with anoxia found in the fiber mat as the result of increased bacterial biomass and activity (Owens, 1991). Reduced levels of oxygen may also complicate efforts to assess chemical toxicity. Studies of fish indicated that decreased oxygen led to increases in the toxicity of both organic and inorganic chemicals by about 1.5-fold, as a result of the increased rate of flow across the gills at reduced oxygen levels. The effect on lethal and sublethal toxicities appeared slight; however, this activity resulted in higher concentrations of pollutants in the vicinity of gill membranes and accompanying higher diffusion of the toxics across the membrane (Rand and Petrocelli, 1984).

Where effluent discharge rates are too low for color to inhibit photosynthesis or in streams that are too shallow for color to significantly attenuate light, algae production can be greatly enhanced by the nutrients contained in the effluent (Stockner and Costella, 1976). Orthophosphate, and particulate nitrogen and phosphorus, the most prevalent nutrients in pulp mill effluents, have been shown to enhance algal productivity at effluent concentrations in the receiving stream of up to 25% (Walsh et al., 1982). However, algal production begins to rapidly decline at particulate nitrogen and phosphorus effluent concentrations above 25%.

Studies of fish populations in pulp and paper mill effluent receiving streams have shown that adverse effects on the reproductive organs, livers, detoxification enzymes, and sexual hormones continue following modernization of technologies, indicating continued water quality and habitat degradation resulting from nonchlorinated nonconventional pollutants (Carey et al., 1993). The principal sources of soluble BOD materials are the black liquor and associated soluble materials from the pulp washing, volatile organics from the condensate streams, and various additives (Poole et al., 1978). A number of studies have investigated improvements in microbial treatment of effluents to reduce BOD, COD, and AOX (e.g., Häggblom and Salkinoja-Salonen, 1991). The proposed secondary wastewater treatment BPT controls should reduce levels of total suspended solids (TSS) released in pulp, paper, and paperboard mill effluents by 110 million kg annually and provide improved aquatic habitat quality by decreasing turbidity and sedimentation in receiving waters as well as by decreasing levels of toxic chemicals that bind to the solids. Poole et al. (1978) noted that biological treatment may not be effective in removing the substances that contribute to the color of the waste stream, although new developments in reducing color would also reduce the total organic content of the effluent, with subsequent reduction in BOD. The proposed BMP for chemical oxygen demand (COD) and color effluent limitations will control losses and discharges of pulping liquors and associated wood extractives to reduce aquatic impacts from loadings of organic and wood extractive constituents.

7.4.3 Recreational Fisheries

Two studies conducted by EPA confirm the use of fish tissue as a good indicator of bioaccumulated TCDD in aquatic ecosystems. The National Dioxin Study, which began in 1983, found concentrations of TCDD in fish tissue that range from below the detection limit of 1 pg TCDD/g wet weight of whole organism to a maximum of 85 pg/g (U.S. EPA, 1987). This study found the most frequent occurrences and highest concentrations of TCDD in fish tissue in fish collected in the Great Lakes and downstream from kraft paper mills. The National Study of Chemical Residues in Fish (NSCRF) sampled bottom-feeding fish and game fish from 388 sites located nationwide (U.S. EPA, 1992c). As a result of the National Dioxin Study, the site locations for the NSCRF were biased toward areas where dioxins were likely to be found (e.g., below the discharge of bleaching pulp and paper mills). In fact, TCDD was detected in fish from 70% of the sites, with a maximum tissue concentration of 204 pg/g and an average concentration of 6.8 pg/g. TCDF was detected in fish from 89% of the sites, with a maximum concentration of 404 pg/g and an average concentration of 13.6 pg/g.

The habitat and physiology of aquatic organisms determine the exposure routes. Water acts as the medium for the transport and partitioning of dioxins and furans between particulate organic matter, sediments, and the biota (U.S. EPA, 1993a). Cook et al. (1990) reported that food ingestion contributed to 75% of the total TCDD uptake in fish and that the uptake from water was considered negligible in the absence of contaminated sediments. Laboratory exposure studies showed that when TCDD was added to water containing contaminated sediments, there was no observed increase in TCDD uptake (Cook et al., 1990). It was concluded that the ingestion of sediment and direct gill contact with suspended sediment were more important in uptake rates than the direct uptake of freely dissolved TCDD via gill ventilation.

The physical and chemical degradation of dioxins and furans occurs very slowly. Fish are exposed to dioxins and furans through the ingestion of contaminated sediments and prey species associated with sediments (U.S. EPA, 1993a). Many species of fish, such as minnows and suckers whose diets include large quantities of detritus, readily ingest sediment and/or suspended sediments. Gizzard shad (*Dorosoma cepedianum*) consume 20% of their wet weight in dry sediment daily and are capable of digesting 50% to 66% of the organic matter contained therein (Mundahl, 1991). The NSCRF found that TCDD was found more commonly and at higher average concentrations in bottom-feeding species such as carp (*Cyprinus carpio*) than in fish species that live higher in the water column (U.S. EPA, 1992c). The concentrations reported in the NSCRF were not normalized for percent lipid concentration, and therefore conclusions regarding the relationship between high tissue concentration and bottom-feeding fish have not been validated.

Human exposure to waterborne pollutants usually occurs through the ingestion of contaminated drinking water or fish tissue. Because of the virtual insolubility and lipophilic nature of TCDD and TCDF, the primary exposure route for these pollutants is through the ingestion of contaminated fish tissue (U.S. EPA, 1984). Human health impacts resulting from the other pollutants in pulp and paper mill effluents are also primarily the result of exposures through contaminated drinking water and ingestion of contaminated fish. A variety of compounds may cause toxic reactions, are suspected of producing abnormal reproductive function, or may be human carcinogens, such as chloroform, methylene chloride, chlorinated phenolics, and dioxins and furans.

International investigations of the effects of dioxins and furans on humans have suggested that several unusual mechanisms are involved in the development of acute and chronic impacts resulting from exposure to these compounds. Epidemiological studies suggest that dioxins are carcinogenic to humans through increased expression of oncogenes and/or decreases in the expression of tumor suppressor genes through the action of the aryl hydrocarbon (Ah) or dioxin receptors; by affecting the regulation of other steroid hormone and growth factor receptors, such as estrogen or epidermal growth factor receptors, to alter cell differentiation and proliferation; or by compromising immune surveillance and viral defense (Silbergeld, 1991). Further work on the noncarcinogenic effects of dioxins indicates that reproductive function may be altered at low levels of exposure.

The potential impacts caused by the ingestion of contaminated drinking water are not evaluated for this assessment because there are no municipal public water intakes within the same river reach or 10 miles downstream from any pulp and paper mill effluent discharge (whichever was the greater distance). For these reasons, the population used to determine the potential impacts to human health was based on the portion of the population that is involved in recreational and subsistence fishing.

7.4.4 Fish Advisories

Fish advisories and bans are the management tools used by state agencies to reduce the health risks to recreational and subsistence anglers that are associated with eating contaminated fish. Fish advisories perform a dual function: (1) they inform the public of the high levels of pollutants found to occur in locally caught species, and (2) they provide guidance as to the safe levels of consumption for various subgroups in the population (e.g., children, adults, pregnant or nursing women).

The two procedures currently available for developing fish consumption advisories are from the U.S. Food and Drug Administration (FDA) and EPA. The FDA is charged with regulating the risks to the general public from contaminants contained in fish that are sold in interstate commerce. The FDA action levels are designed to address national needs, and they are based on national consumption patterns. Also, the FDA takes a risk management approach that considers the economic impact the action levels may have on the commercial fishing industry. In contrast, the EPA approach is designed to provide states with a methodology that assesses the health risk to the state's recreational and subsistence anglers and allows the development of action levels based on the region-specific fishing habits of the groups at risk. FDA action levels are much higher than EPA-derived action levels because of the FDA's national perspective. Action levels derived using the EPA risk assessment approach typically indicate a much higher risk associated with fish consumption because the scope is local, is concerned only with protecting the health of the public, and does not give any consideration to economic impacts. The availability of these two methods has led to inconsistencies in action levels from state to state, which can be particularly confusing to anglers when waterbodies cross interstate boundaries.

From the 1960s through the 1980s, most state agencies used the FDA action levels for setting their fish advisories (Reinert et al., 1991). With the promulgation of the 1987 amendments to the Clean Water Act, EPA developed water-quality-derived procedures based on risk assessment techniques. Some of the states replaced their FDA action levels with those derived by using the EPA procedures. However, a 1989 survey (Table 7-7) showed that of the 37 states reporting to have waterbodies under some sort of fish or shellfish consumption advisory, 34 states still derived some or all contaminant levels of concern from the FDA action levels (Cunningham et al., 1990). Thirty states acknowledged the use of or intent to use a risk assessment methodology, and only 11 states based all of their advisories on risk assessments.

The disparity of state action levels is evident among the fish advisories for streams affected by pulp and paper mills.' Twenty-nine bleaching mills discharge into receiving streams that are presently under fish advisories for dioxins (as of June 1993). These 29 mills are located in 15 states, for which there are 10 different action levels (Table 7-8).

Fish advisories provide the species of fish that may contain the contaminants of concern, recommendations regarding the amount of fish tissue that is safe to consume, and the population subgroups that may be at risk. As of June 1993, 23 receiving streams of bleaching pulp and paper mills had fish advisories in place for dioxins (Table 7-9).

Table 7-7
Various Methodologies and Their Frequency of Use by States for Deriving Action Levels for Issuing Fish Advisories

Methods	Number of States
Derive some or all contaminant levels of concern from FDA action levels	34
Base all advisories on risk assessment	11
Base advisories on risk assessment only when FDA action levels do not exist	10
Currently developing a risk assessment approach	9
Do not plan to use a risk assessment approach	10
Method unknown	11

Notes: 1. Some states may use more than one method.
2. EPA's risk assessment guidelines were used as written or in modified form by 18 states.
3. States used a state method independent of EPA's approach; 8 states used two or more risk assessment methods; 1 state did not specify which risk assessment method was used.

Source: Reinert et al., 1991.

Table 7-8
State Action Levels for Dioxin

State	Action Level for Dioxin ($\mu g/kg$)
Arkansas	0.007
California	Conducts site-specific risk assessments
Florida	0.009
Louisiana	0.002
Maine	0.0015
Maryland	0.0013
Michigan	0.01
Minnesota	0.000032
Mississippi	0.005
New Hampshire	Sets advisories based on risk
North Carolina	0.003
Pennsylvania	25.00 (FDA action level)
Texas	0.007
Virginia	0.003
Wisconsin	0.01

Table 7-9
Receiving Streams of Bleaching Pulp and Paper Mills Under Dioxin Fish Advisories, the Advisory Type, and Species Whose Consumption Is Limited[1]

Receiving Stream	Advisory Type[2]	Fish Species Covered by Advisory
Blackwater River, VA	NCGP	Bottom-feeding species
Houston Ship Channel, TX	NCSP, RGP	Catfish, blue crabs
Kennebec River, ME	NCSP, RGP	All fish species
Escatawpa River, MS	RGP	All fish and shellfish species
Ouachita River, AR	NCSP, RGP	All fish species
Escanaba River, MI	NCGP	All fish species
Androscoggin River, ME	NCSP, RGP	All fish species
Bayou La Fourche, LA	NCGP	All fish and shellfish species
Red River, AR	NCGP	Catfish fillet
Fenholloway River, FL	RGP	All fish species
Codorus Creek, PA	NCGP	Green sunfish
Neches River, TX	NCSP, RGP	All fish and shellfish species
Penobscot River, ME	NCSP	All fish species
St. Louis River, MN[3]	NCSP, RGP	All fish species
Androscoggin River, NH	NCGP	All fish species
Pacific Ocean, CA	NCGP	All fish and shellfish species
Potomac River; N. Branch, MD	NCGP	Bottom-feeding fish, channel catfish, bullhead catfish
Leaf River, MS	RGP	Bottom-feeding species (>22 in or >5 lb)
Roanoke River, VA	NCSP	All fish species, except herring, shad, and shellfish
Rainy River, MN[3]	NCGP, RGP	All fish species
Pigeon River, NC	NCGP	All fish species
Sacramento River, CA	NCGP	All fish species
Wisconsin River, WI[4]	NCGP	Carp, white bass

1 Based on data contained in EPA's Fish Advisory Database as of June 1993.
2 Codes that indicate the advisory type: NCGP: No consumption fish advisory or ban: Advises against consumption of fish or shellfish species by the general population. NCSP: No consumption fish advisory or ban for a subpopulation: Advises against consumption of fish or shellfish species by a subpopulation that could be at potentially greater risk (e.g., pregnant women, nursing mothers, or children). RGP: Restricted consumption fish advisory or ban: Advises restricted consumption (e.g., a limited number of meals or limited sizes of meals per unit time) of fish or shellfish species by the general population. RSP: Restricted consumption fish advisory or ban for a subpopulation: Advises restricted consumption (e.g., a limited number of meals or limited sizes of meals per unit time) of fish or shellfish species by a subpopulation that could be at potentially greater risk (e.g., pregnant women, nursing mothers, or children).
3 Advisory also covers PCBs and mercury in the same fish species.
4 Separate advisory in place for mercury covering same geographic area.

7.5 POTENTIAL ECOLOGIC BENEFITS

7.5.1 Introduction

In an effort to more fully evaluate the benefits of this and future regulatory actions, the Agency has initiated preliminary assessments of the ecologic benefits associated with reducing dioxin concentrations in pulp and paper facility effluent (and consequent reductions in land applied sludges). In this section, these preliminary ecologic risk studies are described in terms of their focus, results, limitations, and implications for future research.

The ecologic assessments are focussed on the potential ecological risks via two types of exposure pathways: aquatic and terrestrial. The endpoints of concern are selected aquatic, avian, and mammalian species of concern. These include bald eagles, ospreys, hawks, bluebirds, raccoons, otters, several species of fish, and other wildlife species that may be exposed to dioxins directly or through the foodchain. Preliminary results suggest that under some modeling scenarios, modest ecologic risks are predicted for several wildlife species due to baseline levels of dioxin originating at pulp and paper facilities.

7.5.2 Ecologic Risks Via Aquatic Exposure Pathways

The aquatic exposure pathways ecologic risk assessment (RCG/Hagler Bailly, 1993) describes the methodologies and results of a modeling process to predict the potential risks posed to ecological receptors by current disposal practices of pulp and paper mill sludges and wastewater streams contaminated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzo-p-furan (TCDF). Two disposal/release practices are considered:

- Point source releases of mill waste streams directly into rivers

- The land application of contaminated sludges (and subsequent runoff into nearby rivers).

The main category of potential wildlife risk addressed in the aquatic pathways assessment is risks posed to piscivorous wildlife (bald eagle, *Haliaeetus leucocephalas*; osprey, *Pandion haliaetus*; and river otter, *Lutra canadensis*) because of TCDD/TCDF accumulation in their diet. These species would be most at risk to TCDD/TCDF contamination because of their position at the top of aquatic food chains and the potential for biomagnification.[1]

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[1] Although dioxin-like compounds can affect fish health and reproduction, available toxicity data indicate that piscivorous wildlife generally are more sensitive than the fish themselves (Eisler, 1986; U.S. EPA, 1993a), or other aquatic organisms such as amphibians, invertebrates, and plants (U.S. EPA, 1993a). Piscivorous wildlife thus are among the most sensitive organisms to TCDD/TCDF contamination in aquatic systems. Reproduction is the most sensitive ecologically relevant endpoint in mammals and birds (Eisler, 1986; U.S. EPA, 1993a).

Ideally, the risks to the endpoints listed above would be evaluated through site-specific studies, environmental data collection, and the development and validation of fate and transport and bioaccumulation models using those data. This site-specific work, however, was beyond the scope of the project. Instead, a generic methodology based on available data on land sludge application sites and mill waste streams from across the country was developed to evaluate whether the two disposal options are generally likely to result in risks to the receptors identified above.

7.5.3 Point Source Discharges

Methods

Current information on effluent discharges of TCDD/TCDF from 100 pulp and paper mills throughout the United States was used, in conjunction with flow data from the receiving waters, to predict sediment and fish TCDD and TCDF concentrations. Fish tissue concentrations were predicted in three ways (RCG/Hagler Bailly, 1993):

1) Using a simple dilution/bioconcentration (BCF) model

2) Using the water column predictions of the dilution/BCF model, a sediment partitioning model (EPA's DRE model, described in RCG/Hagler Bailly, 1993), and biota-sediment accumulation factors (BSAF)

3) Using predicted sediment concentrations from the EPA sediment partitioning model, in conjunction with a simple bio-energetic model of contaminant bioaccumulation.

The first two approaches are also used for estimating fish tissue concentrations and human health risks elsewhere in this RIA. For each of the approaches, the predicted concentrations of TCDD and TCDF in fish tissue are compared to threshold concentrations derived for adverse impacts to otter, bald eagle, and osprey. The critical fish tissue thresholds derived for each species are presented in Table 7-10. Fish tissue threshold concentrations are expressed as TCDD or equivalents (TCDD-EQ), which include other chlorinated dioxin and furan compounds according to their biological potency relative to TCDD (U.S. EPA, 1992d).

Results

Table 7-11 presents the predicted median and 90th percentile fish tissue TCDD-EQ concentrations in receiving waters, given the distribution of effluent discharge levels across U.S. pulp and paper mills (Tetra Tech, 1993a), using the dilution/BCF model, the sediment partitioning model with BSAFs, and the sediment partitioning model in conjunction with the bio-energetic model.

Table 7-10 Threshold Concentrations of TCDD-EQ in Fish	
Endpoint	**Threshold Concentration of TCDD-EQ in Fish (ppt; whole body)**
Causes Adverse Impacts to Otter	9
Causes Adverse Impacts to Osprey	70
Causes Adverse Impacts to Bald Eagle	140

Table 7-11 Predicted TCDD-EQ Whole Fish Tissue Concentrations At Effluent Discharge Points (ppt)		
Model	**Median[1]**	**90th Percentile[1]**
Dilution/BCF	1.2	12.5
Sediment Partitioning/BSAF[2]	0.005	0.05
Sediment Partitioning/ Bio-energetic model:		
sunfish	0.03	0.32
carp	0.03	0.35
walleye	0.07	0.69

1 Based on median and 90th percentile water column concentrations derived by Tetra Tech (1993a).

2 A BSAF of 0.3 for fish was used for the sediment partitioning model (U.S. EPA, 1993a).

The three models predict fish tissue concentrations that differ by three to four orders of magnitude:[2]

- The dilution/BCF model 90th percentile predicted value of 12.5 ppt exceeds the threshold values for adverse impacts to otter.
- The sediment partitioning/BSAF and sediment partitioning/bio-energetic model predict median and 90th percentile fish tissue concentrations below all of the threshold values.

These results suggest only modest (perhaps negligible) risks at baseline conditions; however, several caveats apply that imply the risks may be greater than portrayed by the preliminary analyses. For example, the analysis considers discharges from only one facility at a time, whereas in many river segments there are multiple pulp and paper dischargers. In addition, the simplified modeling scenarios do not account for the contributions made by other sources of dioxins, including sediment banks (which are the cumulative result of historic loadings) or "hot spots" (e.g., locations where sediment sinks spatially concentrate dioxins). Evaluation of multiple sources and historical loadings can best be evaluated on a site-specific basis, for different rivers and streams can differ dramatically in point sources of TCDD and in sediment transport characteristics. Such site-specific analysis is beyond the scope of the present study.

7.5.4 Land Application

Potential risks posed by the land application of sludges contaminated with TCDD and TCDF are assessed by estimating river sediment concentrations of TCDD/TCDF at the point at which runoff from the land application site may enter the river, and then estimating the downstream dilution of this sediment concentration. Watershed input parameters for sediment dilution with distance downstream were derived from the drainage basin of the Wisconsin River, a large river draining a northern forested region of the United States (RCG/Hagler Bailly, 1993). The resultant sediment concentrations are used to predict fish tissue concentrations using the sediment partitioning model described above, and these fish tissue concentrations are compared with the critical tissue levels for protection of otters, ospreys, and bald eagles.

Using the bio-energetic uptake model to predict fish tissue concentrations indicates that while the median scenario does not result in risks to piscivores, the 90th percentile scenario results in predicted fish tissue concentrations in different species of between 4.3 and 9.2 ppt,

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[2] The sediment partitioning model accounts for the strong tendency of TCDD/TCDF to adhere to organic carbon particulate matter, hence that model (either in conjunction with BSAFs or a bio-energetic model) best addresses the fate of TCDD/TCDF in the water column (relative to the dilution/BCF model).

whole body (Table 7-12). Walleye whole body concentrations also exceed the river otter threshold of 9 ppt.

Combining the results of the bio-energetic fish bioaccumulation model on the 90th percentile application scenario with the incremental dilution factors obtained from the Wisconsin River drainage basin, the tissue concentration in the upper trophic level walleye will not decline to below the most stringent state fish consumption advisory threshold (Maine's criterion of .3 ppt) until 40 km to 50 km downriver of the application site. The fish flesh concentration will, however, have declined to below the critical otter concentration of 9 ppt by 10 km downstream. Thus, the 90th percentile land application scenario on a river equivalent to the Wisconsin could result in risks of fish advisories being imposed over 50 km of river and chronic reproductive risks to 2 otters (assuming an otter density of approximately one animal per 4 river km (Melquist and Hornocker, 1983, as cited in Melquist and Dronkert, 1987). The median and 90th percentile concentrations predicted using the BSAF model are all below the threshold concentrations.

Table 7-12
Fish Tissue Concentrations Predicted Using Bio-energetic Model
(ppt TCDD-EQ Whole Fish)

Fish Species	Median Application Scenario	90th Percentile Application Scenario
Sunfish	0.23	4.33
Carp	0.25	4.68
Walleye	0.49	9.21

7.5.5 Discussion

The results of the preliminary aquatic pathways ecologic risk assessment indicate that, given simplifying modeling assumptions, at current discharge levels an individual pulp and paper point source discharger poses modest (perhaps negligible) risks to otters, ospreys or bald eagles, or of fish consumption advisories in a hypothetical large river. However, this result must be interpreted with caution. Given the uncertainties inherent in this preliminary ecologic risk modeling process, it is not certain how these hypothetical risks would compare to actual risks in the field. For example, more significant risks to wildlife receptors may exist if several point sources were discharging into the same river area. Furthermore, this analysis considers only the potential risk posed by current point source discharges. Risks from TCDD stored in sediment from historic loadings are not evaluated (i.e., the analysis assumes a background concentration of zero).

The study has also shown that, while most single land application sites would be unlikely to result in risks to otters, ospreys or bald eagles, the largest land application sites receiving sludge with high concentrations of contaminants may do so, and that these risks could extend up to 10 km (for otter) and 50 km (for fish advisories) downstream of the application site. Locations with multiple land application sites, and/or a land application site located near a point source discharger, and/or sites located on smaller river systems may generate more appreciable ecological risks.

The prediction of limited risks should be regarded with caution for two reasons:

1) The modeling process has not accounted for existing sediment loads of TCDD or TCDF. Historical discharge regimes at mill sites may have resulted in greater loadings of contaminants being discharged to receiving bodies than the current levels on which the modeling results are based. Thus, higher discharge rates in the past may have resulted in situations where the existing sediment concentrations are close to or above critical thresholds. If this were the case, current discharge rates may prevent these sediment concentrations from falling below ecotoxicological or fish advisory trigger levels.

   The fact that fish advisories are in force on several northern states rivers because of fish tissue dioxin levels is evidence that historical discharge rates have been greater than are currently practiced and that the sediments in these rivers have acted as contaminant banks. Reducing input rates may slowly reduce the contaminant levels in these sediments and result in fish tissue concentrations falling below the advisory trigger levels.

   The actual dynamics of such situations (i.e., the mass flux of contaminants and the time required for "natural" clean-up) could be investigated only on a site-specific basis. This, however, was beyond the scope of the preliminary analysis.

2) The above analyses describe a hypothetical river system where the dioxin and furan inputs have been uniformly distributed downstream. In actual rivers, however, this may not be the case, and contaminant concentrations may be spatially irregular, i.e., there may be areas of relatively high or of low concentrations. Areas of high concentration ("hot spots") could occur on river sections where flow is impeded, resulting in a greater deposition of fine organic particles carrying greater contaminant concentrations.

   In such areas of impeded flow (e.g., behind dams or in backwaters), other aspects of the sediment-fish-water dynamic might result in higher fish tissue concentrations. For example, the BSAFs used in the analyses above are representative of the suite of fish species likely to be found in a river. In depositional areas behind dams or backwaters, however, bottom-feeding, warm water fish such as carp and catfish might have a greater proportional representation in the fish community. Given their dietary habits and high lipid content, this community shift could result in an effective increase in the BSAF and, therefore, higher fish tissue concentrations in general.

Furthermore, in depositional areas where the sediments are largely fine-grained and the water is slow-moving, the dynamics between sediment, water, and organisms may be altered in such a way that the water column concentration of TCDD/TCDF is increased. This could increase the fish tissue concentrations by enhancing gill uptake.

Thus, while the current discharge and land application rates might not result in a significant level of risk to receptors under the hypothetical scenario, it is possible that on real rivers the local discharge history and the river's morphology may alter this conclusion.

7.5.6 Ecologic Risks From Terrestrial Pathways

A preliminary assessment of terrestrial pathway risks associated with land disposal of dioxin-laden sludges from pulp and paper facilities (Abt Associates, 1993) was conducted in a fashion similar to that described above for the aquatic pathway. The general results also are similar to those derived from the aquatic pathway. Specifically, the preliminary ecologic risk assessment found that, depending on the land application scenario, low level risks (risk quotient values between 1 and 10) were found for raccoons, shrews, hawks and bluebirds at both central tendency and high-end exposure scenarios. These preliminary findings suggest that although baseline risks are not likely to be extremely high, some species in some application settings are likely to face modest risks.

7.6 SUMMARY OF QUALITATIVE BENEFITS

Reductions in air emissions of individual hazardous air pollutants (HAPs) are expected to reduce carcinogenic risks as well as other human health impacts. Health benefits are also expected from emission reductions of volatile organic compounds (VOCs), which are a precursor to the formation of ozone. VOC reductions will also produce welfare benefits associated with reductions in crop losses and plant damages. Additionally, the proposed regulation is expected to significantly decrease emissions of total reduced sulfur compounds. Total reduced sulfur emissions are responsible for the odor problem often associated with pulp and paper production. These total reduced sulfur emission decreases are expected to result in improved health and welfare benefits due to the alleviation of the odor problem. Finally, limited negative benefits will result from small increases in carbon monoxide, nitrogen oxide, sulfur dioxide, and particulate matter; because these increases are not appreciable, their negative impacts on benefits will be minimal.

Water-related benefits to aquatic life include reduction of toxic, conventional, and nonconventional pollutants to levels below those considered to impact the biota of receiving waters. Such impacts include acute and chronic toxicity, as well as sublethal effects on metabolic or reproductive functions, physical destruction of spawning habitat, and loss of prey organisms. Water quality improvements beneficial to human health concerns are the reduction in ambient water contaminant concentrations to levels protective of human health for drinking water or ingestion of chemically-contaminated fish. These human health benefits of particular concern include reduction in both carcinogenic risks and noncarcinogenic hazards for recreational and subsistence anglers. Water quality improvements are also expected to impact streams presently affected by state fish consumption advisories and bans established in response to concerns about chemical contaminants in pulp and paper mill effluent.

The Agency has also performed a preliminary assessment of the ecologic benefits associated with reducing dioxin concentrations in pulp and paper mill effluent. The assessment focussed on the potential risks to selected aquatic, avian, and mammalian species via two types of exposure pathways: aquatic and terrestrial. The results suggest that under some modeling scenarios, modest ecologic risks are predicted for several wildlife species due to baseline levels of dioxin originating at pulp and paper facilities.

8.0 QUANTITATIVE ASSESSMENT OF BENEFITS

8.1 INTRODUCTION

This chapter provides quantified and monetized estimates, to the extent feasible, of the national-level air- and water-related benefits of the proposed rule. Then, because some of the benefits are highly site-specific, quantitative estimates of benefits for three case study sites are presented in Chapter 9.0. Finally, a comparison of the potential benefits and costs is provided in Chapter 10.0.

8.2 AIR BENEFITS METHODOLOGIES

This section summarizes the methodologies used to quantify the potential health and environmental impacts of reduced air pollutant emissions resulting from the implementation of the integrated regulation. Several approaches for quantifying some benefit categories are presented while other benefit categories are left unquantified due to lack of data.

To ensure that an economically efficient regulatory alternative is chosen, an incremental analysis must be performed. Therefore, benefits for several regulatory alternatives will be presented. Potential impacts were evaluated for the proposed regulation (proposed alternative 26) and two regulatory alternatives more stringent than the proposed regulation, regulatory alternatives 24 and 25. Of the three regulatory alternatives evaluated, regulatory alternative 25 achieves the greatest emission reductions. The impacts were calculated using mill-specific information for the 160 mills that will be affected by the NESHAP portion of the regulation. Pollutant emission and emission reduction data are taken from data detailed in the Background Information Document.

The potential impacts of reducing hazardous air pollutant emissions can be separated into two health benefits categories. The first health benefit category evaluated will be the reduction in annual cancer incidences due to carcinogenic HAP emission reductions. This approach uses emissions data and the Human Exposure Model, version I (HEMI), to estimate the annual cancer risk caused by HAP emissions from the pulp and paper industry. This benefit category is calculated as the difference in annual cancer incidences at baseline and after implementation of each regulatory alternative. The benefit category will then be monetized by applying a range of benefit values for each cancer incidence reduced. This approach provides a range of the monetized benefits associated with this category.

The second category of health benefits expected to result from reduced HAP emissions is reduced human exposure to noncarcinogenic HAP emissions. For each noncarcinogenic HAP for which the Agency had health benchmark information, the Agency performed a baseline and post-regulation exposure assessment to estimate the number of people exposed to above health benchmark levels of noncarcinogenic HAPs. The total quantified benefits attributable to reducing noncarcinogenic HAP emissions is the difference in the number of people exposed to above health benchmark levels of each of the pollutants examined at baseline emissions and at calculated post-regulation emissions. Lack of valuation data prevents the Agency from monetizing this benefits category.

Estimating the benefits of controlling volatile organic compound emissions is a difficult task. The control of VOC emissions is important because VOC emissions in the atmosphere may possibly transform into ambient ozone. Since reductions in VOC emissions lead to reduced ozone formation, benefits data for reducing VOC emissions are indirectly derived from the known benefits of reducing ambient ozone levels.

The method used to monetize the benefits of reducing VOC emissions applies average benefit per Megagram estimates to the total amount of VOC emission reductions calculated for each regulatory alternative. This calculation estimates the total monetized benefits expected to result from the implementation of each regulatory alternative. This approach assumes a linear relationship between the transformation of VOC into ozone.

This valuation approach uses a benefit per Megagram estimate extrapolated from a previous study that assessed the nationwide benefits of reducing ambient ozone concentrations. The study quantified the acute health effects and agricultural benefits expected to result from various levels of VOC control. The extrapolated benefit per Megagram estimate will be used to represent the lower-bound estimate of the range since the estimate does not account for important benefit categories such as chronic health effects.

In addition to presenting a method for quantifying some health and welfare benefit categories attributable to VOC emission reductions, the Agency also conducted an incremental VOC cost-effectiveness analysis for the MACT portion of the integrated rule. Since lack of data prevents a complete quantification of all categories of benefits attributable to these emission reductions, this cost-effectiveness analysis presents an additional tool to the Agency for evaluating the various regulatory alternatives.

The fourth category of benefits evaluated, the benefits of reducing total reduced sulfur emissions, will be left unquantified. Chapter 7.0 discussed in detail the potential health and welfare effects associated with total reduced sulfur emissions. However, the effects cannot readily be quantified. Lack of quantifiable effects and benefits data prevents this benefit category from being monetized.

The final category of benefits examined in this section are the negative benefits of increased criteria pollutant emissions expected to result. The approach used to monetize this benefit category is similar to the first method used to monetize VOC emission reductions. The Agency has established a benefit per Megagram estimate for sulfur dioxide and particulate matter. These benefit estimates will be used to represent the average negative benefits expected to result from their emission increases. Lack of benefits data associated with carbon monoxide and nitrogen oxide emissions prevent the negative benefits of these emission increases from being monetized.

8.3 LIMITATIONS SPECIFIC TO THE AIR BENEFITS ESTIMATES

Lack of information for several benefit categories precludes a full quantification of all benefits categories. A qualitative discussion of the most relevant air-related benefit categories is presented in Chapter 7.0. However, not all the benefit categories discussed in Chapter 7.0 were quantified. Other categories of benefits were quantified but were not readily monetized. Specific limitations of the benefits analysis as related to air quality are set forth below.

8.3.1 Hazardous Air Pollutants

The benefits assessment was limited to analyzing the pollutants for which emissions information was available. Toxicity data was available for the majority of the HAPs emitted by this source category. These two pieces of data (along with other data) were input into the HEMI to conduct a risk and exposure assessment. (Refer to the Appendix to Chapter 8.0 for a complete explanation of the limitations of the HEMI inputs and assumptions.)

Data on the most emitted and most toxic HAPs were available so the that a risk assessment could be performed. The risk assessment quantified the benefits in terms of reducing cancer risk resulting from reduced emissions of carcinogenic HAPs. Although some carcinogenic HAPs may have been omitted from the risk assessment, their effect on the results of this analysis is expected to be minimal. The results of this risk assessment will be monetized since estimated values for reducing risk are available.

An exposure assessment for the noncarcinogenic HAPs was also performed. As with the risk assessment, this analysis was limited to the pollutants for which toxicity and emissions information was available. The exposure assessment quantified the number of people exposed to levels above the health benchmark for each pollutant. However, the results of this assessment cannot be used to monetize this benefit category since information on valuing reduced exposure is not available. The omission of this benefit category from the monetized benefits analysis will lead to an underestimation of the total expected benefits from the proposed regulation.

8.3.2 Volatile Organic Compounds

The largest category of benefits expected to result from the proposed regulation are the benefits resulting from VOC emission reductions. VOC emissions are of concern because they are precursors to the formation of ozone. Although data limitations prevent us from quantifying the amount of VOC that is actually transformed into ozone, the approach for valuing the benefits of reducing VOC emissions will be derived from the monetized benefits of reducing ozone. This approach depends upon a linear relationship between the transformation of VOC into ozone.

The approach used to monetize the benefits of reduced VOC emissions attempts to estimate the average benefit of reducing a Megagram of VOC emissions. The estimates represent average values and do not reflect differences in the benefits of achieving the first unit of emission reduction versus the benefits of achieving the last unit of emission reduction. The benefit estimates also ignore the impact of the value of each unit in emission reduction or the geographic placement of the emission reduction.

This valuation approach uses average dollar per Megagram estimates extrapolated from a previous study that assessed the nationwide benefits of reducing ambient ozone concentrations. Recall from Chapter 7.0 that the control of VOC emissions is important because these emissions transform into ozone. The adverse health and welfare effects of ozone were discussed in the same section. These benefits were compared to the predicted nationwide VOC emission reductions to calculate an average benefit estimate.

This approach results in an underestimation of the expected benefits from VOC control because only acute health effects and agricultural benefits were monetized in this study. As discussed earlier in the qualitative section, many health professionals are more concerned about the chronic effects (caused by repeated exposure) of ozone rather than the acute effects. The acute effects of ozone exposure appear to be reversible while the chronic effects seem to cause permanent physical damage. These differences would lead us to conclude that the monetized benefits of reducing ozone exposure would be greater for the chronic effects compared to the acute effects. However, due to lack of data, the chronic effects have not been monetized. This omission will lead to an underestimation of the monetized benefits of the proposed regulation.

This valuation approach for estimating the benefit of controlling VOC also omits several categories of welfare benefits. The study from which the benefit estimates were extrapolated quantified the benefits in terms of increased crop yields. Although the benefits expected from increased crop yields may be the largest category of benefits pertaining to the welfare effects of controlling VOC emissions, welfare benefit categories such as visibility and materials damage have been left unquantified. These omissions will lead to an underestimation of the expected benefits of reducing VOC emissions.

In addition to the method presented above to value VOC emission reductions, the Agency attempted to develop a second approach for valuing these emission reductions. This approach can be viewed as a cost avoidance approach.

The purpose of the MACT requirement of the integrated regulatory alternative is to reduce emissions of hazardous air pollutants. However, the Agency has also examined the impact of the proposed regulation on the emissions of other air pollutants regulated under the Clean Air Act. An evaluation of the MACT requirement revealed that VOC emissions are also expected to greatly decrease. Sources that comply with the proposed regulation will decrease their VOC emissions without having to implement additional control strategies that would have been required by their respective state or local agencies.

This second approach attempted to derive VOC benefit values from a study previously developed by the Agency (E.H. Pechan & Associates, 1991). The study assessed the average cost-effectiveness of various control options for reducing VOC emissions in designated VOC nonattainment areas. The study estimated the costs associated with stationary source controls mandated by the 1990 Clean Air Act Amendments (CAAA) as well as other controls, such as controls suggested in existing control technique guidelines (CTGs). Additionally, the study estimated the VOC emission reductions expected to be achieved by the various control technologies. The study used the various control costs and the associated VOC emission reductions to estimate the cost-effectiveness ($/Mg) of the various VOC control technologies.

This second approach attempted to use the range of cost-effectiveness estimates to value the benefit of reducing VOC emissions from this industry. The rationale for using this approach is that the mandates of the CAAA would have required the sources in VOC nonattainment areas to implement a strategy to control their VOC emissions. However, by complying with the proposed integrated regulatory alternative, the sources in this industry that are located in VOC nonattainment areas will avoid the additional cost of complying with the VOC control requirement.

The estimates of positive VOC cost-effectiveness values presented in the study ranged from $2/Mg to $20,000/Mg ($1991). The study estimated that some VOC controls were expected to result in cost savings; however, only positive cost-effectiveness values are presented in the above range. Although this range provides the Agency with another approach for valuing VOC emission reductions, several limitations discourage the use of these estimates.

The cost-effectiveness values presented in the study represent the average cost-effectiveness that a group of sources is expected to incur. The average cost-effectiveness value represents the total cost of achieving the VOC control and the total VOC emissions expected to result. The average cost-effectiveness estimates do not reflect differences in the benefits of achieving the first unit of emission reduction. An incremental cost-effectiveness estimate would distinguish the last unit of emission reduction from the first unit and is expected to be higher than the average cost-effectiveness estimate. Lack of data provided in the study prevent incremental cost-effectiveness values from being calculated.

A second issue is the calculation of VOC emission reductions. The study assumed that all emission sources were uncontrolled at the baseline. This method led to relatively higher estimates of potential VOC emissions reductions since it assumed that state or local regulations did not exist to control some of these emission. This assumption does not accurately reflect the current state of control due to various reasons. One reason may be that state or local agencies may have their own environmental regulations apart from the regulations analyzed in the study. The state or local agencies would use the local environmental regulations to require sources in their respective areas to implement some level of VOC control. If the baseline assumption had accounted for some level of existing VOC control, the VOC emission reduction potential would be less than estimated, and, assuming the cost of control increases with increasing levels of control, the cost-effectiveness of the VOC control would have been higher.

Due to the above limitations, the Agency does not recommend this second approach for valuing VOC emission reductions from this industry.

8.3.3 Sulfur and Criteria Air Pollutants

Another large category of benefits, the benefits of reducing total reduced sulfur (TRS) emission, will be left unquantified and therefore, unmonetized. As discussed in Chapter 7.0, the control of TRS emissions is expected to lead to the alleviation of the odor problem often associated with pulp and paper production. Although odor problems have been linked to causing adverse health symptoms to the respiratory and cardiovascular systems, these symptoms are not readily quantified. Therefore, this benefit category will not be included in the total monetized benefits. The omission of this benefit category will lead to an underestimation of the total benefits of the proposed regulation.

8.3.4 Negative Benefits from Air Emission Increases

Chapter 7.0 discussed the negative benefits expected to result due to increases in emissions of four criteria pollutants - CO, NO_x, SO_2, and PM. The health and welfare effects of these pollutants are discussed but data are not available to quantify these effects. If monetized, the benefits of these categories would be negative since the emissions of these pollutants are predicted to increase as a result of the proposed regulation. The negative effects of these emission increases however, are expected to be minimal since the magnitude of their emission increases are much smaller than the decreases in emissions of the other pollutants, especially VOC. Nevertheless, the omission of these negative effects from the monetization of the benefits will lead to an upward bias of the expected benefits.

Considering all categories of benefits that are left unquantified, the results of the monetized benefits is expected to result in an underestimation of the total benefits. The positive but unmonetized benefits of reducing exposure to noncarcinogenic HAPs, reducing chronic effects of VOC exposure, reducing welfare effects such as poor visibility and materials damage resulting form VOC emissions, and reducing odor (and potentially health) problems caused by TRS emissions are expected to outweigh the negative but unmonetized benefits of increasing emissions of CO, NO_x, SO_2, and PM.

8.4 AIR BENEFITS ESTIMATES

8.4.1 Human Health Risk Reductions

As discussed in Chapter 7.0, a HAP was classified as significant if its emission and toxicologic data indicated that it would adversely affect human health. Of the HAPs that are emitted that are known carcinogens, five belong in this category. Based on toxicity and emissions information, chloroform, carbon tetrachloride, formaldehyde, methylene chloride, and acetaldehyde were evaluated for the cancer risk they posed.

A risk assessment of these HAPs was performed. Risk assessment is a tool for estimating the health effects that individuals or populations may experience as a result of exposure to hazardous chemicals. This risk assessment was performed through the use of a model called the Human Exposure Model, version I (HEMI), using 1990 census data. The following discussion will summarize some of the information used in the HEMI model. Refer to the Air Quality Assessment Document for a more complete explanation of the HEMI model, its inputs, and its assumptions.

One important input to the HEMI model was the unit risk estimate (URE) of each pollutant. The UREs of the analyzed pollutants are presented in Table 8-1. UREs represent the increased cancer risk from a lifetime (70-year) exposure to a concentration of 1 $\mu g/m^3$ in the ambient air. The URE is the result of a dose-response estimate that quantitatively defines the relationship between the exposure or dose of a chemical and the magnitude of the health response. Therefore, the URE is an expression of carcinogenic potency.

The URE is often considered a conservative estimate of cancer risk due to the following assumptions used when determining the URE. Proof of systemic toxicity in humans is not essential when quantifying the URE. Scaling factors can be applied to well-conducted

Table 8-1
Unit Risk Estimates of Carcinogenic HAPs

HAP	URE
Acetaldehyde	2.2×10^{-6}
Carbon Tetrachloride	1.5×10^{-5}
Chloroform	2.3×10^{-3}
Formaldehyde	1.3×10^{-3}
Methylene Chloride	4.7×10^{-7}

animal studies to account for differences between humans and animals. The use of scaling factors may lead to a conservative estimate of the URE. Also, epidemiologic and/or toxicologic studies are conducted at doses higher than those typically encountered in the environment. The URE is considered a conservative estimate because an extrapolation from high to low dose must be made to determine cancer risk from exposure to levels typically seen in the human population.

The HEMI model uses the URE, along with other information such as emission rates, to characterize the risk posed to individuals and the population located within a 50 km radius of each pulp and paper plant. The results of the HEMI analysis are presented in Table 8-2. The maximum individual risk (MIR) is presented for each of the HAPs analyzed both for emissions at the baseline and for expected emissions after all plants comply with the proposed regulation. The MIR for each pollutant expresses the risk experienced by the most exposed individual in the defined population. The MIR estimates the probability that the most exposed individual in the population will develop cancer when exposed to each pollutant at the defined emission rate. The MIR is not an expression of risk experienced by the general population.

Table 8-2
Maximum Individual Risk from Exposure to Carcinogenic HAPs

HAP	Baseline MIR	Post-Regulation MIR
Acetaldehyde	1.2×10^{-4}	1.5×10^{-5}
Carbon Tetrachloride	9.1×10^{-7}	8.8×10^{-7}
Chloroform	2.9×10^{-4}	1.1×10^{-4}
Formaldehyde	3.5×10^{-4}	2.6×10^{-4}
Methylene Chloride	4.1×10^{-6}	4.9×10^{-6}

Table 8-3 presents the annual cancer incidences that are believed to result from the emissions of the individual pollutants. The reduction in the annual cancer incidences is the difference in incidences between the baseline and after compliance. The total reduction in annual cancer incidences expected from the proposed regulation is 0.39 of a statistical life. (0.39 is the sum of the reductions in the exposed population for the individual pollutants.) This approach assumes additivity of cancer incidences but does not take into account any synergistic or antagonistic effects that may result from exposure to chemical mixtures. Therefore, the quantified benefit of this category is the reduction of the annual cancer incidence rate by 0.39 of a statistical life.

Table 8-3 Annual Cancer Incidences from Exposure to HAPs		
HAP	Baseline Annual Cancer Incidences	Post-Regulation Annual Cancer Incidences
Acetaldehyde	0.023	0.006
Carbon Tetrachloride	0.001	0.000
Chloroform	0.350	0.060
Formaldehyde	0.160	0.083
Methylene Chloride	0.002	0.002
TOTAL	0.54	0.15

However, to do an incremental analysis, cancer risk data was also needed for several other regulatory alternatives. Instead of using the HEMI (which is time intensive) to assess the cancer risk at the various regulatory alternatives, a linear relationship was assumed between the emissions of the carcinogenic HAPs and the annual cancer incidence rate. The annual emission reductions of the three pollutants contributing most to the annual cancer incidence rate (acetaldehyde, chloroform, and formaldehyde) at the baseline and the proposed regulatory alternative were compared to the emission reduction data for the same pollutants at the other regulatory alternatives. This information was then used to extrapolate the expected number of annual cancer incidences at various regulatory alternatives given the HEMI output for the proposed regulation. The expected reduction in annual cancer incidence at each regulatory alternative is presented in Table 8-4.

Table 8-4 Annual Cancer Incidence Associated with Reductions in Air Emissions			
HAP	Proposed Regulation (Alternative 26)	Reg. Alt. 24	Reg. Alt. 25
Total Reduction in Annual Cancer Incidence	0.39	0.39	0.43

To value the reduction in cancer mortality risk, the value of a statistical life must be estimated. A variety of values have been estimated for reducing risk. These estimates range from $2 million to $10 million ($1992) per statistical life and have been derived mainly from willingness-to-pay and wage-risk studies (Fisher et al., 1989). Estimates from willingness-to-pay studies assess an entire group's willingness to pay to reduce each member's risk by a small amount rather than attempting to value any particular individual's life. Wage-risk studies estimate the wage premium associated with greater risks of death on the job. Due to the lack of consensus on the value of reducing risk, benefit estimates for reducing annual cancer incidences will be presented as a range. A low, high, and average estimate will be presented for each regulatory alternative.

The total monetized benefit for reducing cancer risk for each of the regulatory alternatives is presented in Table 8-5. The results are presented as a range since a range for estimating the value of reducing risk is used.

Table 8-5
Total Value of Reducing Cancer Risk Associated with Reductions in Air Emissions
(Millions of 1992 Dollars)

Value	Proposed Regulation (Alternative 26)	Regulatory Alternative 24	Regulatory Alternative 25
Average	$2.51	$2.51	$2.77
Range	$0.79 - $4.19	$0.79 - $4.19	$0.88 - $4.66

HAPs that are not proven human carcinogens but that are linked with adverse affects on human health were also evaluated. Based on toxicity and emission information, an exposure assessment was performed for acrolein, acetaldehyde, 2-butanone, hydrochloric acid, hexane, and toluene. For noncarcinogens, the dose-response is expressed in terms of an inhalation reference-dose concentration (RfC). Using the RfC methodology, a benchmark concentration is calculated below which adverse effects are not expected to occur.

The RfC is a benchmark concentration value that represents an estimate of the "safe" daily exposure of the human population to a specific chemical. The RfC is based on the premise that a threshold exists for adverse effects caused by a chemical. The RfC applies to exposures through the inhalation route and is an estimate of the lifetime dose that would not pose significant risk to the population, including sensitive subgroups. The RfCs for the above mentioned HAPs are presented in Table 8-6. The exposure assessment uses the RfC as a health benchmark to determine the number of people in the population exposed to concentrations of a chemical above the RfC. We can use this model, along with baseline and post-regulation data, to determine the reduction in the number of people exposed to concentrations above the RfC to being exposed to concentrations below the health benchmark.

Although the RfC analysis was performed on six chemicals, significant baseline exposure was shown to result from only two HAPs - acrolein and acetaldehyde. An analysis of post-regulation emissions showed that significant decreases in the number of people exposed to concentrations above the RfC occurred for only one chemical, acrolein. The analysis predicted that an estimated 1,285,000 people would have their exposure reduced from being above the RfC health benchmark to being below the benchmark.

Table 8-6
Reference Dose Concentration Values of Noncarcinogenic HAPs

HAP	RfC
2-Butanone (MEK)	1000 $\mu g/m^3$
Acetaldehyde	9 $\mu g/m^3$
Acrolein	.02 $\mu g/m^3$
Hexane	200 $\mu g/m^3$
Hydrochloric Acid	7 $\mu g/m^3$
Toluene	400 $\mu g/m^3$

Exposure to acrolein has been linked with causing abnormal cell changes and acute bronchopneumonia in rats. Other animal studies have shown a relationship between acrolein inhalation and upper respiratory tract lesions, inflammation and necrosis in the respiratory epithelium, ulceration and necrosis of the olfactory epithelium, depressed body weight, and suppressed pulmonary antibacterial defenses. The significance of the RfC benchmark is that exposures to levels below the RfC are considered "safe" because exposures to concentrations of the chemical at or below the RfC have not been linked with any observable health effects.

8.4.2 Other Air Quality Related Benefits

This section addresses the expected positive benefits of reducing VOC emissions as well as the expected negative benefits of increasing emissions of CO, NO_x, SO_2, and PM. Several methodologies for valuing VOC emission reductions are possible. The methodology for valuing the VOC emission reductions extrapolates benefit per Megagram estimates from previous studies that have attempted to estimate nationwide benefits from reduced ambient ozone concentrations. The estimated benefits of reduced ozone levels are compared to the predicted nationwide VOC emission reductions to calculate an average benefit per Megagram of VOC emission reduction. Table 8-7 presents VOC emission reduction data as well as emissions data for the other criteria pollutants for the three regulatory alternatives analyzed.

The approach for valuing VOC emissions reductions extrapolates benefit per Megagram estimates from an ozone study conducted by the Office of Technology Assessment (U.S.

Table 8-7
Criteria Pollutant Emission Reductions (Mg/yr)
(Increases in Emissions are in Parentheses)

Criteria Pollutant	Proposed Regulation (Alternative 26)	Regulatory Alternative 24	Regulatory Alternative 25
VOC	715,923	733,754	734,661
CO	(316)	(316)	(2,169)
NO_x	(1,265)	(1,265)	(8,736)
SO_2	(168,224)	(168,224)	(168,256)
PM	(127)	(127)	(287)

Congress, 1989). This study attempted to estimate the nationwide benefits that might result from reduced ambient ozone concentrations. This study attempted to estimate the reduction in ambient ozone concentrations that might be achieved through VOC emission reductions required by a national VOC standard. In addition, the study attempted to monetize several categories of benefits that would result from a reduction in ambient ozone levels. These categories included acute health effects and agricultural effects.

We can estimate the average benefit per Megagram of VOC emissions reduction by comparing the estimated total benefits to the estimated total VOC emission reductions. Since ranges of estimates are provided in the study, this approach will also provide ranges of benefit estimates.

The first category of benefits expected to result from VOC emission reductions is the acute health effects category. The study estimated that a reduction of approximately 8 million Mg/yr of VOC emissions would result in monetized acute health benefits in the range of $69 million to $640 million dollars per year ($1992). These values were derived from a combination of epidemiologic studies, clinical studies, and willingness-to-pay studies. The above estimates translate to valuing avoided acute health effects from VOC emission reductions in the range of approximately $9 to $548 per Megagram ($1992). This value ignores the chronic effects of VOC emissions, which are thought to be more damaging than acute effects.

In addition to valuing acute health effects, the study also attempted to value the effect that reduced VOC emissions would have on crops. Ozone levels currently found in rural areas are linked with reducing growth rates and yields of crops such as soybeans and oats. Lower VOC levels are expected to reduce ambient ozone concentrations, which in turn will increase crop yields. The study estimated that a reduction of approximately 8 million Mg of VOC emissions would result in total agricultural benefits ranging from $691 million to $1267 million ($1992) while a reduction of approximately 11 million Mg of VOC would result in total agricultural benefits of $1,293 million to $2,456 million ($1992). These total benefits translate into an average benefit values per Megagram of VOC emission reductions of approximately $114 to $223 ($1992).

The calculated benefits of the above ranges for VOC emission reductions are presented in Table 8-8. Note that the total benefit values represent the total benefit categories that were readily monetized but do not include several important categories of benefits for which quantified benefits data were not available.

Table 8-8
Extrapolated Benefit/Mg Values for VOC Reductions
Total Value of VOC Emission Reductions (Millions of 1992 Dollars per Year)

VOC Benefits[1]	Proposed Regulation (Alternative 26)	Regulatory Alternative 24	Regulatory Alternative 25
Acute Health Benefits:			
Average	$199.38	$204.35	$204.60
Range	$6.44 - $392.33	$6.60 - $402.10	$6.61 - $402.59
Agricultural Benefits:			
Average	$120.63	$123.64	$123.79
Range	$81.62 - $159.65	$83.65 - $163.63	$83.75 - $163.83
Total Annual Benefits From VOC Emission Reductions:			
Average	$320.02	$327.99	$328.39
Range	$88.06 - $551.98	$90.25 - $565.72	$90.36 - $566.42

1 This approach for valuing VOC emission reductions ignores the chronic health effects associated with repeated exposure to ozone. This omission results in an underestimation of the total value of reduced ambient ozone levels. This conclusion is based on evidence (provided in Chapter 7.0) citing the possibility of reversing the adverse health effects due to acute ozone exposure versus the permanent adverse health effects due to chronic ozone exposure.

8.4.3 Incremental VOC Cost-Effectiveness Analysis of MACT

Although the quantified benefits analysis in this RIA presents one approach for valuing the benefits of reduced VOC emissions (and therefore, reduced ambient ozone levels), data limitations prevent a complete quantification of all categories of benefits attributable to VOC emission reductions. Since lack of data prevent all VOC benefit categories from being monetized, a direct comparison of benefits to costs may not be helpful in determining the desirable regulatory alternative. However, an assessment of the incremental cost-effectiveness of VOC emission control and a comparison of these estimates to a policy-established benchmark may be useful. The VOC cost-effectiveness analysis will represent the cost of the air emission controls relative to the expected VOC emission reductions attributable to the controls.

The add-on control costs presented in this analysis include the cost to control pulping and bleaching area vents as well as the costs to control emissions from wastewaters. Although the aggregation of these costs are expected to accurately represent the cost of MACT requirements, the use of a VOC cost-effectiveness analysis may underestimate the benefits of these requirements. In particular, the VOC cost-effectiveness analysis ignores the benefit of HAP emission reductions and BOD effluent reductions that these controls will also achieve. The result of the "jointness" of the benefits of the MACT requirements is that the VOC cost-effectiveness values presented in this analysis will be overestimated.

It is difficult to estimate the magnitude of the VOC cost-effectiveness overestimation. The Agency has estimated a range of monetized values for the benefits of reduced annual cancer risk attributable to reduced carcinogenic HAP emissions. The total annual benefits of the annual cancer risk reductions has been estimated to range from $0.79 million to $4.66 million ($1992), depending on the regulatory alternative examined. If the VOC cost-effectiveness calculation were to account for this benefit category, the magnitude of the VOC cost-effectiveness overestimation could be characterized as being relatively small. However, the Agency has also estimated the reductions in exposure attributable to reductions in emissions of noncarcinogenic HAPs. Unfortunately, lack of data prevent these health benefits from being monetized. The effect of this lack of valuation prevents a conclusion from being drawn regarding the magnitude of the benefits attributable to noncarcinogenic HAP emission reductions. Therefore, the Agency cannot confidently characterize the magnitude of the VOC cost-effectiveness overestimation.

The incremental VOC cost-effectiveness analysis begins with the regulatory alternative that includes the MACT floor level of control. The MACT floor is defined as the minimum level of control statutorily required of sources. Regulatory alternative 26, which is the basis of the draft proposed integrated rule, includes controls to meet effluent limitations plus MACT floor level controls. The total cost of implementing the MACT portion of regulatory alternative 26 is approximately $251.81 million annually. This regulatory alternative is expected to result in a reduction of VOC emissions by approximately 716,000 Mg annually. Therefore, the incremental cost-effectiveness, averaged across multiple emission points, of the MACT floor requirements above the baseline level of control is approximately $350/Mg. In other words, the average cost of reducing each Mg of VOC emissions at the MACT floor level of control is $350.

The next most stringent level of control that was identified was regulatory alternative 24, which includes control of additional pulping area vents not controlled at the MACT floor. The total annual cost of the MACT portion of this regulatory alternative is estimated to be approximately $281.3 million annually. This level of control is estimated to achieve an annual VOC emission reduction of approximately 734,000 Mg. The incremental VOC cost-effectiveness of going from regulatory alternative 26 to regulatory alternative 24 is approximately $1,650/Mg.

The last regulatory alternative that will be examined in this analysis is regulatory alternative 25. This regulatory alternative would require control of the bleach plant scrubber exhaust which is not controlled at the floor. The total annual cost of implementing the MACT portion of this regulatory alternative is approximately $348.42 million. This level of control is expected to reduce VOC emissions by approximately 735,000 Mg annually. Given these data, the incremental VOC cost-effectiveness of implementing regulatory alternative 25 rather than regulatory alternative 24 is approximately $74,040/Mg.

Table 8-9 presents the incremental VOC cost-effectiveness values for the MACT portion of each regulatory alternative discussed in this analysis. One approach for analyzing the significance of these incremental VOC cost-effectiveness values is to compare these values to policy-based cost-effectiveness guidance developed by the Agency in 1985 (U.S. EPA, 1985). The policy-based VOC cost-effectiveness value for new source performance standards (intended to address VOC emissions nationally) was established at $1,570/Mg ($1991). If the majority of the benefits of the MACT requirements are expected to be derived from VOC emission reductions rather than HAP emission reductions, using the policy-based VOC cost-effectiveness value to determine the desirable regulatory alternative to implement may be a reasonable approach.

Table 8-9
VOC Incremental Cost-Effectiveness of MACT Controls

	Reg. Alt. 26	Reg. Alt. 24	Reg. Alt 25
Incremental Cost (Million $1991)	$251.81	$29.49	$67.12
Incremental Emission Reduction (Mg)	715,900	17,800	900
Incremental Cost-Effectiveness ($/Mg)	$352/Mg	$1,650/Mg	$74,000/Mg

The incremental VOC cost-effectiveness analysis reveals that regulatory alternative 26 can be justified as a desirable option since the incremental VOC cost-effectiveness of implementing regulatory alternative 26 is much less than the policy-based benchmark value. This analysis also indicated that regulatory alternative 25 is a clearly undesirable option since the incremental cost-effectiveness of this regulatory alternative is much greater than the established benchmark value. The conclusion about the desirability of implementing regulatory alternative 24 is less clear. The incremental cost-effectiveness of implementing regulatory alternative 26 is approximately $1650/Mg. This value is slightly greater than the

$1570/Mg benchmark value. However, as noted earlier, this VOC cost-effectiveness value ignores the additional benefits of HAP and BOD control. If we take into account the overestimation of the VOC cost-effectiveness value due to the omission of the HAP and BOD benefits, the conclusion of the incremental VOC cost-effectiveness analysis may be that regulatory alternative 24 may be a desirable regulatory alternative.

Although the incremental VOC cost-effectiveness of regulatory alternative 26 is significantly less than the established benchmark, the Agency has little data to draw conclusions regarding the net benefits of the MACT portion of any of the regulatory alternatives presented in this analysis. The purpose of this incremental VOC cost-effectiveness analysis is to provide the Agency with an additional method for evaluating the relative merits of the various regulatory alternatives.

8.5 WATER BENEFITS METHODOLOGIES

This section summarizes the water-benefits methodologies used in the regulatory impact analysis to estimate potential impacts to aquatic life and human health resulting from exposure to bleaching pulp and paper mill effluent. Potential impacts were evaluated for each BAT process change option and baseline conditions in order to evaluate and compare the environmental "benefit" of implementing various BAT control technologies.

Estimating in-stream contaminant concentrations for various flow conditions is the first step in evaluating impacts on aquatic life and human health. Loadings data have been obtained from EAD in kilograms of pollutant discharged per year for each chemical discharged from a facility under baseline conditions and each selected BAT option. The loadings data are used to derive effluent concentrations for each chemical. The effluent concentrations are derived by dividing the loading by the plant flow. The in-stream concentration is then calculated by multiplying the effluent concentration by the stream dilution factor, i.e., plant flow/(plant flow + stream flow). Stream dilution factors are derived for three measures of low-flow conditions of the stream at the mill effluent: 1Q10 flow (i.e., the lowest flow measured over a 10-year period), 7Q10 flow (i.e., the lowest 7-day average flow in a 10-year period), and harmonic mean flow (HMF) (U.S. EPA, 1991b). Site-specific 7Q10 flows and HMFs are obtained for each of the mills, as reported in *Risk Assessment for 2,3,7,8-TCDD and 2,3,7,8-TCDF Contaminated Receiving Waters from U.S. Chlorine-Bleaching Pulp and Paper Mills* (U.S. EPA, 1990c). Site-specific 1Q10 flows are derived by multiplying gage-specific 1Q10 flows measured downstream of mill effluents by the percent contribution of the gage flow associated with the site-specific stream (i.e., site-specific stream flow/gage flow). Given the limited data available, the percent contribution of the gage flow is calculated by dividing the mill-specific 7Q10 flow by the gage-measured 7Q10 flow.

Surrogate flows are derived for 17 mills that discharge to open waters (e.g., oceans, estuaries, lakes). These flows are calculated by using the following equation:

$$F_o = (D * F_p) - F_p$$

where:

F_o	=	surrogate open water body flow
D	=	dilution factor (as provided by U.S. EPA (1990c) and regional EPA personnel)
F_p	=	mill plant flow.

A dilution factor for one mill is not available; therefore, a surrogate flow cannot be calculated. Also, because no HMF flow is available for one mill, no human health risk estimates are calculated for that mill. Facility-specific effluent flows and receiving stream flows for all of the mills evaluated in this assessment are included as part of the CBI record.

8.5.1 Estimating Impacts to Human Health

Potential impacts on human health are evaluated on a site-specific basis by (1) comparing estimated in-stream contaminant concentrations to health-based AWQCs; (2) estimating the potential carcinogenic risk and noncarcinogenic hazards from the consumption of contaminated fish tissue; and (3) estimating the annual incidence of cancer in the potentially exposed angler population.

Comparison to AWQCs for the Protection of Human Health

For 100 mills that discharge into 68 receiving streams, the in-stream contaminant concentrations under HMF conditions are compared to health-based AWQCs for ingestion of aquatic organisms (12 pollutants) and ingestion of water and aquatic organisms (13 pollutants). The contaminants are listed below:

- Acetone
- 2-Butanone
- Chloroform
- 4-Chlorophenol
- 2,4,-Dichlorophenol
- 2,6-Dichlorophenol (water and organisms only)
- Methylene chloride
- Pentachlorophenol
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,4,6-Tetrachlorophenol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol.

The HMF concentration, which is more reflective of average in-stream concentrations, is used for this assessment because health-based AWQCs are derived for lifetime exposure conditions rather than for subchronic or acute conditions. Exceedences of health-based AWQCs are quantified by dividing the predicted in-stream concentration under HMF conditions by the health-based AWQC for each chemical discharged from each facility under each selected BAT option and baseline conditions.

Estimation of Carcinogenic Risks and Noncarcinogenic Hazards

Potential impacts on human health are also evaluated by estimating potential carcinogenic risks and noncarcinogenic hazards. This assessment, conducted in accordance with available EPA guidance including *Risk Assessment Guidance for Superfund* (U.S. EPA, 1989a) and *Assessing Human Health Risk from Chemically Contaminated Fish and Shellfish: A Guidance Manual* (U.S. EPA, 1989b), is performed for the following contaminants:

Systemic Pollutants with Reference Doses:		Carcinogens:
Acetone	Pentachlorophenol	Chloroform
2-Butanone	2,3,7,8-TCDD	Methylene chloride
Chloroform	2,3,7,8-TCDF	Pentachlorophenol
4-Chlorophenol	2,3,4,6-Tetrachlorophenol	2,3,7,8-TCDD
2,4-Dichlorophenol	2,4,5-Trichlorophenol	2,3,7,8-TCDF
Methylene chloride		2,4,6-Trichlorophenol

As outlined in EPA guidance, the technical approach for conducting a risk assessment involves a three-step process:

1) *Toxicity Assessment.* An attempt was made to obtain human health toxic effect values for the 26 contaminants of potential concern using EPA data sources such as IRIS (U.S. EPA, 1992e) and HEAST (U.S. EPA, 1992f). Based on the list of chemicals of potential concern, only 11 of the total number of chemicals have available reference dose values (RfDs) and 6 have cancer slope factors (q1*s).

2) *Exposure Assessment.* The exposure assessment involves identifying exposure pathways of concern, estimating exposure point concentrations, and estimating chronic daily intakes.

    - *Identifying Exposure Pathways of Concern.* Water-related exposure pathways and target populations are identified as part of this step. Pathways quantitatively evaluated include only ingestion of fish by recreational and subsistence anglers. Potential risks associated with ingestion of drinking water were to be evaluated only for mills upstream and within the same reach or within 10 miles of a municipal public water intake. None of the mills evaluated for this assessment meet these criteria, however, and therefore potential exposure, cancer risk, and noncarcinogenic hazards associated with ingestion of drinking water are not evaluated.

- *Estimating Exposure Point Concentrations.* The exposure point concentration (EPC) is the average concentration contacted over the duration of the exposure period. For the fish ingestion pathway, fish tissue EPCs are calculated using two separate approaches. In the first approach, EPCs are calculated by multiplying the contaminant-specific BCF by the estimated in-stream concentration under HMF conditions for 11 systemic pollutants and 6 carcinogens using a simple dilution calculation. The second approach, which involves the use of the Dioxin Reassessment Evaluation (DRE) Model developed by EPA's Office of Research and Development (still under EPA review) (U.S. EPA, 1993c), is applicable only for estimating EPCs for 2,3,7,8-TCDD and 2,3,7,8-TCDF. Rather than using an in-stream contaminant concentration and the above water-based BCF, the DRE model estimates fish tissue concentrations of dioxin and furan by calculating the equilibrium between the contaminants in fish tissue and those adsorbed to the organic fraction of sediments suspended in the water column. The in-stream concentration under HMF conditions is used to estimate exposure point concentrations because the exposure pathways evaluated represent lifetime exposure conditions rather than subchronic or acute conditions.

- *Estimating Chronic Daily Intakes.* Chronic daily intakes (CDIs) are estimated using exposure models presented in EPA guidance (U.S. EPA, 1989a, 1989b) for each chemical discharged from a facility under each regulatory alternative and baseline conditions. CDIs are expressed in terms of milligrams of contaminant contacted per kilogram of body weight per day (i.e., mg/kg/day). The CDI is calculated by combining the EPC and exposure parameter estimates (e.g., ingestion rate, exposure frequency, exposure duration, body weight, averaging time) using a chemical intake equation. CDIs are estimated for evaluating both carcinogenic risks (based on a lifetime average daily dose) and noncarcinogenic hazards (based on an average daily dose during the exposure period). CDIs are estimated for both baseline conditions and estimated future conditions assuming implementation of various selected BAT options.

The equation and exposure parameter values used to estimate CDIs for ingestion of fish are presented below:

$$CDI = \frac{(EPC)(BCF)(CF_1)(CF_2)(CF_3)(IR)(EF)(ED)}{(BW)(AT)}$$

where:

CDI	=	chronic daily intake (mg/kg/day)
EPC	=	exposure point concentration (in-stream concentration under HMF conditions) (μg/L)
BCF	=	bioconcentration factor (unitless)
CF_1	=	conversion factor (10^3 mg/g)
CF_2	=	conversion factor (L/kg)
CF_3	=	conversion factor (10^{-9} g/μg)
IR	=	ingestion rate. At this time no site-specific fish ingestion studies are available for quantifying ingestion patterns in the vicinity of specific mill effluents. Therefore, several studies were compiled to assess average ingestion rates for recreational and subsistence angler populations. For recreational anglers an ingestion rate of 25 g/day, which represents the midpoint of the reported range of average ingestion rates for recreational anglers of approximately 20 to 30 g/day (Connelly et al., 1990; Pierce et al., 1981; West et al., 1989) is used. For subsistence anglers an average daily ingestion rate of 145 g/day, which assumes that an individual eats one average-size fish meal per day, is used. The ingestion rate for subsistence anglers is also supported by a study conducted by Pao et al. (1982)
EF	=	exposure frequency (365 days/year) (U.S. EPA 1989a, 1989b)
ED	=	exposure duration (30 years for recreational anglers and 70 years for subsistence anglers) (U.S. EPA 1989a, 1991a)
BW	=	body weight (70 kg) (U.S. EPA 1989a, 1991a)
AT	=	averaging time (70 years x 365 days/year for carcinogens and 30 years [for recreational anglers] or 70 years [for subsistence anglers] x 365 days/year for noncarcinogens).

3) *Risk Characterization.* Carcinogenic risks and noncarcinogenic hazards are estimated for chemicals with available toxicity criteria for the pathways quantitatively evaluated in this study.

Potential Carcinogenic Risks. The potential carcinogenic risks associated with the discharges of 100 mills and 6 pollutants are expressed as an increased probability of developing cancer over a lifetime (i.e., excess individual lifetime cancer risk) (U.S. EPA, 1989a). Carcinogenic risks are quantified using the equation below:

$$Cancer\ risk_i = CDI_i * SF_i$$

where:

Cancer $risk_i$	=	the potential carcinogenic risk associated with exposure to chemical *i* (unitless)
CDI_i	=	chronic daily intake for chemical *i* (mg/kg/day)
SF_i	=	slope factor for chemical *i* $(mg/kg/day)^{-1}$.

If the carcinogenic risk exceeds 10^{-2}, then EPA guidance (U.S. EPA, 1989a) recommends using the following equation to estimate carcinogenic risk:

$$Cancer\ risk_i = 1 - e^{(-CDI_i * SF_i)}$$

where:

Cancer $risk_i$	=	increased carcinogenic risk associated with exposure to chemical *i* (unitless)
CDI_i	=	chronic daily intake for chemical *i* (mg/kg/day)
SF_i	=	slope factor for chemical *i* $(mg/kg/day)^{-1}$.

Chemical-specific cancer risks are summed in accordance with EPA guidance (U.S. EPA, 1989a) in order to quantify the combined cancer risk associated with exposure to a chemical mixture. The total potential carcinogenic risk is estimated for each exposure pathway, for each facility, and for each selected BAT option and baseline conditions.

Potential Noncarcinogenic Hazards. Noncarcinogenic hazards are evaluated for 100 mills and 11 systemic human toxicants by comparing the estimated dose (i.e., CDI) with a reference dose (RfD). The hazard quotient, which is used to quantify the potential for an adverse noncarcinogenic effect to occur, is calculated using the following equation:

$$HQ_i = \frac{CDI_i}{RfD_i}$$

where:

HQ_i	=	hazard quotient for chemical *i* (unitless)
CDI_i	=	chronic daily intake for chemical *i* (mg/kg/day)
RfD_i	=	reference dose for chemical *i* (mg/kg/day).

If the hazard quotient exceeds unity (i.e., 1), then an adverse health effect may occur. The higher the hazard quotient, the more likely that an adverse noncarcinogenic effect will occur as a result of exposure to the chemical. If the estimated hazard quotient is less than unity, then an adverse noncarcinogenic effect is highly unlikely to occur.

EPA recommends summing chemical-specific hazard quotients for contaminants with similar endpoints to evaluate the combined noncarcinogenic hazard from exposure to a chemical mixture (U.S. EPA, 1989a). The sum of the chemical-specific hazard quotients is called the hazard index. Using this approach assumes that chemical-specific noncarcinogenic hazards are additive. Limited data are available for actually quantifying the potential synergistic and/or antagonistic relationships between chemicals in a chemical mixture. For this assessment, only the hazard quotients that had similar target organs and toxicological mechanisms that may result in the effect were summed (i.e., 2,3,7,8-TCDD and 2,3,7,8-TCDF).

Estimation of Increased Incidence of Cancer. In addition to estimating the potential carcinogenic risk associated with consuming contaminated fish tissue, an attempt is made to estimate the increased annual incidence of cancer that would occur at the estimated risk levels. For the purpose of this assessment, the potentially exposed population is considered to be a fraction of the recreational and subsistence anglers that reside in the vicinity of the discharge and thus might be expected to use the receiving stream for their recreational and subsistence fishing activities. Estimates of the number of recreational and subsistence anglers potentially exposed are based on site-specific recreational fishing license data and creel survey data for several receiving streams for chlorine bleaching pulp and paper mills.

The number of recreational fishing licenses sold in counties bordering the river reaches where each discharge occurs was obtained from state fishery officials. For the purpose of this assessment, it is assumed that 95% of these licenses were sold to recreational anglers and 5% were sold to subsistence anglers. Actual creel survey data from eight receiving streams with bleaching pulp and paper mills are used to estimate the fraction of the total number of licensed anglers who reside in the vicinity of a discharge and who actually use the particular receiving stream for their recreational and subsistence fishing activities. The estimated number of anglers using the stream based on creel survey data is compared to the total number of licensed anglers in counties surrounding the reach where the discharge occurs. The resulting ratio represents an estimate of the fraction of all licensed anglers in the area who fish on the receiving stream. These ratios range from 0.69 to 0.005. The average of these ratios (0.29) is used to extrapolate for all of the mills the number of licensed anglers who actually fish on the receiving stream in question by multiplying the total number of licensed anglers in counties bordering the receiving stream by 0.29.

For receiving streams with fish advisories in place, it is assumed that many recreational anglers would adhere to the advisory and not use the stream in question. However, based on the existing literature, it is assumed that most anglers are unaware of fish advisories or continue to use receiving streams for their fishing activities in spite of the presence of fish advisories.

Only a limited number of studies that examine angler behavior in response to fish consumption advisories are available. In general, these studies have produced relatively similar results, finding a significant (but not complete) level of awareness of advisories by anglers and some degree of behavioral change. However, the results do not substantiate an assumption that most recreational anglers would stop eating contaminated fish altogether. Studies conducted by Silverman (1990) and Knuth and Velicer (1990) indicate that approximately 54 to 90% of all anglers are aware of state fish advisories in place on receiving streams where they fish. These studies indicate that between 10 and 31% of anglers who are aware of fish advisories either change their fishing location or participation in fishing activities as a result of the fish advisories. The remainder of those anglers aware of the fish advisories continue to fish and either change their consumption habits or change their preparation methods. The studies by Knuth and Velicer (1990) also found that there was confusion as to which waters were considered contaminated (37% of anglers actually fishing in contaminated waters said they were fishing in uncontaminated waters), and other studies indicate that fewer anglers are aware of fish advisories than those found in studies conducted by Silverman (1990) and Knuth and Velicer (1990). For example, Belton et al. (1986) found that as few as 50% of anglers in New York and New Jersey were aware of fish advisories in place on receiving streams where they fish.

For the purpose of this environmental assessment, a conservative estimate of a 20% decrease in fishing activity due to the presence of a fish advisory is assumed based on the changes in fishing location and participation reported in the literature (Silverman, 1990; Knuth and Velicer, 1990). The actual number of anglers still fishing on receiving streams with fish advisories in place is calculated by multiplying the total number of licensed anglers in counties bordering the receiving stream reach by 0.95 (i.e., percent of total licensed anglers considered to be recreational anglers), then multiplying the result by 0.29 (i.e., percent of recreational anglers estimated to actually use the receiving stream in question for their fishing activities) and by 0.80 (i.e., percent of anglers who continue to use a receiving stream for their fishing activities in spite of the presence of a fish advisory). It is assumed that fish advisories do not change the fishing habits of subsistence anglers.

In addition to the anglers themselves, it is assumed that families of anglers would also be exposed to contaminated fish. Therefore, for each mill, the estimated number of recreational and subsistence anglers are each multiplied by 2.63, the size of the average U.S. household as determined by the 1990 census (U.S. Census Bureau, 1992), to estimate the size of the total potentially exposed population. The total number of potentially exposed recreational and subsistence anglers and their family members for each mill is then multiplied by the estimated increased individual lifetime cancer risk for each mill. These values are then divided by 70 (i.e., approximate number of years in a lifetime) to estimate the annual increased incidence of cancer in recreational and subsistence anglers and their families.

<u>Estimation of Populations Exposed to Contaminant Levels that Exceed RfDs.</u> The potential number of people exposed to contaminant levels exceeding RfDs were also estimated. This estimate was based on the number of recreational/subsistence anglers and their family members estimated to be exposed to fish tissue contaminant levels in which RfDs were exceeded. The total population exposed for each mill is the same as that used to estimate

the potential increased incidence of cancer. However, only those populations potentially exposed to contaminants from mills for which RfDs were exceeded were counted. It should be noted that this method will result in an estimate that will exceed the actual number of people expected to incur a noncancer effect. It only reflects the estimated number of people exposed to contaminant levels that exceed RfDs.

8.5.2 Fish Consumption Advisories: Comparison with State Action Levels

Twenty-three fish advisories for dioxins were in place as of June 1993 on stream segments located downstream of 29 bleaching pulp and paper mills (including 2 open ocean locations in close proximity to pulp mill outfalls). For this assessment, modeled fish tissue (fillet) levels of 2,3,7,8-TCDD and 2,3,7,8-TCDF in the receiving stream are compared to the state action levels to estimate whether the selected BAT options by themselves are sufficient to eliminate the fish advisories. Fish tissue concentrations are estimated using two separate approaches. First, fish tissue concentrations are calculated by multiplying the estimated in-stream concentrations (expressed as 2,3,7,8-TCDD and 2,3,7,8-TCDF toxicity equivalents) under HMF conditions by the chemical-specific bioconcentration factor (BCF = 50,000 for 2,3,7,8-TCDD and 8,000 for 2,3,7,8-TCDF). Fish tissue concentrations are also estimated using ORD's Dioxin Reassessment Evaluation Model, as described previously. Exceedences of state action levels are quantified by dividing the estimated fish tissue concentration by the state action level for each selected BAT option. Because it is not the purpose of this assessment to determine the validity of the current fish advisories, baseline conditions are not evaluated.

Two states, in which four dioxin/furan-related fish advisories are in place, do not have specific state threshold values for initiating fish advisories. One of these states currently issues fish advisories when the potential increased individual cancer risk associated with the consumption of fish tissue reaches 10^{-6} (a daily consumption rate of 6.5 g/day is assumed). The one advisory examined for this assessment, however, was set based on a potential increased individual cancer risk of 10^{-5}. The second state has fish advisories in place for rivers as well as ocean waters. Fish advisories issued for rivers are based on the results of site-specific risk assessments. Risk assessments are not performed for fish advisories issued in ocean waters; instead, generic advisories are issued by the state. In addition, receiving stream flow data are unavailable for one of the receiving streams. Therefore, threshold exceedence comparisons can be conducted for only 24 of the 29 mills. The advisory issued in the one state that was based on a 10^{-5} risk level is affected by only one facility and is evaluated based on estimated individual cancer risk. Therefore, the total number of facilities examined in this assessment is 25. These 25 mills are assumed to have an impact on the fish advisories on 20 receiving streams.

For those fish advisories affected by discharges from more than one facility, no attempt is made to estimate the cumulative effect of the combined discharges. Instead, each faculty is evaluated separately to determine whether the fish advisory threshold limits would be exceeded under selected BAT options.

8.5.3 Other Water Quality Related Benefits

Aquatic life impacts are evaluated for 101 mills discharging to 68 receiving streams for the following 26 pollutants:

- Acetone
- 2-Butanone
- 4-Chlorocatechol
- Chloroform
- 4-Chlorophenol
- 6-Chlorovanillin
- 4,5-Dichlorocatechol
- 2,4-Dichlorophenol
- 2,6-Dichlorophenol
- 2,6-Dichlorosyringaldehyde
- 5,6-Dichlorovanillin
- Methylene chloride
- Pentachlorophenol
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 3,4,5,6-Tetrachlorocatechol
- 3,4,5,6-Tetrachloroguaiacol
- 2,3,4,6-Tetrachlorophenol
- 3,4,5-Trichlorocatechol
- 3,4,6-Trichlorocatechol
- 3,4,5-Trichloroguaiacol
- 3,4,6-Trichloroguaiacol
- 4,5,6-Trichloroguaiacol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol
- 3,4,5-Trichlorosyringol.

Potential impacts on aquatic life are evaluated on a site-specific basis by comparing modeled in-stream contaminant concentrations with aquatic life criteria and toxicity values (acute and chronic AWQCs) for these 26 pollutants. The in-stream concentrations under 1Q10 flow conditions are compared to acute AWQCs for each chemical discharged from each mill under each selected BAT option and baseline conditions. The in-stream concentrations under 7Q10 flow conditions are compared to chronic AWQCs. Exceedences of AWQCs are quantified by dividing the modeled in-stream concentrations for each flow condition by the respective AWQC for each chemical.

8.6 LIMITATIONS SPECIFIC TO THE WATER BENEFITS ESTIMATES

The methodologies used for the water quality and environmental assessments are subject to certain limitations and uncertainties. Some of the problems encountered in the analyses resulted from lack of available data or lack of research to evaluate methodological assumptions.

For example, because a dilution factor is missing for one mill that discharges to an open water body, a surrogate flow cannot be calculated. In addition, 1Q10 flow data are not available for five mills and therefore 7Q10 flows are used to estimate acute aquatic life risks for those mills. No human health risk estimates are calculated for the mill lacking HMF flow data. Neither potential risks to aquatic life nor potential risks to human health are evaluated for one mill because contaminant loadings data are unavailable.

Every effort was made to use methods and approaches that EPA considers to be standard practice. Certain assumptions may still be required, however, for the evaluation of combined noncarcinogenic hazards from exposure to a chemical mixture. EPA recommends summing chemical-specific hazard quotients to obtain a hazard index (U.S. EPA, 1989a). Using this approach assumes that chemical-specific noncarcinogenic hazards are additive. Limited data are available for actually quantifying the potential synergistic and/or antagonistic relationships between chemicals in a chemical mixture. Other areas of uncertainty are inherently associated with the risk assessment process (U.S. EPA, 1989a, 1989b) but will not be discussed here. Key uncertainties identified during the environmental assessment are discussed below.

8.6.1 Uncertainties Associated With Risk Estimates.

Several uncertainties specific to this study notably affect the results of the dioxin and furan risk assessment. Ninety-nine percent of the estimated carcinogenic risks and noncarcinogenic hazards calculated in this study can be attributed to 2,3,7,8-TCDD and 2,3,7,8-TCDF. Therefore, the assumptions and methods used to analyze the dioxin and furan data will affect the interpretation of the results of the regulatory impact analysis and comparisons. Areas of uncertainty relative to the dioxin and furan risk assessment include:

- Bioconcentration factors used in the risk assessment
- Use of one-half the EPA-designated detection limit to estimate loadings for all nondetect congeners for each selected BAT option and to develop pollutant discharge levels
- Aquatic life toxic effect values, cancer slope factors (q1*), reference doses (RfDs), and toxic equivalency factors (TEFs), which are currently under review by EPA, used in the risk assessment.

The bioconcentration factor (BCF) of 50,000 used in these calculations for 2,3,7,8-TCDD is based on a measured value from laboratory research on rainbow trout, a pelagic freshwater species having a lipid content of approximately 7% (Cook et al., 1991). A higher BCF may be more appropriate for fish with a higher lipid content. Bioconcentration factors for 2,3,7,8-TCDD may be estimated on the basis of the ratio of 10,000 per 1% lipid when the total amount of the chemical in water is considered (Cook, 1993). The BCF of 8,000 used for 2,3,7,8-TCDF was based on the following rationale: relative BCFs measured by Merhle et al. (1988) for TCDD (39,000) and TCDF (6,049) for the same lowest exposure concentration of TCDD where fish were least affected, in the same species of fish, yield a ratio of 6.45. Dividing 50,000 by 6.45 yields 7,752, which rounds to 8,000.

BCF values are dependent on the characteristics of individual chemicals. Bioconcentration is a partitioning process between the lipids of the organisms and the surrounding water, and is based on the amount of freely dissolved chemical available to fish through bioconcentration across the gills. BCFs, however, may be affected not only by variations in lipid content of different fish species but also by age of the fish; exposure level; how the concentration of the compound in water is measured (freely dissolved or total chemical); low bioavailability (the dioxins are highly hydrophobic); dissolved organic carbon content of the water (the higher the organic carbon content, the lower the bioavailability of hydrophobic chemicals); organic carbon in sediments; slow uptake rates; migration patterns of fish; and other factors that may lead to measured BCFs lower than those predicted.

EPA recommends that BCF values calculated from the log P-log BCF relationship be used in the calculation of reference tissue and ambient concentrations (U.S. EPA, 1991c). However, the report also notes that methods for calculating BCF values do not include metabolism, which will reduce the BCF. Thus, calculated BCFs will be conservative, and measured values may be necessary to obtain more precise values for chemicals that are metabolized. Furthermore, uptake of strongly hydrophobic compounds such as dioxins and furans will also be governed by bioaccumulation, the net uptake of the chemical from exposure to food and sediments as well as water. Because of these factors, many of the TCDD/TCDF congeners do not bioaccumulate in fish (Cook et al., 1991).

The simple dilution approach used in this analysis assumes that using the loadings for dioxins and furans and mill-specific dilution factors allows estimation of an appropriate water concentration for these chemicals and permits the use of BCFs. However, this approach ignores the complexity of the interactions of these highly hydrophobic chemicals with sediment organic carbon and suspended particulates in the effluent, resulting in reduced bioavailability, losses to sediments through sorption and deposition, and losses from volatilization and photolysis reactions. Thus the simple dilution approach oversimplifies the processes involved in the uptake of contaminants by fish.

A number of studies are currently under way to assess alternative measures of the potential for accumulation of dioxins and furans in fish (bioaccumulation factors, bioavailability indices, biota-to-sediment accumulation factors, regulatory bioaccumulation multipliers) based on water column and bottom sediment concentrations that can be used in the absence of site-specific measurements (e.g., Sherman et al., 1992; U.S. EPA, 1993a). Therefore, the new model developed by EPA's Office of Research and Development (which is still under EPA review) is also used in this assessment to calculate fish tissue concentration by calculating the equilibrium between dioxin in fish tissue and dioxin adsorbed to the organic fraction of sediments suspended in the water column. The use of the biota-to-sediment accumulation factor (BSAF) should predict more consistently the bioaccumulation potential of these chemicals, although some assumptions are still necessary (U.S. EPA, 1993a). The BSAF is calculated based on the following equation:

$$BSAF = \frac{C_{lipid}}{C_{oc}}$$

where:

BSAF	=	biota-to-sediment accumulation factor (unitless)
C_{lipid}	=	concentration of contaminant in lipid of fish (mg/kg)
C_{oc}	=	concentration of contaminant in bottom sediment organic carbon (mg/kg).

The BSAF used for 2,3,7,8,-TCDD in this assessment was 0.09, which was based on the BSAF estimated for lake trout in Lake Ontario. A biota suspended solids accumulation factor (BSSAF) is similar to a BSAF except that the organic carbon normalized concentration is that of suspended solids rather than bottom sediments. EPA has stated that there are currently no data available for assignment of BSSAFs (U.S. EPA, 1993a). However, using data from Lake Ontario, EPA estimates that the BSSAF would be 0.3 for lake trout, which is three-fold higher than the BSAF estimated for lake trout in Lake Ontario (i.e., 0.09). EPA, however, suggests the use of available BSAFs as a lower bound for BSSAFs (U.S. EPA, 1993a). Therefore, for this assessment, the BSSAF for 2,3,7,8-TCDD is assumed to be the same as the BSAF.

The loadings values for 2,3,7,8-TCDD and 2,3,7,8-TCDF used in this analysis included one-half detection limit values for those contaminants which were not detected in the effluent. As shown in the simple dilution results, 2,3,7,7-TCDD and 2,3,7,8-TCDF contributed the vast majority of the total carcinogenic risk for all the selected BAT options. A significant portion of this risk is associated with the use of one-half the EPA-designated detection limit for these congeners. A recent report by Loftus et al. (1992) noted that the level of detection of the method used is important in the usefulness of the results for assessment of human risk.

EPA is currently reassessing the human health risk associated with exposure to dioxin. The dioxin slope factor and reference doses, as well as the TEF approach, used in this assessment are based on previously published values and do not represent the results of the dioxin reassessment, which are currently being developed.

The estimated reduction in fish consumption advisories resulting from process change implementation determined in this study assumes that the pulp and paper mill effluents are the only source of 2,3,7,8-TCDD and 2,3,7,8-TCDF. Furthermore, although the discharge of these compounds may cease or be minimized, sediment contamination may continue for years, with pollutants continuing to accumulate in organisms. Site-specific monitoring may be required to determine actual fish tissue concentrations and to assess the appropriateness of fish consumption advisories following process changes.

An additional area of uncertainty involves the estimates of populations exposed to contaminated fish tissue. For the purpose of this study, angler population estimates were based on data extrapolated from the number of fishing licenses sold in counties bordering receiving stream reaches and creel survey data. The actual number of people using these receiving streams for their fishing activities is not known. In addition, the number of recreational anglers who change their fishing habits as a result of a fish advisory is based on a few studies with relatively few data.

8.7 WATER BENEFITS ESTIMATES

8.7.1 Human Health Risk Reductions

Two different methods—the Simple Dilution (SD) approach and the Dioxin Reassessment Evaluation (DRE) Model approach—are used to determine fish tissue (i.e., fillet) concentrations for the following 6 carcinogens and 11 systemic toxicants for 100 mills located near 68 receiving streams:

Carcinogens:	Systemic Toxicants:	
Chloroform	Acetone	Pentachlorophenol
Methylene chloride	2-Butane	2,3,7,8-TCDD
Pentachlorophenol	Chloroform	2,3,7,8-TCDF
2,3,7,8-TCDD	4-Chlorophenol	2,3,4,6-Tetrachlorophenol
2,3,7,8-TCDF	2,4-Dichlorophenol	2,4,5-Trichlorophenol
2,4,6-Trichlorosyringol	Methylene chloride	

The DRE modeling approach is used only to evaluate cancer risk and noncancer hazards associated with 2,3,7,8-TCDD and 2,3,7,8-TCDF. The simple dilution method is used to evaluate cancer risk and noncancer hazards for all of the contaminants listed above. The two models are used to evaluate the potential accumulation of contaminants in fish and the resulting impacts on human health from the consumption of contaminated fish and to project the effect of the selected BAT options on existing dioxin-related fish advisories.

The simple dilution approach is a very conservative methodology that assumes that all of the pollutant loadings discharged to a receiving stream, including TCDD and TCDF, are available to the biota, particularly fish. The DRE approach uses a model developed by EPA's Office of Research and Development (currently under EPA review) (U.S. EPA, 1993c). The model assumes that the bioavailability of dioxins is dependent on the levels of suspended solids in the discharge and the receiving stream. Because two models are used in this assessment, the results are presented as a range. The results from the DRE model provide the lower end of the range, and the results from the simple dilution approach provide the upper end.

Carcinogenic Risk

Average individual lifetime cancer risks and the reduction in annual cancer cases resulting from the regulation are shown in Tables 8-10 and 8-11. It is estimated that for combined recreational and subsistence anglers, implementation of the selected BAT options would eliminate between 5 (DRE approach) and 35 (simple dilution approach) cancer cases per year resulting from the consumption of contaminated fish tissue. Using the DRE approach, it is estimated that the number of cancer cases per year would be reduced from less than six under baseline conditions to less than one under the selected BAT options. Using the simple dilution approach, it is estimated that the number of cancer cases per year would be reduced from 37.5 under baseline conditions to 2.5 under the selected BAT options. We monetize these reductions in cancer cases by standard values reported in the literature for the value of a statistical life ($2 to $10 million, in 1992 dollars; U.S. EPA, 1989c; Violette and Chestnut, 1983; 1986). These benefits are shown in Table 8-12.

Noncarcinogenic Risk

The DRE model is used only to evaluate the noncancer hazard associated with 2,3,7,8-TCDD and 2,3,7,8-TCDF. The estimated number of mills in the four bleaching subcategories exceeding reference doses (RfDs) for 2,3,7,8-TCDD and 2,3,7,8-TCDF for recreational anglers using the DRE approach is reduced from 34 mills under baseline conditions to 7 (a 79% reduction) after the implementation of the selected BAT options (Table 8-13). The selected BAT totally chlorine-free option for papergrade sulfite mills results in the complete elimination of baseline exceedences for two mills. Of the seven mills projected to exceed RfDs after the implementation of the selected BAT options, one is a dissolving kraft mill, four are bleached papergrade kraft/soda mills, and two are dissolving sulfite mills.

Table 8-10
Average Individual Lifetime Cancer Risk for Recreational and Subsistence Anglers at Baseline and at Selected BAT Estimated Using Two Water Quality Models (Simple Dilution and DRE)

Subcategory	Recreational Anglers				Subsistence Anglers			
	DRE		Simple Dilution		DRE		Simple Dilution	
	Baseline	Selected Option	Baseline	Selected Option	Baseline	Selected Option	Baseline	Selected Option
Dissolving Kraft	10^{-3}	10^{-5}	10^{-3}	10^{-4}	10^{-2}	10^{-4}	10^{-2}	10^{-3}
Bleached Papergrade Kraft/Soda	10^{-4}	10^{-5}	10^{-4}	10^{-5}	10^{-3}	10^{-4}	10^{-2}	10^{-4}
Dissolving Sulfite	10^{-4}	10^{-5}	10^{-4}	10^{-4}	10^{-3}	10^{-3}	10^{-3}	10^{-3}
Papergrade Sulfite	10^{-5}	Eliminated	10^{-5}	Eliminated	10^{-4}	Eliminated	10^{-3}	Eliminated

Table 8-11
Annual Cancer Cases for Recreational and Subsistence Anglers at Baseline and at Selected BAT Estimated using Two Water Quality Models (Simple Dilution and Dioxin Reassessment Evaluation)

Subcategory	Recreational Anglers				Subsistence Anglers			
	DRE		Simple Dilution		DRE		Simple Dilution	
	Baseline	Selected Option	Baseline	Selected Option	Baseline	Selected Option	Baseline	Selected Option
Dissolving Kraft	0.14	<0.01	0.7	0.04	0.12	<0.01	0.55	0.03
Bleached Papergrade Kraft/Soda	2.81	0.30	19.28	0.91	2.36	0.24	15.73	0.70
Dissolving Sulfite	0.18	0.17	0.53	0.50	0.13	0.12	0.38	0.35
Papergrade Sulfite	0.07	Eliminated	0.18	Eliminated	0.06	Eliminated	0.14	Eliminated
Total	3.20	0.47	20.69	1.45	2.67	0.36	16.80	1.08

NOTES:
1. Total estimated number of cancer cases per year (recreational and subsistence) under baseline conditions using the DRE approach = 5.87
2. Total estimated number of cancer cases per year (recreational and subsistence) under proposed BAT options using the DRE approach = 0.83
3. Total estimated number of cancer cases per year (recreational and subsistence) under baseline conditions using the simple dilution approach = 37.49
4. Total estimated number of cancer cases per year (recreational and subsistence) under proposed BAT options using the simple dilution approach = 2.53
5. Estimated number of reduced cancer cases per year (recreational and subsistence) using the DRE approach = 5.04
6. Estimated number of reduced cancer cases per year (recreational and subsistence) using the simple dilution approach = 34.96

Table 8-12
National-Level Water-Related Human Health Benefits of the Pulp and Paper Regulation

Approach	Cancer Cases Per Year			Annual Benefits Range[1] (Millions 1992 Dollars)
	Baseline	Regulatory Option	Reduction	
SD Approach	38	3	35	$70 - $350
DRE Approach	6	1	5	$10 - $50
Benefits Range				$10 - $350

1 Based on value of a statistical life reported in the literature as $2 to $10 million (1992 dollars) (U.S. EPA, 1989c; Violette and Chestnut, 1983; 1986).

Table 8-13
Number of Mills Exceeding RfDs for Recreational and Subsistence Anglers at Baseline and at Selected BAT Estimated Using Two Water Quality Models (Simple Dilution and DRE)

Subcategory	Recreational Anglers				Subsistence Anglers			
	DRE		Simple Dilution		DRE		Simple Dilution	
	Baseline	Selected Option	Baseline	Selected Option	Baseline	Selected Option	Baseline	Selected Option
Dissolving Kraft	1	1	1	1	2	1	2	1
Bleached Papergrade Kraft	29	4	54	17	57	17	70	46
Dissolving Sulfite	2	2	5	4	5	4	5	5
Papergrade Sulfite	2	0	4	0	4	0	7	0
Total	34	7	64	22	68	22	84	52
Percent Reduction	79%		66%		68%		38%	

For subsistence anglers, the estimated number of mills in the four bleaching subcategories exceeding RfDs for 2,3,7,8-TCDD and 2,3,7,8-TCDF using the DRE approach is reduced from 68 at baseline conditions to 22 (a 68% reduction) after the implementation of the selected BAT options. The selected BAT totally chlorine-free option for papergrade sulfite mills results in the complete elimination of baseline exceedences for four mills. Of the 22 mills predicted to exceed RfDs after the implementation of the selected BAT options, 1 is a dissolving kraft mill, 17 are bleached papergrade kraft/soda mills, and 4 are dissolving sulfite mills.

2,3,7,8-TCDD and 2,3,7,8-TCDF are estimated to be responsible for more than 99% of the projected noncarcinogenic hazard using the simple dilution approach. Two additional pollutants, 4-chlorophenol and 2,4,5-trichlorophenol, are projected to exceed their RfDs using the simple dilution approach but only at baseline conditions and only for bleached papergrade kraft/soda facilities. One mill is estimated to exceed the RfD for 4-chlorophenol for recreational anglers under baseline conditions using the simple dilution approach. Four mills are estimated to exceed the RfD for 4-chlorophenol for subsistence anglers under baseline conditions using the simple dilution approach. Two mills are estimated to exceed the RfD for 2,4,5-trichlorophenol for subsistence anglers under baseline conditions.

The estimated number of mills exceeding RfDs for recreational anglers for the four bleaching subcategories using the simple dilution approach is reduced from 64 mills under baseline conditions to 22 (a 66% reduction) after the implementation of the selected BAT options. The selected BAT totally chlorine-free option for papergrade sulfite mills results in the complete elimination of baseline exceedences for four mills. Of the 22 mills projected to exceed RfDs after the implementation of the selected BAT options, 1 is a dissolving kraft mill, 17 are bleached papergrade kraft/soda mills, and 4 are dissolving sulfite mills. All predicted exceedences under the selected BAT options are for 2,3,7,8-TCDD.

For subsistence anglers, the estimated number of mills exceeding RfDs for the four bleaching subcategories using the simple dilution approach is reduced from 84 at baseline conditions to 52 (a 38% reduction) after the implementation of the selected BAT options. The selected BAT totally chlorine-free option for papergrade sulfite mills results in the complete elimination of baseline exceedences for seven mills. Of the 52 mills exceeding RfDs after the implementation of the selected BAT options, 1 is a dissolving kraft mill, 46 are bleached papergrade kraft/soda mills, and 5 are dissolving sulfite mills. All predicted exceedences under the selected BAT options are for 2,3,7,8-TCDD and 2,3,7,8-TCDF.

The estimated number of people potentially exposed to contaminant levels exceeding RfDs (Table 8-14) is based on the total number of recreational/subsistence anglers and their family members who reside in counties bordering river reaches into which bleaching mills discharge and for which exposure to fish tissue contaminant levels is predicted to result in exceedences of RfDs for contaminants of concern. The total population exposed for each mill is the same as that used to estimate the potential increased incidence of cancer. However, only those populations potentially exposed to contaminants from mills for which RfDs are exceeded are counted. It should be noted that this method results in an estimate that exceeds the actual number of people expected to incur a noncancer effect. It reflects only the estimated number of people exposed to contaminant levels that exceed RfDs. Using the DRE approach, there is a predicted 59.2% reduction in the size of the population exposed to contaminant levels exceeding RfDs under selected BAT options as compared to baseline conditions. There is a predicted 68.1% reduction using the simple dilution approach.

Table 8-14
Populations Potentially Exposed to Noncarcinogenic Hazards Under Baseline Conditions and After Implementation of the Selected BAT Options, Estimated Using the Simple Dilution and DRE Approaches

	DRE			Simple Dilution		
	Recreational Angler	Subsistence Angler	Total	Recreational Angler	Subsistence Angler	Total
Baseline	511,488	51,363	562,851	964,547	63,994	1,028,541
Selected BAT Options	210,387	19,534	229,921	288,646	39,477	328,123
Percent reduction	59.2%			68.1%		

8.7.2 Lifting of Fish Consumption Advisories

As of June 1993, 23 receiving streams (including open waterbodies) had fish advisories in place for dioxins. Twenty-nine chlorine-bleaching pulp and paper mills discharge to these receiving streams in the vicinity of the fish advisory locations and thus are considered to contribute to the fish tissue concentrations of dioxins that have resulted in the issuance of the advisories. Because of limitations in available information, the potential beneficial impacts of the selected BAT options on the lifting of dioxin-related fish advisories can be assessed for only 25 mills, which affect 20 fish advisories. For 24 facilities that discharge to 19 receiving streams with fish advisories in place, the impacts of the selected BAT options are analyzed by comparing modeled 2,3,7,8-TCDD and 2,3,7,8-TCDF fish tissue (i.e., fillet) concentrations for each selected BAT option, obtained by using the simple dilution and DRE modeling approaches, to state-specific fish advisory action levels. With the exception of one dissolving kraft facility and one papergrade sulfite facility, these mills are all in the bleached papergrade kraft/soda subcategory. The comparison of estimated fish tissue concentrations to state advisory action levels cannot be done for four mills because the states in which they are located issue risk-based advisories based on site-specific determinations rather than using state action levels. However, the risk level used to issue one of the four advisories is known to be 10^{-5}; therefore, this risk level can be compared to the cancer risk estimated for that particular mill. In addition, receiving stream flow data are unavailable for one receiving stream.

Three of the receiving streams that currently have dioxin-related fish advisories in place also have advisories in place in the same locations for other contaminants: two have advisories in place for mercury and PCBs, and the third has an advisory in place for mercury. These contaminants are not being regulated by the proposed pulp, paper, and paperboard rule. As a result, even if the dioxin-related advisories are lifted as a result of BAT implementation, advisories for the other contaminants of concern will remain in place.

The results of this analysis (Table 8-15) indicate that 14 (using simple dilution approach) to 19 (using the DRE approach) existing dioxin-related fish advisories could potentially be lifted after implementation of the selected BAT options. However, using the DRE approach, two of the receiving streams for which dioxin-related fish advisories are projected to be lifted after BAT implementation will still have advisories in place for other contaminants. Using the simple dilution approach, one receiving stream for which the dioxin-related fish advisory is projected to be lifted after BAT implementation will still have a nondioxin-related advisory in place.

Table 8-15
Number of Receiving Streams That Would Exceed Dioxin-Related State Fish Advisory Threshold Limits Under Various Regulatory Alternatives at Current and Selected BAT Conditions, Estimated Using the Simple Dilution and DRE Approaches

Discharge Conditions	Simple Dilution	DRE
Current Conditions	20	20
Selected BAT Option Conditions	6	1
Potentially Eliminated Advisories at Selected BAT	14	19

8.7.3 Other Water Quality-Related Benefits

The water quality-related benefits analyzed for the environmental assessment include the reduction in exceedences of contaminant-specific ambient water quality concentrations thought to be protective of aquatic life and human health. Potential impacts on aquatic life are evaluated by comparing modeled in-stream contaminant concentrations to aquatic life water quality criteria or toxic effect values (referred to as ambient water quality concentrations, or AWQCs, for the protection of freshwater aquatic life). These aquatic life AWQCs include published EPA water quality criteria or toxic levels derived from the scientific literature for pollutants for which EPA criteria are not available. Modeled in-stream concentrations are compared to both acute AWQCs and chronic AWQCs when available. For the human health assessments, in-stream contaminant concentrations were compared to health-based toxic effect values (referred to as ambient water quality concentrations, or AWQCs, for the protection of human health) for (1) ingestion of aquatic organisms and (2) ingestion of water and aquatic organisms.

Aquatic Life Benefits

Only one contaminant (pentachlorophenol) at two bleached papergrade kraft/soda mills is projected to exceed acute aquatic life AWQCs under baseline conditions (Table 8-16). With the implementation of the selected BAT options, it is projected that no exceedences of acute aquatic life AWQCs will occur.

The implementation of the selected BAT options for each of four bleaching subcategories eliminates the exceedences of chronic aquatic life AWQCs for dioxin (with the exception of one mill in the bleached papergrade kraft/soda subcategory) and eight other chlorinated organic compounds that are projected to occur as a result of baseline-level discharges (Table 8-16). The following pollutants are predicted to exceed chronic aquatic life AWQCs under baseline conditions:

- 4-Chlorocatechol
- Pentachlorophenol
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 3,4,5,6-Tetrachloroguaiacol
- 3,4,5-Trichloroguaiacol
- 4,5,6-Trichloroguaiacol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol.

Table 8-16
Estimated Number of Pollutants and Mills Exceeding Aquatic Life AWQCs

BAT Process Change Option	Number of Pollutants and Mills (in parenthesis) with Projected AWQC Exceedences							
	Acute AWQCs Aquatic Life				Chronic AWQCs Aquatic Life			
	DK	PK	DS	PS	DK	PK	DS	PS
Baseline	0	1(2)	0	0	3(1)	9(27)	0	0
Selected BAT Option	0	0	0	0	0	1(1)	0	0
Total Number of Pollutants and Mills (in parenthesis) with Exceedences	Baseline = 1(2) Selected BAT Options = 0				Baseline = 9(28) Selected BAT Options = 1(1)			

The estimated number of mills exceeding chronic aquatic life AWQCs at baseline is reduced from 28 mills to 1 mill after implementation of the selected BAT options.

Human Health Benefits

The implementation of the selected BAT options for each of the four bleaching subcategories is projected to reduce the number of mills that exceed health-based AWQCs for ingestion of both *organisms* and *water and organisms* from 97 mills at baseline conditions to 78 after BAT implementation (Table 8-17). Health-based AWQCs for protection from the ingestion of contaminated *organisms* are exceeded under baseline conditions for the following five contaminants:

- Chloroform
- Pentachlorophenol
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,4,6-Trichlorophenol.

Table 8-17
Estimated Number of Pollutants and Mills Exceeding Health-Based AWQCs

Process Change Option	Number of Pollutants and Mills (in Parenthesis) with Projected AWQC Exceedences							
	(Organisms) Human Health				(Water and Organisms) Human Health			
	DK	PK	DS	PS	DK	PK	DS	PS
Baseline	3(3)	5(80)	2(5)	2(9)	7(3)	8(80)	4(5)	4(9)
Selected BAT Option	2(2)	2(71)	2(5)	0	3(2)	4(71)	4(5)	0
Total Number of Pollutants and Mills (in Parenthesis) with Exceedences	Baseline = 5(97) Selected BAT Options = 2(78)				Baseline = 8(97) Selected BAT Options = 5(78)			

Not all 97 mills exceed health-based AWQCs for all 5 contaminants under baseline conditions. The selected BAT chlorine-free option for the papergrade sulfite subcategory eliminates all health-based AWQC exceedences for ingestion of organisms. The selected BAT options for the dissolving kraft, bleached papergrade kraft/soda, and dissolving sulfite subcategories reduce the number of contaminants for which health-based AWQC exceedences are projected to occur to two: 2,3,7,8-TCDD and 2,3,7,8-TCDF.

Three additional health-based AWQCs, for a total of eight, are projected to exceed health-based AWQCs for protection from the ingestion of contaminated *water and organisms* under baseline conditions. These eight exceedences are for the following contaminants:

- Chloroform
- 4-Chlorophenol
- 2,6-Dichlorophenol
- Methylene chloride
- Pentachlorophenol
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,4,6-Trichlorophenol.

Not all mills are projected to exceed the health-based AWQCs for all eight contaminants under baseline conditions. As expected, all exceedences of health-based AWQCs for the ingestion of water and organisms for the papergrade sulfite subcategory are eliminated with the implementation of the selected BAT option (totally chlorine-free bleaching). The selected BAT options for the dissolving kraft, bleached papergrade kraft/soda, and dissolving sulfite subcategories are projected to reduce the number of contaminants for which health-based AWQC exceedences occur to five:

- Chloroform (DS mills only)
- 2,6-Dichlorophenol (PK mills only)
- Pentachlorophenol
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF.

Not all the mills projected to exceed the health-based AWQCs exceed them for all five contaminants.

8.7.4 Avoided Sludge Disposal Costs

The regulation is likely to affect practices for disposal of wastewater sludges from pulp and paper facilities. Currently, the primary methods for disposing of pulp and paper sludge are landfills (56%), surface impoundments (18%), and by incineration (21%) (ERG, 1993b). Less than 5% of all pulp and paper sludge is disposed of through land application and beneficial reuse (such as compost, landfill capping material, and animal bedding). Land application and beneficial reuse are less expensive disposal options, but are not commonly practiced because of the high levels of dioxin in the sludges. The regulation will reduce levels of dioxin in the sludges, and therefore, these practices are likely to become more viable (ERG, 1993b). Estimates of the costs of various sludge disposal methods are provided in Table 8-18.

Table 8-18 Costs of Sludge Disposal Methods ($1992)[1]	
Disposal Technique	**Cost per Dry Metric Ton (dmt)**
Onsite Landfill	$120
Municipal Landfill	$171
Surface Impoundment	$100
Incineration	$147
Agricultural Application	$42
Forestry Application	$80
Mine Reclamation	$32
Compost/Other	$97

Source: (ERG, 1993b)
1 Updated to 1992 dollars with the Construction Cost Index.

A recent economic analysis conducted for EPA used a costing model to estimate disposal cost savings that may result from the regulation (ERG, 1993b). Under the proposed integrated rulemaking, all sludge is expected to fall below 3 ppt TCDD. The present value savings are estimated to be $596.0 million (1992 dollars) if all sludges with concentrations less than 25 ppt can be land-applied. The annualized savings are estimated at $56.3 million (based on a 7% discount rate).

8.8 ADDITIONAL POTENTIAL BENEFITS: RECREATIONAL ANGLING

Much of the water-related benefits from environmental controls are typically derived from recreational uses of a waterbody. These types of benefits are also often highly site specific, making them difficult to estimate on a national or regional scale. A quantified benefits analysis of three case study sites (see Chapter 9.0) was undertaken to provide more meaningful insight into how these benefits might arise from the pulp and paper regulation. However, while these sites are fairly representative of the sites impacted by the regulation (see Chapter 9.0), there is presently no conceptually sound method for extrapolating from case study results to aggregate estimates.

In order to ensure that water-related benefits are not left out of the national-level benefit-cost assessment of the regulation, this section provides an estimate of national recreational angling benefits. The methodology used to derive these benefits relies on wide generalizations, such as assumptions about the number of recreational anglers, and does not take into consideration the site-specific characteristics of the receiving streams that will influence recreational use (e.g., substitute sites). Therefore, the results are intended only to provide a rough approximation of the potential magnitude of recreational benefits that can be expected to result from the regulation.

8.8.1 Benefits are Derived from Lifting of Fish Consumption Advisories

As shown earlier, the regulation is expected to result in the elimination of between 14 and 19 fish consumption advisories under the SD and DRE dioxin tissue concentration modeling approaches, respectively (out of the 20 stream segments with consumption advisories that were investigated). The reduced contaminant concentrations in fish signalled by the lifting of advisories may generate benefits to recreational anglers by increasing the value of their experience and/or increasing angling participation at the site. For this assessment of national-level benefits, we estimate the increased value of the fishery to the angler, using benefits transfer, based on research conducted by Lyke (1992). Estimates derived from a potential increase in angling activity are also presented for comparison.

8.8.2 Baseline Value of the Fishery

In the human health risk assessment, recreational angling populations at each site were calculated as follows. First, the number of licensed anglers was obtained for counties bordering the river reach into which the mill discharges, and 95% were assumed to be recreational anglers. The number of anglers using the specific stream in question was then assumed to be 29% of these local resident recreational anglers, based on data from various creel surveys.[3] If an advisory was in effect for a stream, this number was reduced by 20% (as suggested by the literature on fish consumption advisories) to account for angler behavior in response to the advisory.[4] This methodology produces estimates of the number of recreational anglers at each site with a fish consumption advisory.

Since, for this assessment, benefits are assumed to accrue from the recision of an advisory, we calculate the baseline value of the fishery for only those sites where advisories are expected to be rescinded by the regulation (all but 5 of the sites investigated under the SD approach and all but 1 of the sites investigated under the DRE method). We multiply the number of recreational anglers by U.S. Fish and Wildlife Service (FWS) estimates of the average number of angling days per angler in each state to calculate the implied number of

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[3] The 0.29 ratio is based on data from 7 sites, some of which have advisories in effect (see Tetra Tech, 1993b). This ratio appears to be conservative for estimating anglers at sites near large population centers (although it may overestimate anglers at less popular sites).

[4] For studies of angler response to fish consumption advisories see West et al., 1993; Belton et al., 1986; Knuth and Velicer, 1990; Fiore et al., 1989; Vena, 1992; and Silverman, 1990. This literature suggests that, for anglers aware of advisories, changes in preparation methods and consumption habits are more common than changes in fishing locations or participation.

angling days.[5] The FWS estimates range from 15.7 days per year in California to 27.2 days per year in Florida (U.S. DOI, 1989). This results in an estimate of between 1.97 million and 2.04 million baseline fishing days for the SD and DRE approaches, respectively, as shown in Table 8-19.[6] Valuing these days using a range of average consumer surplus values for warm and cold water fishing reported in the literature ($23.55 and $37.81, respectively, in 1992 dollars (Walsh et al., 1988)), we obtain a baseline value of the fishery of between $46.48 million to $77.08 million per year.

8.8.3 Value of a Contaminant Free Fishery

The baseline fishery value calculated above reflects the value to recreational anglers under current conditions characterized by an advisory against fish consumption. Research has shown that anglers may place a significantly higher value on a "contaminant free" fishery. Lyke (1992) estimated the consumer surplus associated with Wisconsin's recreational Lake Michigan trout and salmon fishery, and the value of the fishery if it were "completely free" of contaminants that "may threaten human health." Lyke's results are based on a multiple site trip generation travel cost model using data collected from licensed anglers prior to the 1990 season. The incremental benefit values obtained range from between 11.1% and 31.3% of the value of the fishery under current conditions, indicating the significance of the toxins contamination problem in terms of how present anglers value the fishery.[7]

The description "free of contaminants that may threaten human health" may be equated by anglers with the lifting of consumption advisories. We apply Lyke's results to those sites where advisories are expected to be lifted to estimate potential benefits. Given a baseline value for these subsets of sites of $63.11 million to $104.55 million per year, Lyke-based benefits (11.1% to 31.3% of baseline value) total $5.16 million to $24.12 million per year.

In reality, while the above estimate provides a general sense of the magnitude of the recreational angling benefits that may arise from the regulation nationwide, case-specific analysis is required to more accurately predict the benefits associated with each site. Applying benefits transfer in this broad fashion is likely to underestimate benefits for some areas and overestimate them at others. Many of the sites shown in Table 8-19 are not of comparable value to those surveyed by Lyke. In contrast, one manner in which Lyke-based

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[5] Two sites for which case studies were performed, the Penobscot River and the Wisconsin River, use estimates of baseline angling days as calculated in the case study analyses.

[6] These estimates may be conservative for some large urban areas, such as the Houston Ship Channel site. The advisory for the Houston Ship Channel extends well into Galveston Bay, the most popular angling site in Texas.

[7] The range in results is attributable to whether a linear logic or constant elasticity of scale functional form is used in the estimation.

Table 8-19
Calculation of Baseline Recreational Angling Days for the SD and DRE Approaches

Site	Recreational Anglers[1]	FWS Mean Fishing Days per Angler	Baseline Angling Days (With Advisory)[2]	
			SD	DRE
Blackwater River, VA	4,477	18.4	*	19,111
Houston Ship Channel, TX	181,190	17.6	739,834	739,834
Kennebec River, ME	25,869	16.5	99,025	99,025
Escatawpa River, MS	15,229	21.3	75,253	75,253
Ouachita River, AR	17,053	24.9	98,509	98,509
Escanaba River, MI	10,153	21.7	51,113	51,113
Androscoggin River, ME	29,536	16.5	113,066	113,066
Red River, AR	27,508	24.9	158,909	158,909
Fenholloway River, FL	3,702	27.2	*	23,362
Codorus Creek, PA	34,738	27.1	218,403	218,403
Neches River, TX	70,867	17.6	289,365	289,365
Penobscot River, ME**	-	-	49,548	49,548
St. Louis River, MN	94,882	18.7	*	*
Androscoggin River, NH	1,757	20.4	8,316	8,316
Potomac River, MD	4,751	18.3	20,171	20,171
Leaf River, MS	1,549	21.3	7,652	7,652
Roanoke River, VA	5,699	18.4	24,328	24,328
Rainy River, MN	7,493	18.7	*	*
Pigeon River, NC	4,929	19.7	*	22,526
Wisconsin River, WI**	-	-	20,000	20,000
Total	-	-	1,973,492	2,038,490

Note: Although the dioxin-related advisories for the St. Louis and Wisconsin Rivers are expected to be lifted under the DRE approach, a fish consumption advisory will remain in place for the river because of advisories for contaminants other than dioxin. Benefits were included in this analysis for the Wisconsin River because the dioxin-related advisory is known to be the major concern (see also Chapter 9.0).

1 Calculated by multiplying total licensed anglers by 0.95.

2 Calculated for sites where advisory is expected to be rescinded by the regulation.

* Advisory not expected to be lifted for this site.

** Case study results for baseline angler days used in lieu of estimates based on licensed anglers in adjacent counties.

benefits are considered to be conservative is that they only apply to licensed anglers and exclude other groups (e.g., Native Americans) that fish but are not required to hold licenses. The results also may be understated because they apply only to waters currently under fish consumption advisories; recreational angling benefits are also anticipated for other sites affected by pulp and paper industry wastewater discharges.

8.8.4 Benefits from Increased Angling Participation

Recision of fish consumption advisories may also have a positive impact on the level of angling effort. Indeed, a 20% decrease in the number of anglers using a site was assumed where advisories are in place (based on the fish consumption advisory literature). For those streams where the regulation is expected to result in a lifting of the advisory, angling participation can also be assumed to increase by this same proportion.

Given the baseline value of the subset of fisheries where advisories will be lifted ($46.48 million to $77.08 million per year, as shown above), a potential 20% increase in angling activity would generate benefits of $9.30 million to $15.42 million per year. Using this approach, the range of benefits estimated approximates that produced by our application of the Lyke approach. However, no attempt has been made to account for substitute sites or discern the extent to which these benefits would merely reflect a shift in national-level activity.

8.8.5 Summary of Recreational Angling Benefits

Based on a transfer of benefits estimated for a contaminant-free fishery by Lyke (1992), we estimate potential national-level recreational angling benefits from the pulp and paper rulemaking of between $5.16 million and $24.12 million per year. Since recreational values are likely to comprise a large part of the water-related benefits from the regulation, this category of benefits is important to consider in a benefit-cost analysis. However, due to the wide range of assumptions necessary to produce national-level estimates (summarized in Table 8-20), these results are intended to provide only a general sense of the magnitude of angling benefits. Site-specific analysis would be required to produce more credible national-level results.

8.9 COMBINED AIR AND WATER NATIONAL-LEVEL QUANTITATIVE BENEFITS

The combined range of national-level air and water benefits from the regulation are shown in Table 8-21. The total benefits from the regulation are estimated to range from $160.4 million to $986.6 million per year.

Table 8-20
Factors and Assumptions Influencing the Potential Magnitude of National-Level Recreational Angling Benefits Using the Lyke Approach

Factor	Assumption Made	Potential Bias	Comments
1. Number of anglers on stream segment	29% of licensed anglers in counties bordering stream reach (Tetra Tech, 1993b)	Negative	Potentially underestimates use levels for largest population areas
2. Effect of fish consumption advisory on angler behavior	20% decrease in angler participation (and conversely, a 20% increase in participation when advisory is lifted) on stream segments with an advisory	Indeterminate	Limited information available on angler response to consumption advisories
3. Omission of stream segments not under a fish consumption advisory	Recreational angling benefits estimated only for streams segments where a consumption advisory is expected to be rescinded	Negative	Recreational angling benefits are anticipated for other sites affected by pulp and paper industry discharges
4. Prediction of potential recision of advisories	SD and DRE fish tissue concentration modeling accurately predicts impact of regulation on advisories	Positive	Models may not accurately account for site-specific problems such as contaminated sediments
5. Estimated value of a "contaminant free" fishery	11.1% to 31.3% increase in baseline value	Positive	Lyke's estimate for Great Lakes trout and salmon fishery may overestimate value of less popular fisheries
6. Use of either Lyke approach or increase in participation approach (rather than aggregating both)	Benefits generated from an increase in value of angling experience (Lyke)	Negative	Recreational angling benefits may be additive and accrue both from an increase in value and an increase in participation

Table 8-21
Potential National Level Air- and Water-Related Benefits of the Pulp and Paper Regulation

Benefit Category	Millions of 1992 Dollars per Year
Air	
·Cancer Risk Reduction	$0.8 - $4.2
·VOC Benefits[1]	$88.1 - $552.0
Air Benefits Range	$88.9 - $556.2
Water	
·Human Health[2]	$10.0 - $350.0
·Recreational Angling	$5.2 - $24.1
·Avoided Costs of Sludge Disposal	$56.3
Water Benefits Range	$71.5 - $430.4
Combined Air and Water Benefits Range	$160.4 - $986.6

1 The method used to value VOC emission reductions ignores the chronic health effects associated with repeated exposure to ozone. This omission results in an underestimate of the total value of reduced ambient ozone levels.

2 Lower bound uses DRE approach health benefit estimate. Upper bound based on SD approach health benefit estimate.

9.0 QUANTIFIED CASE STUDY BENEFITS ASSESSMENTS

9.1 OVERVIEW OF SITES AND APPROACH

The benefits analysis presented in this RIA is intended to provide insight into both the types and potential magnitude of the economic benefits expected to arise as a result of the pulp and paper rulemaking. Because benefits are often highly site-specific, this portion of the benefits analysis is based on a case study approach, using benefits transfer where feasible, and relying on qualitative discussion of how benefits may be generated where confidentiality agreements preclude calculation of quantitative results. The case studies include segments of: 1) the Penobscot River in Maine; 2) the Wisconsin River, located in central Wisconsin; 3) the lower Columbia River in Washington and Oregon; and 4) the Leaf River in Mississippi.

Water-based benefits are often highly site-specific, making it difficult to undertake meaningful benefits analysis on a national scale. The case study approach was used because it is more amenable to meaningful benefit-cost analyses than are studies of larger areas. Although the results obtained for a case study site may or may not apply to the regulation as a whole, the case study approach does provide a pragmatic and realistic perspective of how a proposed program can generate benefits, the types of benefits anticipated, and how these benefits compare to costs. An analysis of the representativeness of the case study sites with respect to the universe of sites impacted by the regulation is presented later in this chapter.

The case study sites were selected to provide geographic representation of the impacts of the regulation, taking data availability into consideration as well. As shown earlier in this RIA, the impacted facilities lie in the northeast, southeast, northcentral, and northwest regions of the U.S. In the northeast, 7 chlorine beaching plants are located in Maine, two of which discharge to the Penobscot River. In the north central U.S., the Wisconsin River receives discharges from 5 facilities out of a total of 13 in the region. Likewise, a concentration of mills in the Pacific Northwest are located on the lower Columbia River. And, finally, a large number of mills are located in the southeastern U.S., from which we chose the Leaf River site. This site was also chosen to utilize an earlier study of the impacts of process changes on the concentrations of dioxins in fish tissue and on the fish consumption advisory for the river (Tetra Tech, 1993c), which provides a retrospective look at how process changes have generated benefits.

9.2 THE PENOBSCOT RIVER CASE STUDY

9.2.1 Introduction

The Penobscot River is the site of a sensitive Atlantic Salmon run and, as a result of a major restoration effort, the state's most active salmon sport fishery. The river now accounts for approximately 83% of the total salmon catch (kept and released) in Maine. The river is also important to the Penobscot Indian Nation, whose territory includes 146 islands located in the river. Consumption of any species of fish from the Penobscot is cautioned by a fish consumption advisory, however. Dioxins were first detected in fish tissue samples in 1983, and a fish consumption advisory was issued for the 1988 fishing season for the section of the river below Lincoln to the estuary (56.5 miles).

The Penobscot receives discharges from 5 pulp and paper mills and 10 major municipal sources over its entire length of 103 miles (Mitnik, 1991). Two of these mills are bleached kraft facilities that would be covered by the proposed standards, as shown in Figure 9-1. Recent sampling (completed under Maine's Dioxin Monitoring Program) of smallmouth bass and white suckers from below the two bleached kraft mills indicated significant levels of dioxin, but at levels statistically significantly lower than those detected from 1986 to 1990 (Mower, 1991). Effluent concentrations of dioxin below the Old Town mill were also lower in 1990 than in previous years, and may have contributed to the lower levels in fish tissue (Mower, 1991). No new data for the Lincoln plant effluent or sludge after 1989 was available for comparison.

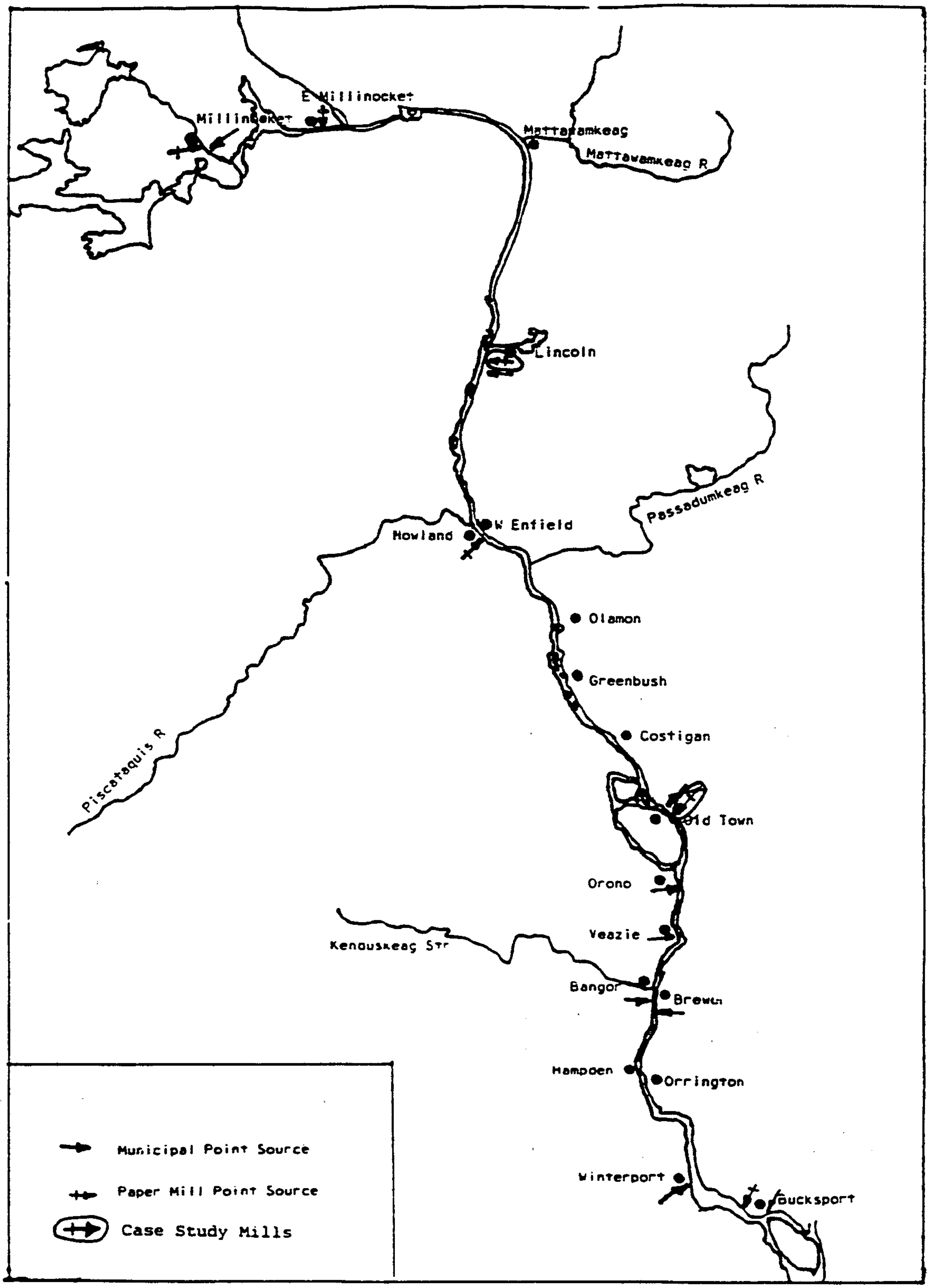
9.2.2 Potential Impact of the Regulation

Process changes such as those incorporated into the technology basis of the regulations may result in lower concentrations of dioxins in fish tissue. As mentioned above, sampling results from Maine's Dioxin Monitoring Program showed the lower dioxin concentrations in fish coincided with lower effluent concentrations from one of the mills. If the process changes result in concentrations of dioxins in fish tissue falling below the state threshold level, the consumption advisory could be lifted.

As summarized in Chapter 8.0, the regulation is expected to eliminate a large number of advisories using either the simple dilution (SD) or Dioxin Reassessment Evaluation (DRE) approaches. The analysis for the Penobscot River indicates that the fish consumption advisory would be lifted as a result of the proposed standards. For both plants, the model results indicate that fish tissue concentrations associated with the selected regulatory options would not exceed the state threshold level using either the SD or DRE approaches.

Several types of benefits may result from lifting the fish consumption advisory on the Penobscot River. First, there is a reduction in human health risk associated with the lower dioxin concentrations. Both subsistence and recreational angler populations would receive benefits in the form of reduced excess cancer risk. Second, benefits may accrue to anglers from the knowledge of the reduced contaminant levels signaled by the lifting of the advisory and/or there may be an increase in angling use of the river. Third, the reduced levels of

Figure 9-1
Penobscot River



dioxins in fish will generate ecologic benefits, notably for piscivorous birds and mammals. The potential magnitude of these benefits is discussed below.[8]

9.2.3 The Magnitude of the Potential Benefits of the Regulation

Human Health Benefits

Human health benefits from reduced ingestion of dioxin can be estimated from information on exposed population, consumption rates, and pre- and post-regulation risk levels, to determine the incidence of excess cancers avoided by the regulation. This methodology is discussed in Section 8.2.2. and the results, shown in Table 9-1, do not indicate significantly different results between the two modeling approaches. Valuing the reduced incidence of cancer attributable to the regulation under the two approaches by the standard values associated with the "value of a statistical life" reported in the literature ($2 to $10 million (1992 dollars) per statistical fatality (U.S. EPA, 1989c; Violette and Chestnut, 1983; 1986), results in benefits range of between $0.04 million to $0.40 million per year.

One issue with potential to impact estimates of human health benefits is the potential presence of populations regularly consuming fish quantities in excess of the advisory. The Penobscot Nation, which traditionally has relied upon the Penobscot fishery for sustenance, is perhaps the largest such population in the basin. Because they possess treaty-protected rights to the Penobscot River fishery, members of the Penobscot tribe fishing on the reservation are not subject to state catch limits and may engage in traditional spearing and netting activities.

In a 1991 survey of Penobscot Nation tribal members, 24% of respondents reported that they ate fish caught from the Penobscot River (Penobscot Nation Department of Natural Resources, 1991). Of those who eat Penobscot River fish, 13% (6 respondents, or 4% of all survey respondents[9]) stated that they ate one or more fish meals per week during fishing season, with 4% stating that they ate more than two fish meals per day.[10] Hence, despite consumption advisories, a substantial number of tribal members appear to be consuming fish from the river. Additionally, it is likely that this figure is an underestimate of actual consumption rates, since the individuals who practice a "traditional" lifestyle — tribal

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[8] Increased angling effort for the Penobscot is not examined because of congestion problems and catch limits for the Atlantic salmon fishery, and a lack of baseline data on other river fisheries.

[9] Surveys were mailed to all tribal members over the age of 18 residing in Maine. Of 858 surveys mailed, 21 were undeliverable and 210 were returned, yielding a 25% response rate. 47 respondents answered a question asking how many fish meals were eaten during fishing season and during the rest of the year.

[10] An average daily ingestion rate of 145 grams/day (4.7 ounces) was used to model carcinogenic risks to subsistence anglers.

Table 9-1
Estimated Individual Lifetime Cancer Risk and Reduction in Excess Cancer Cases Resulting from the Selected Regulatory Option for the Penobscot River

Exposed Population	Lifetime Cancer Risk: Baseline	Lifetime Cancer Risk: Selected Regulatory Option	Annual Reduction in Excess Cancer Cases
SD Approach			
Lincoln Mill			
Recreational Anglers	1.1E-04	3.3E-06	0.02
Subsistence Anglers	1.5E-03	4.4E-05	0.02
Old Town Mill			
Recreational Anglers	1.7E-05	3.4E-06	0.00
Subsistence Anglers	2.3E-04	4.6E-05	0.00
Total			0.04
DRE Approach			
Lincoln Mill			
Recreational Anglers	3.9E-05	3.3E-06	0.01
Subsistence Anglers	5.2E-04	1.3E-05	0.01
Old Town Mill			
Recreational Anglers	5.3E-06	9.1E-7	0.00
Subsistence Anglers	7.1E-05	1.2E-05	0.00
Total			0.02

Source: Tetra Tech, 1993b

members who spend a great deal of time on the reservation fishing and hunting — generally do not respond well to written surveys and thus are probably underrepresented in the survey results (Banks, 1992). Consequently, the Penobscot Nation represents one important population subcategory that may reap more significant health benefits than the modeled health risk reductions suggest.

Recreational Angling Benefits — Value of a Contaminant Free Fishery

Anglers may also derive value from the knowledge of reduced contaminant levels in fish, such as that signaled by the lifting of the consumption advisory. Research has shown anglers to be willing to pay for a "contaminant free" fishery. Lyke (1992) estimated the consumer surplus associated with Wisconsin's recreational Lake Michigan trout and salmon fishery, as well as the value of the fishery if it were "completely free" of contaminants that "may threaten human health." Lyke's results are based on a multiple site trip generation travel cost model using data collected from licensed anglers prior to the 1990 season. The values obtained range from between 11.1% and 31.3% of the value of the fishery under current conditions, indicating the significance of the toxins contamination problem in terms of how present anglers value the fishery.[11]

The meaning of "free of contaminants that may threaten human health" may be equated by anglers with the lifting of consumption advisories, which is expected to occur on the Penobscot as a direct result of the regulation. Lyke's results may not be directly applicable to the Penobscot River site in other respects, however, given the differences in the fishing experiences between the open water Great Lakes environment and the Penobscot River fishery. Nonetheless, both are popular fisheries (with the Penobscot being the most active Atlantic salmon fishery in Maine) currently plagued by contamination problems.

Lyke's results reflect a percentage of the baseline value of the fishery. The baseline value of the Penobscot River Atlantic salmon fishery is estimated by multiplying the number of angling days by the average consumer surplus per day of anadromous fishing reported in the literature of $66.70 (in 1992 dollars) (Walsh et al., 1988). Salmon angling days estimated by a 1988 survey totaled 24,140 (RCG/Hagler, Bailly, 1989); another survey indicated 26,676 resident days for 1989 (Boyle, et al., 1992). Thus, the value of the fishery is estimated at between $1.6 million and $1.8 million, and Lyke's results imply benefits of between <u>$0.18 million and $0.56 million per year</u> are generated from reduced toxins. These benefits may actually be conservative because they only apply to licensed anglers and exclude other groups (e.g., Native Americans) that fish but are not required to hold licenses.

These benefits apply only to the Atlantic salmon fishery and the level of activity associated with other Penobscot River fisheries is not known. However, if we estimate, as an uppermost bound, that angling days for all other fisheries combined number as high as the

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[11] The range in results is attributable to whether a linear logic or constant elasticity of scale functional form is used in the estimation.

Atlantic salmon fishery and value these days by the average consumer surplus per coldwater fishing day reported in the literature of $37.82 (in 1992 dollars), the upper-bound estimate of the remaining fisheries is between $0.91 million to $1.0 million. Applying the Lyke results implies angler benefits apart from the Atlantic Salmon fishery may be as high as <u>$0.10 million to $0.31 million per year</u>.

Tribal Benefits

As mentioned above, the Penobscot Nation is greatly affected by water quality on the Penobscot River due to its location on Penobscot River islands. In this section, two types of benefits to tribal members will be examined: 1) angling benefits, and 2) benefits to the tribe of restoration of traditional or subsistence uses of the Penobscot River and fishery. While there may be overlap between each type of benefit, each utilizes specific valuation approaches and is thus discussed separately.

<u>Angling Benefits to Tribal Members.</u> In the 1991 survey of the Penobscot membership mentioned above, 61 respondents (29%) indicated that they had used the river in the past year for fishing, and 130 had used the river for some type of recreation over the past two years. Two-thirds of the respondents to the survey noted that they have concerns about eating fish from the Penobscot River, and 95% of those with concerns noted pollution problems as the principal concern. (Almost a quarter of respondents mentioned dioxin, carcinogens, and the consumption advisory specifically.)

According to the survey, 24% of tribal respondents eat fish caught from the Penobscot River.[12] Given the traditional fishing-based lifestyle of the Penobscot tribe, and the high level of concern about the contamination of Penobscot River fish, there is most likely significant unmet demand for opportunities to harvest edible fish from the river among tribal members. When asked whether they would fish for Atlantic Salmon if it were more available for sustenance fishing on the reservation, 90% of survey respondents answered "yes."[13] Hence it is likely that a lifting of the consumption advisory would foster significantly increased angling, enjoyment of that angling, and fish consumption among tribal members.

In the section above, a range of benefits to Maine (licensed recreational) anglers was estimated for a contaminant-free fishery, reflecting between 11.1% and 31.3% of its baseline value. Per-capita angling benefits for tribal members may, however, exceed those for other Penobscot River anglers. Because the tribe has treaty-reserved fishing rights, state catch limits do not apply. Even the consumption limit of one salmon per angler per year does not apply to the Penobscot; instead, tribal members are limited to possession of no more than

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[12] As noted above, however, this estimate may be low since it is believed that many tribal members who lead a "traditional" (hunting and fishing-based) lifestyle tend not to respond well to written surveys.

[13] Due to an error, only 69 individuals answered this question. 62 answered "yes," and 7 answered "no."

10 salmon at any time. Therefore, a rescission of the consumption advisory could reasonably lead to even higher consumer surplus values for tribal fishermen.

Benefits Provided by Traditional or Subsistence Uses of the Penobscot River and Fishery. The Penobscot Nation possesses sustenance fishing rights, reserved in the Indian Land Claims Settlement. These special rights, and the traditional outlook of the Penobscot Nation toward the health of the river and fishery, suggest that the Penobscots place a high value on these resources. From the tribal perspective, rather than simply providing recreational (or even economic) opportunities, the Penobscot River plays a much more extensive role in the tribe's well-being. According to a statement prepared by the tribe's Director of Natural Resources (Banks, 1992), "any threats to the river's ecological health is a loss of the tribe's spiritual health..." Due to this holistic view of the role of the Penobscot River, water quality improvements may provide higher levels of benefits to Penobscot tribal members than to many other users (and nonusers) of the river. To suggest a rough, monetized value for these traditional or "sustenance"[14] benefits, this section examines cases in which other tribes throughout the U.S. have negotiated or settled for compensation for the loss of such uses; the range of per-capita settlements can then be applied to the Penobscot case to suggest a rough range of valuation estimates for water quality improvements leading to higher traditional or sustenance values.[15]

The valuation of subsistence uses is a relatively new area; therefore, it is necessary to draw upon precedents which, although not identical to the Penobscot situation, may have key factors in common. Several settlements and negotiations have involved compensation to U.S. tribes for loss of traditional or subsistence uses of natural resources; cases are summarized below. These cases provide a rough range of values for cultural services provided by natural resources in a "subsistence-based society"[16]. The settlements and negotiations reviewed all attempt to arrive at a "just" or acceptable compensation level for a tribal loss of a traditional or subsistence resource; such settlements may differ from an estimate of benefits to tribal members for restoration of a resource (e.g., the Penobscot River fishery) to which the tribe retains treaty rights. However, the settlements reviewed provide reference points suggesting levels at which subsistence or traditional resources have been valued in past tribal cases. Although some of the cases outlined may not reflect a fully

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[14] Often described as a "subsistence" use, the traditional use of the fishery is often referred to by the Penobscot Tribe as a "sustenance" use.

[15] Many reviewers, including many members of the Penobscot Nation, may consider any attempt to place a monetary value on the benefits received by the Penobscots from the river and river fish to be severely deficient. However, given the requirement that this RIA compare the benefits of the pulp and paper rulemaking with its costs, this important category of benefits should not be overlooked.

[16] In addition to providing for basic nutritional needs, natural resources used by a subsistence-based society may provide cultural services, such as contributing to tribal identification and cohesion, self-reliance, closeness to nature, and providing elements of religious and social traditions. More detailed discussion of these additional values may be found in Brown and Burch (1992).

voluntary acceptance of compensation, they provide basic information on tribes' past willingness to accept compensation for unavoidable resource losses or losses that have already occurred.

Awards are expressed in terms of annual payment per capita, so that a range can be established and compared to potential benefits to the Penobscot Tribe of a water quality improvement. Lump sum payments have been divided by the number of enrolled tribal members and, where applicable, the present value of a stream of payments has been calculated and divided by the number of enrolled tribal members. These per-capita values are annualized so that yearly per-capita equivalents may be presented.

Unique conditions of each "precedent" case affect final compensation levels and their applicability to an estimate of benefits of restoring traditional resource uses. In addition to variation among the specific resources in question in these cases, the settlements reviewed also reflect the perceived strengths and weaknesses of each tribe's legal claim.

Among the applicable cases are the following:

- Compensation to the Yakima, Umatilla, Warm Springs, and Nez Perce tribes for inundation of Columbia River salmon fisheries. Evidence suggests that the final settlement was not entirely voluntary. In 1992 dollars, the 1956 settlement would amount to $1,078 per capita annually.

- Tentative compensation to the Mille Lacs Band for loss of rights to commercially harvest game fish and big game and for restrictions on intensive harvest methods. This tentative settlement preserves important traditional rights, including netting and spearing of fish, and it addresses tribal fishing rights both on and off the reservation. The tentative settlement would provide annual compensation of $1,050 per capita for four years and would convey 7,500 acres of land and an exclusive fishing zone to the band.

- Compensation to the Grand Portage, Bois Forte, and Fond du Lac Bands of the Chippewa for limited loss of hunting and fishing rights. The settlement focuses on off-reservation rights to the resource. The bands maintain the right to continue a variety of traditional activities through this agreement. The settlement provides annual compensation of $635-$2,025 per capita.

- An offer of compensation to the Lac du Flambeau Band, which was rejected, for a ten-year loss of hunting and fishing rights on ceded lands. The loss again involved off-reservation resources, as opposed to the on-reservation resource rights clearly belonging to the Penobscots. The settlement would have provided $1,424 per capita for each of the ten years.

- Compensation to the Three Affiliated Tribes of the Fort Berthold Reservation and the Standing Rock Sioux Tribe for taking of lands and loss of resource and traditional uses. The explicit recognition and valuation of traditional tribal uses in this case provides a relevant point of reference to the benefits assessment. The combined original and 1992 settlements provide awards amounting to $1,564 and $465 annually per capita on the two reservations. Further claims may be pursued.

Settlements and tentative settlements reviewed cover a wide range of resource losses and a broad time span. Nevertheless, annualized per-capita settlements (or tentative settlements) are relatively consistent, ranging from $823 (population-weighted average of combined original and 1992 awards to Fort Berthold and Standing Rock) to $1,424 (offer of compensation for ten-year curtailment of resource rights, rejected by Lac du Flambeau Band). Table 9-2 summarizes the per-capita compensation levels specified in the settlements reviewed, noting those cases in which settlements may not have been entirely voluntary.

The per-capita settlements associated with natural resource losses on other reservations can serve as a point of reference to suggest an appropriate range of baseline valuation levels for the Penobscot Tribe. When applied to the current Penobscot tribal enrollment of 2,033, the annual per-capita settlement range of $823-$1,424 discussed above would yield an annual valuation range of $1,673,159 - $2,894,992 for the tribe's traditional uses of its natural resources, including the Penobscot fishery. If this baseline resource value were increased by just 10-20% as a result of reducing dioxin contamination to levels allowing fish consumption advisories to be rescinded, then benefits to Penobscot tribal members would be in the range of $0.17 million - $0.53 million per year.

Ecologic (and Other Nonuse) Benefits

Individuals may value reduced toxic concentrations in the nation's waters apart from any values associated with their direct or indirect use of the resource. These nonuse values are difficult to estimate absent carefully designed and executed primary research (i.e., the contingent valuation method), but there are some rough rules of thumb and other benefits transfer techniques that may be applied to provide a rough sense of the potential magnitude of nonuse values.

Ecologic and other Nonuse Benefits Relevant to the Regulation. Dioxin has been found to pose risk to aquatic-associated wildlife, with the most sensitive ecologically important endpoints for mammals and birds being reproductive effects (U.S. EPA, 1993a). Since dioxins have been measured in fish tissue at levels sufficient to initiate fish consumption advisories for the protection of human health, adverse impacts on fish-eating wildlife, such as the bald eagles that nest along the lower Penobscot River, are also of concern. Some bald eagles in Maine have been found with toxic levels of dioxin and reproductive problems possibly due to high levels of mercury and dioxin and have also been noted at inland nesting

Table 9-2
Summary of Settlements for Tribal Loss of Natural Resource Uses

Case	Per Capita Compensation	Comments
Loss of salmon fishery at Celilo Falls: U.S. Congress and Yakima, Umatilla, Warm Springs, Nez Perce	1956 settlement: $3,755 cash payment (1954), equivalent to <u>$19,602 in 1991 dollars</u>; if annualized at 5.5%, <u>payments over a permanent loss period would = $1,078</u>	Tribes retained fishing rights, but fishing grounds were inundated. Evidence suggests that settlement was not voluntary.
Limited loss of hunting and fishing rights: State of MN and Chippewa Bands	1985 settlement: <u>Weighted per capita average - $885 annually</u> $2,025 annually - Grand Portage $800 annually - Bois Forte $635 annually - Fond du Lac Present value (50 years, i = 5.5%): $34,286 - Grand Portage $13,545 - Bois Forte $10,752 - Fond du Lac	Tribes maintain commercial fishing rights, but agree to specific zones and catch limits.
Loss of right to commercially harvest game fish and big game; restrictions on intensive harvest methods: State of MN and Mille Lacs Band	Tentative settlement: <u>$1,050 annually for four years</u> (Present value of $3,612) <u>Plus</u> 7,500 acres of land and 6,000 acre exclusive fishing zone	Tentative settlement would provide the band with $10 million over four years, plus additional resources noted. Present value of total settlement, using a 5.5% discount rate, would be $8.8 million.
Loss of lands and resource uses due to Garrison and Oahe Dams: U.S. Congress and Fort Berthold and Standing Rock Reservations	Combined original award and 1992 settlement: <u>Weighted per capita average - $823 annually</u> Fort Berthold: Total per capita value of $28,428 in current dollars. <u>Annualized value of award = $1,179.</u> Standing Rock: Total per capita value of $8,463 in current dollars. <u>Annualized value of award = $409.</u>	Original awards to tribes contained specific component for "intangible" losses, which is addressed in Chapter 4.0 and omitted from these calculations. 1992 settlement was to correct underpayment in total compensation of original packages. Per capita figures at left combine original (1949 and 1958) awards, adjusted to their 1992 values, with the present value of the 1992 settlement. Annualized values reflect total per capita values annualized at 5.5% over a permanent loss period. Further claims may be pursued.
Compensation for ten-year loss of hunting and fishing rights on ceded lands: State of WI and Lac du Flambeau Band	Settlement rejected: Per capita total value - $8,900-$14,240 <u>Annual per capita value - $890-$1,424</u> (Spread over 10-year period of lost resource use)	$35.6 million offered to tribe and rejected.

sites, although there is no conclusive scientific evidence as to what is causing the problem (Boucher, 1993).

As noted in Chapter 7.0, preliminary assessments have been performed by the Agency on the risks to wildlife posed by dioxin wastestreams from pulp and paper mills (RCG/Hagler Bailly, 1993; Abt Associates, 1993). The ecologic assessments focus on potential wildlife risks posed by point source discharges of effluent containing dioxin, and the land application of dioxin-laden sludges. The endpoints of concern are wildlife species (including bald eagles, ospreys, hawks, raccoons, and otters) potentially exposed to dioxin from pulp and paper facility operations via either aquatic or terrestrial exposure pathways. Preliminary results of these initial assessments of wildlife risks indicate that under some modeling scenarios, modest ecologic risks to several wildlife species of concern are associated with current levels of dioxin in effluent and sludges originating from pulp and paper facilities.

The proposed regulation will result in decreased concentrations of dioxin in plant effluent, and individuals may value this result in and of itself, particularly if additional scientific research confirms a linkage between such loading reductions and potential ecologic benefits. Furthermore, these lower effluent levels will result in lower concentrations of dioxin in sediment and, thus, lower concentrations in fish tissue.

Potential Magnitude of Nonuse Values. Two methods of benefits transfer are available for providing rough estimates of the potential magnitude of nonuse value benefits associated with the regulation. The first approach involves applying a rough "rule of thumb" of assigning nonuse values as half the value of recreational fishing benefits. This rule of thumb is based on an extensive review of the economics literature providing empirical evidence of the use and nonuse values associated with improved water quality and/or fisheries (Fisher and Raucher, 1984). This review indicated that nonuse values have been estimated to be *at least* half as great as recreational values, and concluded that if nonuse values were potentially applicable to a policy action, that using a 50% approximation was rough but, with proper caveating, was preferred to omitting nonuse values from a benefit-cost analysis.

Use of this "rule of thumb" implies a nonuse value of the regulation of between $0.14 and $0.44 million per year. This value is obtained from the recreational angling benefits estimated for the Atlantic Salmon and other river fisheries. Angling benefits to tribal members, which were not estimated, are thus left out of the calculation. However, nonuse values to tribal members can be assumed to be implicitly included in the estimate of restoration values to the Penobscot Nation.

A second approach to estimating nonuse values in this context is to apply literature-based estimates of household willingness to pay for clean waters to the residents of the watershed. Mitchell and Carson (1984) found in a 1981 national survey that nonusers were willing to pay an average of $179.65 per household annually (updated to 1992 dollars) to have the nation's waters made fishable, of which roughly two-thirds ($119.77 per household) could be attributed to the desire to have in-state waters all made fishable (Mitchell and Carson, 1986).

Applying this result to the 54,063 households in Penobscot County, a total of $6.4 million per year is derived as an estimate on the nonuse values associated with improvements in "local" water quality such that it fully supports its use as a fishery.[17] If we assume that the regulation contributes between 5% and 10% of the credit for attaining the fishery use status (lifting of the fish consumption advisory), then this approach yields a nonuse benefit value of $0.32 and $0.65 million per year.[18]

9.2.4 Summary of Water-Related Benefit Estimates

A summary of the potential benefits resulting from regulation at the Penobscot River site is shown in Table 9-3. In dollars per year, the regulation is expected to generate benefits on the order of $0.63 to $2.45 million in the Penobscot River basin.

Table 9-3
Potential Water-Related Benefits of the Pulp and Paper Regulation for the Penobscot River (Millions of 1992 Dollars per Year)

Benefit Category	Millions per Year
Human Health[1]	$0.04 - $0.40
Angling	
Recreational (Based on Lyke, 1992)	
Atlantic Salmon	$0.18 - $0.56
Other River Fisheries[2]	$0.10 - $0.31
Tribal	+
Restoration of Subsistence Use to Penobscot Nation	$0.17 - $0.53
Ecologic (and other Nonuse)	$0.14 - $0.65
Total	**$0.63 - $2.45**

\+ Positive benefits expected; benefits not estimated.
1 Benefits to recreational and subsistence anglers.
2 Upper-bound estimate based on assumption of angling days equal to Atlantic salmon fishing days.

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17 Nonuse values are thus based on household-level values obtained from nonusers, applied to all households. This then captures the nonuse values held by those households that are users.

18 While the analysis indicates that regulation may be associated with a lifting of the consumption advisory on the Penobscot River, other actions such as remediation of contaminated sediments may also be necessary or sufficient for lifting the advisories.

9.2.5 Air Benefits

Air-related benefits of the pulp and paper rulemaking for the Penobscot River mills are derived based on the methodology presented in Chapter 8.0. For the case study sites, these benefits are associated with VOC emission reductions.[19] Annual benefits of between $0.37 million and $2.30 million are expected for the Penobscot site, as shown in Table 9-4.

Table 9-4
VOC Emission Reductions and Benefits for the Penobscot River[1]
(Millions of 1992 Dollars per Year)

	Penobscot River
Annual VOC Emission Reductions (Mg/yr)	2,989
Annual Benefits[2]	
Acute Health Effects	$0.03 - $1.64
Agricultural Benefits	$0.34 - $0.67
Total VOC Reduction Benefits	**$0.37 - $2.30**

1 The approach for monetizing VOC benefits ignores the chronic health effects associated with repeated exposure to ozone. This omission results in an underestimation of the total value of reduced ambient ozone levels.

2 Monetized based on U.S. EPA/OTA study using benefit range per Mg of $9 - $548 (1992 dollars) for acute health effects and $114 - $223 (1992 dollars) for agricultural effects.

Source: U.S. EPA/OAR/OAQPS/ESD.

9.3 THE WISCONSIN RIVER CASE STUDY

9.3.1 Introduction

In the northcentral U.S., five pulp and paper facilities in relative close proximity to one another are located on the Wisconsin River. This section of the river runs through a five county area in central Wisconsin which includes Marathon, Portage, Wood, Adams, and Juneau counties. Below these counties, the river runs southwest to its confluence with the Mississippi River to form the southwestern border between Wisconsin and Iowa.

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[19] Air-related human health benefits for the case study sites are assumed to be negligible since national benefits are on the order of $0.8 million to $4.0 million (a reduction of 0.4 cancer cases per year) and some negative benefits associated with increases in some air emissions are expected.

The Wisconsin River provides both important recreational opportunities as well as habitat for wildlife, including important endangered species. The large lakes formed in the Petenwell and Castle Rock flowages, in particular, support fishing and other water-related consumptive and nonconsumptive activities. The Petenwell and Castle Rock flowages are the second and fourth largest lakes in the state, respectively, with a combined 180 miles of shoreline. Visitors to Petenwell Park are able to view large numbers of bald eagles, a federally listed endangered species, which nests along the river. Another large undeveloped natural area surrounds Lake DuBay, also formed by the Wisconsin River.

The use and nonuse values associated with the Wisconsin River water resources are currently limited by environmental quality, with significant impacts from dioxin contamination. These impacts are seen most concretely in a dioxin-related fish consumption advisory designed to protect against excess cancer risk in humans. Consumption of dioxin-contaminated fish also has the potential for impacting fish-eating birds and mammals such as bald eagles and mink. Thus, the rulemaking can enhance the use and nonuse values associated with the Wisconsin River water resources to the extent that it contributes to lowered concentrations of dioxin in the ecosystem, generating benefits from increased use as well as from protecting important fish and wildlife species.

9.3.2 Resource Use

Recreational Fishing

Demand for recreational facilities in the case study area is high, especially within the lakes along the river, including Lake DuBay and the Petenwell and Castle Rock flowages. The primary uses of the river and river parks are passive day-use, swimming, fishing, picnicking, boating, waterskiing, canoeing, camping and hunting. Fishing has long been a popular activity on the Wisconsin River. According to a recent state survey, the five county region forming the case study site is the third most popular region in the state for fishing (Wisconsin Department of Natural Resources, 1991a). Whereas only 100,000 anglers were reported to live in the region, twice that many were reported to fish there.

Fish found in this section of river include walleye, northern pike, bass, panfish, carp, white sucker, redhorse, perch, largemouth bass, bluegill, black crappie, rock bass, pumpkinseed, bullhead, bowfin, and burbot (Nickel and Collins, 1992; Foth & Van Dyke, 1991; Portage County Park Commission, 1990). Muskie is also becoming a prominent game fish in the river, and has being stocked by the Wisconsin Department of Natural Resources (DNR) and a local organization, Muskies Today, Ltd. Muskies Today also plans to stock the river with other species, such as walleye, in the future. The organization currently raises fish in the old Wisconsin Rapids sewage plant in Wood County, and is in the process of adding hatching equipment to the operation (Wood County, 1991).

Peak season on the Wisconsin River is from March through April, when carp are concentrated around the dams. Creel studies have been conducted during peak season on selected portions of the river. The results from a 1987 survey, shown in Table 9-5, indicate approximately 10,400 angling days for these two months. Given the data represent only six sites and a two-month period, we conservatively assume total angling effort on the river may be twice this level, or 20,800 days. To obtain a baseline value for the fishery, the average consumer surplus values for warm and cold water fishing reported in the literature ($23.55 and $37.81, respectively, in 1992 dollars (Walsh et al., 1988)) are utilized. This implies a baseline value of between $489,800 and $786,400.

Table 9-5
Creel Surveys of Selected Wisconsin River Sites[1]

Site	County	Fishing Hours	Fishing Days[2]
Lake Wausau	Marathon	14,672	1,834
BEP Tailwater	Marathon	6,076	760
Mosinee Tailwater	Marathon	5,478	685
Petenwell Tailwater	Juneau	19,506	2,438
Castle Rock Dam	Juneau	8,104	1,013
Nekoosa Tailwater	Wood	29,295	3,662
Total		83,141	10,392

1 Surveys conducted by Wisconsin Department of Natural Resources. Survey period for all sites except Lake Wausau was March - April, 1987. Lake Wausau survey was conducted April-May, 1984. At this time of year, walleye are concentrated around dams and fishing levels are at a peak high.

2 Fishing days based on an eight hour day. The statewide average fishing day is five hours per day (U.S. DOI, 1989).

High levels of dioxin have resulted in the issuance of health advisories for consumption of certain fish species that may pose excess cancer risks. Advisories related to dioxin contamination have been issued for carp and small mouth bass within the case study area as summarized in Table 9-6. The advisory for the Petenwell Flowage was initially issued in 1983 at which time health advisories were issued by Wisconsin authorities if fish tissue samples contained concentrations above 25 ppt. A more stringent threshold level of 10 ppt was set in 1990, which made the Castle Rock Flowage also subject to an advisory.

Several surveys of fishing habits indicate that changing fishing locations or fishing less is a predominant response for those anglers that are aware of and make behavioral changes in response to fish consumption advisories (Knuth and Velicer, 1990; Silverman, 1990; Vena,

Table 9-6 Dioxin-Related Fish Consumption Advisories within the Wisconsin River Case Study Area[1]			
River Section	Group 1 Low Health Risk	Group 2 Women and Children Should Not Eat	Group 3 No One Should Eat These Fish[2]
Nekoosa Dam to Petenwell Dam (Petenwell Flowage)	-	-	Carp[3] White bass[4]
Petenwell Dam to Castle Rock Dam (Castle Rock Flowage)	-	-	Carp[4]

1 Source: Wisconsin Department of Natural Resources, 1992.
2 Levels of contamination are higher than one or more health standard in 50% or more of fish tested.
3 Consumption advisory initially issued in 1983.
4 Consumption advisory initially issued in 1990.

1992). Thus, the consumption advisory may be impacting the current level of angling in the river. Meanwhile, excess cancer risk is experienced by those ignoring the advisory.

Commercial Fishing

At one time, there was commercial netting of carp along the river. Commercial bans were instituted in the case study area at the time that fish consumption advisories were issued. Commercial fishing was banned in the Petenwell Flowage in 1983, when high concentrations of dioxin were found in carp there. In 1990, commercial fishing of carp was also banned in the Castle Rock flowage (Amerhein, 1992).

Subsistence Fishing

Subsistence fishing may also be important in the case study area although there are no data to indicate the extent to which this occurs. A local East Asian population, the Hmong, is known to heavily utilize local fish as a source of protein (Xiong, 1992). A 1992 survey of the Hmong reported a total of 3,576 people, or 502 families in the area.

Hunting

The case study area is a popular hunting site in Wisconsin. A recent survey of state recreational activities found that of the 135,000 individuals hunting in the five county region, only 75,000 actually lived within the region (Wisconsin Department of Natural Resources, 1991a). In 1991, 6,073 waterfowl stamps were distributed to residents within the five counties of interest. Also, a total of 604 trapping licenses were issued, covering all five counties (Wisconsin Department of Natural Resources, 1991b). These represented 6.5% and 10.0% of state sales, respectively.

However, hunting opportunities, especially for waterfowl, have diminished due to pollution and the loss of wetlands in the case study area. In the early 1970's, the five county region was a major staging area for bluebill ducks, which were present possibly in the tens of thousands, and to a lesser extent for canvasback and redhead ducks. These species are no longer present within the region and are believed to have disappeared as early as 1983 (Haug, 1993). The bluebill ducks are believed to have left because their primary food source, fingernail clams, are believed to have been eliminated by mercury contamination. There is no data available, however, to substantiate this theory (Haug, 1993). The disappearance of the canvasback and redhead ducks is believed to be linked to the draining of wetlands within the region.

Waterfowl species currently present and hunted along the river include ruffed grouse, woodcock and turkeys. Turkeys have appeared within the last five to six years and are now hunted in modest amounts on both sides of the river (Haug, 1993). Mammalian species that are trapped or hunted include the mink, raccoon, river otter, muskrat, gray squirrel, and white tailed deer. Of these species, mink and river otter are most susceptible to dioxin contamination because they feed on river fish. Muskrats and raccoon, which feed on crawfish, are also likely to be exposed to dioxin concentrations in the case study area.

Nonconsumptive Recreation

Several areas along the river, especially the major flowages, provide public facilities for wildlife viewing, birdwatching, and other nonconsumptive activities. Three major parks are located along the river at Lake DuBay and the Petenwell and Castle Rock flowages. Bald eagles nest along the Wisconsin River at the Petenwell Flowage, where they are visible to visitors of the park. The birds are present in greatest numbers during the winter and spring seasons, when a section of the water is kept open by the power company (Nickel and Collins, 1992). Currently five bald eagle nests and eight osprey nests are located along the river within the case study area (Meyers, 1993).

State data indicate the recreation opportunities in Adams, Juneau, and Wood County, which include state and county park day-use areas, camping facilities, boat launches, fishing sites, hunting access, and hiking trails, account for 421,000 recreation occasions annually. Although this data is not broken down by activity, the state recreation survey indicates that nature and wildlife viewing is an important activity in the state (46% of adults who participated in outdoor recreation in Wisconsin participated in nature and wildlife observation) (Wisconsin Department of Natural Resources, 1991a). If we assume that 50% of this activity level is associated with nonconsumptive use of the resources, a total of 210,500 recreation outings are estimated for the area. Valuing these days at between $18.71 (based on Loomis, 1988, updated to 1992 values) and $26.34 (based on Walsh et al., 1990, updated to 1992 values), the baseline value of nonconsumptive wildlife recreation amounts to between $3.9 million and $5.5 million per year.

Nonuse

Federally and state listed endangered and threatened species inhabiting the case study area are shown in Table 9-7. Federally listed species include the bald eagle, which are found in large numbers near the Petenwell flowage, and the endangered winged mapleleaf mussel.

Candidates for federal listing include the lake sturgeon, blanding's turtle, eastern massasauga snake, salamander mussel, and the paddlefish (Wisconsin Department of Natural Resources, 1993). State listed species include the osprey, red-shouldered hawk, great egret, and a number of fish and mussels (Wisconsin Department of Natural Resources, 1993).

Mammalian populations in the case study area at risk of impact from dioxin include mink, river otter, raccoon, and to a lesser extent muskrat (because they are primarily herbivores). Waterfowl species that are likely being impacted by dioxin through dietary exposure include bald eagles, osprey, great blue heron, and king fisher.

9.3.3 Magnitude of the Potential Benefits of the Regulation

Human Health Benefits

The calculation of human health benefits from reduced ingestion of dioxin was discussed in Chapter 8.0. The results for the Wisconsin River mills are not significantly different between the two modeling approaches. Table 9-8 shows the results for the SD methodology, the more conservative of the two approaches (resulting in higher risk levels), implying an upper bound for the benefits estimate.[20] Valuing the reduced incidence of cancer attributable to the regulation by the standard values associated with the "value of a statistical life" reported in the literature ($2 to $10 million (1992 dollars) per statistical fatality (U.S. EPA, 1989c; Violette and Chestnut, 1983; 1986), indicates potential upper-bound benefits range of $0.42 million to $2.1 million per year.

[20] Although this represents an upper bound for estimating fish tissue concentrations, total excess cancer cases may be understated due to the number of anglers using the river being greater than predicted by the methodology described in Chapter 8.

Table 9-7
Endangered Species found along Wisconsin River Case Study Site

Federally Listed Species		Status	
Bald Eagle		E	
Winged Maple Leaf (mussel)		E	
State Listed Species	**Status**	**State Listed Species**	**Status**
Buckhorn (mussel)	T	Salamander Mussel*	T
Lake Sturgeon	R	Paddlefish*	T
Black Buffalo (fish)	T	Creek Heelsuppter (mussel)	R
Blangling's Turtle*	T	Moneyface (mussel)	T
Paper Pondshell (mussel)	R	N. Ribbon Snake	E
Wood Turtle	T	Netted Nut-Rush (plant)	E
Red-Shouldered Hawk	T	N. Harrier (bird)	R
Bullhead (mussel)	E	Bog Bluegrass*	T
Hop-Like Selge (plant)	E	Redfin Shiner (fish)	T
Speckled Chub (fish)	T	Great Egret (bird)	T
White Lady's Slipper (plant)	T	Marsh Valerian (plant)	T
Eastern Massasauga (reptile)*	E	Double Crested Cormorant	T
Linear-Leaved Sundew (plant)	T	Black Crowned Night Heron	R
False Asphodel (plant)	T	Osprey (bird)	T
Ebony Shell (mussel)	E	Round Pigtae (mussel)	R
Winged Mapleleaf (mussel)	E		

Notes: * Currently under consideration for Federal listing
E = Endangered
T = Threatened
Source: Wisconsin Department of Natural Resources, 1993

Table 9-8
Estimated Individual Lifetime Cancer Risk Reduction in Excess Cancer Cases Resulting from the Selected Regulatory Option for the Wisconsin River
(Simple Dilution Approach)

Exposed Population by Mill	Lifetime Cancer Risk		Annual Reduction in Excess Cancer Cases
	Baseline	Selected Regulatory Option	
Nekoosa			
Recreational Anglers	1.8E-04	7.0E-06	0.03
Subsistence Anglers	2.5E-03	9.5E-05	0.03
Rothschild			
Recreational Anglers	4.7E-06	0.0	0.00
Subsistence Anglers	6.4E-05	0.0	0.00
Wisconsin Rapids			
Recreational Anglers	1.3E-04	1.3E-05	0.03
Subsistence Anglers	1.7E-03	1.7E-04	0.03
Brokaw			
Recreational Anglers	1.3E-05	0.0	0.0
Subsistence Anglers	1.8E-04	0.0	0.0
Port Edwards			
Recreational Anglers	2.7E-04	0.0	0.05
Subsistence Anglers	3.7E-03	0.0	0.04
Total			0.21

Source: Tetra Tech, 1993a

Recreational Fishing Benefits

Recreational angling benefits may accrue from the regulation as a result of an increase in the consumer surplus associated with the activity and/or an increase in use of the resources. Research has shown anglers to be willing to pay for a "contaminant free" fishery. Lyke (1992) estimated the consumer surplus associated with Wisconsin's recreational Lake Michigan trout and salmon fishery, based on a multiple site trip generation travel cost model using data collected from licensed anglers prior to the 1990 season. Lyke also estimated a the value of the fishery if it were "completely free" of contaminants that "may threaten human health." The values obtained range from between 11.1% and 31.3% of the value of fishery under current conditions, indicating the significance of the toxins contamination problem in terms of how present anglers value the fishery.[21]

Analysis of fish tissue concentrations associated with the regulatory options for the Wisconsin River mills indicates the regulatory controls may result in a recision of the dioxin-related fish consumption advisory for the river.[22] This lifting of the consumption advisory may be equated by anglers with "free of contaminants that may threaten human health" as described in Lyke's survey.[23] Lyke's results may not be directly applicable to the Wisconsin River site in other respects, however, given the significant differences in the fishing experiences, with open water salmonid fishing on Lake Michigan presumably higher valued. Therefore, this type of benefit is not estimated here.

A recision of the fish consumption advisory is also likely to have a positive impact on the level of angling effort on the Wisconsin River. If the regulation results in a 10% increase in effort, an additional 2,080 angling days are expected. Valuing these days by a range of consumer surplus values for warm and cold water fishing reported in the literature ($23.55 and $37.81, respectively, in 1992 dollars (Walsh et al., 1988)), results in benefits of $49,000 to $78,600 per year.

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[21] The range in results is attributable to whether a linear or constant elasticity functional form is used in the estimation.

[22] The advisory for the Wisconsin River impacts a section of the river below three bleaching mills. For this particular situation, the mill discharging the highest concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF was used for evaluating the changes that would result from the regulatory options because no expedient methodology for evaluating the cumulative impacts of effluents from the 3 mills was available (Tetra Tech, 1993a).

[23] The dioxin-related advisory is the main cause for concern on this segment of the Wisconsin River, and recommends 'no consumption' of carp or white bass from the Castle Rock and Petenwell flowages. Dioxin concentrations recorded from the river are some of the highest in the region (J. Amerhein, personal communication). While recision of the dioxin-related advisory will leave a mercury-related advisory still in place for the river, mercury is considered much less severe of a problem for the Wisconsin River and is responsible only for a 'limited consumption' advisory for walleye over 18 inches (J. Amerhein, personal communication).

Nonconsumptive Recreation Benefits

An important form of nonconsumptive recreation is wildlife observation. Because the toxic compounds addressed by the regulation have the potential to impact populations of many piscivorous avian and mammalian species sought and valued by wildlife observers and photographers, there are potential benefits associated with the program.

However, analysis indicates current levels of dioxin in effluent from the Wisconsin River mills are not sufficient to pose risks to wildlife (Memorandum from RCG/Hagler Bailly to Lynn Blake-Hedges, Office of Toxic Substances, U.S. EPA, August 6, 1993; and as discussed in detail below). Thus, the impact on populations of species of special concern (e.g., bald eagles, osprey, otter, mink, etc.), is expected to be small, and nonconsumptive use benefits are not calculated.

Ecologic (and Other Nonuse) Benefits

Individuals may value reduced toxic concentrations in the nation's waters apart from any values associated with their direct or indirect use of the resource. These nonuse values are difficult to estimate absent carefully designed and executed primary research (i.e., the contingent valuation method), but there are some rough rules of thumb and other benefits transfer techniques that may be applied to provide a rough sense of the potential magnitude of nonuse values.

Ecologic and other Nonuse Benefits Relevant to the Regulation. Dioxin has been found to pose risk to aquatic-associated wildlife, with the most sensitive ecologically important endpoints for mammals and birds being reproductive effects (U.S. EPA, 1993a). Since dioxins have been measured in fish tissue at levels sufficient to initiate fish consumption advisories for the protection of human health, adverse impacts on fish-eating wildlife, such as the bald eagles that nest along the Wisconsin River, are also of concern.

As noted in Chapter 7.0, preliminary assessments have been performed by the Agency on the risks to wildlife posed by dioxin wastestreams from pulp and paper mills (RCG/Hagler Bailly, 1993; Abt Associates, 1993). The ecologic assessments focus on potential wildlife risks posed by point source discharges of effluent containing dioxin, and the land application of dioxin-laden sludges. The endpoints of concern are wildlife species (including bald eagles, ospreys, hawks, raccoons, and otters) potentially exposed to dioxin from pulp and paper facility operations via either aquatic or terrestrial exposure pathways. Preliminary results of these initial assessments of wildlife risks indicate that under some modeling scenarios, modest ecologic risks to several wildlife species of concern are associated with current levels of dioxin in effluent and sludges originating from pulp and paper facilities.

As part of the preliminary assessment of wildlife risks, a land application scenario was evaluated specifically for the Wisconsin River drainage area. For a single land application site, using the 90th percentile application scenario (but assuming no background levels of dioxin, or other sources of dioxin in the drainage from other land application sites, point source discharges, or historic loads bound in sediment), resulting estimates of fish tissue concentrations were sufficiently high to result in potential fish consumption advisories over a 50 km stretch of the river, and risks to otters over a 10 km river segment (RCG/Hagler Bailly, 1993).

The proposed regulation will result in decreased concentrations of dioxin in plant effluent, and individuals may value this result in and of itself, particularly if scientific research confirms a linkage between such loadings and risks to wildlife. Furthermore, these lower effluent levels will result in lower concentrations of dioxin in sediment and thus in fish tissue.

Potential Magnitude of Nonuse Values. Two methods of benefits transfer are available for providing rough estimates of the potential magnitude of nonuse value benefits associated with the regulation. The first approach involves applying a rough "rule of thumb" of assigning nonuse values as half the value of recreational fishing benefits. This rule of thumb is based on an extensive review of the economics literature providing empirical evidence of the use and nonuse values associated with improved water quality and/or fisheries (Fisher and Raucher, 1984). This review indicated that nonuse values have been estimated to be *at least* half as great as recreational values, and concluded that if nonuse values were potentially applicable to a policy action, that using a 50% approximation was rough but, with proper caveating, was preferred to omitting nonuse values from a benefit-cost analysis. Using this approach implies nonuse benefits of between associated with the regulation of between $24,500 and $39,300 per year.[24]

A second approach to estimating nonuse values in this context is to apply literature-based estimates of household willingness to pay for clean waters to the residents of the watershed. Mitchell and Carson (1984) found in a 1981 national survey that nonusers were willing to pay an average of $179.65 per household annually (updated to 1992 dollars) to have the nation's waters made fishable, of which roughly two-thirds ($119.77 per household) could be attributed to the desire to have in-state waters all made fishable (Mitchell and Carson, 1986). Applying this result to the 104,563 households in the five county area (Adams, Juneau, Marathon, Portage, and Wood), a total of $12.5 million per year is derived as an estimate on the nonuse values associated with improvements in "local" water quality such that it fully supports its use as a fishery.[25] If we assume that the regulation contributes between 1% and 5% of the credit for attaining the fishery use status (lifting of the fish consumption

[24] These benefits may be conservative given the conservative estimate of baseline angling days and thus recreational angling benefits.

[25] Nonuse values are thus based on household-level values obtained from nonusers, applied to all households. This then captures the nonuse values held by those households that are users.

advisory), then this approach yields a nonuse benefit value of $626,200 and $1.25 million per year.[26]

9.3.4 Summary of Water-Related Benefit Estimates

A summary of the potential benefits resulting from regulation on the Wisconsin River is shown in Table 9-9. In dollars per year, the regulation is expected to generate benefits on the order $0.49 to $3.43 million for the case study area.

Table 9-9
Potential Water-Related Benefits of the Pulp and Paper Regulation for the Wisconsin River
(Millions of 1992 Dollars per Year)

Benefit Category	Millions per Year
Human Health[1]	$0.42 - $2.1
Recreational Angling	$0.05 - $0.08
Ecologic/Nonuse	$0.02 - $1.25
Total	**$0.49 - $3.43**

1 Benefits to recreational and subsistence anglers.

9.3.5 Air Benefits

Air-related benefits of the pulp and paper rulemaking for the Wisconsin River mills are derived based on the methodology presented in Chapter 8.0. For the case study sites, these benefits are associated with VOC emission reductions.[27] Annual benefits of between $0.86 million and $5.4 million are expected for the Wisconsin River site, as shown in Table 9-10.

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26 While the analysis indicates that regulation may be associated with a lifting of the consumption advisory on the Penobscot River, other actions such as remediation of contaminated sediments may also be methods of reducing fish tissue concentrations sufficiently to lift the advisory.

27 Air-related human health benefits for the case study sites are assumed to be negligible since national benefits are on the order of $0.8 million to $4.0 million (a reduction of 0.4 cancer cases per year) and some negative benefits associated with increases in some air emissions are expected.

Table 9-10
VOC Emission Reductions and Benefits for the Wisconsin River[1]
(Millions of 1992 Dollars per Year)

	Wisconsin River
Annual VOC Emission Reductions (Mg/yr)	7,006
Annual Benefits[2]	
Acute Health Effects	$0.06 - $3.84
Agricultural Benefits	$0.80 - $1.56
Total VOC Reduction Benefits	**$0.86 - $5.4**

1 The approach for monetizing VOC benefits ignores the chronic health effects associated with repeated exposure to ozone. This omission results in an underestimation of the total value of reduced ambient ozone levels.

2 Monetized based on U.S. EPA/OTA study using benefit range per Mg of $9 - $548 (1992 dollars) for acute health effects and $114 - $223 (1992 dollars) for agricultural effects.

Source: U.S. EPA/OAR/OAQPS/ESD.

9.4 LOWER COLUMBIA RIVER CASE STUDY

9.4.1 Introduction

The Columbia River and its tributaries comprise the dominant water system in the Northwest United States. The fourth largest river in North America and second largest in the U.S., the Columbia River drainage spans 219,000 square miles in the U.S. and 39,500 square miles in Canada. Originating on the west slope of the Canadian Rocky Mountain Range, the river flows for over 1,200 miles until it reaches the Pacific Ocean near Astoria, Oregon (U.S. DOE, 1991). The Columbia River basin is rich in natural resources that provide for the needs and services of both people and the environment.

The Columbia River system supports many industries both directly and indirectly. Industries include fishing, transportation, agriculture, forestry, manufacturing, hydroelectric power, as well as recreation. Numerous facilities and water related projects have been constructed on the river to provide power, flood control, irrigation, navigation, and recreational opportunities. In addition to these facilities, numerous industries have developed along the river and in many cases use the river to transport products and raw materials as well as carry away effluent and discharges from manufacturing processes, including eight pulp and paper manufacturers of which six are located in the stretch below Bonneville referred to as the lower Columbia.

The Columbia River basin is also home to a variety of fish and wildlife that rely directly or indirectly on the river and its tributaries. The river system is an integral component of the ecosystem and supports numerous populations of fish and wildlife. As one of the world's foremost habitats for anadromous fish (i.e., salmon and steelhead trout), the Columbia river through the quality and quantity of its fishery and aquatic resources, plays a vital and indispensable role in the environmental quality of the region.

Due in part to the numerous adverse impacts of industry and development on the habitat and ecosystems of the Columbia River, there has been a significant decline in the populations of anadromous fish in the basin. The U.S. Department of Energy reports:

The Columbia River Basin is world-renowned as a producer of salmon and steelhead, two types of anadromous fish. But the abundance of these fisheries is not what it used to be. Irrigation, timber harvesting, commercial fishing, mining, pollution, power production, flood control, and other factors related to human population increases have contributed to the decline of the anadromous fish population in the basin. (U.S. DOE, 1991, p. 38)

This underscores the complexity of the issues surrounding water quality in the Columbia basin. There are many contributors to the observed decline in aquatic resources, leading to the impossibility of isolating the impacts associated with any one of them. This case study focuses on the potential contribution to the decline of aquatic resources posed by the release of dioxins and other contaminants into the river from the production of bleached paper products. Human health benefits, nonconsumptive benefits, and ecologic and other nonuse benefits are also examined.

9.4.2 Resource Uses

Recreational Fishing

The case study area, shown in Figure 9-2, supports a substantial fishery that provides recreation to thousands of anglers. Popular species caught in the lower Columbia include shad, walleye, steelhead, sturgeon, and several species of salmon. In 1991, anglers made an estimated 301,000 trips to the lower Columbia River between February and October. Of this total, 46% (139,800) were for salmonids and resulted in a catch of 9,300 adult salmon, 1,900 jack salmon, 7,400 steelhead, and 500 cutthroat trout (Melchar and King, 1992). Recreational angling for sturgeon accounted for 47% (140,900) of the total trips, with an additional 15,700 trips over the three winter months (i.e., January, November and December). These 156,700 trips resulted in catches of 22,700 sturgeon (Melchar and King, 1992). Angling for shad accounted for the remaining 7% (20,300) of trips in 1991, resulting in a catch of 100,600 (Melchar and King, 1992).

To further characterize the extent of potential recreational fishing in the lower Columbia, Table 9-11 indicates the share of the population of Washington counties along the lower Columbia engaged in recreational fishing. The percent of the population reported to sport fish ranges from 8% in Skamania County to over 28% in Wahkiakum County. Clark

Figure 9-2
Columbia River Basin

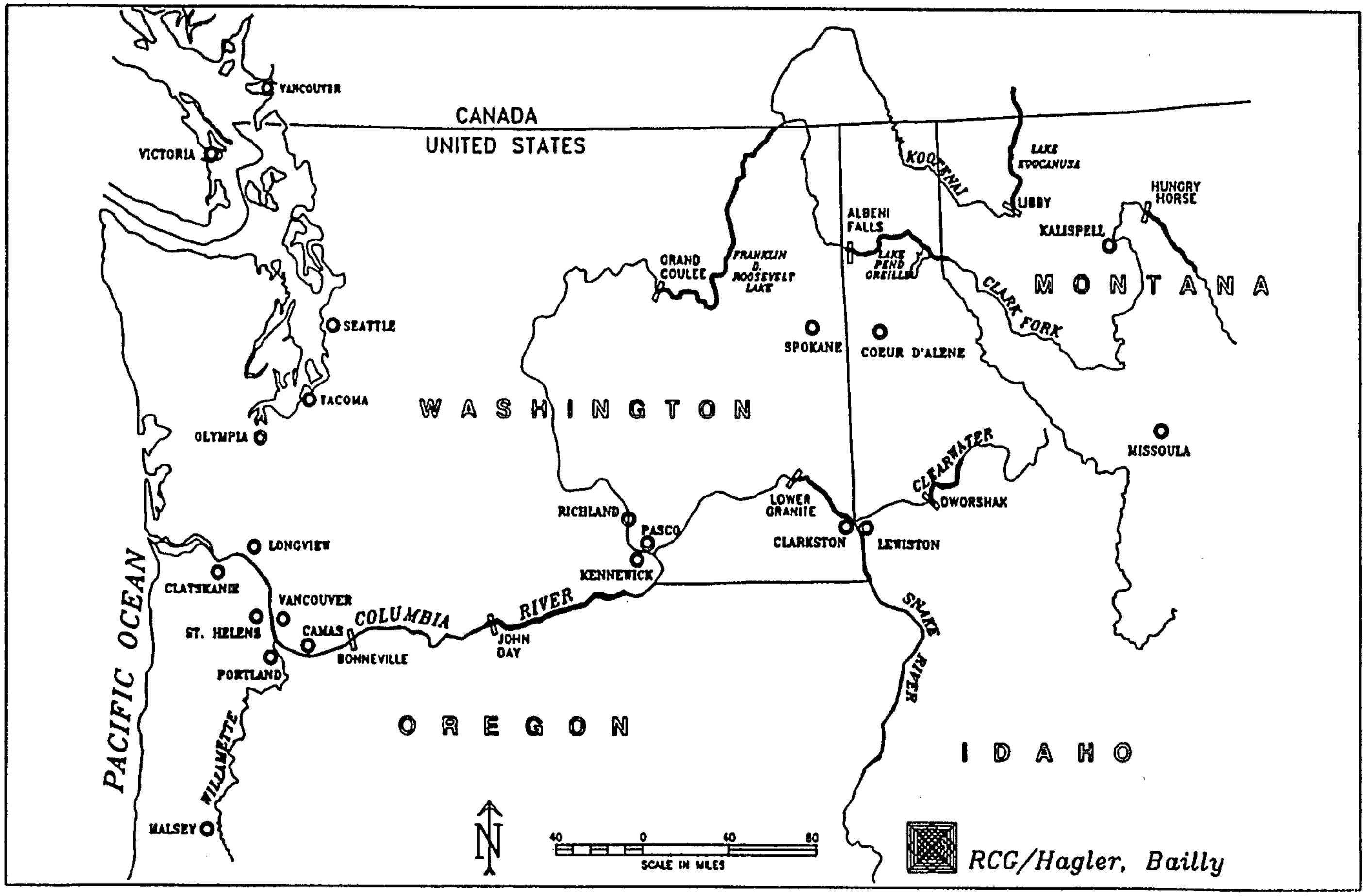

Table 9-11
Population and Number of Recreational Anglers in Washington Counties Along the Lower Columbia River (1989)

County	Number of Anglers	Population of County	Percentage of Anglers
Clark	25,547	220,400	11.59%
Cowlitz	11,199	82,100	13.64%
Pacific	4,200	17,700	23.73%
Skamania	650	8,100	8.02%
Wahkiakum	1,000	3,500	28.57%
Total	42,596	331,800	13%

Source: Washington State Department of Fisheries, 1990.

County, which is the most populous Washington county along the lower Columbia, reports nearly 12% of its population engages in recreational fishing.

Table 9-11 and the estimated trip data for the lower Columbia River demonstrate the extent of the demand for recreational fishing along the lower Columbia. These figures also demonstrate that many anglers on the lower Columbia are not local, and in some cases travel considerable distances to participate in the fishery. Although data pertaining specifically to the lower Columbia are not available, Melchar and King indicate that nearly every state is represented by sport anglers in Washington. Over 70,000 anglers were nonresidents of Washington and accounted for over 100,000 salmon caught (statewide). Given the considerable distances travelled by many of these nonresident anglers, the value of the fishery as indicated by this demand is substantial.

To estimate the net economic value of this fishery to recreationalists we rely on the values presented by Walsh et al. (1992) for anadromous and cold water fishing. Walsh et al., report mean consumer surplus values of $66.75 and $37.84 (updated to 1992 dollars) for anadromous and cold-water fishing, respectively.

When applied to the total number of anadromous fishing trips for the lower Columbia, this yields an estimate of $9.33 million in net economic value associated with the salmon fishery. Valuing sturgeon and shad trips by the value for cold-water fishing, yields a value of $6.7 million for the cold-water fishery in the lower Columbia River. The combined baseline value of the lower Columbia River fishery is $16 million.

Commercial Fishing

The waters of the lower Columbia have a significant biological capacity which has translated into a valuable commercial fishery. Commercial species harvested from the lower Columbia include: chum salmon, chinook salmon, coho salmon, sockeye salmon, Columbia River smelt, shad, sturgeon, carp, and salmon eggs. The total catch of these species from the Columbia River in 1990 amounted to nearly 3 million pounds (Washington State Department of Fisheries, 1990)

Nonconsumptive Use and Ecologic Value

The abundance of both aquatic and terrestrial wildlife in and along the lower Columbia River is testimony to the natural qualities and importance of the habitat. The river supports critical habitat for migratory birds in the Pacific flyway and is the most valuable anadromous fish waterway in the continental U.S. Several areas are specifically recognized for their support of wildlife and have been designated as National Wildlife Refuges. Three National Wildlife Refuges (Ridgefield, Columbian White-Tailed Deer, and Lewis and Clark) and one Wildlife Management Area are located along the river's banks. These areas provide undisturbed habitat for many of the terrestrial wildlife along the lower Columbia.

The 1985 National Survey of Fishing, Hunting and Wildlife-Associated Recreation reveals at a highly aggregate level the extent to which Washington and Oregon residents participate in nonconsumptive recreational activities. This survey indicated that about 652,600 Washington residents and 634,400 Oregon residents (16 years and older) took trips of at least 1 mile in the U.S. for the primary purpose of "observing, photographing, or feeding wildlife in 1985" (U.S. DOI, 1989). This level of nonconsumptive participation represents 12.1 million days (6.8 and 5.3 million days for residents of Washington and Oregon, respectively).[28]

Although there are no data indicating what proportion of these days were spent in the case study region, we can assume that 1% are spent on the lower Columbia. This assumption appears reasonable given the abundance of wildlife viewing opportunities along the lower Columbia which includes three National Wildlife Refuges.[29] This results in an estimate of approximately 1.2 million days per year. Valuing these days at between $18.71 (based on Loomis, 1988, updated to 1992 values) and $26.34 (based on Walsh et al., 1990, updated to

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[28] This estimate of the 12.1 million days is conservative in that it assumes no population growth and that levels today are the same as they were in 1985.

[29] This figure is also reasonably supported by population estimates in neighboring counties which total over 330,000 in Washington and over 650,000 in the three Oregon counties resulting in nearly 1 million residents in the region. Additionally, with over 300,000 angling trips recorded for the lower Columbia river, there is likely to be many visitors accompanying these anglers that are likely to be engaged in nonconsumptive uses. Therefore, the one percent figure is likely to be a conservative estimate of the number of nonconsumptive recreators in the region.

1992 values), the baseline value of nonconsumptive wildlife recreation amounts to between $2.3 million and $3.2 million per year.

In addition to the more populous species of wildlife, a number of species in the lower Columbia River region have been classified as threatened or endangered under the Endangered Species Act. These include a number of salmon species that travel through the lower Columbia from spawning grounds far upstream on their way to and from the ocean. Terrestrial species include bald eagles, peregrine falcons, Columbian white-tailed deer, and the marbled murrelet (Plenert, 1992).

Bald eagles have recovered significantly from numbers reported in the mid 1950s through the 1970s. "Present day estimates of the numbers of bald eagle nesting pairs in the Pacific Northwest show a consistent rate of recovery to a level beyond the numbers set as the goal of the U.S. Fish and Wildlife Service (U.S. FWS) to remove them from the Threatened Species category." (Williams, 1992). However, recent reports of dioxin levels in the eggs of bald eagles has generated concern about the long run impacts of dioxin concentrations in higher trophic levels of the food chain and, in particular, for predator species that are threatened or endangered.

There is uncertainty concerning the cause of reported declines in the productivity of some nesting areas along the lower Columbia. The hazard of some chemicals such as DDT/DDE to the successful reproduction of the eagles is well known and documented, and was likely a key factor in the decline of bald eagle populations from the 1950s to the 1970s. As reported by Bill Williams, PhD in his congressional testimony, "To date, there has been no scientifically documented linkage between low levels of dioxin in bird eggs and reproductive failure. The levels of dioxin (50-60 ppt) found in these eggs are thousands of times lower than the pesticide residues, and are an order of magnitude below the levels attributed to any in-ovo effects." (Williams, 1992, p. 90).

In addition to the uncertain effects on the reproductive success of bald eagles, other species have been identified as potentially at risk. These include black-crowned night herons, Caspian terns, and Forester terns. Researchers observed a deformed Forester tern embryo that was characteristic of PCB and dioxin contamination (Plenert, 1992). Mink and river otters were also collected and studied, however, no mink were found along the river below Portland, an area which historically supported very large populations.

9.4.3 <u>The Magnitude of the Potential Benefits of the Regulation</u>

Human Health Benefits

The primary pathway of significant human exposure to dioxins in the lower Columbia River is through ingestion of fish. In spite of sampled fish tissue concentrations that exceed EPA and state criteria for the protection of human health (Washington State Department of

Ecology, 1990), the State of Washington has not issued a formal fish consumption advisory. The state has, however, provided notice to anglers to reduce their consumption of fatty tissues and skin from fish caught in the lower Columbia (Patrick, 1993).

Benefits associated with reductions in health risk have been calculated based upon estimated changes in the lifetime cancer risks for each of the six mill sites located in the lower Columbia basin. For each of the sites, estimates of the exposed population (including recreational anglers and subsistence anglers) were combined with estimates of the cancer reduction attributable to each site to estimate the change in the incidence of cancer (see Table 9-12). Valuing the reduced incidence of cancer attributable to the regulation under the two modeling approaches by the standard values associated with the "value of a statistical-life" reported in the literature ($2 million to $10 million (1992 dollars) per statistical fatality (see Violette and Chestnut, 1983; 1986; U.S. EPA, 1989c)), results in a benefits range of between $0.32 million and $4.7 million.

Recreational Angling Benefits

It is not clear what impact lower concentrations of dioxin will have on the recreational fishery. As described previously, the lower Columbia River supported over 300,000 recreational fishing trips in 1991 with a resulting catch of over 50,000 salmon and sturgeon and over 100,000 shad. Marginal increases in the productivity and reproductive success of fish and other aquatic biota could be expected from significant decreases in the levels of in-stream dioxin concentrations. Increases in the fishery productivity will lead to increases in the catch rates of recreational anglers. This in turn could lead to marginal increases in the number of angling trips supported by the lower Columbia. Alternatively, positive benefits may accrue from increased angling effort in response to awareness of decreased contaminant concentrations in fish tissue.

A range of possible benefits can be estimated based upon a sensitivity analysis of fish population responses to an 85% decrease in fish tissue concentrations of dioxin. These benefits can be modelled as either an increase in the willingness to pay of each of the individual anglers (holding constant the number of anglers and activity occasions) for an improvement in the catch rates, or equivalently, as an increase in the number of anglers (holding their willingness to pay constant), (in actuality, a combination of these effects can be expected). To illustrate a possible range in values we will assume that willingness to pay is held constant at the values given above and that the increased productivity of the fishery is met with greater numbers of anglers. These estimates, presented in Table 9-13, range from $0.81 million for a 5% increase in the productivity of the fishery to $2.4 million per year for 15% increase in the productivity of the fishery.[30] Again it must be cautioned that

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[30] The effect of this approach is consistent with the approach used by Lyke (1992) in which the estimated marginal value of a healthrisk free fishery ranged from 11% to 31% of the net economic baseline value of the fishery. By considering improvements of between 5% and 15% in the net economic value of the fishery we approximate the lowerbounds estimated by Lyke and therefore may be conservative in our estimates.

Table 9-12
Estimated Individual Lifetime Cancer Risk and Reduction in Excess Cancer Cases Resulting from the Selected Regulatory Options for the Columbia River

Exposed Population	Lifetime Cancer Risk		Annual Reduction in Excess Cancer Cases
	Baseline	Selected Regulatory Option	
SD Approach			
Camas, WA Mill			
Recreational Anglers	3.8E-04	9.4E-05	0.27
Subsistence Anglers	5.2E-03	1.3E-03	0.20
St. Helens, OR Mill			
Recreational Anglers	9.0E-06	2.3E-07	0.00
Subsistence Anglers	1.2E-04	3.2E-06	0.00
Halsey, OR Mill			
Recreation Anglers	3.6E-05	3.2E-06	0.00
Subsistence Anglers	4.8E-04	4.3E-05	0.00
Longview, WA Mill			
Recreational Anglers	9.1E-07	2.2E-07	0.00
Subsistence Anglers	1.2E-05	3.0E-06	0.00
Clatskanie, OR Mill			
Recreational Anglers	3.3E-06	1.9E-07	0.00
Subsistence Anglers	4.4E-05	2.6E-06	0.00
Longview, WA Mill (2nd)			
Recreational Anglers	3.6E-06	1.6E-07	0.00
Subsistence Anglers	4.9E-05	2.1E-06	0.00
Total			0.47
DRE Approach			
Camas, WA Mill			
Recreational Anglers	1.2E-04	2.3E-05	0.19
Subsistence Anglers	1.6E-03	3.1E-04	0.07
St. Helens, OR Mill			
Recreational Anglers	8.5E-07	1.8E-08	0.00
Subsistence Anglers	1.1E-05	3.1E-07	0.00
Halsey, OR Mill			
Recreational Anglers	9.8E-06	9.2E-07	0.00
Subsistence Anglers	1.3E-04	1.2E-05	0.00
Longview, WA Mill			
Recreational Anglers	2.8E-07	6.4E-08	0.00
Subsistence Anglers	3.8E-06	8.7E-07	0.00
Clatskanie, OR Mill			
Recreational Anglers	1.1E-06	5.7E-08	0.00
Subsistence Anglers	1.4E-05	7.7E-07	0.00
Longview, WA Mill (2nd)			
Recreational Anglers	2.4E-06	4.6E-08	0.00
Subsistence Anglers	3.2E-05	6.2E-07	0.00
Total			0.16

Source: Tetra Tech, 1993a.

Table 9-13 Estimated Range of Benefits to the Recreational Fishery Due to Changes in the Concentration of Dioxins (Millions of 1992 Dollars per Year)				
Fishery	Baseline ($)	5% Increase	10% Increase	15% Increase
Anadromous	9.33	0.47	0.93	1.40
Cold-Water	6.7	0.34	0.67	1.01
Total	$16.0	$0.81	$1.60	$2.41

these values are subject to great uncertainty owing to the lack of scientific dose-response evidence relating fish populations to changes in dioxin concentrations.

Commercial Fishery Benefits

The Columbia River supports a viable and profitable commercial fishery that is dependent on a clean and healthy environment for its productivity. Excluding shellfish, the Columbia River has generated on average over $5 million annually. Commercial species that are caught in the Columbia River include: chinook, chum, coho, and sockeye salmon, smelt, sturgeon, shad, salmon eggs, carp, and shellfish. Table 9-14 presents five year average quantities and values for each of the important commercial species except for shellfish. The shellfish figures, although important, were not separated out in the data from the Pacific ocean catch figures, thus biasing the catch figures from the Columbia River.

Table 9-14 Average Commercial Landings of Fish and Shellfish in the Columbia River (Average over 1985-1989)		
Species	Pounds (1000s)	Catch Value (1000s)
Chinook	2,729	$3,654
Chum	11	$8.7
Coho	1,018	$1,303
Sockeye	82	$145
Columbia River Smelt	2,615	$275
Sturgeon	233	$294
Shad	16	$3
Total	6,704	$5,683
Source: Washington State Department of Fisheries, 1990.		

As with the recreational fishery, impacts to the commercial fishery from changes in dioxin concentration are uncertain. However, we can gain some insight into the potential range of benefits by looking at a range of changes in the amount of fish caught for commercial purposes, assuming that increased productivity of the fishery translates directly into higher catch rates for commercial fishing operations.

Using a rough rule of thumb developed by Crutchfield et al. (1982) and Huppert (1990), the sum of consumer and producer surplus associated with commercial fisheries amounts to between 50% and 90% of the gross value of ex-vessel landings. Table 9-15 computes the benefits associated with dioxin reduction using the 50% level and Table 9-16 computes the benefits using the 90% rule of thumb. This analysis suggests that the net economic benefits to commercial fishing from improved fishery productivity are likely to range from $0.14 million to $0.77 million per year.

Nonconsumptive Use Benefits

Nonconsumptive uses associated with improvements in water quality in the lower Columbia River include increases in wildlife observation. Because of the bioaccumulation of dioxins with each successive trophic level of the food chain, reductions in dioxins and other contaminants are likely to be associated with improved in the reproductive success and biological productivity of avian and mammalian species that are sought and valued by wildlife observers and photographers. It is difficult to estimate the extent to which these values may be enhanced under the regulated decrease in dioxin and other contaminant levels

Table 9-15
Estimated Range of Benefits to the Commercial Fishery Due to Changes in the Concentration of Dioxins (50% of the Value of Ex-Vessel Landings)
(Thousands of 1992 Dollars)

Fishery	Baseline	5% Increase	10% Increase	15% Increase
Chinook	1,827	91.35	182.70	274.05
Chum	4.3	0.22	0.43	0.65
Coho	652	32.60	65.20	97.80
Sockeye	73	3.65	7.30	10.95
Columbia River Smelt	138	6.90	13.80	20.70
Sturgeon	147	7.35	14.70	22.05
Shad	1.5	0.08	0.15	0.23
Total	$2,842.80	$142.15	$284.28	$426.43

Table 9-16
Estimated Range of Benefits to the Commercial Fishery Due to Changes in the Concentration of Dioxins (90% of the Value of Ex-Vessel Landings)
(Thousands of 1992 Dollars)

Fishery	Baseline	5% Increase	10% Increase	15% Increase
Chinook	3,289	164.45	328.90	493.35
Chum	7.7	0.39	0.77	1.16
Coho	1,173.6	58.68	117.36	176.04
Sockeye	131.4	6.57	13.14	19.71
Columbia River Smelt	248.4	12.42	24.84	37.26
Sturgeon	264.6	13.23	26.46	39.69
Shad	2.7	0.14	0.27	0.41
Total	$5,117.40	$255.88	$511.74	$767.62

in the lower Columbia River. Analysis of the current levels of dioxin in effluents of the Columbia River mills indicates the impact to wildlife is likely to be small (Memorandum dated August 6, 1993, from RCG/Hagler, Bailly to Lynn Blake Hedges, Office of Toxic Substances, U.S. EPA). However, greater populations of bald eagles, falcons, mink and otter as well as increased survival probabilities of threatened and endangered species can increase the number of visits and the marginal value of nonconsumptive recreation days. If the proposed changes in dioxin levels can be associated with a 5% increase in the baseline value of these activities, then nonconsumptive benefits would amount to between <u>$0.11 million and $0.16 million per year</u>.

Ecologic (and other Nonuse) Benefits

Individuals may value reduced toxic concentrations in the nation's waters apart from any values associated with their direct or indirect use of the resource. These nonuse values are difficult to estimate absent carefully designed and executed primary research (i.e., the contingent valuation method), but there are some rough rules of thumb and other benefits transfer techniques that may be applied to provide a rough sense of the potential magnitude of nonuse values.

<u>Ecologic and Nonuse Benefits Relevant to the Regulation.</u> Significantly high concentrations of dioxin have been found to pose risk to aquatic-associated wildlife, with the most sensitive ecologically important endpoints for mammals and birds being reproductive effects (U.S.

EPA, 1993a). Detectable levels of dioxin found in some eggs of bald eagles nesting along the lower Columbia River may be affecting their reproductive success.

As noted in Chapter 7.0, preliminary assessments have been performed by the Agency on the risks to wildlife posed by dioxin wastestreams from pulp and paper mills (RCG/Hagler Bailly, 1993; Abt Associates, 1993). The ecologic assessments focus on potential wildlife risks posed by point source discharges of effluent containing dioxin, and the land application of dioxin-laden sludges. The endpoints of concern are wildlife species (including bald eagles, ospreys, hawks, raccoons, and otters) potentially exposed to dioxin from pulp and paper facility operations via either aquatic or terrestrial exposure pathways. Preliminary results of these initial assessments of wildlife risks indicate that under some modeling scenarios, modest ecologic risks to several wildlife species of concern are associated with current levels of dioxin in effluent and sludges originating from pulp and paper facilities.

The proposed regulation will result in decreased concentrations of dioxin in plant effluent, and individuals may value this result in and of itself, particularly if scientific research confirms a linkage between such loadings and risks to wildlife. Furthermore, these lower effluent levels will result in lower concentrations of dioxin in sediment and thus in fish tissue.

Potential Magnitude of Nonuse Values. Two methods of benefits transfer are available for providing rough estimates of the potential magnitude of nonuse value benefits associated with the regulation. The first approach involves applying a rough "rule of thumb" of assigning nonuse values as half the value of recreational fishing benefits. This rule of thumb is based on an extensive review of the economics literature providing empirical evidence of the use and nonuse values associated with improved water quality and/or fisheries (Fisher and Raucher, 1984). This review indicated that nonuse values have been estimated to be *at least* half as great as recreational values, and concluded that if nonuse values were potentially applicable to a policy action, that using a 50% approximation was rough but, with proper caveating, was preferred to omitting nonuse values from a benefit-cost analysis.

Use of this "rule of thumb" implies a nonuse value of the regulation of between $0.41 and $1.21 million per year. This value is obtained from the recreational angling benefits estimated for the lower Columbia River fisheries.

A second approach to estimating nonuse values in this context is to apply literature-based estimates of household willingness to pay for clean waters to the residents of the watershed. Mitchell and Carson (1984) found in a 1981 national survey that nonusers were willing to pay an average of $179.65 per household annually (updated to 1992 dollars) to have the nation's waters made fishable, of which roughly two-thirds ($119.77 per household) could be attributed to the desire to have in-state waters all made fishable (Mitchell and Carson, 1986). Applying this result to the approximately 373,308 households in the Washington and Oregon counties along the lower Columbia, results in an a total estimate of $44.7 million per year for nonuse values associated with improvements in "local" water quality such that it fully supports its use as a fishery.[31] If we assume that the regulation contributes between 5% and 10% of the credit for attaining a fishable status in terms of acceptable levels of risk to subsistence and recreational anglers, then this approach yields a nonuse benefit value of $2.24 and $4.47 million per year.[32]

9.4.4 Summary of Water-Related Benefits Estimates

Estimates of the total economic value of benefits associated with the proposed reduction in dioxin and other contaminant loadings on the lower Columbia River are determined by summing across the low and high values in each of the four categories. Table 9-17 summarizes the low and high values for each of the categories and presents total value estimates. The estimate for the total value ranges from $1.79 million to $12.51 million per year. The estimate for the total value depends critically upon the assumed value for a statistical life as represented in the human health category.

Table 9-17
Potential Water-Related Benefits of the Pulp and Paper Regulation for the Columbia River
(Millions of 1992 Dollars per Year)

Benefit Category	Millions per Year
Human Health	$0.32 - $4.7
Recreational Fishing	$0.81 - $2.41
Commercial Fishing	$0.14 - $0.77
Nonconsumptive Use	$0.11 - $0.16
Ecological and Nonuse	$0.41 - $4.47
Total	**$1.79 - $12.51**

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31 Nonuse values are thus based on household-level values obtained from nonusers, applied to all households. This then captures the nonuse values held by those households that are users.

32 There are a number of development and industrial issues (described earlier) that have adversely affected the fishery in the lower Columbia river. We can not isolate the magnitude of the impact from dioxin and other contaminants from the pulp and paper industry.

9.4.5 Air Benefits

Air-related benefits of the pulp and paper rulemaking for the Columbia River mills are derived based on the methodology presented in Chapter 8.0. For the case study sites, these benefits are associated with VOC emission reductions.[33] Annual benefits of between $4.22 million and $26.47 million are expected for the Columbia River site, as shown in Table 9-18.

Table 9-18
VOC Emission Reductions and Benefits for the Columbia River[1]
(Millions of 1992 Dollars per Year)

	Columbia River
Annual VOC Emission Reductions (Mg/yr)	34,329
Annual Benefits[2]	
Acute Health Effects	$0.31 - $18.81
Agricultural Benefits	$3.91 - $7.65
Total VOC Reduction Benefits	**$4.22 - $26.47**

1 The approach for monetizing VOC benefits ignores the chronic health effects associated with repeated exposure to ozone. This omission results in an underestimation of the total value of reduced ambient ozone levels.
2 Monetized based on U.S. EPA/OTA study using benefit range per Mg of $9 - $548 (1992 dollars) for acute health effects and $114 - $223 (1992 dollars) for agricultural effects.
Source: U.S. EPA/OAR/OAQPS/ESD.

9.5 LEAF RIVER CASE STUDY

9.5.1 Introduction

This case study, based on a fish advisory study of the Leaf River prepared for EPA by Tetra Tech (1993b), provides a retrospective look at how process changes may impact environmental conditions at a site. In particular, process changes reported by the mill appear to correspond with near-term declines of dioxin in fish tissue (to the point that the fish consumption advisory was relaxed).

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33 Air-related human health benefits for the case study sites are assumed to be negligible since national benefits are on the order of $0.8 million to $4.0 million (a reduction of 0.4 cancer cases per year) and some negative benefits associated with increases in some air emissions are expected.

The Leaf River in Mississippi receives discharges from Georgia-Pacific Corp.'s pulp and paper mill in New Augusta, Mississippi. High levels of dioxin were detected in the plant's effluent and fish tissue samples collected below the mill in the late 1980's, and a fish consumption advisory was issued for the river in 1989. The Georgia-Pacific Corp. is the only known direct discharger of dioxin to the Leaf River, although 44 potential dischargers were found through a search of probable industries (Tetra Tech, 1993b).

9.5.2 Contaminant Levels in Effluent and Fish Tissue

The mill began discharging to the river in late 1984, and, beginning in 1987, high levels of dioxin were detected in the plant's effluent and fish tissue samples downstream from the mill in the National Bioaccumulation Study (NBS) and EPA's "104-mill study". Effluent concentrations of TCDD and TCDF measured 200 ppq and 410 ppq (U.S. EPA, 1990a), respectively, while whole body samples of channel catfish measured 98.9 ppt TCDD and largemouth bass fillet samples measured 3.8 ppt TCDD (U.S. EPA, 1991d). No fish advisory was in effect for the river at this time.

9.5.3 Initiation of Process Changes and Sampling Effort

In 1989, process changes were initiated at the Georgia-Pacific Corp. facility, including improved chemical addition; increased use of peroxide; addition of a new chlorine dioxide generator; elimination of chlorine bleaching; and other confidential changes. These process modifications are designed to reduce the formation of dioxin in pulp and paper mill discharges. At the same time, the Mississippi Cooperative Study was initiated between the State of Mississippi and Mississippi pulp and paper mills and routine sampling of fish tissue from above and below the mill began (Tetra Tech, 1993b). A one-time sediment sampling was also conducted at the same sites by the Mississippi Department of Environmental Quality (DEQ). TCDD was not detected in sediments and low levels of TCDF were detected at only two sites (Tetra Tech, 1993b).[34] This result was noted as surprising, given the high levels of dioxins found in bottom-feeding fish (Tetra Tech, 1993b).

9.5.4 History of Fish Advisory and State Criteria for Dioxin

A fish advisory for the Leaf River was initiated in November of 1989 when sampling under the Mississippi Cooperative Study showed dioxin levels in channel catfish to exceed the state threshold level (Tetra Tech, 1993b). The state had also at this time significantly lowered its level of concern for dioxin from 25-50 ppt to 3-7 ppt. However, the fish tissue

[34] One of the sampling sites is located below the mill in the segment of the river with the fish advisory. The other site is 25 miles upstream from the mill at the site of an old wood-treating facility where dioxin had been found in the past (Tetra Tech, 1993b).

concentrations previously detected in the NBS study exceeded both criteria. The advisory impacted 12 mile segment of the river below the mill, and by October 1990, after additional sampling, was extended to 45 miles of the river and included the Pascagoula River as well.

The state's criteria for dioxin was further revised in December of 1990, to 5 ppt for limited consumption and 25 ppt for no consumption. The new criteria allowed the fish advisory for the Pascagoula River to be lifted and the advisory for the Leaf River to be relaxed to limited consumption of catfish only (Tetra Tech, 1993b). While these changes in the advisory reflect the less stringent state criteria, the advisory for the Leaf River was subsequently (in early 1992) removed for fish under 5 pounds (approximately 22 inches or more). The more important result given the changes to the state's criteria is the downward trend noted in the fish tissue samples. In particular, sampling from the Cooperative Study revealed a downward trend in dioxin levels in all fish, and especially in smaller, younger catfish (Tetra Tech, 1993b). A single sample of 5 channel catfish collected near New Augusta contained 24 ppt of dioxin in 1989; the level at this site declined to 8 ppt in 1990, and to 3.6 ppt in 1992 (MS DEQ in Tetra Tech, 1993b).

9.5.5 Summary

The downward trend of dioxin detected in fish tissue samples near the Georgia-Pacific Corp. corresponds with the process changes initiated at the plant from 1989 through 1991. These changes also correspond to the relaxing of the fish consumption advisory for the river, however, given the noted changes to the state's criteria for dioxin, the more significant result is the observed reductions in dioxin concentrations in fish samples. Dioxin concentrations of 98.9 ppt in whole body samples were first detected in the NBS Study. Under the Mississippi Cooperative Study, measured concentrations declined from 24 ppt in 1989, to 3.6 ppt in 1991. Thus, the history of events associated with the mill illustrates that measurable ecosystem improvements appear to result from process changes in the pulp and paper industry. These types of improvements might also be expected from the proposed regulation, with reductions in fish tissue concentrations, and potential elimination of advisories expected from the process change options.

9.6 REPRESENTATIVENESS OF CASE STUDIES

The case study approach enables us to conduct a detailed evaluation of the anticipated benefits. How much this tells us about the benefits for all of the affected sites depends on the representativeness of the case study sites, i.e., do they represent a cross section of the sites or only a narrow portion. This issue is examined through use of two distinct approaches. Approach 1 simply evaluates whether the percentage of national benefits represented by case study benefits is similar to the percentage of national costs represented by case study costs. Approach 2 develops "profiles" for case study facilities reflecting population and receiving water characteristics to assess the representativeness of expected benefits.

9.6.1 Approach 1: Case Study Results as a Percentage of National Benefits and Costs

One means of assessing whether the case study benefits and costs are representative of the universe of sites is to evaluate the percentage of national benefits represented by the case studies, and to compare them with the percentage of national costs represented by these studies. In this section, such a comparison is made for the Wisconsin River and Columbia River case studies. The Penobscot River case study is not included in this comparison because cost information for this site is confidential.

In Table 9-19, benefits and costs for the Wisconsin River and Columbia River sites are compared to national benefits and costs. If the case studies were perfectly representative, they would comprise the same percentage of national costs as national benefits. For these two sites, benefits comprise slightly less than 5% of total national benefits, and costs

Table 9-19
Case Study Benefits and Costs as a Percent of National Benefits and Costs

	Air	Water	Air and Water Combined
Wisconsin River			
Benefits	1.0%	0.7-0.8%	0.8-0.9%
Costs[1]			
Compliance			2.6%
Social			2.6%
Columbia River			
Benefits	4.7-4.8%	2.5-2.9%	3.7-4.0%
Costs[1]			
Compliance			7.7%
Social			7.1%
Wisconsin and Columbia Rivers[2]			
Benefits	5.7%	3.2-3.7%	4.6-4.8%
Costs[1]			
Compliance			10.3%
Social			9.7%

1 Because mill-specific costs are not broken down between air-quality and water-quality control components, only combined compliance and social costs are presented.
2 Totals may not add due to rounding.

comprise approximately 10% of total national costs.[35] The case studies reviewed thus comprise a significantly higher percentage of costs than of benefits, perhaps underrepresenting potential benefits and overrepresenting potential costs. These results suggest that other sites may have greater net benefits than do the case studies.

9.6.2 Approach 2: Comparison of Receiving Water and Demographic Characteristics

Under this approach, profiles of case study facilities, reflecting characteristics of the surrounding population and of receiving water, are developed to allow a comparison with the universe of facilities. First, the methodology for developing profiles for each of the sites is described. Second, sites are categorized from low to high potential benefits. Finally, the representativeness of the case study sites based on this categorization is evaluated.

Developing Profiles of the Affected Sites

A number of site characteristics have an impact on the benefits associated with a reduction in pollutant discharges. These include attributes of the receiving water and of the surrounding population. This information is used to develop "profiles" for each of the facilities. These profiles are then used to distinguish the sites according to the degree of expected benefits.

A similar technique is used in a study by Naughton and Desvousges (1985) that estimates the recreation benefits of Best Conventional Pollution Control Technology (BCT) Regulations for the pulp and paper industry. They develop profiles for 21 river reaches that include socio-economic data, a physical description of the river and its recreation potential, and water quality characteristics. The latter include the expected loadings changes under BCT regulations. The river reach profiles are used to qualitatively assess whether the expected recreation benefits per family are likely to be zero, low, low-to-moderate, or moderate. Estimates of per-family benefits are derived using three of the sites as case studies, and the values are transferred to the remaining sites. Aggregate benefits for a river reach are then estimated based on assumptions regarding the recreational "market" size. Finally, the river reaches are categorized by size of expected annual recreation benefits: $0, $100,000 to $500,000, $500,000 to $1 million, and $1 million to $3 million.

The profiles developed below will be used only to ascertain whether the sites selected as case studies are representative of the areas affected by the regulated mills. The profiles are divided into two attribute categories: water characteristics and population characteristics.

Receiving Water Characteristics. Characteristics of a receiving water body will affect benefits arising from the regulation. One important characteristic, the relationship between

[35] These two sites also account for 2% to 3.2% of the reduction in cancer incidences in exposed angler populations that can be attributed to the regulation. This is consistent with the 3.2% to 3.7% of national water benefits, since human health benefits are an important component of water benefits.

effluent and stream flow, affects the concentration of pollutants in the ecosystem. If effluent is diluted substantially upon entering a river, its impact on the ecosystem will be less than if the effluent entered a smaller waterway. Consequently, the benefits associated with reduced effluent concentrations would be higher in the second instance. Stream flow is highly variable over time; accordingly, dilution statistics for the mean flow and a low flow are used to characterize this relationship. These statistics are the HMF and 7Q10 used in the Environmental Assessment (Tetra Tech, 1993a).

To develop profiles of water quality attributes, the percent reductions for the regulated contaminants for the case studies are compared to the reductions for all facilities.[36] As an alternative method for qualifying changes in water quality, we use the AWQCs exceedence results. The exceedence results are based on comparisons between estimated in-stream concentrations of the contaminants and human health or aquatic life AWQCs. The regulation's impact on exceedences for the case studies is compared to the corresponding impacts on all facilities.

Other water attributes that may affect benefits include water body type (e.g., river or bay), present degree of contamination, and presence of contaminants excluded from the current regulation. Effluent entering a river will disperse in a different way than effluent entering a bay. A dummy variable is used to distinguish the open water bodies from the rivers/streams. Changes in water conditions are proxied by changes in the number of exceedences.

Ideally, we would want to include other water quality parameters, particularly any that indicate the presence of additional pollutants. This presence may reduce benefits associated with the regulation. For example, if dioxin reductions led to a removal of a fish advisory due to dioxin content, we would anticipate recreation, ecosystem and health benefits. However, if there is also a PCB fish advisory which was not affected by the regulation, then it is likely that the benefits will be much smaller. These parameters have not been included in the river reach profiles. Information provided by the STORET database shows that some of the river reaches have other documented types of pollution, such as mercury or PCB contamination.

User Population Characteristics. Population characteristics also affect benefits of regulation. Areas having larger affected populations and higher per capita incomes will generally

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[36] Ideally, the dilution factors would be used in conjunction with loadings results to evaluate the change in water quality for the various facilities. The loadings data for a baseline scenario would be compared with loadings data for the selected process change to determine the reductions by contaminant. Toxic weights are used to scale the loadings results arriving at an estimate of the baseline and regulated loadings in toxic equivalents. The dilution factors would be applied to the toxic-weighted loadings to quantify the change in water quality. Our results show that reductions in toxic-weighted loadings at the case study facilities are representative of three-fourths of all facilities. The remaining one-fourth have larger reductions in toxic-weighted loadings. Consequently, benefits associated with the case studies will tend to underrepresent benefits at these facilities.

experience higher benefits. (This assumes that the water-related benefits of lower concentrations are localized. They accrue primarily to the population residing near the affected river reach, i.e., the reach below the mill.) River reach definitions were taken from STORET. The affected population is defined as persons living in counties that are contiguous with the reach.

Given the irregularity of county size and location vis a vis a river, this approach inevitably leads to uneven geographic definitions of affected populations. This is problematic for assigning benefits, particularly for recreation benefits since they are typically assumed to vary with distance from a recreation site. However, county-level data is the most practical form of data, given that income statistics are most readily available at the county level. We have estimated population densities in order to compensate for possible biases that our spatial definitions may introduce. All socio-economic data comes from the 1990 U.S. Census (U.S. Department of Commerce, 1992). Finally, the analysis also considers whether there were any relatively prominent recreation areas or ecosystems are located within the affected region, e.g., a national or state park or a national wildlife reserve.

Assessment of Case Study Representativeness

The site attributes were used to categorize the sites by degree of expected benefits. First, the sites were classified within the two attribute dimensions. In the water attribute dimension, the sites were ranked by whether the regulation was expected to have a large or small impact on water quality. In the socio-economic dimension, the sites were classified according to whether the benefits were expected to be large, medium, or small for a given change in water attributes.

Socio-Economic Attribute Rankings. Socio-economic attributes were used to rank the facilities by low, medium, high, and very high expected aggregate benefits.[37] Attributes considered were population, population density, and per capita income. Each location was assigned a ranking in each of the categories.[38] These rankings were aggregated across the three categories to obtain an overall rank. This rank determined whether an affected area was classified as having low, medium, high, or very high expected benefits from the socio-economic perspective. Finally, qualitative adjustments were made to account for the

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[37] The very high category includes the two facilities that discharge into the Houston Ship Channel. We included this category to differentiate this area, with an affected population that exceeds 2.8 million, from other areas that have large populations which do not exceed 1 million.

[38] Rankings on a scale of 1 to 3 or 1 to 4 were assigned in the following manner. Sites with populations below 100,000 were assigned a 1, those with populations between 100,000 and 250,000 were assigned a 2, those with population between 250,000 and 2.8 million were given a 3 and the two sites with populations of 2.8 million were given a 4. Locations with fewer than 200 persons/square mile were ranked 1, those with 200-400 persons/square mile were given a 2, those with densities of 400-1,000 were given a 3, and the two locations with densities above 1,000 were given a 4. Sites with personal income below $10,600 were given a 1, those with incomes between $10,600 and $12,900 were given a 2, and those above $12,900 a 3.

presence of unique features which will tend to increase benefits, such as the presence of a National Wildlife Reserve or a State Recreation Area.

Table 9-20 shows how the final benefit rankings for the facilities are distributed among the four benefit levels. The first row shows this distribution for all of the facilities. The second row shows the same distribution for the case study facilities (the four case study areas have a total of 15 facilities). The Wisconsin River and Penobscot River case studies are classified as having medium benefits. The Leaf River case study has low benefits, and the Columbia River case study facilities have benefits ranging from low to high. Since the case studies cover the range of benefits, we can conclude that they are representative from the socio-economic perspective.[39]

Table 9-20
Socio-Economic Distribution of Facilities Across Potential Benefit Levels

	Benefits Categories			
	Low	Medium	High	Very High
All Facilities	37	57	5	2
Case Study Facilities	4	9	1	0

Receiving Water Attributes. Current loadings data indicate that the case study sites are representative of all facilities in terms of loadings reductions. Regulatory impacts on loadings for the case study sites are similar to aggregate loadings impacts across all sites. Tables 9-21 and 9-22 show how the regulation is expected to impact pollution loadings. Table 9-21 shows the impacts for all of the sites[40], and Table 9-22 shows impacts for the case study sites only. For each pollutant, we indicate the baseline loadings and the loadings expected under the regulation. These are followed by the change in loadings and finally a percentage reduction in loadings. The percentage reductions for the case study sites are similar to those of all of the sites.

[39] Although our case studies don't include one of the two facilities at the very high benefits level, we don't expect this to pose a problem for the analysis. Both of these facilities discharge into the Houston Ship Channel where extensive industrial usage suggests that fishing and recreation benefits may be small.

[40] It is expected that some of the results in Table 9-21 may change as a consequence of revisions to the selected option for dissolving sulfate mills. However, the overall results are expected to remain valid.

Table 9-21
Regulatory Impact on Pollution Loadings at All Facilities (Pounds per Year)

Pollutant	Baseline	With Regulatory Option	Reduction	Percent Reduction
2,3,4,6-Tetrachlorophenol	2,893.1	733.8	2,159.3	74.64%
2,3,7,8-TCDD	0.1	0.0	0.1	97.87%
2,3,7,8-TCDF	0.3	0.0	0.3	99.30%
2,4,5-Trichlorophenol	77,762.2	684.3	77,077.9	99.12%
2,4,6-Trichlorophenol	24,832.6	1,029.1	23,803.5	95.86%
2,4-Dichlorophenol	16,159.3	798.6	15,360.7	95.06%
2,6-Dichlorophenol	3,499.3	892.1	2,607.1	74.50%
2,6-Dichlorosyringaldehyde	6,035.7	1,483.8	4,551.9	75.42%
2-Butanone	164,333.3	28,645.2	135,688.1	82.57%
3,4,5,6-Tetrachlorocatechol	9,111.5	1,525.5	7,586.0	83.26%
3,4,5,6-Tetrachloroguaiacol	14,718.9	1,401.8	13,317.1	90.48%
3,4,5-Trichlorocatechol	19,840.9	1,535.3	18,305.6	92.26%
3,4,5-Trichloroguaiacol	57,871.8	831.5	57,040.3	98.56%
3,4,5-Trichlorosyringol	7,918.5	1,853.9	6,064.7	76.59%
3,4,6-Trichlorocatechol	5,043.3	1,476.3	3,567.0	70.73%
3,4,6-Trichloroguaiacol	2,371.7	719.4	1,652.3	69.67%
4,5,6-Trichloroguaiacol	10,709.6	880.3	9,829.4	91.78%
4,5-Dichlorocatechol	10,424.8	965.7	9,459.1	90.74%
4-Chlorocatechol	155,608.5	956.6	154,651.8	99.39%
4-Chlorophenol	1,054,692.6	748.3	1053,944.4	99.93%
5,6-Dichlorovanillin	6,659.0	1,572.4	5,086.6	76.39%
6-Chlorovanillin	9,596.8	1,888.6	7,708.3	80.32%
Acetone	196,376.7	123,777.0	72,599.7	36.97%
Chloroform	1,138,453.5	7,054.2	1,131,399.3	99.38%
Methylene Chloride	31,967.6	5,931.7	26,035.9	81.44%
Pentachlorophenol	49,114.9	1,476.0	47,639.0	96.99%

Source: ERG, 1993a.

Table 9-22
Regulatory Impact on Pollution Loadings at Case Study Facilities Only (Pounds per Year)

Pollutant	Baseline	With Regulatory Option	Reduction	Percent Reduction
2,3,4,6-Tetrachlorophenol	231.1	66.3	164.8	71.31%
2,3,7,8-TCDD	0.0	0.0	0.0	100.00%
2,3,7,8-TCDF	0.0	0.0	0.0	100.00%
2,4,5-Trichlorophenol	9,551.2	66.3	9,484.9	99.31%
2,4,6-Trichlorophenol	4,379.7	77.4	4,302.3	98.23%
2,4-Dichlorophenol	2,089.8	68.0	2,021.8	96.75%
2,6-Dichlorophenol	215.3	83.2	132.0	61.33%
2,6-Dichlorosyringaldehyde	600.3	134.0	466.3	77.69%
2-Butanone	15,981.5	2,702.0	13,279.4	83.09%
3,4,5,6-Tetrachlorocatechol	1,021.9	130.9	891.0	87.19%
3,4,5,6-Tetrachloroguaiacol	1,777.8	143.6	1,634.2	91.92%
3,4,5-Trichlorocatechol	1,855.3	132.3	1,723.0	92.87%
3,4,5-Trichloroguaiacol	6,810.7	66.3	6,744.4	99.03%
3,4,5-Trichlorosyringol	1,177.5	200.4	977.1	82.98%
3,4,6-Trichlorocatechol	365.7	132.3	233.4	63.83%
3,4,6-Trichloroguaiacol	235.0	67.0	168.0	71.50%
4,5,6-Trichloroguaiacol	1,339.6	76.4	1,263.2	94.30%
4,5-Dichlorocatechol	724.1	83.4	640.7	88.48%
4-Chlorocatechol	10,478.7	85.5	10,393.2	99.18%
4-Chlorophenol	58,760.9	67.5	58,693.4	99.89%
5,6-Dichlorovanillin	514.3	134.0	380.4	73.95%
6-Chlorovanillin	790.7	163.1	627.6	79.37%
Acetone	17,969.1	11,923.8	6,045.3	33.64%
Chloroform	129,121.7	633.5	128,488.2	99.51%
Methylene Chloride	3393.5	546.8	2,846.7	83.89%
Pentachlorophenol	5,345.8	141.2	5,204.6	97.36%

Source: ERG, 1993a.

This similarity in loadings reductions does not necessarily mean that the case studies are representative with respect to changes in water quality. There is some indication that the case studies may not be representative of a subset of facilities, particularly those discharging into waters with lower dilution capacities (i.e., a high effluent-to-river flow ratio) or, alternatively, those who discharge into open waters. The small HMF dilution factors for the case studies indicate relatively high dilution; the highest value even under low stream flow conditions is 0.03. While overall, most sites have similar dilution factors, there are some that have factors in excess of 0.50. The benefits that accrue to the case study facilities will tend to underestimate benefits at facilities where the effluent is less diluted. Furthermore, none of the case study sites discharges into an open body of water. Consequently, it is difficult to assess whether the case study benefits tend to under- or over-estimate benefits at the (approximately) 18 open water sites.

Exceedence results are known for Aquatic Life Acute and Chronic AWQCs and for two Human Health AWQCs (organisms, and water and organisms). From these, we determine which facilities have dioxin exceedences under the baseline scenario and under the selected process option. We compare the changes in dioxin exceedence status for the case study facilities with the changes for all facilities.

Overall, 29 facilities show exceedences of Aquatic Life Chronic AWQCs for at least one contaminant under baseline conditions. Of these facilities, 25 exceed the criteria for dioxin and 3 exceed the criteria for furan. The furan exceedences vanish under the selected process change options, and only 1 facility continues to exceed the dioxin criteria. In fact, all of the exceedences found under baseline conditions cease except for this single dioxin exceedence. Thus there are potential aquatic life benefits associated with the process changes. However, the case study facilities are not among the facilities having exceedences under baseline conditions. Consequently, the case study benefits will tend to underestimate aquatic life benefits. A similar argument can be made for exceedences of Aquatic Life Acute AWQCs. In this case, two facilities show exceed the criteria for pentachlorophenol under baseline conditions, but not under the process change scenarios. Neither of these facilities is among the case studies.

Dioxin exceedence occurrence data for Human Health AWQCs are the same for both the Organism AWQC and the Water and Organism AWQC. Overall, 97 facilities exceed the human health criteria for dioxin under baseline conditions. About 80% of these facilities (78) continue to exceed the criteria under the selected process option. Under baseline conditions, 13 of the 14 case studies have dioxin exceedences. Seven of these facilities continue to have exceedences under the regulation. Thus the impacts on water quality for the case study facilities range from instances where an exceedence persists to those where one is removed by the regulation.

Changes in facility-based risk levels for cancer in the exposed angler populations are an important factor in estimating human health benefits. We compared average baseline risk and post-regulation risk levels for the case studies with those for all facilities. In general, the average risk level for the case studies is below the average risk for all facilities by an order of magnitude. This indicates that the average risk reduction--and the subsequent benefits--for the case study facilities will tend to be smaller than the average risk reductions found at other facilities. However, at the facility level, the case studies represent a wide range of risk reductions.

9.6.3 Conclusions

The socio-economic profile for benefits associated with our case study facilities is, in general, representative of these benefits characteristics for most of the facilities that will be affected by the regulation. Regarding water quality impacts, however, case studies fail to include some characteristic which will have an impact on benefits. For example, none of our case studies have aquatic life AWQC exceedences under baseline conditions. Thus, the case study benefits will tend to underestimate aquatic life benefits for those facilities which have a baseline exceedence, but no exceedence under the selected process option.

The net benefits associated with our case studies are not fully representative of aggregate net benefits. This conclusion is based on the comparison between national estimates of costs and benefits and our case study results shown in Table 9-19. Process changes at case study facilities located on the lower Columbia River and Wisconsin River account for roughly 5% of the expected national benefits. However, they constitute roughly 10% of the compliance costs. Consequently, the net benefits associated with these facilities tend to be lower than net benefits for other facilities.

9.7 RESTORATION COST

9.7.1 Introduction

One approach to assessing the benefits of reducing dioxin discharges is to consider the potential cost savings associated with restoration efforts to clean water bodies impacted by other similar contaminants. Accordingly, in this portion of the analysis, we address restoration cost issues associated with dioxin-contaminated sediments in lakes and rivers. The primary source of information is a U.S. Army Corp of Engineers report, "Review of Removal, Containment, and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes" (U.S. ACOE, 1990). The report identifies technologies that may be feasible for remediating Great Lakes contaminated sediment and that should be considered for demonstration under the ARCS program for Superfund remediation. This analysis provides a condensed assessment of technologies, three restoration cost case studies, and a brief discussion of outstanding issues regarding restoration cost analysis.

9.7.2 Assessment of Technologies

To provide a framework for examining costs, technologies are examined by treatment component. The categories are: removal, transport, pretreatment, treatment, disposal, and effluent (including surface runoff) or leachate treatment. Technologies for no-removal alternatives are termed "nonremoval". The range of cost estimates that were available are as follows: $5.15 - $11.66/cubic yard for removal; and $100 - $1,300/cubic yard for treatment.

Removal Component

The primary objective of the removal step, commonly called dredging, is to excavate contaminated sediment from the waterway. Mechanically removed dredged material may be placed in scows or barges for transport to a disposal site, whereas hydraulically removed material may be placed in a hopper dredge or pumped through a pipeline to a disposal site. Equipment options are numerous, and selection of options depends on the following factors:

- Volume and depth of material to be dredged
- Physical characteristics of the sediment
- Debris
- Physical site restrictions
- Distance to the disposal site
- Compatibility with disposal operations
- Availability of equipment
- Cost of equipment use
- Contamination level of the sediments to be dredged.

Technologies for the removal of contaminated sediment include the following:

- Selection of appropriate hydraulic dredges
- Selection of appropriate mechanical dredges
- Use of operational controls during dredging operations
- Use of turbidity containment technologies during sediment removal.

Costs for dredging are affected by production rate, size of the project, availability of equipment, operational constraints, and other site specific factors. With the exception of foreign dredges, costs for hydraulic dredges are expected to be less than $20/cu yd. Table 9-23 depicts dredging costs for the Great Lakes as reported by U.S. ACOE District, Chicago.

Transport

This section examines technologies used to control contaminated materials while in transit to a disposal site. The primary emphasis during this component of the overall remediation process is toward spill/leak prevention. Primary transportation methods used to move

Table 9-23
Dredging Costs for Great Lakes

Volume (1,000 cu yd)	Disposal Method*	No. of Operations	Unit Cost ($/cu yd)
Hopper			
<100	O	2	$7.79
>100	O/C	3	$5.15
Pipeline			
<50	B/C	8	$11.66
50-100	B/C	4	$7.44
>100	B/C	1	$5.82
Mechanical			
<50	O/U	2	$10.89
50-100	C	4	$10.30
>100	O/C	4	$10.01

Source: U.S. ACOE Division North Central. Costs include contracts for dredging and transportation, preparation of plans and specifications, contract management, and monitoring. Costs do not include confined disposal facility construction/operation/maintenance.
* Code Definitions: O = open lake, B = beach nourishment, U = upland, unconfined, C = confined.

dredged material include the following: pipelines, barges or scows, hopper dredges, railways, and trucks. Cost information is not available at this time.

Pretreatment Component

Pretreatment technologies are defined as technologies that prepare dredged material for additional treatment or disposal. These technologies are designed to accelerate treatment in a disposal site, to reduce the water content of the dredged material, or to separate fractions of the dredged material by particle size. Pretreatment technology options include: dewatering, particle classification, and slurry injection. They are primarily applicable to hydraulically dredged sediment. Cost information is not available at this time.

Treatment Component

Many of the treatment process options are not stand-alone processes, but are components of a system that may involve multiple treatment processes to address multiple contaminant problems. Most of these processes also require one or more of the pretreatment processes discussed above. Source materials for review of these processes include: U.S. EPA publications on hazardous waste technologies, reports published under the Superfund Innovative Technology Evaluation (SITE) program, feasibility studies for Superfund sites dealing with contaminated sediment, and publications dealing with remedial actions for Great Lakes sediments. Technology types for the treatment component are: biological, chemical, extraction, immobilization, radiant energy, and thermal.

Biological. Biological degradation technologies use bacteria, fungi, or enzymes to break down PCBs, pesticides, and other organic constituents into innocuous or less toxic compounds. Because of the dependence of biological processes on carefully maintained environmental conditions, reliability of these processes is questionable. Costs are not well documented, because they have not been widely applied on a large scale. One bioreactor process, Bio-Clean, which is being considered for the Hudson River, is estimated to cost $130 to $270 per cubic yard.

Chemical. Chemical treatment technologies use chelating agents, bond cleavage, acid or base addition, chlorine displacement, oxidation, or reduction in the destruction, detoxification, or removal of contaminants found in contaminated media. The U.S. EPA developed a nucleophilic substitution process that uses alkali metal polyethylene glycol to dechlorinate PCBs. Several modifications have been developed for this process have been developed, and a pilot demonstration for PCB-contaminated soil has been completed demonstrating 99.999% reduction of PCBs at a cost of $200 per ton. In general, costs for these processes are expected to exceed $100/cubic yard.

Extraction. Extractions is the removal of contaminants from a medium by dissolution in a fluid that is later recovered and treated. Soil flushing and soil washing are other terms that are used to describe extraction processes for hazardous waste treatment. Implementability for most of these processes is difficult because of the lack of full-scale development for handling sediment and the problems of solvent recovery and potential toxicity of residual solvents. Costs are not well documented, but are expected to exceed $100/cu yd.

Immobilization. Immobilization technologies are defined as technologies that limit mobility of contaminants for sediment placed in a confined site or disposal area. Implementability for most of these processes is better that chemical or extraction processes because they are not as sensitive to process control conditions. Costs are generally less than $100/ cubic yard.

Thermal Processes. Thermal technology includes: incineration processes, pyrolytic processes, vitrification processes, supercritical and wet air oxidation, and other processes. Implementability is difficult because of: long and tedious permitting requirements, and poor community acceptance. Cost estimates vary: $1,300/cu yd to $200/cu yd. A bench-scale evaluation of in situ vitrification for the New Bedford harbor sediment confirmed that greater than 99% efficiency of PCB destruction could be achieved at a cost of $290 to $330 per ton.

Disposal

The disposal component provides for long-term containment of contaminated dredged material. The most widely used disposal option for dredged materials is a confined disposal facility (CDF). A double membrane liner system for a 100,000 cu yd upland CDF proposed for New Bedford sediment increased the disposal cost by $13/cu yd.

Combined Costs

The combined cost for the removal, treatment and containment of contaminated sediment, as described above, amounts to on the order of $150 to $300 per cubic yard (absent transport and/or pretreatment costs). In the case studies described below, documented costs from Superfund sediment remediation options selected have amounted from $80 to over $1,000 per cubic yard.

9.7.3 Restoration Case Studies

This section examines the costs of sediment remediation for five sites. The analysis is based on data from case studies in EPA's "The Costs and Benefits of Remediation Contaminated Sediments", (ERG, 1992). Case studies were conducted for:

- Sullivan's Ledge--Second Operable Unit New Bedford, MA
- New Bedford Harbor, New Bedford, MA
- Fields Brook, Ashtabula, OH
- General Motors Central Foundry Division Site, Massena, NY
- Eagle Harbor, Kitsap County, WA.

This section briefly describes the conditions of each case study area, reviews the data on remediation costs for each area, and condenses cost estimates into a final summary.

Sullivan's Ledge--Second Operable Unit New Bedford, MA

The second operable unit of the Sullivan's Ledge Superfund site consists primarily of Middle Marsh, a 13-acre fresh water wetland located on the New Bedford Municipal Golf Course in New Bedford, Massachusetts. Sampling during the remedial investigation indicated polychlorinated biphenyls (PCBs, specifically Aroclor 1254) as the major contaminant of concern at the site (it is important to note that EPA evaluated remediation at this site based on a target cleanup level for PCBs only).

EPA selected the dredge and disposal remedial alternative for Sullivan's Ledge (ERG, 1992). EPA believes that the dredge and disposal option will provide short-term and long-term protection of public health and the environment, attain all federal and state applicable rules and regulations (ARAR), reduce the mobility of contaminants in sediment/soils, and be easily implemented and cost-effective. Other treatment technologies include solvent extraction, solidification/stabilization, and incineration. Table 9-24 summarizes the restoration cost by remediation alternative, with costs ranging from $844 to over $5,200 per cubic yard.

Table 9-24
Summary of Sediment Remediation Costs: Sullivan's Ledge

Remediation Alternative	Minimum Volume Excavated (cu yds)	Total Cost of Remediation (Millions $1992)	Cost per unit ($1992/cu yd)
Dredge and Disposal	2,809	$2.4 - $3.9	$844 - $1,395
Dredge, Solvent Extraction	2,809	$6.3 - $11.5	$2,239 - $4,110
Dredge, Solidification	2,809	$4.2 - $8.2	$1,505 - $2,936
Dredge, Incineration	2,809	$7.9 - $14.6	$2,826 - $5,212
Range	2,809	$2.4 - $14.6	$844 - $5,212

Under the selected alternative, four wetland areas will be excavated to a depth of approximately 1.5 feet to remove sediments with PCB concentrations exceeding the target cleanup levels. According to EPA, approximately 5,200 cubic yards would be excavated using a combination of backhoes, dredges, and hand-held shovels. Technicians will dewater the excavated material to ease handling and transport to an offsite landfill. Carbon adsorption wand additional treatment units will remove residual contaminants from the extracted water to protective levels, before the water is discharged. The selected alternative also involves the restoration of wetlands to their previous state, and the implementation of long-term environmental monitoring and institutional controls at the site. Remediation will take approximately 6 months to implement and cost an estimated $2.9 million ($1992).

The other options that include treatment of contaminated sediments prior to disposal permanently remove PCBs and other organic and inorganic compounds. This ensures a higher degree of long-term protection than does disposal without treatment. According to EPA, both treatment and nontreatment alternatives would remove contaminated sediments from the Sullivan's Ledge site, thus ensuring equal degrees of long-term protection.

New Bedford Harbor -- Estuary and Lower Harbor/Bay New Bedford, Massachusetts

New Bedford Harbor is an urban tidal estuary on the western shore of Buzzards Bay in southeastern Massachusetts. Studies have found elevated levels of PCBs, polycyclic aromatic hydrocarbons (PAHs), and heavy metals in sediment, the water column, and fish and shellfish. EPA placed New Bedford Harbor on the interim National Priorities List (NPL) in 1982, and the State of Massachusetts subsequently designated New Bedford Harbor its number one priority site.

The EPA study analyzed 12 remedial options employing a TCL of 10 ppm and 3 remedial options employing a TCL of 50 ppm. The 12 remedial options employing a TCL of 10 ppm fall into three groups: capping; dredge and disposal; and dredge, treatment, and disposal. Table 9-25 compares the remediation alternatives, with the selected option (Alternative B) costing $39 million ($127 per cu yd)[41]

Fields Brook Site -- Sediment Operable Unit[42]

The Fields Brook site is located in the city of Ashtabula, Ohio. Fields Brook flows into the Ashtabula River, which empties into Lake Erie. Various industrial point sources are believed to be responsible for contaminating sediments in Fields Brook.

The sediment alternatives differed in terms of the treatment and final disposal of the sediments once removed. They include: (1) offsite RCRA/TSCA landfilling after dewatering and solidification of sediment; (2) onsite TSCA landfilling after dewatering and solidification of sediment; (3) complete thermal treatment of sediments; and (4) temporary storage onsite in TSCA landfill and thermal treatment of 40% of the sediments removed; and permanent onsite TSCA landfilling of remaining solidified sediments. Alternatives range in cost from $22.0 million (alternative 2 -- onsite TSCA landfilling) to $72.7 million (alternative 3 -- complete thermal treatment) ($1992).

The present value cost of the recommended alternative is $57.0 million ($1992). The annual operating and maintenance costs to cover activities after remediation, such as ongoing landfill maintenance and groundwater monitoring, were estimated at $65,000 ($1992). EPA chose this option because thermal treatment of the most mobile and highly toxic contaminants was considered to offer the most reliable and permanent remedy.

Table 9-26 lists the alternatives and the estimated costs of remediation.

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[41] After selecting Alternative B, EPA proposed an amended cleanup plan to address hot spot areas in Upper Buzzards Bay. The plan proposes to cap and dredge three areas with PCB concentrations exceeding 10 ppm in the Upper Bay. The plan would cap a 17 acre area near New Bedford's wastewater treatment plant (WWTP) outfall and dredge 67,000 cubic yards of sediment in adjacent areas. EPA estimates that the addendum plan will cost an additional $9.7 million over the $39 million estimated for alternative B.

[42] Fields Brook is not a dioxin site. Sediment samples showed varying levels of 55 organic and 22 inorganic contaminants. Tissue analyses from fish caught in the Ashtabula River and Fields Brook revealed the presence of 15 priority pollutants including PCBs, arsenic, and beryllium.

Table 9-25
Comparison of Remedial Alternatives: New Bedford Harbor

Remedial Alternative	Volume of Sediment Remediated	Total Cost (Millions $1992)	Cost per Unit ($1992/cu yd)
TCL=10 ppm			
Capping	358 acres	$49 -- $65	NA
Dredge and Disposal	926,000 cu yd	$61 -- $93	$65 -- $100
Dredge, Treatment, and Disposal	926,000 cu yd	$185 -- $376	$199 -- $406
TCL=50 ppm			
Alternative A	Dispose 112,000 cu yd;cap 77 acres	$36	NA
Alternative B (EPA Selected)	Dredge and Dispose 308,000 cu.yd	$39	$127
Alternative C	Dispose 196,000 cu yd;treat and dispose 112,000 cu yd	$88 -- $101	NA

Table 9-26
Comparison of Sediment Remediation Costs: Fields Brook

Remediation Alternatives	Cost of Remediation ($1992)
Dredge with Offsite Disposal (Alternative 1)	$36.1
Dredge with Onsite Disposal (Alternative 2)	$22.0
Dredge with Solidification and Thermal Treatment (Alternative 3)	$72.7
Dredge with Offsite Thermal Treatment (Alternative 4)[1]	$57.0
Capping[2]	$4.5 -- $9.7

1 EPA Preferred Alternative.
2 EPA did not pursue this option due to uncertain long-term effectiveness.

General Motors Central Foundry Division Site -- Massena, New York

The General Motors site is located in the northeastern corner of St. Lawrence County in Massena, New York. The property is bordered on the north by the St. Lawrence River, to the east by the St. Regis Mohawk Indian Reservation, to the south by the Raquette River, and to the west by the Reynolds Metals Company and the St. Lawrence Seaway Development Corporation. Case study analysis is limited to the costs of remediating contaminated sediments in the St. Lawrence River and on both sides of the boundary with the St. Lawrence River, which is only one portion of the remedial plan for the first operable unit at this site. Although there are four major contaminants the cost analysis focuses on PCB contamination, which is more widespread and at higher levels than the other contaminants.

According to EPA (ERG,1992), there are over 62,000 cubic yards of contaminated river and creek sediments with PCB concentrations above 1 ppm in and along the St. Lawrence River, Raquette River, and Turtle Creek. The feasibility study analyzed two categories of remedial options for contaminated sediments: (1) containment with a graded filter; and (2) dredging sediments with PCB levels over 1 ppm and treating them on site. The containment option assumes that about 75,000 cubic yards of aggregate would be used to construct the graded filter over this area. The present value cost of this option was estimated at $3.9 million ($1992).

All of the removal remedial alternatives would dredge 62,000 cubic yards of river sediments and wetland soils with PCB levels above 1 ppm, dewater dredged sediments, and treat the dewatered sediments on site. The present value costs of these options range from $8.4 million for biological treatment to $34.6 million ($1992) for thermal destruction. EPA considers these costs rough estimates; actual costs could vary 50% higher to 30% lower. Cost estimates are shown in Table 9-27.

Table 9-27
Costs Associated with Sediment Dredging and Onsite Treatment: General Motors

Alternative	Present Value Costs ($1992 Millions)	Costs/cu yd
Dredging and Biological Treatment	$8.4	$135
Dredging and Chemical Destruction	$31.4	$507
Dredging and Chemical Extraction	$23.8	$385
Dredging and Thermal Destruction	$34.6	$559
Dredging and Thermal Extraction	$31.4	$507
Dredging and Solidification	$18.5	$298

Source: Draft feasibility study for GM Site, November 1989.

Eagle Harbor

Eagle Harbor is approximately 2-square-kilometer embayment on the east side of Bainbridge Island, Kitsap County, Washington, in Central Puget Sound. EPA believes that numerous point sources are responsible for contaminating Eagle Harbor and has notified ten parties with facilities that they could be subject to cost-recovery actions under CERCLA. In addition to high concentrations of PAHs, the elevated levels of PCBs, dioxins, and dibenzofurans in some areas of the harbor are also measured.

Three alternatives were designed to achieve the State of Washington's sediment management standards and reduce site cancer risks to the superfund target range. The alternatives differ in their ability to reduce the toxicity and mobility of sediment contaminants, long-term effectiveness and permanence, feasibility, and cost. The present discounted cost of the three alternatives ranges from \$25.2 to \$161.9 million (\$1992).

EPA proposed its preferred site-wide alternative in December 1991. The plan calls for the removal of mercury hotspots and disposal of dredged material in a municipal or hazardous waste landfill. Further, the plan would cap contaminated sediments exceeding state criteria and would allow for natural recovery to remediate sediments in areas where contaminant concentrations are expected to fall below state criteria within ten years. In the east harbor, the plan proposes interim action to cap sediments and postpones further remedial actions until further study has been completed. The cost of the proposed plan (\$14.7 -- \$38.1) million (\$1992) is less than the other alternatives because it does not include the cost of remediating the subtidal PAH problem. Table 9-28 lists costs of remediation by alternative.

Table 9-28
Costs of Remediation: Eagle Harbor

Remediation Alternative	Cost of Remediation (Millions \$1992)
Site-Wide Alternative A	\$25.2
Site-Wide Alternative B	\$161.9
Site-Wide Alternative C	\$81.0
EPA Preferred Interim Alternative	\$14.7 -- \$38.1

9.7.4 Conclusions

The options for sediment remediation are numerous. For this reason, it is difficult to estimate detailed guidelines for remediation costs. This analysis has attempted to provide a range of cost estimates by technology and case study area, as summarized in Table 9-29.

Table 9-29
Costs of Sediment Remediation at Five Superfund Sites
($1992)

Site	Volume of Sediment Remediated (cu yd)	Unit Costs ($/cu yd)	Range of Remediation Costs ($ Millions)
New Bedford Harbor			
10 ppm alternatives	926,000	$54 - $406	$49.4 - $376.3
50 ppm alternatives	308,000	$118 - $328	$36.0 - $101.0
EPA selected alternative	428,300	$115	$49.5
Fields Brook			
All alternatives	44,500 - 53,000	$414 - $1,633	$22.0 - $72.7
EPA selected alternative	52,000	$1,096	$57.0
Eagle Harbor			
All alternatives	401,000 - 562,000	$44 - $404	$25.2 - $161.9
EPA selected alternative	133,000 - 182,000	$81 - $287	$14.7 - $38.1
Massena			
All alternatives (1 ppm)	62,000	$135 - $559	$8.4 - $34.6
EPA selected alternative	NA	NA	NA
Sullivan's Ledge			
All alternatives (2-15 ppm)	2,809	$844 - $5,212	$2.4 - $14.6
EPA selected alternative	2,809	$844 - $1,395	$2.4 - $3.9

NA = Not available.
Source: ERG, 1992.

Key factors that impact sediment-related remediation cost estimates include: level of contamination, type of loadings (PCB, dioxin, PAH), and geographic features of clean-up site (river, wetland, bay). The combination of these factors determine the type and level of remediation that is necessary. Consequently, the technology- and site-specific remediation cost figures noted in this analysis are rough estimates that could vary substantially.

These remediation estimates have been presented here to indicate the potential magnitude of costs associated with addressing problems associated with dioxins (and similar, persistent toxic compounds) that are found in sediment. Current loadings of dioxins from pulp and paper mills are not expected to be associated, in and of themselves, with dioxin concentrations in sediment that motivate these types of remedial actions. Nonetheless, current loadings contribute to sediment contamination and, hence, some fraction of the illustrative remediation costs may be interpreted as reflecting a societal value associated with reduced loadings. The case studies show that restoration costs may amount to between $80 to as much almost $1,400 per cubic yard of sediment contaminated. However, because of the above noted concerns, these potential cost savings have not been incorporated into the assessment of benefits.

9.8 CONCLUSIONS

Because the benefits of environmental regulations are often highly site-specific, a benefits analysis based on a case-study approach was used to illustrate the type and potential magnitude of the benefits expected to arise as a result of the pulp and paper rulemaking. The benefits analysis is geared toward indicating: (1) the types of benefits to be anticipated; (2) a general approach for describing and, as feasible, estimating these benefits; and (3) the general magnitude of the monetized worth of several categories of benefits.

It is important that the inherent limitations of the analysis be recognized and appreciated. The case studies focus on empirically tractable benefit categories and omit several types of potential benefits. In addition, numerical estimates of these benefits are based on a benefits transfer approach. These benefits may not be directly transferable and/or may not accurately portray the values associated with unique sites. Finally, there is limited scientific linkage between the regulated pollutants and the observed impacts to ecological resources. The extent to which the regulation may be associated with benefits accruing from improvements in these resources, especially given a host of other regulatory and remedial actions underway, is uncertain. It is also important to recognize that the benefits of the regulation are likely to include long-term (i.e., delayed) ecologic benefits. The persistence and toxicity of compounds such as dioxin implies that benefits may exhibit characteristics that make them less amenable to empirical evaluation for two reasons: (1) temporally, most of the direct benefits are likely to be delayed for many years, and (2) structurally, the benefits are largely of the "ecologic" or "nonuse" variety.

Because they are based on case study sites, the results presented in this chapter may not be fully representative of the regulated universe. Based on a review of socio-economic profiles, the case study facilities are, in general, representative of these benefits characteristics for most of the facilities that will be affected by the regulation. However, water quality profiles show that the case study benefits will tend to underestimate aquatic life benefits for the universe of facilities. Additionally, the net monetized benefits associated with the case studies are not fully representative of aggregate net benefits. Process changes at case study facilities located on the lower Columbia River and Wisconsin River account for roughly 5% of the expected national benefits, while they constitute roughly 10% of national costs. Consequently, the net benefits associated with these facilities tend to be lower than expected net benefits for other facilities.

A restoration costing technique was also used to illustrate the benefits of the regulation. Benefits of reducing dioxin discharges can be implied by considering the potential cost savings associated with restoration efforts to clean water bodies impacted by other similar contaminants. Key factors in the determination of costs are highly site specific, however, making a meaningful cost range difficult to estimate. In addition, these costs relate to the remediation of sediments contaminated by historical discharges, and current loadings of dioxins from pulp and paper mills can only be associated with a fraction of the illustrative remediation costs.

10.0 COMPARISON OF BENEFITS TO COSTS

10.1 NATIONAL LEVEL RESULTS

A comparison of the total annualized costs of the regulation to the total annual benefits at the national level is presented in Table 10-1. Both private costs and social costs of the regulation are presented. Private costs reflect the combined cost of compliance with the air and water regulations while social costs also include the opportunity costs borne by society for pollution control. The results indicate that the annual costs of the regulation are commensurate with the annual benefits at the national level.

Table 10-1
Comparison of National Level Annual Benefits to Costs for the Pulp and Paper Rulemaking

Benefits	Millions of 1992 Dollars per Year
Air Benefits[1]	\$88.9 - \$556.2
Water Benefits[2]	\$71.5 - \$430.4
Combined Air and Water Benefits Range	\$160.4 - \$986.6
Combined Air and Water Compliance Cost	\$599.5
Social Costs[3]	\$947.8

1 Benefits include human cancer risk reductions associated with HAP emission reductions and acute health and agricultural benefits associated with VOC emission reductions. Refer to Chapter 8.0 for a complete explanation of the benefit categories that were left unmonetized due to a lack of data.
2 Benefits include human health risk reductions and avoided costs for sludge disposal.
3 Does not include government administrative costs.

10.2 CASE STUDY RESULTS

Comparison of total benefits to costs for the case studies is presented in Table 10-2. Both private and social costs of the regulation are presented (social costs add the opportunity costs of pollution control borne by society to the private compliance cost estimates). The case study results indicate that those benefits that could be quantified and monetized, although less than the costs of the regulation, are of the same order of magnitude. However, an analysis of the representativeness of the case study sites revealed the case study benefits comprise slightly less than 5% of the total national benefits, while case study costs comprise approximately 10% of the total national costs. Because the case studies tend to underrepresent potential benefits and overrepresent potential costs, other sites affected by the regulations are expected, on average, to have greater net benefits than found for the case studies.

Table 10-2
Comparison of Potential Annual Air- and Water-Related Benefits to the Potential Costs of the Pulp and Paper Regulation for the Case Study Sites
(Millions of 1992 Dollars per Year)

	Penobscot River	Wisconsin River	Columbia River
Water-Related Benefits	$0.6 - $2.5	$0.5 - $3.4	$1.8- $12.5
Air-Related Benefits	$0.4 - $2.3	$0.9 - $5.4	$4.2 - $26.5
Total Benefits	$1.0 - $4.8	$1.4 - $8.8	$6.0 - $39.0
Combined Air and Water Compliance Cost for Reg. Alt. 26	A	$15.5	$46.0
Total Social Costs[1]	A	$24.9	$67.5

A Confidentiality agreements preclude disclosure of total costs for this site.
1 Social cost estimates do not include worker dislocation and government administrative costs.

11.0 REFERENCES

Abt Associates. 1993. Revision of Assessment of Risks to Terrestrial Wildlife from TCDD and TCDF in Pulp and Paper Mill Sludge. Draft Report to EPA.

Amerhein, J. 1992. Personal Communication. Wisconsin Department of Natural Resources, Fisheries Division.

Andersson, T., L. Forlin, J. Hardig, and A. Larsson. 1988. Physiological disturbances in fish living in coastal water polluted with bleached kraft pulp mill effluents. *Canadian Journal of Fish and Aquatic Science*. **45**:1525-1536.

Banks, J. 1992. Appendix A: The Penobscot Nation's View of the Benefits Provided by Atlantic Salmon. Prepared by Penobscot Department of Natural Resources. January 15.

Belton, T., Roundy, R., and Weinstein, N. (November 1986) Urban Fisherman: Managing the Risks of Toxic Exposure. *Environment*, **28**(9): 19-37.

Boucher, N. 1993. What is poisoning the eagles of Maine?. *The Boston Globe Magazine*. **July 4**: 13-16.

Boyle, K.J., M.F. Teisl, and S.D. Reiling. 1992. Qualitative and Economic Evaluations of Atlantic Salmon Fishing on the Penobscot River. Prepared by University of Maine, Department of Agricultural and Resource Economics. Staff Paper No. 436. March.

Broman, D., C. Näf, C. Rolff, Y. Zebühr, B. Fry, and J. Hobbie. 1992. Using ratios of stable nitrogen isotopes to estimate bioaccumulation and flux of polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) in two food chains from the northern baltic. *Environ. Toxicol. Chem.* **11**:331-345.

Brown, T. and E. Burch. 1992. Estimating the Economic Value of Subsistence Harvest of Wildlife in Alaska. In *Valuing Wildlife Resources in Alaska*, ed. G. Peterson, C. Swanson, D. McCollum, and M. Thomas. Westview Press. Boulder, Colorado.

Carey, J. 1993. Personal Communication. Environment Canada.

Carey, J.H., P.V. Hodson, K.R. Munkittrick, and M.R. Servos. 1993. Recent Canadian studies on the physiological effects of pulp mill effluent on fish. Prepared for Environment Canada, Fisheries and Oceans.

Connelly, N.A., T.L. Brown, and B.A. Knuth. 1990. New York Statewide Angler Survey. Prepared for the New York State Department of Environmental Conservation, Albany, NY. April.

Cook, P.M. 1993. Personal Communication. U.S. EPA, Duluth, Minnesota. February 17 and July 19.

Cook, P.M., M.K., Walker, D.W. Kuehl, and R.E. Peterson. 1991. Pages 143-168 in M.A. Gallo, R.J. Scheuplein, and K.A. Van Der Heijden, eds., *Banbury Report 35: Biological Basis for Risk Assessment of Dioxins and Related Compounds.* Cold Spring Harbor Laboratory Pres, Plainview, NY.

Cook, P.M., A.R. Batterman, B.C. Butterworth, K.S. Lodge, and S.W. Kohlbry. 1990. Laboratory study of TCDD bioaccumulation by lake trout from Lake Ontario sediments, food chain, and water. In: *Lake Ontario TCDD bioaccumulation study - final report.* Ch. 6. U.S. Environmental Protection Agency, Region 2, New York.

Cooper, K. 1989. Effects of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans on aquatic organisms. *CRC Critical Review in Aquatic Sciences.* 1:227-242.

Crutchfield, J.A, S. Langdon, O.A. Mathisen, and P.H. Poe. 1982. The Biological Economic and Social Values of a Sockeye Salmon Stream in Bristol Bay, Alaska: A Case Study of Taimina river. University of Washington, Fisheries Research Institute Circular #82-2.

Cunningham, P.A., J.M. McCarthy, and D. Zeitlin. 1990. Results of the 1989 census of state fish/shellfish consumption advisory programs. Research Institute Report. Research Triangle Park, NC.

E.H. Pechan & Associates, Inc. 1991. Cost-effectiveness of Stationary Source VOC and NO_x Controls. Prepared for U.S. EPA, Office of Air Quality and Planning Standards, Research Triangle Park, N.C. July 22.

Eisler, R. 1986. Dioxins Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish Wildlife Service, *Biol. Rep.* 85(1.8).

ERG. 1993a. Economic Impact and Regulatory Flexibility Analysis of Proposed Effluent Guidelines and NESHAP for the Pulp, Paper, and Paperboard Industry. Draft.

ERG. 1993b. Economic Analysis of Impacts of Integrated Air/Water Regulations for the Pulp and Paper Industry on Disposal on Wastewater Sludge. Draft Final Report. August 17. Prepared for U.S. EPA, Office of Pollution Prevention and Toxics.

ERG. 1992. Clean Water Reauthorization Study: Analysis of the Costs and Benefits of Remediating Contaminated Sediment. Prepared by Eastern Research Group for the Office of Water, U.S. EPA. February 28.

Fiore, B. J., Anderson, H. A., Hanrahan, L. P., Olson, L. J., and Sonzogni, W. C. (March/April 1989) Sport Fish Consumption and Body Burden Levels of Chlorinated Hydrocarbons: A Study of Wisconsin Anglers. *Archives of Environmental Health*, 44(2): 82-88.

Fisher, A., L.G. Chestnut, and D.M. Violette. 1989. The Values of Reducing Risks of Death: A Note on New Evidence. *Journal of Policy Analysis and Management*, 8(1): 88-100.

Fisher, A., and R. Raucher. 1984. Intrinsic Benefits of Improved Water Quality: Conceptual and Empirical Perspectives, In: *Advances in Applied Microeconomics*, Vol. 3, V.K. Smith, editor, JAI Press.

Foth & Van Dyke. 1991. Marathon County Comprehensive Outdoor Recreation Plan. February.

Gilbertson, M. 1989. Effects on fish and wildlife populations. In *Halogenated biphenyls, terphenyls, napthalenes, dibenzodioxins and related products.* Elsevier, NY.

Haggblom, M. and M. Salkinoja-Salonen. 1991. Biodegradability of chlorinated organic compounds in pulp bleaching effluents. *Water Sci. Tech.* 24:161-170.

Hart, C.W. Jr., and S.L.H. Fuller. 1979. *Pollution ecology of estuarine invertebrates.* Academic Press, Inc., New York.

Hart, C.W. Jr., and S.L.H. Fuller. 1974. *Pollution ecology of freshwater invertebrates.* Academic Press, Inc., New York.

Haug, J. 1993. Personal Communication. Wisconsin Department of Natural Resources, Wisconsin Rapids Area Office.

Huppert, D.D. 1990. Economic Benefits from Commercial Fishing. Draft Report to National Marine Fisheries Service.

Knuth, B.A. and C.M. Velicer. 1990. Receiver-centered Risk Communication for Sportfisheries: Lessons from New York Licensed Anglers. Paper presented at the American Fisheries Society Annual Meeting, Pittsburgh, Pennsylvania. August.

Loftus, M.E., L.M. Barraj, and J.R. Tomerlin. 1992. Effect of the limit of detection on exposure assessment. *J. AOAC Intern.* 75(5):911-915.

Loomis, J.B. 1988. Valuing Nonconsumptive Use and Values of Game and Nongame Wildlife in California: Results of Surveys on Deer, Birds and Mono Lake (unpublished). University of California, Davis.

Lyke, A. J. 1992. Multiple Site Trip Generation and Allocation: A Travel Cost Model for Wisconsin Great Lakes Sport Fishing, Draft, Ph.D. Thesis, University of Wisconsin-Madison, Madison, Wisconsin.

Mathtech, Inc. 1988. Revised Benefit Analysis of Hypothetical Particulate Matter Control Regulations for Selected Municipal Waste Combustors. Report prepared for the U.S. Environmental Protection Agency, Research Triangle Park, NC.

McMaster, M.E., G.J. Van Der Kraak, C.B. Portt, K.R. Munkittrick, P.K. Sibley, I.R. Smith, and D.G. Dixon. 1991. Changes in mepatic mixed-function oxygenase (MFO) activity, plasma steroid levels and age at maturity of a white sucker population exposed to bleached Kraft mill effluent. *Aquatic Toxicology* **21**:199-218.

Mehrle, P.M., D.R. Buckler, E.E. Little, L.M. Smith, J.D. Petty, P.H. Peterman, D.L. Stalling, G.M.De Graeve, J.J. Coyle, and W.J. Adams. 1988. Toxicity and bioconcentration of 2,3,7,8-tetrachlorodibenzodioxin and 2,3,7,8-tetrachlorodibenzofuran in rainbow trout. *Environ. Toxicol. Chem.* 7:47-62.

Melcher, C. E. and S. D. King. 1992. The 1991 Lower Columbia River and Buoy 10 Recreational Fisheries. Publication of the Oregon Department of Fish and Wildlife, Fish Division, Columbia River Management.

Melquist, W.E. and A.E Dronkert. 1987. River Otter, In: *Wild Furbearer Management and Conservation in North America*, edited by M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch. Ontario Trappers Association.

Meyers, M. 1993. Personal Communication. Wisconsin Department of Natural Resources, Wildlife, Monona, Wisconsin.

Mitchell, R.C., and R.T. Carson. 1986. The Use of Contingent Valuation Data for Benefit/Cost Analysis in Water Pollution Control. Resources for the Future, Washington, D.C. September.

Mitchell, R.C., and R.T. Carson. 1984. An Experiment in Determining Willingness to Pay for National Water Quality Improvements. Resources for the Future, (for U.S. Environmental Protection Agency), Washington, D.C.

Mitnik. P. 1991. Penobscot River Basin Waste Load Allocation. Prepared by State of Maine, Department of Environmental Protection, Division of Environmental Evaluation and Lake Studies. January.

Mower, B. 1991. Dioxin Monitoring Program: State of Maine, 1991. Prepared by Department of Environmental Protection, Augusta, Maine. February 7.

Mundahl, N.D. 1991. Sediment processing by gizzard shad, *Dorosoma cepedianum*, in Acton Lake, Ohio, U.S.A. *J. Fish Biol.* **38**:565-572.

National Research Council. 1979. Odors from Stationary and Mobile Sources. Prepared by Committee on Odors from Stationary and Mobile Sources, Assembly of Life Sciences, National Research Council. Published by the National Academy of Sciences.

Naughton, M.C., and W.H. Desvousges. 1985. Water Quality Benefits of the BCT Regulations for the Pulp and Paper Industry. Draft Report. Prepared for the Economic Studies Branch, U.S. EPA, Washington, DC.

Newman, E. and P. Karas. 1988. Effects of pulp mill effluent on a Baltic coastal fish community. *Water Sci. Technol.* **20**:95-106.

Nickel, F.W. and P.S. Collins. 1992. Adams County Comprehensive Outdoor Recreation Plan. Prepared by Adams County Parks and Recreation Department.

Ostro, B. 1987. Air Pollution and Morbidity Revisited: A Specification Test. *Journal of Environmental Economics and Management* **14**(1): 87-98.

Owens, J.W. 1991. The hazard assessment of pulp and paper effluents in the aquatic environment: A review. *Environ. Toxicol. Chem.* **10**:1511-1540.

Pao, E.M., K.H. Fleming, P.M. Guenther, and S.J. Mickle. 1982. Foods commonly eaten by individuals: Amount per day and per eating occasion. Home Economics Research Report No. 44. U.S. Department of Agriculture, Hyattsville, MD.

Patrick, Glen. 1993. Personal Communication, July 22, 1993.

Penobscot Nation Department of Natural Resources. 1991. Results of the 1991 Penobscot River Users Survey Conducted by the Department of Natural Resources.

Pierce, R.S., D.T. Noviello, S.H. Rogers. 1981. Commencement Bay seafood consumption report. Preliminary report. Tacoma-Pierce County Health Department, Tacoma, WA.

Plenert, Marvin L. 1992. Regional Director, Pacific Region, U.S. FWS, Testimony before the Subcommittee on Regulation, Business Opportunities, and Energy of the Committee on Small Business, House of Representatives, 102 Congress, Portland, OR, January 18, 1982, Serial No. 102-59, Washington D.C.

Poole, N.J., D.J. Wildish, and D.D. Kristmanson. 1978. The effects of the pulp and paper industry on the aquatic environment. *CRC Crit. Rev. Environ. Control* **8**:153-195.

Portage County Park Commission. 1990. Portage County Comprehensive Outdoor Recreation Plan. 1990-1995 Update.

Rabert, W.S. 1990. An update on the environmental effects of TCDD and TCDF releases from pulp and paper mills on aquatic and terrestrial animals. U.S. Environmental Protection Agency, Environmental Effects Branch, Health and Environmental Review Division, Office of Toxic Substances, Washington, DC. June.

Radian, Inc. 1993. Methodology for determining BAT pollutant loadings for the revision of pulp and paper effluent limitation guidelines (support for estimates released to the public February 24, 1993) prepared for U.S. Environmental Protection Agency, Commodities Branch, Engineering and Analysis Division, Office of Science and Technology, Washington, DC. Prepared by Radian Corporation, Herndon, VA. June, 1993.

Rand, G.M., and S.R. Petrocelli. 1984. *Fundamentals of aquatic toxicology*. Hemisphere Publishing Company, New York.

RCG/Hagler Bailly. 1993. Preliminary Assessment of Aquatic Pathway Risks to Wildlife from the Disposal of Pulp and Paper Mill Wastes Contaminated with Dioxin and Furan. Prepared for U.S. EPA, Office of Pollution Prevention and Toxics. October 14.

RCG/Hagler, Bailly. 1989. Fishing for Atlantic Salmon in Maine: An Investigation into Angler Activity and Management Options. Final Draft. Prepared by R.D. Rowe, A.M. Michelson, and E.R. Morey for Mr. Fred Ayer, Bangor Hydro-Electric Company. September.

Reinert, R.E., B.A. Knuth, M.A. Kamrin, and Q.J. Stober. 1991. Risk assessment, risk management, and fish consumption advisories in the United States. *Fisheries.* pp 5-12.

Sherman, W.R., R.E. Keenan, and D.G. Gunster. 1992. A re-evaluation of bioconcentration factors for TCDD. *J. Toxicol. Environ. Health* **37**:211-229.

Silbergeld, E.K. 1991. Carcinogenicity of dioxins. *J. Nat. Cancer Inst.* **83**(17):1198-1199.

Silverman, W.M. 1990. Michigan's Sport Fish Consumption Advisory: A Study in Risk Communication. Thesis submitted for the degree of Master of Science at the University of Michigan. May.

Sodergren, A., B.E. Bengston, P. Jonsson, S. Lagergren, A. Larsson, M. Olsson, and L. Renberg. 1988. Summary of Results from the Swedish project "Environment/cellulose" *Water Sci. Technol.* **20**:49-60

Stockner, J.G., and A.C. Costella. 1976. Marine phytoplankton growth in high concentrations of pulpmill effluent. *Journ. Fish. Res. Bd. Can.* **33**:2758-2765.

Tetra Tech. 1993a. The Environmental Assessment for the Pulp, Paper & Paperboard Industry Effluent Guidelines Regulatory Impact Analysis. Volume 1: Methodology and Results. Prepared for U.S. EPA, OST.

Tetra Tech. 1993b. Fish Advisory for the Leaf River, Mississippi: A Case Study. Supporting Document prepared for U.S. EPA, Standards and Applied Science Division. October 31.

Tetra Tech Inc. 1993. Confidential Business Information on Pulp and Paper Mill Effluent Discharge Data, obtained from Tetra Tech, Inc.

Thomann, R.V. 1989. Bioaccumulation model of organic chemical distribution in aquatic food chains. *Environ. Sci. Technol.* **23**:699-707.

Thut, R.N., and D.C. Schmiege. 1991. Processing Mills. *Influences of forest and rangeland management on salmonid fishes and their habitats*. Amer. Fish. Soc. Spec. Publ. **19**:369-387.

U.S. ACOE. 1990. Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes. Prepared for U.S. EPA, Great Lakes National Program Office. December.

U.S. DOE. 1991. The Columbia River System: The Inside Story. Published for the Columbia River System Operation Review, a joint project of the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Bonneville Power Administration.

U.S. DOI. 1989. 1985 National Survey of Fishing, Hunting and Wildlife-Associated Recreation. Prepared by U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, DC. March.

U.S. Census Bureau. 1992. U.S. 1990 Census Data. U.S. Census Bureau Public Relations Office, Personnel Communication.

U.S. Congress, Office of Technology Assessment. 1989. Catching our breath: Next steps for reducing urban ozone, OTA-O-412. Washington DC: U.S. Government Printing Office. July.

U.S. Department of Commerce. 1992. 1990 Census of Population and Housing: Summary Social, Economic, and Housing Characteristics. Prepared by Economics and Statistics Administration, Bureau of the Census. June

U.S. EPA. 1993a. Interim Report on Data and Methods for Assessment of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Risks to Aquatic Life and Associated Wildlife. Prepared by the Office of Research and Development, Washington, DC. EPA/600/R-93/055. March.

U.S. EPA. 1993b. Development document for proposed effluent limitation guidelines and standards for the pulp, paper, and paperboard point source category. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1993c. Estimating Exposure to dioxin-like compounds. Vol. III: Site-specific assessment procedures. Draft. U.S. EPA, Office of Health and Environmental Assessment, Exposure Assessment Group, Washington, DC. July.

U.S. EPA. 1992a. Categorization assessment report for pulp and paper analytes detected during the short-term sampling 1988-1990. Office of Science and Technology, Washington, DC.

U.S. EPA. 1992b. Categorization assessment report for pulp and paper analytes detected during the long-term sampling 1991-1992. Office of Science and Technology, Washington, DC.

U.S. EPA. 1992c. National study of chemical residues in fish. Volume 1. EPA 823-R-92-008a. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC. September.

U.S. EPA. 1992d. Human Health Risk Assessment for Dioxin in Pulp and Paper Sludge: Technical Support Document for the Land Application Rule, Fish Ingestion Pathway. Prepared by Abt Associates, Inc., Bethesda, MD.

U.S. EPA. 1992e. Integrated Risk Information System (IRIS). U.S. EPA, Health Criteria and Assessment Office, Washington, DC. Revised in October.

U.S. EPA. 1992f. Health Effects Assessment Summary Tables (HEAST). FY-1992. U.S. EPA, Office of Solid Waste and Emergency Response. Washington, DC.

U.S. EPA. 1991a. Human health evaluation manual, supplemental guidance: "standard default exposure factors." OSWER Directive 9285.6-03. Office of Solid Waste and Emergency Response, Washington, DC. March 25, 1991.

U.S. EPA. 1991b. Technical Support Document for Water Quality-Based Toxics Control. U.S. EPA Office of Water, Washington, DC. EPA/50512-90-001.

U.S. EPA. 1991c. Assessment and control of bioconcentratable contaminants in surface waters. U.S. Environmental Protection Agency, Office of Water, Office of Research and Development, Washington, DC. Draft, March 1991.

U.S. EPA. 1991d. Bioaccumulation of selected pollutants in fish, A national study. Draft. U.S. Environmental Protection Agency, Office of Science and Technology, Washington DC.

U.S. EPA. 1990a. U.S. EPA/Paper Industry Cooperative Dioxin Study "The 104 Mill Study": Statistical Findings and analyses. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC.

U.S. EPA. 1990b. Integrated risk assessment for dioxins and furans from chlorine bleaching in pulp and paper mills. U.S. EPA, Office of Pesticides and Toxic Substances, Washington, DC.

U.S. EPA. 1990c. Risk assessment for 2,3,7,8-TCDD and 2,3,7,8-TCDF contaminated receiving waters from U.S. chlorine-bleaching pulp and paper mills. U.S. EPA, Office of Water Regulations and Standards, Washington, DC. September.

U.S. EPA. 1989a. Risk assessment guidance for superfund. Volume I: human health evaluation manual (Part A). Interim Final. OSWER Directive 9285.7-01a. Office of Solid Waste and Emergency Response. Washington, DC. December 1989.

U.S. EPA. 1989b. Assessing human health risk from chemically contaminated fish and shellfish: a guidance manual. Office of Water Regulations and Standards, Washington, DC. September 1989.

U.S. EPA. 1989c. Monetized Health Benefits of Regulating Sewage Sludge Use and Disposal. Final report prepared by Abt Associates, Inc. for the Office of Policy Analysis and Office of Water Regulations and Standards, U.S. EPA, Washington, DC.

U.S. EPA. 1988. U.S. EPA/paper industry cooperative dioxin screening study ("Five mill study"). U.S. EPA, Office of Water Regulations and Standards, Washington, DC. March. EPA-440/1-88-025.

U.S. EPA. 1987. The national dioxin study. U.S. EPA, Office of Water Regulations and Standards, Washington, DC.

U.S. EPA. 1985. Guidelines for Cost-Effectiveness of New Source Performance Standards. Memorandum from C.L. Elkins and M. Russell to A.J. Barnes. September 11.

U.S. EPA. 1984. Ambient water quality criteria for 2,3,7,8-tetrachlorodibenzo-p-dioxin. U.S. EPA, Office of Water Regulations and Standards, Washington, DC.

U.S. Office of Management and Budget. 1989. Regulatory Impact Guidance. Appendix V of Regulatory Program of the United States Government. April 1, 1988-March 31, 1989.

Vena, J.E. 1992. Risk Perception, Reproductive Health Risk and Consumption of Contaminated Fish in a Cohort of New York State Anglers. Progress Report of the New York State Angler Cohort Study for the Great Lakes Protection Fund, Department of Social and Preventive Medicine, SUNY Buffalo, Buffalo, New York.

Versar, Inc. 1993. Toxicity Data for Pulp and Paper Analytes.

Violette, D.M. and L.G. Chestnut. 1986. Valuing Risks: New Information on the Willingness to Pay for Changes in Fatal Risks. Contract #68-01-7047. Report to the U.S. EPA, Washington, DC.

Violette, D.M. and L.G. Chestnut. 1983. Valuing Reduction in Risks: A Review of the Empirical Estimates. Environmental Benefits Analysis Series. EPA-230-05-83-003. U.S. EPA, Washington, DC.

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1992. Benefit Transfer of Outdoor Recreation Demand Studies, 1968-1988. *Water Resources Research* **28**: 707-713.

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1990. Nonmarket Values from Two Decades of Research on Recreation Demand. V.K. Smith and A.N. Link (eds.), *Advances in Applied Micro-Economics* **5**: 167-193. JAI Press, Inc.

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1988. Review of Outdoor Recreation Economic Demand Studies with Nonmarket Benefit Estimates: 1968-1988. Prepared by Colorado Water Resources Research Institute. Technical Report No. 54. December.

Walsh, G.E., K.M. Duke, and R.B. Foster. 1982. Algae and crustaceans as indicators of bioactivity of industrial wastes. *Water Res.* **16**:879-883.

Washington State Department of Ecology. 1990. 1990 Statewide Water Quality Assessment 305(B) Report. Water Quality Program, State of Washington. June.

Washington State Department of Fisheries. 1990. 1990 Fisheries Statistical Report. State of Washington, Department of Fisheries.

West, P.C., J.M. Fly, R. Marans, F. Larkin, and D. Rosenblatt. 1993. 1991-92 Michigan Sport Anglers Fish Consumption Study. University of Michigan, School of Natural Resources, Natural Resource Sociology Research Lab. Technical Report #6. May.

West, P.C. M.J. Fly, R. Marans, and F. Larkin. 1989. Michigan sports anglers fish consumption survey, Supplemental I, Nonresponse bias and consumption suppression effect adjustment. Natural Resource Sociology Research Lab, Technical Report No. 2. School of Natural Resources, University of Michigan, Ann Arbor.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* **18**(2):6-22.

Williams, Bill A. 1992. Testimony before the Subcommittee on Regulation, Business Opportunities, and Energy of the Committee on Small Business, House of Representatives, 102 Congress, Portland, OR, January 18, 1982, Serial No. 102-59, Washington D.C.

Wisconsin Department of Natural Resources. 1993. Endangered Resources Information Review (Log Number 92-641), Provided by Wisconsin Department of Natural Resources, Bureau of Endangered Resources.

Wisconsin Department of Natural Resources. 1992. Health Guide for People who eat Sport Fish from Wisconsin Waters. Prepared by Wisconsin Division of Health. PUBL-IE-019. April.

Wisconsin Department of Natural Resources. 1991a. Wisconsin Statewide Comprehensive Outdoor Recreation Plan: 1991-1996. Prepared by Wisconsin Department of Natural Resources, Madison, Wisconsin. October.

Wisconsin Department of Natural Resources. 1991b. Report of 1991 License Sales. Prepared by Wisconsin Department of Natural Resources, Madison, Wisconsin.

Wood County. 1991. Wood County, Wisconsin: Parks, Recreation, and Open Spaces Plan. 1991 Update. Prepared by Wood County Planning Office.

Xiong, L. 1992. Personal Communication. Hmong Association, Wausau, Wisconsin.

APPENDIX TO CHAPTER 8

AIR QUALITY ASSESSMENT DOCUMENT
PULP AND PAPER MILL RISK CHARACTERIZATION

A.0 INTRODUCTION

The purpose of this document is to present the methodology for analyzing the human health effects associated with hazardous air pollutant (HAP) emission sources to be regulated by the Pulp and Paper National Emission Standard for Hazardous Air Pollutants (NESHAP). Although this source category emits a wide variety of HAPs, only a small portion of the HAPs are emitted in sufficient quantities to pose a threat to human health. Therefore, the analysis presented in this document will focus on the health effects associated with exposure (through inhalation) to HAPs identified as significant.

A.1 ESTIMATING HEALTH EFFECTS

The major pathways for human exposure to environmental contaminants are through inhalation, ingestion, or dermal contact. Airborne contaminants may be toxic to the sites of immediate exposure, such as skin, eyes, and linings of the respiratory tract. Toxicants may also cause a spectrum of systemic effects following absorption and distribution to various target sites such as liver, kidneys, and central nervous system.

Exposure to contaminants in the air can be acute, subchronic, or chronic. Acute exposure refers to a very short-term (i.e., less than or equal to 24 hours), usually single-dose, exposure to a contaminant. Health effects often associated with acute exposure include: central nervous system effects such as headaches, drowsiness, anesthesia, tremors, and convulsions; skin, eye, and respiratory tract irritation; nausea; and olfactory effects such as awareness of unpleasant or disagreeable odors. Many of these effects are reversible and disappear with cessation of exposure. Acute exposure to very high concentrations or to low levels of highly toxic substances can, however, cause serious and irreversible tissue damage, and even death. A delayed toxic response may also occur following acute exposure to certain agents.

Chronic exposures are those that occur for long periods of time (from many months to several years). Subchronic exposure falls between acute and chronic exposure, and usually involves exposure for a period of weeks or months. Generally, the health effects of greatest concern following intermittent or continuous long-term exposures are those that cause either irreversible damage and serious impairment to the normal functioning of the individual, such as cancer and organ dysfunction, or death.

The risk associated with exposure to a toxic agent is a function of many factors, including the physical and chemical characteristics of the substance, the nature of the toxic response and the dose required to produce the effect, the susceptibility of the exposed individual, and the exposure situation. In many cases, individuals may be concurrently or sequentially exposed to a mixture of compounds, which may influence the risk by changing the nature and magnitude of the toxic response.

A.1.1 Estimation of Cancer Potency

The unit risk estimate (URE, unit risk factor, cancer potency estimate) is used by the Environmental Protection Agency (EPA) in its analysis of carcinogens. It is defined as the lifetime cancer risk occurring in a hypothetical population in which all individuals are exposed throughout their lifetime (assumed to be 70 years) to an average concentration of 1 $\mu g/m^3$ of the pollutant in the air they breathe. Unit risk estimates can be used for two purposes: (1) to compare the carcinogenic potency of several agents with one another, and (2) to give a rough indication of the public health risk that might be associated with estimated air exposures to these agents (U.S. EPA, 1986a).

In the development of UREs, EPA assumes that if experimental data show that a substance is carcinogenic in animals, it may also be carcinogenic in humans. The EPA also assumes that any exposure to a carcinogenic substance poses some risk (U.S. EPA, 1986a). This nonthreshold presumption is based on the view that as little as one molecule of a carcinogenic substance may be sufficient to transform a normal cell into a cancer cell. Exposed individuals are represented by a referent male having standard weight, breathing rate, etc. (no reference is made to factors such as race or state of health).

The data used for the quantitative estimate can be of two types: (1) lifetime animal studies, and (2) human studies where excess cancer risk has been associated with exposure to the agent. It is assumed, unless evidence exists to the contrary, that if a carcinogenic response occurs at the dose levels used in the study, then responses will occur at all lower doses with an incidence determined by the extrapolation model.

There is no solid scientific basis for any mathematical extrapolation model that relates carcinogenic exposure to cancer risks at the extremely low concentrations that must be dealt with in evaluating environmental hazards. For practical reasons, such low levels of risk cannot be measured directly either by animal experiments or by epidemiologic studies. We must, therefore, depend on our current understanding of the mechanisms of carcinogenesis for guidance as to which risk extrapolation model to use. At present, the dominant view of the carcinogenic process is that most agents that cause cancer also cause irreversible damage to DNA. This position is reflected by the fact that a very large proportion of agents that cause cancer are also mutagenic. There is reason to expect that the quantal type of biological response, which is characteristic of mutagenesis, is associated with a linear nonthreshold dose-response relationship. Indeed, there is substantial evidence from mutagenesis studies with both ionizing radiation and a wide variety of chemicals that this type of dose-response model is the appropriate one to use. This is particularly true at the lower end of the dose-response curve. At higher doses, there can be an upward curvature probably reflecting the effects of multistage processes on the mutagenic response. The linear nonthreshold dose-response relationship is also consistent with the relatively few epidemiologic studies of cancer responses to specific agents that contain enough information to make the evaluation possible (e.g., radiation-induced leukemia, breast and thyroid cancer, skin cancer induced by arsenic in drinking water, liver cancer induced by aflatoxins in the diet). There is also some evidence from animal experiments that is consistent with the linear nonthreshold model (e.g., liver tumors induced in mice by 2-acetylaminofluorene in the large scale ED01 study at the National Center for Toxicological Research and the initiation stage of the two-stage carcinogenesis model in rat liver and mouse skin).

Because of this evidence, the linear nonthreshold model is considered to be a viable model for any carcinogen, and unless there is direct evidence to the contrary, it is used as the primary basis for risk extrapolation to low levels of exposure (U.S. EPA, 1984a).

The mathematical formulation chosen to describe the linear nonthreshold dose-response relationship at low doses is the linearized multistage model. The linearized multistage model is applied to the original unadjusted animal data. Risk estimates produced by this model from the animal data are then scaled to a human equivalent estimate of risk. This is done by multiplying the estimates by several factors to adjust for experimental duration, species differences, and, if necessary, exposure route conversion. The conversion factor for species differences is currently based on models for equitoxic dose (U.S. EPA, 1986a). The unit risk values estimated by this method provide a plausible, upper-bound limit on public risk at lower exposure levels if the exposure is accurately quantified; i.e., the true risk is unlikely to be higher than the calculated level and could be substantially lower, including zero risk.

The method that has been used in most of EPA's quantitative risk assessments assumes dose equivalence in units of mg/body weight raised to the 2/3 power for equal tumor response in rats and humans. This method is based on adjustment for metabolic differences. It assumes that metabolic rate is roughly proportional to 2/3 power of body weight (as would be the case for a perfect sphere). The estimate is also adjusted for lifetime exposure to the carcinogen considering duration of experiment and animal lifetime (U.S. EPA, 1986a).

For unit risk estimates for air, animal studies using exposure by inhalation are preferred. When extrapolating results from the inhalation studies to humans, consideration is given to the following factors:

- The deposition of the inhaled compound throughout the respiratory tract
- Retention half-time of the inhaled particles
- Metabolism of the inhaled compound
- Differences in sites of tumor induction.

Unit risk estimation from animal studies is only an approximate indication of the actual risk in populations exposed to known concentrations of a potential carcinogen. Differences between species (lifespan, body size, metabolism, immunologic responses, target site susceptibility), as well as differences within species (genetic variation, disease state, diet), can cause actual risk to be much different. In human populations, variations occur in genetic constitution, diet, living environment, and activity patterns. Some populations may demonstrate a higher susceptibility due to certain metabolic or inherent differences in their response to the effects of carcinogens. Also, UREs are based on exposure to a referent adult male. There may be an increased risk with exposure to fetuses, children, or young adults. Finally, humans are exposed to a variety of compounds, and the health effects, either synergistic, additive, or antagonistic, of exposure to complex mixtures of chemicals are not known (U.S. EPA, 1986a; U.S. EPA, 1984b).

EPA Unit Risk Estimates

As explained above, UREs are used by EPA in analyses of carcinogens. EPA has developed UREs for several compounds that are emitted from pulp and paper mills via the ambient air. The UREs in Table A-1 have been derived by EPA's Human Health Assessment Group (HHAG)11, and most have been verified by the Agency's Carcinogen Risk Assessment Verification Enterprise (CRAVE) or are under CRAVE review. As shown in Table A-1, these estimates range in value from $1.8x10^{-6}/\mu g/m^3$ for methylene chloride to $2.3x10^{-5}/\mu g/m^3$ for chloroform.

A.2 DETERMINING NONCANCER HEALTH EFFECTS

Although cancer is of great concern as an adverse health effect associated with a chemical or a mixture of chemicals, many other health effects may be associated with these exposures. These effects may range from subtle biochemical, physiological, or pathological effects to gross effects such as death. The effects of greatest concern are the ones that are irreversible and impair the normal functioning of the individual. Some of these effects include respiratory toxicity, developmental and reproductive toxicity, central nervous system effects, and other systemic effects such as liver and kidney toxicity, cardiovascular toxicity, and immunotoxicity.

For chemicals that give rise to toxic endpoints other than cancer and gene mutations, there appears to be a level of exposure below which adverse health effects usually do not occur. Benchmark levels, termed inhalation reference concentrations (RfCs), are derived from an experimentally obtained no-adverse-effect level or a lowest-observed-effect level by consistent application of generally order-of-magnitude uncertainty factors that reflect various types of data used to estimate the RfC. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of daily exposure to the human population (including sensitive populations) that is likely to be without an appreciable risk of deleterious effects.

There is no RfC for the mixtures of HAP emitted from the facilities covered by pulp and paper mills, however RfCs are available for a limited number of specific HAP compounds. Table A-2 shows, for pulp and paper mills, those compounds for which RfCs were developed and evaluated in the risk characterization.

Table A-1
Pulp and Paper Mill Carcinogen List

Compound	Unit Risk Estimate ($\mu g/m^3$)	Basis[1]
Acetaldehyde (75-07-0)	$2.2x10^{-6}$	CRAVE verified (class B2)
Carbon Tetrachloride (56-23-5)	$1.5x10^{-5}$	CRAVE verified (class B2)
Chloroform (67-66-3)	$2.3x10^{-5}$	CRAVE verified (class B2)
Formaldehyde (50-00-0)	$1.3x10^{-5}$	HHAG URE (class B1)
Methylene Chloride (75-09-2)	$4.7x10^{-7}$	HHAG URE (class B2)

Notes: The corresponding unit risk estimates are subject to change.
( ) = Chemical Abstract Service (CAS) Number.
1 Cancer unit risk estimates (URE) were either (1) verified by the Carcinogen Risk Assessment Enterprise (CRAVE) work group or (2) the Human Health Assessment Group (HHAG), but not yet verified by CRAVE.

Table A-2
Pulp and Paper Mill Non-cancer Health Effects Assessment

Chemical	Effect Level ($\mu g/m^3$)
Acetaldehyde[1] (75-07-0)	9.0
Acrolein (107-02-8)	0.02
2-Butanone (MEK) (78-93-3)	1000
Hexane (110-54-3)	200
Hydrogen Chloride (7647-01-0)	7
Toluene (108-88-3)	400

( ) = Chemical Abstracts Service (CAS) Number.
1 Also a potential carcinogen.
2 Derived by Pollutant Assessment Branch from oral data. Not peer reviewed.

A.3 RISK CHARACTERIZATION

The Human Exposure Model version 1 (HEM) was used to estimate the number of people potentially exposed to predicted ambient concentrations specified compounds emitted from 161 pulp and paper mills in the United States. By combining numerical expressions of public exposure with the URE, two types of public cancer risks are produced. The first, maximum individual risk (lifetime cancer risk to the most exposed individuals) relates to the persons estimated to live in the area of highest concentration as predicted by the computer model. As used here, the word "maximum" does not mean the greatest possible risk of cancer to the public. It is based only on the maximum annual average exposure estimated by the procedure used. The second, called aggregate risk, is a summation of all the risks to peoples that are estimated to be living within the vicinity (50 kilometers) of a source and is summed for all 161 mills. For convenience, aggregate risk is divided by 70 years and is expressed as cancer incidences per year.

In addition, HEM was used in the evaluation of chronic noncancer health effects. No acute exposures were estimated because information on peak releases were not available.

A.3.1 Human Exposure Model (U.S. EPA, 1986b)

A numerical expression of public exposure, i.e. of the numbers of people exposed to various predicted concentrations of HAP compounds, is needed to help estimate the benefits of controlling HAP emissions that are released into the ambient air. The numerical expression of public exposure is based on two estimates: (1) an estimate of the magnitude and location of annual average air concentrations of the HAP compounds near emitting sources; and (2) an estimate of the number of people living near emitting sources.

The Pollutant Assessment Branch of EPA's air program office uses the Human Exposure Model (HEM) to make these quantitative estimates of public exposure associated with a pollutant. The HEM consists of an atmospheric dispersion model that includes meteorological data (National Weather Service) and population distribution estimates based on 1990 Bureau of Census data to calculate public exposure.

A pulp and paper mill model plant with three emission points was placed at 161 locations. The model plant parameters are shown in Table A-3. Inputs to the HEM dispersion model for each pulp and paper mill model included: (1) mill locations by latitude and longitude; (2) emission rate for specific HAP from waste water treatment and process vents; (3) height of the emission source in meters; (4) stack gas exit velocities in meters/second; (5) stack gas temperatures; (6) building cross-sectional area; and (7) for process vents inside stack diameter. Through specification of a latitude and longitude to define each mill's location, meteorological data (an annual average estimate of five years worth of data is typical) from the nearest airport of the 348 airports contained in the HEM is brought into the analysis.

Table A-3
Pulp and Paper Mill Model Emission Sources[1]

Emission Source	Stack Height (Meters)	Stack Gas Velocity (Meters/Sec)	Stack Gas Temperature (Deg. Kelvin)	Stack Diameter (Meters)
Pulping Vent	11	9	335	1.0
Bleaching Vent	15	7	319	1.0
Wastewater Treatment	1	0.1	295	—

1 An emission source of the above characteristics was modeled at each of 161 mills provided a chemical listed on Table A-1 or Table A-2 was emitted from the emission source. All chemicals were not emitted from all emission sources for all mills.

The meteorological data as well as the model plant emission and stack information are used to estimate the concentration and distribution of individual HAP from distances of 200 m to 50 km from the emitting source. Specifying the latitude and longitude also brings into the analysis the population distribution near the plant.

A.3.2 Pollutant Concentrations Near a Source

The dispersion model that is contained within HEM is a climatological model that uses a sector-averaged Gaussian dispersion algorithm that has been simplified to improve computational efficiency. Stability array (STAR) summaries are the principal meteorological input to HEM. The STAR data are standard climatological summaries formulated for use in EPA models and available for major U.S. meteorological monitoring sites from the National Climatic Center, Ashville, N.C. A STAR summary is a joint-frequency-of-occurrence of wind speed, atmospheric stability, and wind direction, classified according to Pasquill's categories. The STAR summaries in HEM reflect five years of meteorological data for each of the 348 sites. The model produces polar coordinate receptor grid points consisting of 10 downwind distances located along each of 16 radials that correspond to wind directions. Concentrations are estimated by the dispersion model for each of the 160 receptors located on this grid. The radials are separated by 22.4 degree intervals beginning with 0.0 degrees and proceeding clockwise to 337.5 degrees. The 10 downwind distances for each radial are 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0, 30.0, 40.0 and 50.0 kilometers. The center of the receptor grid for each plant is assumed to be mill center. Concentrations at population blocks were calculated by using a log-linear interpolation scheme.

A.3.3 People Living Near a Mill

To estimate the number and distribution of people residing within 50 kilometers of pulp and paper mills, the HEM model uses 1990 census data (PL 94-171) from the U.S. Bureau of Census. This data base consists of population distributed by census block. PL 94-171 contains population centroid coordinates (latitude and longitude) and the 1990 population of each block (approximately 6,900,000) in the United States. A centroid is the area weighted center of a census block. A census block contains on average about 36 people. The HEM identifies the population around each mill, by using the geographical coordinates of the mill, and identifies, selects, and stores for later use those blocks with coordinates falling within 50 kilometers of the mill center (U.S. EPA, 1986b).

A.3.4 Estimating Potential Exposure

The HEM uses the estimated ground level concentrations of a pollutant together with population data to calculate public exposure. For each of 160 receptors placed around a plant, the concentration of the pollutant and the number of people estimated to be exposed to concentrations are identified. Since there is an approximate linear relationship between the logarithm of concentration and the logarithm of distance from a mill, the entire population of the census block is assumed to be exposed to the concentration that is logarthmically interpolated radially and arithmetically interpolated azimuthally from the four receptors bounding a census block. The HEM multiplies people at the census block times the concentrations they are predicted to be exposed to, to produce exposure estimates and sums these products over the 161 mills in the analysis.

Exposure Calculation

HEM multiplies the concentration of HAP at ground level at each of the 160 receptors around the plant by the number of people exposed to that concentration to produce exposure estimates. The total exposure, as calculated by HEM, is illustrated by the following equation:

$$\text{Total exposure} = \sum_{i=1}^{N} (Pi)\,(Ci)$$

Where:

Σ	=	summation over all grid points where exposure is calculated
Pi	=	population associated with grid point i
Ci	=	annual average pollutant concentration at grid point i
N	=	number of grid points.

HEM takes an annual snapshot of risk and therefore assumes that: (1) conditions leading to the predicted concentrations do not change and thus the annual average exposure for the year in question persists for the duration of the averaging time of the URE which is a lifetime equal to 70 years; (2) people stay at the same location the entire year and are exposed continuously to the predicted HAP concentrations; (3) the terrain around the plant is flat; and (4) concentrations of HAP are the same inside and outside of the residence.

Annual Cancer Incidence

One expression of risk is annual cancer incidence, a measure of aggregate risk. Aggregate risk is the summation of risks from inhaling a HAP to people estimated to be living within the vicinity (50 km) of an emitting source. It is calculated by multiplying the estimated concentrations of the pollutants by the URE by total population exposure (the number of people exposed to different concentrations times those concentrations). This estimate reflects the number of excess cancers among the total population if the conditions leading to the exposure do not change from year to year, and the many other assumptions required by quantitative risk assessment are correct.

The following example uses assumptions rather than actual date and uses fewer levels of exposure rather than the large number produced by HEM. The assumed unit risk estimate is 3.3×10^{-5} at 1 $\mu g/m^3$ and the assumed exposures are:

Ambient Air Concentrations ($\mu g/m^3$)	Number of People Exposed to Given Concentration
2	1,000
1	10,000
0.5	100,000

The probability of developing cancer if continuously exposed for the averaging time of the URE (70 years) is given by the following:

Concentration	URE	Probability of Cancer
2	3.3×10^{-5}	6.6×10^{-5}
1	3.3×10^{-5}	3.3×10^{-5}
0.5	3.3×10^{-5}	1.7×10^{-5}

The lifetime cancer incidence for the exposed population is found by the following:

Probability of Cancer at each Exposure Level	Number of People at each Exposure Level	After 70 years of Exposure
0.066	1,000	6.6×10^{-5}
3.3×10^{-5}	10,000	0.33
1.7×10^{-5}	100,000	1.7
		TOTAL = 2.1

The aggregate risk or lifetime cancer incidence is 2.1. For statistical convenience, the number of cancer cases per year on average is routinely estimated (U.S. EPA, 1985). This is done by simply dividing 2.1 by 70 years to give 0.03. The number of cancer cases predicted are assumed to occur in the exposed population of 111,000.

Maximum Individual Risk

The maximum individual risk (MIR) refers to the person or persons estimated to live in the area of highest ambient air concentrations as determined by HEM. The MIR reflects the probability of an individual developing cancer as a result of continuous exposure to the estimated maximum ambient air concentration for the averaging time of the URE (70 years). The use of the word "maximum" in maximum individual risk does not mean the greatest possible risk of cancer to the public. It is based only on the maximum exposure estimated by the procedure used (U.S. EPA, 1986b), and it does not incorporate uncertainties in the exposure estimate or the URE.

MIR is calculated by multiplying the highest HAP concentration to which people are predicted to be exposed by the URE for that HAP. Note that people must be predicted to be exposed to the concentration. It is very common that the highest concentration predicted is not the value used in the MIR calculation because people are not exposed to it. In other words, the highest concentration that is calculated is often not used in the estimation. This calculation would apply to that census block that is usually close to and downwind from the mill that emits relatively large quantities of a potent HAP.

MIR = URE x Highest ambient air concentration to which anyone is predicted to be exposed

A.4 NONCANCER HEALTH EFFECTS

The assessment of noncancer health effects associated with chronic exposures to HAP chemicals of concern is based on a direct comparison of chemical-specific health benchmark to the HEM predicted annual average ambient concentrations at receptor locations around a source emitting HAP. These predicted annual concentrations represent an estimation of highest average daily ambient concentration experienced over a year. Ambient concentrations that are less that the RfC are not likely to be associated with health risks. The probability that adverse effects may be observed in a human population increases as the frequency of exposures exceeding the RfC increases and the size of the excess increases.

A.5 SUMMARY OF RESULTS

Table A-4 presents a summary of the results of the cancer risk characterization for 5 compounds that are potential human carcinogens. The results are for baseline and the proposed regulatory alternative. These compounds are emitted into the air from pulp and paper mills and each has a verified URE. Note that according to the EPA "Guidelines for the Health Risk Assessment of Mixtures", a number of factors such as data on similar mixtures and the interactions among chemicals must be considered before additivity can be assumed (U.S. EPA, 1986c). In addition, the estimated MIR for each chemical did not always occur at the same plant. MIR ranged from about 9 in ten million to 3.5 in ten thousand, and annual incidence was less than one incidence per year summed over 161 mills for each chemical. EPA estimated that an approximated 35 million people reside within 50 kilometers of the 161 mills. Table A-5 shows the number of people estimated to be exposed to various risk levels. These are also summed over 161 mills.

Table A-6 presents a summary of the results of the noncancer risk characterization of two compounds emitted by this source category. In addition to presenting the RfC for each compound, this table also presents the number of people estimated to be at or above the RfC at baseline emission levels and predicted post-regulation emission levels. The number of people exposed to various concentrations greater or equal to the RfCs for acrolein and acetaldehyde are shown in Table A-7.

A.6 ANALYTICAL UNCERTAINTIES REGARDING ESTIMATION OF EXPOSURE/RISK

A.6.1 Unit Risk Estimate

The low-dose extrapolation model used and its application to epidemiology and animal data have been the subject of substantial comment by health scientists. The uncertainties are large and are too complex to be summarized here. Readers who wish to pursue the subject in detail should see the following Federal Register notices: (1) EPA's "Guidelines for Carcinogenic Risk Assessment, " 51 FR 33972 (September 24, 1986); and (2) EPA's "Chemical Carcinogens; A Review of the Science and Its associated Principles," 50 FR 10372 (March 14, 1985).

Significant uncertainties associated with the URE include: (1) selection of dose response model; (2) selection of study used to estimate the URE; (3) presence or absence of a threshold; (4) appropriateness of animal model to represent the human population; (5) potency of complex mixtures; and (6) individual human variability.

Table A-4
Summary of Pulp and Paper Mill Carcinogenic Risk Characterization
(Comparison of Baseline and Proposed Regulation)

Regulatory Option	Baseline		Proposed Regulation	
Potential Carcinogen	Maximum Individual Risk (MIR)	Annual Cancer Incidence	Maximum Individual Risk (MIR)	Annual Cancer Incidence
Chloroform	$2.9x10^{-4}$	0.35	$1.1x10^{-4}$	0.06
Carbon Tetrachloride	$9.1x10^{-7}$	0.00056	$8.8x10^{-7}$	0.00091
Formaldehyde	$3.5x10^{-4}$	0.16	$2.6x10^{-4}$	0.083
Methylene Chloride	$4.1x10^{-6}$	0.0021	$4.9x10^{-6}$	0.0018
Acetaldehyde	$1.2x10^{-4}$	0.023	$1.5x10^{-5}$	0.0059

Table A-5
Distribution of Risks by Chemicals

	Number of People at or Above Risk Level	
	Baseline	Proposed Regulation
Chloroform Risk Level		
$1x10^{-4}$	2,760	11
$1x10^{-5}$	296,000	34,700
$1x10^{-6}$	4,870,000	723,000
Formaldehyde Risk Level		
$1x10^{-4}$	999	275
$1x10^{-5}$	78,900	37,700
$1x10^{-6}$	1,500,000	832,000
Acetaldehyde Risk Level		
$1x10^{-5}$	2,760	24
$1x10^{-6}$	177,000	17,600
Methylene Chloride Risk Level		
$1x10^{-5}$	0	0
$1x10^{-6}$	1,030	2,650
Carbon Tetrachloride Risk Level		
$1x10^{-6}$	0	0

Table A-6 Summary of Pulp and Paper Mill Risk Characterization (Comparison of Baseline and Proposed Regulation)		
Compound (RfC)	Baseline People Estimated To Be At Or Above RfC	Proposed Regulation People Estimated To Be At Or Above RfC
Acrolein ($0.02\ \mu g/m^3$)	2,000,000	625,000
Acetaldehyde ($9\ \mu g/m^3$)	52	0

Table A-7 Distribution of Population Above the RfC		
	Number of People At Or Above RfC	
Predicted Concentration ($\mu g/m^3$)	Baseline	Proposed Regulation
Acrolein		
2.0	378	0
1.0	6,500	324
0.5	24,100	3,000
0.2	131,000	20,700
0.1	320,000	68,800
0.05	714,000	214,000
0.02	1,910,000	625,000
Acetaldehyde		
9.0	52	0

A.6.2 Emissions/Model Plants

Identical model emission sources were used at each mill. Uncertainties associated with the model plant include: (1) location--was the model plant located at the site of an actual facility? (2) representativeness of the model plant as assumlng that ambient air begins 200 meters from a significant emission point may overstate exposure for pulp and paper mill which are typically very large, (3) the location of emission points about plant property since all emission were assumed to be emitted from the center of the mill, (4) representativeness of emission point characteristics, e.g. stack height, etc., (5) representativeness of the meteorology from the nearest meteorological site to that of the facility, and (6) how well the dispersion model in HEM predicts ambient HAP concentrations.

A.6.3 Public Exposure

The basic assumptions implicit in the methodology are that all exposure occurs at the area weighted centroids of census blocks, that people stay at the same location all year, that the conditions that lead to the predicted ambient air concentrations remain unchanged for the averaging time of the URE, e.g., 70 years, and that the concentrations are the same inside and outside the residences. People can and do live closer to the pulp and paper mills than the census block centroid. This will produce an underestimate of potential exposure the extent of which will vary from mill to mill. From these it can be seen that public exposure is based on a hypothetical rather than a realistic premise.

A.6.4 The Public

The following are relevant to the exposed population:

- Studies show that all people are not equally susceptible to pollution and cancer. There is no numerical recognition of the "most susceptible" subset of the population exposed.
- Studies show that whether or not exposure to a particular carcinogen results in cancer may be affected by the person's exposure to other substances. The public's exposure to other substances is not numerically recognized.
- Workplace exposures are not numerically approximated.
- Studies show that there is normally a long latency period between exposure and onset of cancer. This has not been numerically recognized.

- The people exposed are not located by actual residences. They are located in the Bureau of Census data for 1980 by population centroids of census districts.

A.6.5 Ambient Air Concentrations

The following are relevant to the estimated ambient air concentrations used in this analysis:

- Flat terrain was assumed in the dispersion model. Concentrations much higher than those estimated could result if emissions impacted on elevated terrain near a plant.

- The estimated concentrations do not account for the additive impact of emissions from plants located close to one another.

- Meteorological data specific to plant sites are not used in the dispersion model. As explained, meteorological data from the nearest National Weather Service station, usually an airport, nearest the plant site are used. Site-specific meteorological data could result in significantly different estimates of predicted concentrations.

- With few exceptions, the emission rates are based on assumptions and on limited emission tests.

- Only the inhalation route of exposure was addressed in the estimation of adverse health effects for the air portion of the benefit analysis. Air emissions that make their way to other exposure pathways would increase the estimated risks. The effect has not been quantified.

A.7 REFERENCES

U.S. EPA. 1986a. Health Assessment Document for Nickel and Nickel Compounds. U.S. EPA, Office of Health and Environmental Assessment, Washington, DC. EPA-600/8-83-012FF.

U.S. EPA. 1986b. User's Manual for the Human Exposure Model (HEM). U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA/450/5-86-001.

U.S. EPA. 1986c. Guidelines for the Health Risk Assessment of Chemical Mixtures. 51 FR 34014. September 24.

U.S. EPA. 1985. Inorganic Arsenic NESHAPs: Response to Public Comment on Health, Risk Assessment, and Risk Management. U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA/450/5-85-001.

U.S. EPA. 1984a. Carcinogen Assessment of Coke Oven Emissions. U.S. EPA, Office of Health and Environmental Assessment, Washington, DC. EPA-600/8-82-003F.

U.S. EPA. 1984b. Health Assessment Document for Carbon Tetrachloride. U.S. EPA, Office of Health and Environmental Assessment, Cincinnati, OH. EPA-600/8-82-001F.