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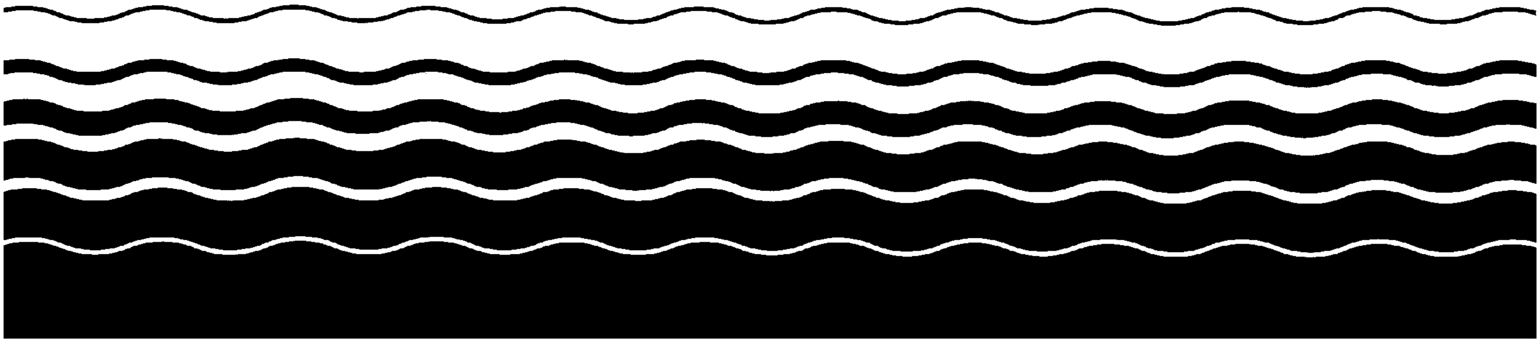
Environmental Assessment for Final Effluent Limitations Guidelines and Standards for the Landfills Point Source Category



Acknowledgments and Disclaimer

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Executive Summary

This environmental assessment quantifies the water quality-related benefits associated with achievement of the Best Available Technology (BAT) limitations promulgated by EPA to regulate nonhazardous landfills. Using site-specific analyses of current conditions and changes in discharges associated with the regulation, the U.S. Environmental Protection Agency (EPA) estimated instream pollutant concentrations for 26 priority and nonconventional pollutants from direct discharges using stream dilution modeling.

EPA assessed the potential impacts and benefits to aquatic life by comparing the modeled instream pollutant concentrations to published EPA aquatic life criteria guidance or to toxic effect levels. EPA projected potential adverse human health effects and benefits by (1) comparing estimated instream concentrations to health-based water quality toxic effect levels or criteria, and (2) estimating the potential reduction of carcinogenic risk and noncarcinogenic hazard (systemic) from consuming contaminated fish or drinking water.

The assessment estimated upper-bound individual cancer risks, population risks, and systemic hazards using modeled instream pollutant concentrations and standard EPA assumptions. The assessment evaluated modeled pollutant concentrations in fish and drinking water to estimate cancer risk and systemic hazards among the general population, sport anglers and their families, and subsistence anglers and their families. Because of the hydrophobic nature of the two chlorinated dibenzo-p-dioxin (CDD) congeners under evaluation, EPA projected human health benefits for only these pollutants by using the Office of Research and Development's Dioxin Reassessment Evaluation (DRE) model to estimate the potential reduction of carcinogenic risk and noncarcinogenic hazard from consuming contaminated fish. EPA used the findings from the analyses of reduced occurrence of instream pollutant concentrations in excess of both aquatic life and human health criteria or toxic effect levels to assess improvements in recreational fishing habitats that are impacted by nonhazardous landfill wastewater discharges (ecological benefits). EPA expects these improvements in aquatic habitats will improve the quality and value of recreational fishing opportunities.

In addition, the report presents the potential fate and toxicity of pollutants of concern associated with nonhazardous landfill wastewater on the basis of known characteristics of each chemical. The report includes reviews of recent literature and studies, as well as information obtained from State environmental agencies, as evidence of documented environmental impacts on aquatic life, human health, and on the quality of receiving water.

Performed analyses included discharges from a representative sample set of 37 direct nonhazardous landfills. EPA extrapolated results to the national level (approximately 143 nonhazardous landfills), based on the statistical methodology used for estimated costs, loads, and economic impacts. This report provides the results of these analyses.

Comparison of Instream Concentrations with Ambient Water Quality Criteria (AWQC)

Nonhazardous Landfills (Sample Set)

The water quality modeling results for 37 direct nonhazardous landfills discharging 26 pollutants to 35 receiving streams indicate that at **current** discharge levels, instream concentrations of 1 pollutant will likely exceed **acute aquatic life criteria** or toxic effect levels in 1 of the 35 receiving streams. Instream concentrations of 2 pollutants will likely exceed **chronic aquatic life criteria** or toxic effect levels in 9 percent (3 of the total 35) of the receiving streams. The landfills guidelines will reduce pollutant loadings by 39 percent. The landfills guidelines also will eliminate **acute aquatic life** excursions and reduce the **chronic aquatic life** excursions to 1 pollutant in the 3 receiving streams. Additionally, at **current** and **BAT** discharge levels, EPA projects no excursions of **human health criteria** or toxic effect levels.

Nonhazardous Landfills (National Extrapolation)

Extrapolating the modeling results of the sample set yields 143 nonhazardous landfills, discharging 26 pollutants to 139 receiving streams. From the extrapolated instream pollutant concentrations, the analysis projects 2 pollutants will exceed **chronic aquatic life criteria** or toxic effect levels in 24 percent (34 of the total 139) of the receiving streams at **current** discharge levels. The landfills guidelines will reduce excursions of **chronic aquatic life criteria** to 1 pollutant in the 34 receiving streams. **BAT** discharge levels will eliminate the excursions of **acute aquatic life criteria** or toxic effect levels due to 1 pollutant in 2 receiving streams.

Human Health Risks and Benefits

Projections for the sample set show that the landfills guidelines will reduce total excess annual cancer cases from the ingestion of contaminated fish for direct wastewater discharges by 3.5E-4 cancer cases. The monetary value of benefits to society from these avoided cancer cases is $700-$3,800 (1992 dollars). Results, extrapolated to the national level, project the reduction of total excess annual cancer cases to be 1.0E-3 cases with monetary benefits estimated at $2,100-$11,000 (1992 dollars). Projections indicate systemic toxicant effects from fish consumption for direct nonhazardous landfill discharges. For the sample set, projections indicate that systemic effects will result from the discharge of 1 pollutant to 1 receiving stream at both **current** and **BAT** discharge levels. Estimates indicate an affected population of 328 subsistence anglers and their families. Results, extrapolated to the national level, project an estimated population of 643 subsistence anglers and their families affected from the discharge of 1 pollutant to 2 receiving streams.

Ecological Benefits

The analysis projects no potential ecological benefits of the final regulation resulting from improvements in recreational fishing habitats. The final regulation will not completely eliminate instream concentrations in excess of aquatic life and human health ambient water quality criteria (AWQC) in any stream receiving wastewater discharges from direct nonhazardous landfills.

The estimated benefit of improved recreational fishery opportunities is only a limited measure of the value to society of the improvements in aquatic habitats expected to result from the final regulation. Additional benefits, which could not be quantified in this assessment, include increased assimilation capacity of the receiving stream, protection of terrestrial wildlife and birds that consume aquatic organisms, maintenance of an aesthetically pleasing environment, and improvements to other recreational activities such as swimming, water skiing, boating, and wildlife observation. Such activities contribute to the support of local and State economies.

Pollutant Fate and Toxicity

EPA identified 32 pollutants of concern (priority, nonconventional, and conventional) in wastestreams from nonhazardous landfills. In this assessment, EPA evaluated the potential fate and toxicity of 26 of these pollutants on the basis of the known characteristics of each chemical.

Most of the 26 pollutants have at least one known toxic effect. Using available physical-chemical properties and aquatic life and human health toxicity data for these pollutants, the analysis determined that 5 exhibit moderate to high toxicity to aquatic life, 7 are classified by EPA as known or probable/possible human carcinogens, and 20 are human systemic toxicants. In addition, 7 have EPA drinking water values (MCLs or secondary MCLS), and 6 are designated by EPA as priority pollutants. In terms of projected partitioning among media, 9 of the evaluated pollutants are moderately to highly volatile (potentially causing risk to exposed populations via inhalation), 1 has a moderate potential to bioaccumulate in aquatic biota (potentially accumulating in the food chain and causing increased risk to higher trophic level organisms and to exposed human populations via consumption of fish and shellfish), 2 are moderately to highly adsorptive to solids, and 2 are slowly biodegraded.

Evaluations do not include the impacts of the 2 conventional and 4 nonconventional pollutants when modeling the effect of the final regulation on receiving stream water quality or when evaluating the potential fate and toxicity of discharged pollutants. These pollutants are total suspended solids (TSS), 5-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), total dissolved solids (TDS), total organic carbon (TOC) and total phenolic compounds. The discharge of these pollutants may adversely affect human health and the environment. For example, habitat degradation may result from increased suspended particulate matter that reduces light penetration, and thus primary productivity, or from accumulation of sludge particles that alter benthic spawning grounds and feeding habitats. High COD and BOD_5 levels may deplete oxygen concentrations, which can result in mortality or other adverse effects on fish. High TOC levels may interfere with water quality by causing taste and odor problems and mortality in fish.

Documented Environmental Impacts

This assessment also summarizes documented environmental impacts on aquatic life, human health, and receiving stream water quality, based on a review of published literature abstracts, State 304(l) Short Lists, State Fishing Advisories, and contact with State environmental agencies. States identified 2 direct discharging landfills as point sources that cause water quality problems; these are included on their 304(l) Short List. State contacts indicate that of the 2 direct facilities, 1 is no longer a direct discharger and the other is currently in compliance with its permit limits and is no longer a source of impairment. In addition, States issued fish consumption advisories for 2 waterbodies that receive the discharge from 2 direct discharging nonhazardous landfills. One of the advisories is based on dioxin levels. The other advisory is based on chemicals that are not pollutants of concern for the landfills industry.

1. Introduction

The purpose of this report is to present an assessment of the water quality benefits of controlling the discharge of wastewater from nonhazardous landfills to surface waters. This assessment projects potential aquatic life and human health impacts of direct nonhazardous landfill discharges on receiving stream water quality at current and Best Available Technology (BAT) levels by quantifying pollutant releases and by using stream modeling techniques.

The assessment evaluates the potential benefits to human health by (1) comparing estimated instream concentrations to health-based water quality toxic effect levels or U.S. Environmental Protection Agency (EPA) published water quality criteria, and (2) estimating the potential reduction of carcinogenic risk and noncarcinogenic hazard (systemic) from consuming contaminated fish or drinking water. The assessment monetizes reductions in carcinogenic risks using estimated willingness-to-pay values for avoiding premature mortality. Because of the hydrophobic nature of the two chlorinated dibenzo-p-dioxin (CDD) congeners being evaluated, the assessment projects human health benefits for only these pollutants by using the Office of Research and Development's Dioxin Reassessment Evaluation (DRE) model to estimate the potential reduction of carcinogenic risk and noncarcinogenic hazard from consuming contaminated fish. The assessment projects potential ecological benefits by estimating improvements in recreational fishing habitats and, in turn, by estimating a monetary value, including intrinsic benefits, for enhanced recreational fishing opportunities, if applicable.

In addition, the assessment evaluates the potential fate and toxicity of the pollutants of concern associated with nonhazardous landfill wastewater based on known characteristics of each chemical. The assessment also reviews recent literature and studies for evidence of documented environmental impacts (e.g., case studies) on aquatic life and human health, and for impacts on the quality of receiving water.

While this assessment does not evaluate impacts associated with reduced releases of 2 conventional pollutants (total suspended solids [TSS] and 5-day biological oxygen demand [BOD_5]) and 4 classical pollutant parameters (chemical oxygen demand [COD], total dissolved solids [TDS], total organic carbon [TOC], and total phenolic compounds), the discharge of these pollutants may have adverse effects on human health and the environment. For example, habitat degradation may result from increased suspended particulate matter that reduces light penetration and primary productivity, or from accumulation of sludge particles that alter benthic spawning grounds and feeding habitats. High COD and BOD_5 levels may deplete oxygen levels, which may result in mortality or other adverse effects in fish. High TOC levels may interfere with water quality by causing taste and odor problems and mortality in fish.

Following this introduction, Section 2 of this report describes the methodologies used to evaluate projected water quality impacts for direct discharging nonhazardous landfills (including potential human health risks and benefits, and ecological benefits); to evaluate the potential fate and toxicity of pollutants of concern; and to evaluate documented environmental impacts. Section 3 describes data sources used to evaluate water quality impacts such as landfill-specific data; water quality criteria; and information used to evaluate human health risks and benefits, ecological benefits, pollutant fate and toxicity, and documented environmental impacts. Section 4 provides a summary of the results of this assessment, and Section 5 is a complete list of references cited in the report. The various appendices presented in Volume II provide additional detail on the specific information addressed in the main report.

2. Methodology

2.1 Projected Water Quality Impacts

This assessment evaluates water quality impacts and associated risks/benefits of landfill discharges at various treatment levels by (1) comparing projected instream concentrations with ambient water quality criteria,[1] (2) estimating the human health risks and benefits associated with the consumption of fish and drinking water from waterbodies impacted by nonhazardous landfills, and (3) estimating the ecological benefits associated with improved recreational fishing habitats on impacted waterbodies. The assessment analyzes the impact and associated risks/benefits for a representative sample set of 37 direct nonhazardous landfills and extrapolates the results to the national level (approximately 143 landfills) based on the statistical methodology used for estimated costs, loads, and economic impacts. The following sections describe the methodologies used in this evaluation.

2.1.1 Comparison of Instream Concentrations with Ambient Water Quality Criteria

The instream concentration analysis quantifies and compares current and BAT pollutant releases and uses stream modeling techniques to evaluate potential aquatic life and human health impacts resulting from those releases. The analysis compares projected instream concentrations for each pollutant to EPA water quality criteria or, for pollutants for which no water quality criteria have been developed, to toxic effect levels (i.e., lowest reported or estimated toxic concentration). The following two sections (i.e., Section 2.1.1.1 and Section 2.1.1.2) describe the methodology and assumptions used for evaluating the impact of direct discharging landfills.

2.1.1.1 *Direct Discharging Facilities*

Using a stream dilution model that does not account for fate processes other than complete immediate mixing, the analysis calculates projected instream concentrations at current and BAT treatment levels for stream segments with direct discharging nonhazardous landfills. For stream segments with multiple landfills, it sums pollutant loadings, if applicable, before concentrations are calculated. The dilution model used for estimating instream concentrations is as follows.

$$C_{is} = \frac{L/OD}{FF + SF} \text{ x } CF \qquad \text{(Eq. 1)}$$

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[1] In performing this analysis, EPA used guidance documents published by EPA that recommend numeric human health and aquatic life water quality criteria for numerous pollutants. States often consult these guidance documents when adopting water quality criteria as part of their water-quality standards. However, because those State-adopted criteria may vary, EPA used the nationwide criteria guidance as the most representative values.

where:

C_{is} = instream pollutant concentration (micrograms per liter [Fg/L])
L = landfill pollutant loading (pounds/year [lb/year])
OD = landfill operation (days/year)
FF = landfill flow (million gallons/day [gal/day])
SF = receiving stream flow (million gal/day)
CF = conversion factors for units

The analysis uses various sources as described in Section 3.1.1 of this report to derive the landfill-specific data (i.e., pollutant loadings, operating days, landfill flow, and stream flow) used in Eq. 1. One of 3 receiving stream flow conditions (1Q10 low flow, 7Q10 low flow, and harmonic mean flow) is used for the two treatment levels; use depends on the type of criterion or toxic effect level intended for comparison. To estimate potential acute and chronic aquatic life impacts, the analysis uses the 1Q10 and 7Q10 flows, which are the lowest 1-day and the lowest consecutive 7-day average flow during any 10-year period, respectively, as recommended in the *Technical Support Document for Water Quality-based Toxics Control* (U.S. EPA, 1991a). EPA defines the harmonic mean flow as the inverse mean of reciprocal daily arithmetic mean flow values. EPA recommends the long-term harmonic mean flow as the design flow for assessing potential human health impacts, because it provides a more conservative estimate than the arithmetic mean flow. Because 7Q10 flows have no consistent relationship with the long-term mean dilution, they are not appropriate for assessing potential human health impacts.

For assessing impacts on aquatic life, the analysis uses the landfill operating days to represent the exposure duration; the calculated instream concentration is thus the average concentration *on days the landfill is discharging wastewater*. For assuming long-term human health impacts, it sets the operating days (exposure duration) at 365 days. The calculated instream concentration is thus the average concentration *on all days of the year*. Although this calculation for human health impacts leads to a lower calculated concentration because of the additional dilution from days when the landfill is not in operation, it is consistent with the conservative assumption that the target population is present to consume drinking water and contaminated fish every day for an entire lifetime.

Because stream flows are not available for hydrologically complex waters such as bays, estuaries, and oceans, the analysis uses site-specific critical dilution factors (CDFs) or estuarine dissolved concentration potentials (DCPs) to predict pollutant concentrations for landfills discharging to estuaries and bays, if applicable, as follows:

$$C_{es} \ ' \ \left[\left(\frac{L/OD}{FF} \right) \ x \ CF \right] / \ CDF \qquad \text{(Eq. 2)}$$

where:

C_{es} = estuary pollutant concentration (μg/L)
L = landfill pollutant loading (lb/year)
OD = landfill operation (days/year)
FF = landfill flow (million gal/day)
CDF = critical dilution factor
CF = conversion factors for units

$$C_{es} = \frac{L \ x \ DCP \ x \ CF}{BL} \tag{Eq. 3}$$

where:

C_{es} = estuary pollutant concentration (μg/L)
L = landfill pollutant loading (lb/year)
DCP = dissolved concentration potential (milligrams per liter [mg/L])
CF = conversion factor for units
BL = benchmark load (10,000 tons/year)

A survey of States and Regions conducted by EPA's Office of Pollution Prevention and Toxics (OPPT), *Mixing Zone Dilution Factors for New Chemical Exposure Assessments*, Draft Report (U.S. EPA, 1992), provides the site-specific critical dilution factors. The analysis uses acute CDFs to evaluate acute aquatic life effects; whereas it uses chronic CDFs to evaluate chronic aquatic life or adverse human health effects. The assessment assumes that the drinking water intake and fishing location are at the edge of the chronic mixing zone.

The Strategic Assessment Branch of the National Oceanic and Atmospheric Administration's (NOAA) Ocean Assessments Division developed DCPs based on freshwater inflow and salinity gradients to predict pollutant concentrations in each estuary in the National Estuarine Inventory (NEI) Data Atlas. NOAA applies these DCPs to predict concentrations. NOAA did not consider pollutant fate and designed the DCPs strictly to simulate concentrations of nonreactive dissolved substances under well-mixed steady-state conditions given an annual load of 10,000 tons. In addition, the DCPs reflect the predicted estuary-wide response and may not be indicative of site-specific locations.

The analysis determines water quality excursions by dividing the projected instream (Eq. 1) or estuary (Eq. 2 and Eq. 3) pollutant concentrations by EPA ambient water quality criteria (AWQC) or toxic effect levels. A value greater than 1.0 indicates an excursion.

CDD Congeners

Although hydrophobic chemicals like CDD congeners become associated primarily with suspended particulates and sediments, concentrations will be found in the water column near the discharge point. This is particularly true if discharges are assumed to be continuous. Therefore, although the stream dilution approach is conservative, it provides a reasonable estimate of dioxin-related water quality impacts on aquatic life. However, use of the stream dilution model to assess human health impacts (water quality excursions) from the discharge of CDD congeners is inappropriate. EPA uses the Office of Research and Development's Dioxin Reassessment Evaluation (DRE) model, which provides more reliable information regarding the partitioning of CDD between sediment and the water column, and thus their bioavailability to fish, to estimate the carcinogenic and noncarcinogenic risks from these contaminants. (See Section 2.1.2.)

2.1.1.2 *Assumptions and Caveats*

The instream concentration analysis assumes the following:

- Background concentrations of each pollutant in the receiving stream are equal to zero; therefore, the analysis evaluates only the impacts of discharging landfills.

- Landfills operate 365 days per year.

- The analysis uses an exposure duration of 365 days to determine the likelihood of actual excursions of human health criteria or toxic effect levels.

- Complete mixing of discharge flow and stream flow occurs across the stream at the discharge point; therefore, the analysis calculates an "average stream" concentration, even though the actual concentration may vary across the width and depth of the stream.

- The process water at each landfill is obtained from a source other than the receiving stream.

- The pollutant load to the receiving stream is continuous and representative of long-term landfill operations. These assumptions may overestimate risks to human health and aquatic life, but may underestimate potential short-term effects.

- The analysis uses 1Q10 and 7Q10 receiving stream flow rates to estimate aquatic life impacts; harmonic mean flow rates to estimate human health impacts. It estimates 1Q10 low flows using the results of a regression analysis of 1Q10 and 7Q10 flows from representative U.S. rivers and streams conducted by Versar, Inc., for EPA's Office of Pollution Prevention and Toxics (OPPT) (Versar, 1992a). Harmonic mean flows are estimated from the mean and 7Q10 flows as recommended in the *Technical Support Document for Water Quality-*

based Toxics Control (U.S. EPA, 1991a). These flows may not be the same as those used by specific States to assess impacts.

- The analysis does not consider pollutant fate processes such as sediment adsorption, volatilization, and hydrolysis. This may result in estimated instream concentrations that are environmentally conservative (higher).

- The analysis uses water quality criteria or toxic effect levels developed for freshwater organisms in the analysis of landfills discharging to estuaries or bays.

2.1.2 Estimation of Human Health Risks and Benefits

The analysis evaluates the potential benefits to human health by estimating the risks (carcinogenic and noncarcinogenic hazard [systemic]) associated with reducing pollutant levels in fish tissue and drinking water from current to BAT treatment levels. EPA has monetized the reduction in carcinogenic risks using estimated willingness-to-pay values for avoiding premature mortality. The following three sections (i.e., Section 2.1.2.1 through Section 2.1.2.3) describe the methodology and assumptions used to evaluate the human health risks and benefits from the consumption of fish tissue and drinking water derived from waterbodies impacted by direct discharging nonhazardous landfills.

2.1.2.1 *Fish Tissue*

To determine the potential benefits, in terms of reduced cancer cases, associated with reducing pollutant levels in fish tissue, the analysis estimates lifetime average daily doses (LADDs) and individual risk levels for each pollutant discharged from a landfill on the basis of the instream pollutant concentrations calculated at current and BAT treatment levels in the site-specific stream dilution analysis. (See Section 2.1.1.) EPA presents estimates for sport anglers, subsistence anglers, and the general population. LADDs are calculated as follows:

$$LADD = (C \times IR \times BCF \times F \times D) / (BW \times LT) \qquad \text{(Eq. 4)}$$

where:

LADD = potential lifetime average daily dose (milligrams per kilogram per day [mg/kg-day])
C = exposure concentration (mg/L)
IR = ingestion rate (See Section 2.1.2.3 - Assumptions)
BCF = bioconcentration factor, (liters per kilogram [L/kg]; whole body x 0.5)
F = frequency duration (365 days/year)
D = exposure duration (70 years)

BW = body weight (70 kg)
LT = lifetime (70 years x 365 days/year)

The analysis calculates individual risks as follows:

$$R = LADD \times SF \qquad \text{(Eq. 5)}$$

where:

R = individual risk level
LADD = potential lifetime average daily dose (mg/kg-day)
SF = cancer slope factor $(\text{mg/kg-day})^{-1}$

The analysis then applies the estimated individual pollutant risk levels to the potentially exposed populations of sport anglers, subsistence anglers, and the general population to estimate the potential number of excess annual cancer cases occurring over the life of the population. It then sums the number of excess cancer cases on a pollutant, landfill, and overall industry basis. The analysis assumes the number of reduced cancer cases to be the difference between the estimated risks at current and BAT treatment levels.

Because of the hydrophobic nature of the two CDD congeners, the analysis estimates LADDs and individual risk levels for these pollutants based on the pollutant fish tissue concentrations calculated at current and BAT treatment levels using the DRE model. The DRE model calculates the fish tissue concentration by calculating the equilibrium between CDD congeners in fish tissue and CDD congeners adsorbed to the organic fraction of sediments suspended in the water column (Appendix A). The analysis calculates LADDs as follows:

$$LADD = \frac{(CFT \times IR \times F \times D \times CF)}{(BW \times LT)} \qquad \text{(Eq. 6)}$$

where:

LADD = potential lifetime average daily dose (mg/kg-day)
CFT = fish tissue concentration (mg/kg)
IR = ingestion rate (See Section 2.1.2.3 - Assumptions)
F = frequency duration (365 days/year)
D = exposure duration (70 years)

BW = body weight (70 kg)
LT = lifetime (70 years x 365 days/year)
CF = conversion factor

Individual risks are then calculated as shown in Eq. 5.

EPA estimates the monetary value of benefits to society from avoided cancer cases using estimates of society's willingness to pay to avoid the risk of cancer-related premature mortality. Although it is not certain that all cancer cases will result in death, to develop a worst-case estimate, this analysis values avoided cancer cases on the basis of avoided *mortality*. To value mortality, the analysis uses a range of values recommended by an EPA Office of Policy Analysis (OPA) review of studies that quantify individuals' willingness to pay to avoid risks to life (Fisher, Chestnut, and Violette, 1989; and Violette and Chestnut, 1986). The reviewed studies used hedonic wage and contingent valuation analyses in labor markets to estimate the amounts that individuals are willing to pay to avoid slight increases in risk of mortality or will need to be compensated to accept a slight increase in risk of mortality. The willingness-to-pay values estimated in those studies also are associated with small changes in the probability of mortality. To estimate a willingness to pay for avoiding certain or high-probability mortality events, EPA extrapolates the estimated values for a 100 percent probability event.[2] EPA uses the resulting estimates of the value of a "statistical life saved" to value regulatory effects that are expected to reduce the incidence of mortality.

From this review of willingness-to-pay studies, OPA recommends a range of $1.6 to $8.5 million (1986 dollars) for valuing an avoided event of premature mortality or a statistical life saved. A more recent survey of value-of-life studies by Viscusi (1992) also supports this range with the finding that value of life estimates cluster in the range of $3 to $7 million (1990 dollars). For this analysis, EPA adjusts the figures recommended in the OPA study to 1992 using the relative change in the Employment Cost Index of Total Compensation for All Civilian Workers from 1986 to 1992 (29 percent). Using the change in nominal Gross Domestic Product (GDP) instead of change in inflation as the basis for adjustment in the willingness-to-pay values accounts for the expectations that willingness to pay to avoid risk is a normal economic good, and, accordingly, that society's willingness to pay to avoid risk will increase as national income increases. Updating to 1992 yields a range of $2.1 to $11.0 million.

The analysis estimates potential reductions in risks from reproductive, developmental, or other chronic and subchronic toxic effects by comparing the estimated lifetime average daily dose and the oral reference dose (RfD) for a given chemical pollutant as follows:

$$HQ = ORI/RfD \qquad \text{(Eq. 7)}$$

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[2] These estimates, however, do not represent the willingness to pay to avoid the certainty of death.

where:

HQ = hazard quotient
ORI = oral intake (LADD x BW, mg/day)
RfD = reference dose (mg/day assuming a body weight of 70 kg)

The analysis then calculates a hazard index (i.e., sum of individual pollutant hazard quotients) for each landfill or receiving stream. A hazard index greater than 1.0 indicates that toxic effects may occur in exposed populations. The analysis then sums and compares the sizes of the affected subpopulations at the various treatment levels to assess benefits in terms of reduced systemic toxicity. Although the analysis could not estimate the monetary value of the benefits to society that are associated with a reduction in the number of individuals exposed to pollutant levels likely to result in systemic health effects, it expects any reduction in risk will yield human health related benefits.

The analysis does not estimate the noncarcinogenic hazard of the CDD congeners on the basis of the oral intake and RfD because the establishment of an RfD for these pollutants, using the standard conventions of uncertainty, will likely be one or two orders of magnitude below average background population exposures. This situation precludes using an RfD for determining an acceptable level of CDD exposure, because at ambient background levels, effects are not readily apparent (Personal Communication from William Farland, Director of the National Center for Environmental Assessment to Andrew Smith, State Toxicologist, Maine Bureau of Health, January 24, 1997 - Appendix A). Therefore, the analysis evaluates potential systemic effects of the CDD congeners by comparing the estimated LADD (converted to units of toxic equivalent [TEQ] by multiplying by the congener-specific toxic equivalent factor [TEF]) to ambient background levels of 120 picograms (pg) TEQ/day as estimated by EPA in the 1994 Review Draft Document *Health Assessment Document for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds* (U.S. EPA, 1994a). EPA (1994a) estimates that adverse impacts associated with dioxin exposures may occur at or within one order of magnitude of average background exposures. As exposures increase within and above this range, the probability and severity of systemic effects most likely increase. For this assessment, fish tissue exposures greater than one order of magnitude above ambient background concentration indicate that toxic effects may occur in exposed populations. The analysis sums and compares the sizes of the affected subpopulations at the various treatment levels to assess benefits in terms of reduced systemic toxicity.

2.1.2.2 *Drinking Water*

The analysis determines potential benefits associated with reducing pollutant levels in drinking water in a similar manner. The analysis calculates LADDs for drinking water consumption as follows:

$$LADD = (C \times IR \times F \times D) / (BW \times LT) \qquad \text{(Eq. 8)}$$

where:

LADD = potential lifetime average daily dose (mg/kg-day)
C = exposure concentration (mg/L)
IR = ingestion rate (2 L/day)
F = frequency duration (365 days/year)
D = exposure duration (70 years)
BW = body weight (70 kg)
LT = lifetime (70 years x 365 days/year)

The analysis applies estimated individual pollutant risk levels greater than 10^{-6} (1E-6) to the population served downstream by any drinking water utilities within 50 miles from each discharge site to determine the number of excess annual cancer cases that may occur during the life of the population. It evaluates systemic toxicant effects by estimating the sizes of populations exposed to pollutants from a given landfill, the sum of whose individual hazard quotients yields a hazard index greater than 1.0. If applicable, EPA estimates a monetary value of benefits to society from avoided cancer cases, as described in Section 2.1.2.1.

2.1.2.3 *Assumptions and Caveats*

The analyses of human health risks and benefits use the following assumptions:

- A linear relationship exists between pollutant loading reductions and benefits attributed to the cleanup of surface waters.

- The analysis does not assess synergistic effects of multiple chemicals on aquatic ecosystems; therefore, the total benefit of reducing toxics may be underestimated.

- The analysis estimates the total number of persons who might consume recreationally caught fish and the number who rely upon fish on a subsistence basis in each State by assuming that these anglers regularly share their catch with family members; therefore, the number of anglers in each State is multiplied by the State's average household size. The analysis considers the remainder of the population of these States the "general population" consuming commercially caught fish.

- Subsistence anglers make up 5 percent of the resident anglers in a given State; the other 95 percent are sport anglers.

- Commercially or recreationally valuable species occur or are taken in the vicinity of the discharges included in the evaluation.

- Analysis of fish tissue uses ingestion rates of 6.5 grams per day for the general population, 30 grams per day (30 years) + 6.5 grams per day (40 years) for sport anglers, and 140 grams per day for subsistence anglers (U.S. EPA, 1989a).

- A State's resident anglers fish all rivers or estuaries within a State equally, and the fish are consumed only by the population within that State.

- The analysis estimates the size of populations potentially exposed to discharges to rivers or estuaries that border more than one State using only populations within the State in which the landfill is located.

- The analysis estimates the size of the population potentially exposed to fish caught in an impacted water body in a given State using the ratio of impacted river miles to total river miles or impacted estuary square miles to total estuary square miles. The number of miles potentially impacted by a landfill's discharge is 50 miles for rivers and the total surface area of the various estuarine zones for estuaries.

- When estimating the concentration in drinking water or fish, the analysis does not consider pollutant fate processes (e.g., sediment adsorption, volatilization, hydrolysis); consequently, estimated concentrations are environmentally conservative (higher).

2.1.3 Estimation of Ecological Benefits

The analysis evaluates the potential ecological benefits of the final regulation by estimating improvements in the recreational fishing habitats that are impacted by landfill wastewater discharges. The analysis first identifies stream segments for which the final regulation is expected to eliminate all occurrences of pollutant concentrations in excess of both aquatic life and human health AWQC or toxic effect levels. (See Section 2.1.1.) The analysis expects that elimination of pollutant concentrations in excess of AWQC will result in significant improvements in aquatic habitats, which will then improve the quality and value of recreational fishing opportunities. The estimate of the monetary value to society of improved recreational fishing opportunities is based on the concept of a "contaminant-free fishery" as presented by Lyke (1993).

Research by Lyke (1993) shows that anglers may place a significantly higher value on a contaminant-free fishery than a fishery with some level of contamination. Specifically, Lyke estimates the consumer surplus[3]

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[3] Consumer surplus is generally recognized as the best measure from a theoretical basis for valuing the net economic welfare or benefit to consumers from consuming a particular good or service. An increase or decrease in consumer

associated with Wisconsin's recreational Lake Michigan trout and salmon fishery, and the additional value of the fishery if it was completely free of contaminants affecting aquatic life and human health. Two analyses form the basis of Lyke's results.

1. A multiple site, trip generation, travel cost model was used to estimate net benefits associated with the fishery under baseline (i.e., contaminated) conditions.

2. A contingent valuation model was used to estimate willingness-to-pay values for the fishery if it was free of contaminants.

Both analyses used data collected from licensed anglers before the 1990 season. The estimated incremental benefit values associated with freeing the fishery of contaminants range from 11.1 percent to 31.3 percent of the value of the fishery under current conditions.

To estimate the gain in value of stream segments identified as showing improvements in aquatic habitats as a result of the final regulation, the analysis estimates the baseline recreational fishery value of the stream segments on the basis of estimated annual person-days of fishing per segment and estimated values per person-day of fishing. To calculate annual person-days of fishing per segment the analysis uses estimates of the affected (exposed) recreational fishing populations. (See Section 2.1.2.) The analysis then multiplies the number of anglers by estimates of the average number of fishing days per angler in each State to estimate the total number of fishing days for each segment. The analysis calculates the baseline value for each fishery by multiplying the estimated total number of fishing days by an estimate of the net benefit that anglers receive from a day of fishing where net benefit represents the total value of the fishing day exclusive of any fishing-related costs (license fee, travel costs, bait, etc.) incurred by the angler. The analysis uses a range of median net benefit values for warm-water and cold-water fishing days, $27.75 and $35.14, respectively, in 1992 dollars. Summing over all benefiting stream segments provides a total baseline recreational fishing value of landfill stream segments that are expected to benefit by elimination of pollutant concentrations in excess of AWQC.

To estimate the increase in value resulting from elimination of pollutant concentrations in excess of AWQC, the analysis multiplies the baseline value for benefiting stream segments by the incremental gain in value associated with achievement of the "contaminant-free" condition. As noted above, Lyke's estimate of the increase in value ranged from 11.1 percent to 31.3 percent. Multiplying by these values yields a range of expected increase in value for the landfill stream segments expected to benefit by elimination of pollutant concentrations in excess of AWQC.

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surplus for particular goods or services as the result of regulation is a primary measure of the gain or loss in consumer welfare resulting from the regulation.

2.1.3.1 *Assumptions and Caveats*

The ecological benefits analysis uses the following major assumptions:

- The analysis does not consider background concentrations of the landfill pollutants of concern in the receiving stream.

- The estimated benefit of improved recreational fishing opportunities is only a limited measure of the value to society of the improvements in aquatic habitats expected to result from the final regulation; increased assimilation capacity of the receiving stream, improvements in taste and odor, or improvements to other recreational activities, such as swimming and wildlife observation, are not addressed.

- The analysis includes significant simplifications and uncertainties, which may overestimate or underestimate the monetary value to society of improved recreational fishing opportunities. (See Sections 2.1.1.2 and 2.1.2.3.)

- Potential overlap in valuation of improved recreational fishing opportunities and avoided cancer cases from fish consumption may exist. This potential is considered to be minor in terms of numerical significance.

2.2 Pollutant Fate and Toxicity

Human and ecological exposure and risk from environmental releases of toxic chemicals depend largely on toxic potency, inter-media partitioning, and chemical persistence. These factors in turn depend on chemical-specific properties relating to toxicological effects on living organisms, physical state, hydrophobicity/lipophilicity, and reactivity, as well as the mechanism and media of release and site-specific environmental conditions.

The methodology used in assessing the fate and toxicity of pollutants associated with landfill wastewaters consists of three steps: (1) identification of pollutants of concern, (2) compilation of physical-chemical and toxicity data, and (3) categorization assessment. The following sections describe these steps in detail, as well as present a summary of the major assumptions and limitations associated with this methodology.

2.2.1 Pollutants of Concern Identification

From 1992 to 1995, EPA conducted sampling and site visits at hazardous and nonhazardous landfills to determine the presence or absence of priority, conventional, and nonconventional pollutants at landfills located nationwide. EPA collected raw wastewater samples at 13 nonhazardous landfills. More than 400 pollutants were characterized from the sampling, including (1) 233 priority and nonconventional organic compounds, (2) 69 priority and nonconventional metals, (3) 4 conventional pollutants, and (4) 123 priority and nonconventional pollutants (pesticides, herbicides, dioxins, and furans). From this characterization sampling data, EPA identified pollutants of interest, by subcategory, based on their detection at treatable levels in raw wastewaters. EPA also eliminated from this list treatment chemicals and nontoxic parameters. This analysis evaluates the remaining pollutants of concern (32 discharged by nonhazardous landfills, with the exception of 2 conventional and 4 nonconventional pollutants) to assess their potential fate and toxicity on the basis of known characteristics of each chemical.

2.2.2 Compilation of Physical-Chemical and Toxicity Data

The chemical-specific data needed to conduct the fate and toxicity evaluation for this study include aquatic life criteria or toxic effect data for native aquatic species, human health reference doses (RfDs) and cancer potency slope factors (SFs), EPA maximum contaminant levels (MCLs) for drinking water protection, Henry's Law constants, soil/sediment adsorption coefficients (K_{oc}), bioconcentration factors (BCFs) for native aquatic species, and aqueous aerobic biodegradation half-lives (BD).

Sources of the above data include EPA's AWQC documents and updates, EPA's Assessment Tools for the Evaluation of Risk (ASTER) and the associated Aquatic Information Retrieval System (AQUIRE) and Environmental Research Laboratory-Duluth fathead minnow database, EPA's Integrated Risk Information System (IRIS), EPA's 1997 Health Effects Assessment Summary Tables (HEAST), EPA's 1998 Region III Risk-Based Concentration Table, EPA's 1996 Superfund Chemical Data Matrix, EPA's 1989 Toxic Chemical Release Inventory Risk Screening Guide, Syracuse Research Corporation's CHEMFATE database, EPA and other government reports, scientific literature, and other primary and secondary data sources. To ensure that the examination is as comprehensive as possible, the analysis takes alternative measures to compile data for chemicals for which physical-chemical property and/or toxicity data are not presented in the sources listed above. To the extent possible, EPA estimates values for the chemicals using the quantitative structure-activity relationship (QSAR) model incorporated in ASTER or, for some physical-chemical properties, using published linear regression correlation equations.

(a) Aquatic Life Data

The analysis obtains ambient criteria or toxic effect concentration levels for the protection of aquatic life primarily from EPA's AWQC documents and EPA's ASTER. For several pollutants, EPA has published ambient water quality criteria for the protection of freshwater aquatic life from acute effects. The acute value represents a maximum allowable 1-hour average concentration of a pollutant at any time that protects aquatic life from lethality. For pollutants for which no acute water quality criteria have been developed by EPA, the analysis uses an acute value from published aquatic toxicity test data or an estimated acute value from the ASTER QSAR model. When the analysis uses values selected from the literature, measured concentrations from flow-through studies under typical pH and temperature conditions are preferred. In addition, the test organism must be a North American resident species of fish or invertebrate. The hierarchy used to select the appropriate acute value is listed below in descending order of priority:

1. National acute freshwater quality criteria

2. Lowest reported acute test values (96-hour LC_{50} for fish and 48-hour EC_{50}/LC_{50} for daphnids)

3. Lowest reported LC_{50} test value of shorter duration, adjusted to estimate a 96-hour exposure period

4. Lowest reported LC_{50} test value of longer duration, up to a maximum of 2 weeks exposure

5. Estimated 96-hour LC_{50} from the ASTER QSAR model

The analysis uses BCF data from numerous data sources, including EPA AWQC documents and EPA's ASTER. Where measured BCF values are not available, the analysis estimates the parameter using the octanol/water partition coefficient or solubility of the chemical. Lyman et al. (1982) details such methods. The analysis then reviews multiple values and selects a representative value according to the following guidelines:

- Resident U.S. fish species are preferred over invertebrates or estimated values.

- Edible tissue or whole fish values are preferred over nonedible or viscera values.

- Estimates derived from octanol/water partition coefficients are preferred over estimates based on solubility or other estimates, unless the estimate comes from EPA's AWQC documents.

The analysis uses the most conservative value (i.e., the highest BCF) among comparable candidate values.

(b) Human Health Data

Human health toxicity data include chemical-specific RfD for noncarcinogenic effects and potency SF for carcinogenic effects. The analysis obtains RfDs and SFs first from EPA's IRIS, and secondarily uses EPA's HEAST or EPA's Region III RBC Table. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious noncarcinogenic health effects over a lifetime (U.S. EPA, 1989b). A chemical with a low RfD is more toxic than a chemical with a high RfD. Noncarcinogenic effects include systemic effects (e.g., reproductive, immunological, neurological, circulatory, or respiratory toxicity), organ-specific toxicity, developmental toxicity, mutagenesis, and lethality. EPA recommends a threshold level assessment approach for these systemic and other effects, because several protective mechanisms must be overcome prior to the appearance of an adverse noncarcinogenic effect. In contrast, EPA assumes that cancer growth can be initiated from a single cellular event and, therefore, should not be subject to a threshold level assessment approach. The SF is an upper bound estimate of the probability of cancer per unit intake of a chemical over a lifetime (U.S. EPA, 1989b). A chemical with a large SF has greater potential to cause cancer than a chemical with a small SF.

Other chemical designations related to potential adverse human health effects include EPA assignment of a concentration limit for protection of drinking water, and EPA designation as a priority pollutant. EPA establishes drinking water criteria and standards, such as the MCL, under authority of the Safe Drinking Water Act (SDWA). Current MCLs are available from EPA's Office of Water. EPA has designated 126 chemicals and compounds as priority pollutants under the authority of the Clean Water Act (CWA).

(c) Physical-Chemical Property Data

The analysis uses 3 measures of physical-chemical properties to evaluate environmental fate: Henry's Law constant (HLC), an organic carbon-water partition coefficient (K_{oc}), and aqueous aerobic biodegradation half-life (BD).

HLC is the ratio of vapor pressure to solubility and is indicative of the propensity of a chemical to volatilize from surface water (Lyman et al., 1982). The larger the HLC, the more likely the chemical will volatilize. The analysis obtains most HLCs from EPA's Office of Toxic Substances (OTS) 1989 *Toxic Chemical Release Inventory Risk Screening Guide* (U.S. EPA, 1989c) or from the QSAR system (U.S. EPA, 1998-1999) maintained by EPA's Environmental Research Laboratory in Duluth, Minnesota.

K_{oc} is indicative of the propensity of an organic compound to adsorb to soil or sediment particles and, therefore, to partition to such media. The larger the K_{oc}, the more likely the chemical will adsorb to solid material. The analysis obtains most K_{oc} from Syracuse Research Corporation's CHEMFATE database and EPA's 1989 *Toxic Chemical Release Inventory Risk Screening Guide*.

BD is the empirically derived length of time during which half the amount of a chemical in water is degraded by microbial action in the presence of oxygen. BD is indicative of the environmental persistence of a chemical released into the water column. The analysis obtains most BDs from Howard et al. (1991) and Environmental Research Laboratory-Duluth's QSAR.

2.2.3 Categorization Assessment

The objective of evaluating fate and toxicity potential is to place chemicals into groups with qualitative descriptors of potential environmental behavior and impact. These groups are based on categorization schemes derived for the following descriptors:

- Acute aquatic toxicity (high, moderate, or slightly toxic)

- Volatility from water (high, moderate, slight, or nonvolatile)
- Adsorption to soil/sediment (high, moderate, slight, or nonadsorptive)
- Bioaccumulation potential (high, moderate, slight, or nonbioaccumulative)
- Biodegradation potential (fast, moderate, slow, or resistant)

Using appropriate key parameters, and where sufficient data exist, these categorization schemes identify the relative aquatic and human toxicity and bioaccumulation potential for each chemical associated with landfill wastewater. In addition, they identify the potential of each chemical to partition to various media (air, sediment/sludge, or water) and to persist in the environment. The analysis uses these schemes for screening purposes only; they do not take the place of detailed pollutant assessments that analyze all fate and transport mechanisms.

This evaluation also identifies chemicals that (1) are known, probable, or possible human carcinogens; (2) are systemic human health toxicants; (3) have EPA human health drinking water standards; and (4) are designated as priority pollutants by EPA. The results of this analysis can provide a qualitative indication of potential risk posed by the release of these chemicals. Actual risk depends on the magnitude, frequency, and duration of pollutant loading; site-specific environmental conditions; proximity and number of human and ecological receptors; and relevant exposure pathways. The following discussion outlines the categorization schemes and presents the ranges of parameter values that define the categories.

(a) Acute Aquatic Toxicity

Key Parameter: Acute aquatic life criteria/LC_{50} or other benchmark (AT) (Fg/L)

Using acute criteria or lowest reported acute test results (generally 96-hour and 48-hour durations for fish and invertebrates, respectively), the analysis groups chemicals according to their relative short-term effects on aquatic life.

Categorization Scheme:

$AT < 100$	Highly toxic
$1,000 \geq AT \geq 100$	Moderately toxic
$AT > 1,000$	Slightly toxic

This scheme, used as a rule-of-thumb guidance by EPA's OPPT for Premanufacture Notice (PMN) evaluations, indicates chemicals that could potentially cause lethality to aquatic life downstream of discharges.

(b) Volatility from Water

Key Parameter: Henry’s Law constant (HLC) (atm-m^3/mol)

$$HLC = \frac{Vapor\ Pressure\ (atm)}{Solubility\ (mol/m^{3})} \qquad \text{(Eq. 9)}$$

HLC is the measured or calculated ratio between vapor pressure and solubility at ambient conditions. This parameter indicates the potential for organic substances to partition to air in a two-phase (air and water) system. A chemical’s potential to volatilize from surface water can be inferred from HLC.

Categorization Scheme:

$HLC > 10^{-3}$	Highly volatile
$10^{-3} \geq HLC \geq 10^{-5}$	Moderately volatile
$10^{-5} > HLC \geq 3 \times 10^{-7}$	Slightly volatile
$HLC < 3 \times 10^{-7}$	Essentially nonvolatile

This scheme, adopted from Lyman et al. (1982), indicates chemical potential to volatilize from process wastewater and surface water, thereby reducing the threat to aquatic life and human health via contaminated fish consumption and drinking water, yet potentially causing risk to exposed populations via inhalation.

(c) Adsorption to Soil/Sediments

Key Parameter: Soil/sediment adsorption coefficient (K_{oc})

K_{oc} is a chemical-specific adsorption parameter for organic substances that is largely independent of the properties of soil or sediment and can be used as a relative indicator of adsorption to such media. K_{oc} is highly inversely correlated with solubility, well correlated with octanol-water partition coefficient, and fairly well correlated with BCF.

Categorization Scheme:

$K_{oc} > 10{,}000$	Highly adsorptive
$10{,}000 \geq K_{oc} \geq 1{,}000$	Moderately adsorptive
$1{,}000 > K_{oc} \geq 10$	Slightly adsorptive
$K_{oc} < 10$	Essentially nonadsorptive

This scheme evaluates substances that may partition to solids and potentially contaminate sediment underlying surface water or land receiving sewage sludge applications. Although a high K_{oc} value indicates that a chemical is more likely to partition to sediment, it also indicates that a chemical may be less bioavailable.

(d) Bioaccumulation Potential

Key Parameter: Bioconcentration Factor (BCF)

$$BCF = \frac{\text{Equilibrium chemical concentration in organism (wet weight)}}{\text{Mean chemical concentration in water}} \qquad \text{(Eq. 10)}$$

BCF is a good indicator of potential to accumulate in aquatic biota through uptake across an external surface membrane.

Categorization Scheme:

$BCF > 500$	High potential
$500 \geq BCF \geq 50$	Moderate potential
$50 > BCF \geq 5$	Slight potential
$BCF < 5$	Nonbioaccumulative

This scheme identifies chemicals that may be present in fish or shellfish tissues at higher levels than in surrounding water. These chemicals may accumulate in the food chain and increase exposure to higher trophic level populations, including people consuming their sport catch or commercial seafood.

(e) Biodegradation Potential

Key Parameter: Aqueous Aerobic Biodegradation Half-life (BD) (days)

Biodegradation, photolysis, and hydrolysis are three potential mechanisms of organic chemical transformation in the environment. The analysis selects BD to represent chemical persistence on the basis of its importance and the abundance of measured or estimated data relative to other transformation mechanisms.

Categorization Scheme:

$BD \leq 7$	Fast
$7 < BD \leq 28$	Moderate
$28 < BD \leq 180$	Slow
$180 < BD$	Resistant

This scheme is based on classification ranges given in a recent compilation of environmental fate data (Howard et al., 1991). This scheme gives an indication of chemicals that are likely to biodegrade in surface water, and therefore, not persist in the environment. However, biodegradation products can be less toxic, equally as toxic, or even more toxic than the parent compound.

2.2.4 Assumptions and Limitations

The following two sections summarize the major assumptions and limitations associated with the data compilation and categorization schemes.

(a) Data Compilation

- If data are readily available from electronic databases, the analysis does not search other primary and secondary sources.

- Much of the data are estimated and, therefore, can have a high degree of associated uncertainty.

- For some chemicals, neither measured nor estimated data are available for key categorization parameters. In addition, chemicals identified for this study do not represent a complete set of wastewater constituents. As a result, this analysis does not completely assess landfill wastewater.

(b) Categorization Schemes

- The analysis does not consider receiving waterbody characteristics, pollutant loading amounts, exposed populations, and potential exposure routes.

- For several categorization schemes, the analysis groups chemicals using arbitrary order-of-magnitude data breaks. Combined with data uncertainty, this may lead to an overstatement or understatement of the characteristics of a chemical.

- Data derived from laboratory tests may not accurately reflect conditions in the field.

- Available aquatic toxicity and bioconcentration test data may not represent the most sensitive species.

- The biodegradation potential may not be a good indicator of persistence for organic chemicals that rapidly photodegrade or hydrolyze, since the analysis does not consider these degradation mechanisms.

2.3 Documented Environmental Impacts

EPA contacted State environmental agencies and reviewed State 304(l) Short Lists, State fishing advisories, and published literature for evidence of documented environmental impacts on aquatic life, human health, and the quality of receiving water due to discharges of pollutants from landfills. The analysis compiles and summarizes reported impacts by landfill.

3. Data Sources

3.1 Water Quality Impacts

The analysis uses readily available EPA and other agency databases, models, and reports to evaluate water quality impacts. The following six sections describe the various data sources used in the analysis.

3.1.1 Landfill-Specific Data

EPA's Engineering and Analysis Division (EAD) provided projected landfill effluent process flows, landfill operating days, and pollutant loadings (Appendix B) in September 1999. (U.S. EPA, 1999). For each option, EAD calculated the long-term averages (LTAs) for each pollutant of concern using EPA sampling data and industry-supplied data. In the 1994 *Waste Treatment Industry: Landfills Questionnaire*, landfills reported the annual quantity they discharged to surface waters (U.S. EPA, 1994b). EAD multiplied the annual quantity discharged (landfill flow) by the LTA for each pollutant and converted it to the proper units to calculate the loading (in pounds per year) for each pollutant at each landfill.

The analysis identifies the locations of landfills on receiving streams using the U.S. Geological Survey (USGS) cataloging and stream segment (reach) numbers contained in EPA's Industrial Facilities Discharge (IFD) database (U.S. EPA, 1994-1996a). It also uses latitude/longitude coordinates, if available, to locate those landfills that have not been assigned a reach number in IFD. If these sources do not yield information for a landfill, alternative measures are taken to obtain a complete set of receiving streams.

The analysis obtains receiving stream flow data from either the W.E. Gates study data or from measured streamflow data, both of which are contained in EPA's GAGE file (U.S. EPA, 1994-1996b). The W.E. Gates study contains calculated average and low flow statistics based on the best available flow data and on drainage areas for reaches throughout the United States. The GAGE file also includes average and low flow statistics based on measured data from USGS gaging stations. The analysis obtains dissolved concentration potentials (DCPs) for estuaries and bays from the Strategic Assessment Branch of NOAA's Ocean Assessments Division (NOAA/U.S. EPA, 1989-1991) (Appendix C). Critical dilution factors are obtained from the *Mixing Zone Dilution Factors for New Chemical Exposure Assessments* (U.S. EPA, 1992).

3.1.2 Water Quality Criteria

The assessment obtains the ambient criteria (or toxic effect levels) for the protection of aquatic life and human health from a variety of sources including EPA criteria documents, EPA's ASTER, and EPA's IRIS (Appendix D). It uses ecological toxicity estimates when published values are not available. The hierarchies used to select the appropriate aquatic life and human health values are described in the following sections.

3.1.2.1 *Aquatic Life*

EPA establishes water quality criteria for many pollutants for the protection of freshwater aquatic life (acute and chronic criteria). The acute value represents a maximum allowable 1-hour average concentration of a pollutant at any time and can be related to acute toxic effects on aquatic life. The chronic value represents the average allowable concentration of a toxic pollutant over a 4-day period at which a diverse genera of aquatic organisms and their uses should not be unacceptably affected, provided that these levels are not exceeded more than once every 3 years.

For pollutants for which no water quality criteria are developed, the analysis uses specific toxicity values (acute and chronic effect concentrations reported in published literature or estimated using various application techniques). When selecting values from the literature, the analysis prefers measured concentrations from flow-through studies under typical pH and temperature conditions. The test organism must be a North American resident species of fish or invertebrate. The hierarchies used to select the appropriate acute and chronic values are listed below in descending order of priority.

<u>Acute Aquatic Life Values</u>:

1. National acute freshwater quality criteria

2. Lowest reported acute test values (96-hour LC_{50} for fish and 48-hour EC_{50}/LC_{50} for daphnids)

3. Lowest reported LC_{50} test value of shorter duration, adjusted to estimate a 96-hour exposure period

4. Lowest reported LC_{50} test value of longer duration, up to a maximum of 2 weeks exposure

5. Estimated 96-hour LC_{50} from the ASTER QSAR model

<u>Chronic Aquatic Life Values</u>:

1. National chronic freshwater quality criteria

2. Lowest reported maximum allowable toxicant concentration (MATC), lowest-observed-effect concentration (LOEC), or no-observed-effect concentration (NOEC)

3. Lowest reported chronic growth or reproductive toxicity test concentration

4. Estimated chronic toxicity concentration from a measured acute:chronic ratio for a less sensitive species, QSAR model, or default acute:chronic ratio of 10:1

3.1.2.2 *Human Health*

EPA establishes water quality criteria for the protection of human health in terms of a pollutant's toxic effects, including carcinogenic potential, using two exposure routes: (1) ingesting the pollutant via contaminated aquatic organisms only, and (2) ingesting the pollutant via both water and contaminated aquatic organisms. The values are determined as follows:

<u>For Toxicity Protection (ingestion of organisms only)</u>

$$HH_{oo} = \frac{RfD \ x \ CF}{IR_f \ x \ BCF} \qquad \text{(Eq. 11)}$$

where:

HH_{oo} = human health value (µg/L)
RfD = reference dose for a 70-kg individual (mg/day)
IR_f = fish ingestion rate (0.0065 kg/day)
BCF = bioconcentration factor (L/kg)
CF = conversion factor for units (1,000 µg/mg)

<u>For Carcinogenic Protection (ingestion of organisms only)</u>

$$HH_{oo} = \frac{BW \ x \ RL \ x \ CF}{SF \ x \ IR_f \ x \ BCF} \qquad \text{(Eq. 12)}$$

where:

HH_{oo} = human health value (µg/L)
BW = body weight (70 kg)
RL = risk level (10^{-6})
SF = cancer slope factor $(\text{mg/kg-day})^{-1}$
IR_f = fish ingestion rate (0.0065 kg/day)
BCF = bioconcentration factor (L/kg)
CF = conversion factor for units (1,000 µg/mg)

For Toxicity Protection (ingestion of water and organisms)

$$HH_{wo} = \frac{RfD \ x \ CF}{IR_w + (IR_f \ x \ BCF)} \qquad \text{(Eq. 13)}$$

where:

HH_{wo} = human health value (μg/L)
RfD = reference dose for a 70-kg individual (mg/day)
IR_w = water ingestion rate (2 L/day)
IR_f = fish ingestion rate (0.0065 kg/day)
BCF = bioconcentration factor (L/kg)
CF = conversion factor for units (1000 μg/mg)

For Carcinogenic Protection (ingestion of water and organisms)

$$HH_{wo} = \frac{BW \ x \ RL \ x \ CF}{SF \ x \ (IR_w + (IR_f \ x \ BCF))} \qquad \text{(Eq. 14)}$$

where:

HH_{wo} = human health value (μg/L)
BW = body weight (70 kg)
RL = risk level (10^{-6})
SF = cancer slope factor $(mg/kg\text{-}day)^{-1}$
IR_w = water ingestion rate (2 L/day)
IR_f = fish ingestion rate (0.0065 kg/day)
BCF = bioconcentration factor (L/kg)
CF = conversion factor for units (1,000 μg/mg)

The analysis derives the values for ingesting water and organisms by assuming an average daily ingestion of 2 liters of water, an average daily fish consumption rate of 6.5 grams of potentially contaminated fish products, and an average adult body weight of 70 kilograms (U.S. EPA, 1991a). If EPA has established a slope factor, the analysis uses values protective of carcinogenicity to assess the potential effects on human health, The analysis develops protective concentration levels for carcinogens in terms of nonthreshold lifetime risk level using criteria at a risk level of 10^{-6} (1E-6). This risk level indicates a probability of 1 additional case of cancer for every 1 million persons exposed. Toxic effects criteria for noncarcinogens include systemic effects (e.g., reproductive, immunological, neurological, circulatory, or respiratory toxicity), organ-specific toxicity, developmental toxicity, mutagenesis, and lethality.

The hierarchy used to select the most appropriate human health criteria values is listed below in descending order of priority:

1. Calculated human health criteria values using EPA's IRIS RfDs or SFs used in conjunction with adjusted 3 percent lipid BCF values derived from *Ambient Water Quality Criteria Documents* (U.S. EPA, 1980). Three percent is the mean lipid content of fish tissue reported in the study from which the average daily fish consumption rate of 6.5 g/day is derived.

2. Calculated human health criteria values using current IRIS RfDs or SFs and representative BCF values for common North American species of fish or invertebrates or estimated BCF values.

3. Calculated human health criteria values using RfDs or SFs from EPA's HEAST or EPA's Region III RBC Table used in conjunction with adjusted 3 percent lipid BCF values derived from *Ambient Water Quality Criteria Documents* (U.S. EPA, 1980).

4. Calculated human health criteria values using current RfDs or SFs from EPA's HEAST or EPA's Region III RBC Table and representative BCF values for common North American species of fish or invertebrates or estimated BCF values.

5. Criteria from the *Ambient Water Quality Criteria Documents* (U.S. EPA, 1980).

6. Calculated human health values using RfDs or SFs from data sources other than IRIS, HEAST, or Region III RBC Table.

This hierarchy is based on Section 2.4.6 of the *Technical Support Document for Water Quality-based Toxics Control* (U.S. EPA, 1991a), which recommends using the most current risk information from IRIS when estimating human health risks. In cases where chemicals have both RfDs and SFs from the same level of the hierarchy, the analysis calculates human health values using the formulas for carcinogenicity, which always result in the more stringent value, given the risk levels employed.

3.1.3 Information Used To Evaluate Human Health Risks and Benefits

The analysis obtains fish ingestion rates for sport anglers, subsistence anglers, and the general population from the *Exposure Factors Handbook* (U.S. EPA, 1989a). State population data and average household size are obtained from the 1995 *Statistical Abstract of the United States* (U.S. Bureau of the Census, 1995). Data concerning the number of anglers in each State (i.e., resident fishermen) are obtained from the 1991 *National Survey of Fishing, Hunting, and Wildlife Associated Recreation* (U.S. FWS, 1991). The total number of river miles or estuary square miles within a State are obtained from the 1990 *National Water Quality Inventory - Report to Congress* (U.S. EPA, 1990). The analysis identifies drinking water utilities located within 50 miles downstream from each discharge site using EPA's PATHSCAN (U.S. EPA, 1996a). The population served by a drinking water utility is obtained from EPA's Drinking Water Supply Files (U.S. EPA, 1996b) or Federal Reporting Data System (U.S. EPA, 1996c). Total suspended solids (TSS) concentrations (effluent and receiving stream) used in the DRE model are obtained from EAD and from the *Analysis of STORET Suspended Sediments Data for the United States* (Versar, 1992b), respectively (see Section 3.1.1). Willingness-to-pay values are obtained from OPA's review of a 1989 and a 1986 study *The Value of Reducing Risks of Death: A Note on New Evidence* (Fisher, Chestnut, and Violette, 1989) and *Valuing Risks: New Information on the Willingness to Pay for Changes in Fatal Risks* (Violette and Chestnut, 1986). The analysis adjusts values to 1992 on the basis of the relative change in the Employment Cost Index of Total Compensation for all Civilian Workers. Information used in the evaluation is presented in Appendix E.

3.1.4 Information Used To Evaluate Ecological Benefits

The analysis uses the concept of a "contaminant-free fishery" and the estimate of an increase in the consumer surplus associated with a contaminant-free fishery, which are presented in *Discrete Choice Models to Value Changes in Environmental Quality: A Great Lakes Case Study*, a thesis submitted at the University of Wisconsin-Madison by Audrey Lyke in 1993. The analysis uses data concerning the number of resident anglers in each State and average number of fishing days per angler in each State obtained from the 1991 *National Survey of Fishing, Hunting, and Wildlife Associated Recreation* (U.S. FWS, 1991) (Appendix E). Median net benefit values for warm water and cold water fishing days are obtained from *Nonmarket Values from Two Decades of Research on Recreational Demand* (Walsh et al., 1990). The analysis adjusts values to 1992 on the basis of the change in the Consumer Price Index for all urban consumers, as published by the Bureau of Labor Statistics.

3.2 Pollutant Fate and Toxicity

The analysis obtains the chemical-specific data needed to conduct the fate and toxicity evaluation from various sources as discussed in Section 2.2.2 of this report. Aquatic life and human health values are presented in Appendix D, as well as physical-chemical property data.

3.3 Documented Environmental Impacts

The analysis obtains data concerning environmental impacts from State environmental agencies in EPA Regions III and VI, as well as from the 1990 State 304(l) Short Lists (U.S. EPA, 1991b) and the 1995 *National Listing of Fish Consumption Advisories* (U.S. EPA, 1995). Literature abstracts are obtained through the computerized information system DIALOG (Knight-Ridder Information, 1996), which provides access to Enviroline, Pollution Abstracts, Aquatic Science Abstracts, and Water Resources Abstracts.

4. Summary of Results

4.1 Projected Water Quality Impacts

4.1.1 Comparison of Instream Concentrations with Ambient Water Quality Criteria

The results of this analysis indicate the water quality benefits of controlling discharges from nonhazardous landfills to surface waters. The following two sections summarize potential aquatic life and human health impacts on receiving stream water quality for direct discharges. All tables referred to in these sections appear at the end of Section 4. Appendix F presents the results of the stream modeling.

4.1.1.1 *Nonhazardous Landfills - Sample Set*

The analysis evaluates the effects of direct wastewater discharges on receiving stream water quality at **current** and **BAT** treatment levels for 37 nonhazardous landfills discharging 26 pollutants to 35 receiving streams (35 rivers) (Table 1). At **current** discharge levels, these 37 landfills discharge 111,153 pounds per year of priority and nonconventional pollutants (Table 2). The landfills guidelines will reduce these loadings to 67,741 pounds per year at **BAT** levels, a 39 percent reduction.

The analysis shows no human health impacts on receiving stream water quality. It projects that instream pollutant concentrations will not exceed **human health criteria** or toxic effect levels at **current** or **BAT** discharge levels (Table 3).

The assessment projects instream pollutant concentrations will exceed **chronic aquatic life criteria** or toxic effect levels in 9 percent (3 of the total 35) of the receiving streams at **current** and **BAT** discharge levels (Table 3). At **current** discharge levels, 2 pollutants are projected to exceed instream criteria or toxic effect levels (Table 4). **BAT** discharge levels reduce the projected excursions to 1 pollutant. The 1 excursion of **acute aquatic life criteria** or toxic effect levels projected at **current** discharge levels will be eliminated at **BAT** discharge levels (Table 3).

4.1.1.2 *Nonhazardous Landfills - National Extrapolation*

The analysis extrapolates sample set data to the national level using the statistical methodology for estimating costs, loads, and economic impacts. The analysis extrapolates values from the sample set of 37 nonhazardous landfills discharging 26 pollutants to 35 receiving streams (Table 1) to 143 nonhazardous landfills discharging 26 pollutants to 139 receiving streams.

The analysis projects that extrapolated instream pollutant concentrations will not exceed **human health criteria** or toxic effect levels at **current** or **BAT** discharge levels (Table 5). It also projects that the final regulation will reduce excursions of **chronic aquatic life criteria** or toxic effect levels from 2 pollutants to 1 pollutant in 24 percent (34 of the total 139) of the receiving streams with projected excursions (Table

5). The 2 excursions of **acute aquatic life criteria** or toxic effect levels projected at **current** discharge levels in 2 receiving streams will be eliminated at **BAT** discharge levels (Table 5).

4.1.2 Estimation of Human Health Risks and Benefits

The results of this analysis indicate the potential benefits to human health by estimating the risks (carcinogenic and systemic effects) associated with current and reduced pollutant levels in fish tissue and drinking water. The following two sections summarize potential human health impacts from the consumption of fish tissue and drinking water derived from waterbodies impacted by direct discharges. The analysis estimates risks for recreational (sport) and subsistence anglers and their families, as well as the general population. Appendix G presents the results of the modeling.

4.1.2.1 *Nonhazardous Landfills - Sample Set*

The analysis evaluates the effects of direct wastewater discharges on human health from the consumption of fish tissue and drinking water at **current** and **BAT** treatment levels for 37 facilities discharging 26 pollutants to 35 receiving streams (35 rivers) (Table 6).

Fish Tissue — At **current** discharge levels, 9 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 2 carcinogens from 9 nonhazardous landfills (Tables 6 and 7). The analysis projects total estimated risks greater than 10^{-6} (1E-6) for the **general population**, **sport anglers**, and **subsistence anglers**. At **current** discharge levels, total excess annual cancer cases are estimated to be 1.2E-3 (Table 6). At **BAT** discharge levels, 8 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 2 carcinogens from 8 nonhazardous landfills (Tables 6 and 7). The analysis again projects total estimated risks greater than 10^{-6} (1E-6) for the **general population**, **sport anglers**, and **subsistence anglers**. Total excess annual cancer cases will be reduced to 8.5E-04 at **BAT** discharge levels (Table 6). Based on the reduction of total excess cancer cases (3.5E-4), the monetary value of benefits to society from avoided cancer cases is $700-$3,800 (1992 dollars).

The analysis projects systemic toxicant effects (hazard index greater than 1.0) for only subsistence anglers in 1 receiving stream from 1 pollutant at **current** and **BAT** discharge levels (Table 8). An estimated population of 328 subsistence anglers and their families are projected to be affected.

Drinking Water — The analysis projects that no receiving streams will have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) at **current** or **BAT** discharge levels. (Table 9). Therefore, the analysis projects no total excess annual cancer cases. In addition, projections show no systemic toxicant effects (hazard index greater than 1.0) at **current** or **BAT** discharge levels (Table 8).

4.1.2.2 *Nonhazardous Landfills - National Extrapolation*

The analysis extrapolates sample set data to the national level using the statistical methodology for estimating costs, loads, and economic impacts. Extrapolated values are based on the sample set of 37 nonhazardous landfills discharging 26 pollutants to 35 receiving streams (Table 1). The analysis extrapolates these values to 143 nonhazardous landfills discharging 26 pollutants to 139 receiving streams.

Fish Tissue — At **current** discharge levels, 45 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 2 carcinogens from 45 nonhazardous landfills (Table 10). The analysis projects total estimated risks greater than 10^{-6} (1E-6) for the **general population**, **sport anglers**, and **subsistence anglers**. At **current** discharge levels, total excess annual cancer cases are estimated to be 3.1E-3 (Table 10). At **BAT** discharge levels, 43 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 2 carcinogens from 43 nonhazardous landfills. The analysis again projects total estimated risks greater than 10^{-6} (1E-6) for the **general population**, **sport anglers**, and **subsistence anglers**. Total excess annual cancer cases are reduced to 2.1E-3 at **BAT** discharge levels (Table 10). Based on the reduction of total excess cancer cases (1.0E-3), the monetary value of benefits to society from avoided cancer cases is $2,100-$11,000 (1992 dollars).

The analysis projects systemic toxicant effects (hazard index greater than 1.0) for only subsistence anglers in 2 receiving streams from 1 pollutant at **current** and **BAT** discharge levels (Table 11). An estimated population of 643 subsistence anglers and their families are projected to be affected.

Drinking Water — At **current** and **BAT** discharge levels, the analysis projects no receiving streams will have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) (Table 12). Therefore, the analysis projects no total excess annual cancer cases. In addition, it projects no systemic toxicant effects (hazard index greater than 1.0) at **current** or **BAT** discharge levels (Table 11).

4.1.3 Estimation of Ecological Benefits

The results of this analysis indicate the potential ecological benefits of the final regulation by estimating improvements in the recreational fishing habitats affected by direct nonhazardous landfill wastewater discharges. Such impacts include acute and chronic toxicity, sublethal effects on metabolic and reproductive functions, physical destruction of spawning and feeding habitats, and loss of prey organisms. These effects will vary because of the diversity of species with differing sensitivities. For example, lead exposure can cause spinal deformities in rainbow trout. Copper exposure can affect the growth activity of algae. In addition, copper and cadmium can be acutely toxic to aquatic life, including finfish. The following sections summarize the potential monetary benefits as well as additional benefits that are not monetized.

4.1.3.1 *Nonhazardous Landfills - Sample Set*

The analysis evaluates the effects of direct wastewater discharges on aquatic habitats at **current** and **BAT** treatment levels for 37 nonhazardous landfills discharging 26 pollutants to 35 receiving streams (Tables 1 and 3). Because the analysis projects that the final regulation will not completely eliminate instream concentrations in excess of AWQC, EPA does not estimate benefits to recreational (sport) anglers based on improved quality and improved value of fishing opportunities.

4.1.3.2 *Nonhazardous Landfills - National Extrapolation*

The analysis extrapolates sample set data to the national level using the statistical methodology for estimating costs, loads, and economic impacts. The analysis extrapolates values from the sample set of 37 nonhazardous landfills discharging 26 pollutants to 35 receiving streams (Table 1) to 143 nonhazardous landfills discharging 26 pollutants to 139 receiving streams (Table 5).

Because the analysis projects that the final regulation will not project completely eliminate instream concentrations in excess of AWQC, EPA does not estimate benefits to recreational (sport) anglers based on improved quality and improved value of fishing opportunities.

4.1.3.3 *Additional Ecological Benefits*

As noted in Section 2.1.3.1, the estimated benefit of improved recreational fishing opportunities is only a limited measure of the value to society of the improvements in aquatic habitats that are expected to result from the final regulation. Additional ecological benefits include protection of terrestrial wildlife and birds that consume aquatic organisms. The final regulation will also reduce the presence of and discharge of toxic pollutants, thereby protecting aquatic organisms currently under stress, providing the opportunity to reestablish productive ecosystems in damaged waterways, and protecting resident endangered species. In addition, recreational activities such as boating, water skiing, and swimming will be preserved, along with an aesthetically pleasing environment. Such activities contribute to the support of local and State economies.

4.2 Pollutant Fate and Toxicity

Levels of human and ecological exposure, and risk from environmental releases of toxic chemicals depend largely on toxic potency, intermedia partitioning, and chemical persistence. These factors depend on chemical-specific properties relating to toxicological effects on living organisms, physical state, hydrophobicity/lipophilicity, and reactivity, as well as the mechanism and media of release and site-specific environmental conditions. Using available data on the physical-chemical properties and aquatic life and human health toxicity for the 26 nonhazardous landfill pollutants of concern, the analysis determines the following: 5 pollutants exhibit moderate to high toxicity to aquatic life, 20 are human systemic toxicants, 7 are classified as known or probable/possible human carcinogens, 7 have drinking water values (6 with enforceable health-based MCLs and 1 with a secondary MCL for aesthetics or taste), and 6 are designated by EPA as priority pollutants (Tables 13, 14, and 15). In terms of projected environmental partitioning among media, 9 of the 26 evaluated pollutants are moderately to highly volatile (potentially causing risk to exposed populations via inhalation), 1 has a moderate potential to bioaccumulate in aquatic biota (potentially accumulating in the food chain and causing increased risk to higher trophic level organisms and to exposed human populations via fish and shellfish consumption), 2 are moderately to highly adsorptive to solids, and 2 are slowly biodegraded.

4.3 Documented Environmental Impacts

The analysis reviews literature abstracts, State 304(l) Short Lists, and State fishing advisories for documented impacts due to discharges from nonhazardous landfills. States identify 2 direct-discharging nonhazardous landfills as being point sources causing water quality problems and include them on their 304(l) Short List (Table 16). Section 304(l) of the Water Quality Act of 1987 requires States to identify waterbodies impaired by the presence of toxic substances, to identify point-source discharges of these toxics, and to develop Individual Control Strategies (ICSs) for these discharges. The Short List is a list of waters that a State does not expect will achieve applicable water quality standards (numeric or narrative), even after technology-based requirements are met, entirely or substantially because of point-source discharges of Section 307(a) toxics. State contacts indicate that of the 2 direct landfills, 1 is no longer a direct discharger and the other is currently in compliance with its permit limits and is no longer a source of impairment. In addition, 2 nonhazardous landfills are located on waterbodies with State-issued fish consumption advisories (Table 17). One of the advisories concerns dioxin levels. The other advisory concerns chemicals that are not pollutants of concern for the landfill industry.

Table 1. Evaluated Pollutants of Concern (26) Discharged from 37 Direct Nonhazardous Landfills

CAS Number	Pollutant
98555	Alpha-Terpineol
7664417	Ammonia as N
7440393	Barium
65850	Benzoic Acid
7440473	Chromium
120365	Dichlorprop
298044	Disulfoton
142621	Hexanoic Acid
18540299	Hexavalent Chromium
75092	Methylene Chloride
68122	N,N-Dimethylformamide
C-005	Nitrate/Nitrite
95487	o-Cresol
3268879	OCDD
106445	p-Cresol
108952	Phenol
7440246	Strontium
7440326	Titanium
108883	Toluene
20324338	Tripropyleneglycol Methyl Ether
7440666	Zinc
123911	1,4-Dioxane
35822469	1,2,3,4,6,7,8-HpCDD
78933	2-Butanone
67641	2-Propanone
108101	4-Methyl-2-Pentanone

Source: Engineering and Analysis Division (EAD), September 1999.

Table 2. Summary of Pollutant Loadings for Evaluated Direct Nonhazardous Landfills

	Loadings (Pounds-per-Year)*
Current	111,153
BAT	67,741
No. of Pollutants Evaluated	26
No. of Landfills Evaluated	37

* Loadings are representative of pollutants evaluated; conventional and nonconventional pollutants such as TSS, BOD_5, COD, TDS, TOC, and total phenolic compounds, are not included.

Table 3. Summary of Projected Criteria Excursions for Direct Nonhazardous Landfill Dischargers (Leachate)
(Sample Set)

	Acute Aquatic Life	Chronic Aquatic Life	Human Health Water and Orgs.	Human Health Orgs. Only	Total*
Current					
Streams (No.)	1	3	0	0	3
Pollutants (No.)	1 (1.4)	2 (2.3 - 34.0)	0	0	2
Total Excursions	**1**	**4**	**0**	**0**	
BAT					
Streams (No.)	0	3	0	0	3
Pollutants (No.)	0	1 (2.3 - 34.0)	0	0	1
Total Excursions	**0**	**3**	**0**	**0**	

NOTE: Number in parentheses represents magnitude of excursions.
Number of streams evaluated = 35 (35 rivers), number of landfills = 37, and number of pollutants = 26.

* Pollutants may exceed criteria on a number of streams; therefore, total does not equal sum of pollutants exceeding criteria.

Table 4. Summary of Pollutants Projected To Exceed Criteria for Direct Nonhazardous Landfill Dischargers (Leachate)
(Sample Set)

	Number of Excursions							
	Acute Aquatic Life		Chronic Aquatic Life		Human Health Water and Orgs.		Human Health Orgs. Only	
	Current	BAT	Current	BAT	Current	BAT	Current	BAT
Ammonia as N	1 (1.4)	0	1 (7.9)	0	0	0	0	0
Disulfoton	0	0	3 (2.3 - 34.0)	3 (2.3 - 34.0)	0	0	0	0

NOTE: Number of pollutants evaluated - 26.

Table 5. Summary of Projected Criteria Excursions for Direct Nonhazardous Landfill Dischargers (Leachate)
(National Level)

	Acute Aquatic Life	Chronic Aquatic Life	Human Health Water and Orgs.	Human Health Orgs. Only	Total*
Current					
Streams (No.)	2	34	0	0	34
Pollutants (No.)	1 (1.4)	2 (2.3 - 34.0)	0	0	2
Total Excursions	**2**	**36**	**0**	**0**	
BAT					
Streams (No.)	0	34	0	0	34
Pollutants (No.)	0	1 (2.3 - 34.0)	0	0	1
Total Excursions	**0**	**34**	**0**	**0**	

NOTE: Number in parentheses represents magnitude of excursions.
Number of streams = 139, number of landfills = 143, and number of pollutants = 26.

* Pollutants may exceed criteria on a number of streams; therefore, total does not equal sum of pollutants exceeding criteria.

Table 6. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Fish Tissue Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Streams (No.)/Facilities (No.)	9/9	NA/NA
Carcinogens (No.)	2	NA
General Population	1 (2.3E-6)	3.0E-4
Sport Anglers	1 (6.0E-6)	5.4E-4
Subsistence Anglers	9 (1.6E-6 to 5.1E-5)	3.2E-4
TOTAL		**1.2E-3**
BAT		
Streams (No.)/Facilities (No.)	8/8	NA/NA
Carcinogens (No.)	2	NA
General Population	1 (1.8E-6)	2.2E-4
Sport Anglers	1 (4.5E-6)	4.0E-4
Subsistence Anglers	8 (1.0E-6 to 3.9E-5)	2.3E-4
TOTAL		**8.5E-4**

NOTE: Total number of streams evaluated = 35 (35 rivers), number of landfills = 37, and number of pollutants = 26. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.

Number in parentheses represents the range of total cancer risks for stream(s) with risk $>10^{-6}$.

NA = Not Applicable

Table 7. Summary of Pollutants Projected To Cause Human Health Impacts for Direct Nonhazardous Landfill Dischargers
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Anglers	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Anglers
Current:			
Stream No. 1 OCDD 1,2,3,4,6,7,8-HpCDD	 0/NA 0/NA	 0/NA 0/NA	 3.6E-6/1.1E-7 2.8E-6/8.6E-8
Stream No. 2 OCDD 1,2,3,4,6,7,8-HpCDD	 0/NA 0/NA	 0/NA 0/NA	 7.4E-7/1.6E-6 9.7E-7/2.1E-6
Stream No. 3 OCDD 1,2,3,4,6,7,8-HpCDD	 0/NA 0/NA	 0/NA 0/NA	 6.9E-7/3.7E-6 9.2E-7/4.9E-6
Stream No. 4 OCDD 1,2,3,4,6,7,8-HpCDD	 0/NA 0/NA	 0/NA 0/NA	 1.3E-6/2.2E-6 1.3E-6/2.2E-6
Stream No. 5 OCDD 1,2,3,4,6,7,8-HpCDD	 0/NA 0/NA	 0/NA 0/NA	 6.8E-7/1.5E-6 9.0E-7/1.9E-6
Stream No. 6 OCDD 1,2,3,4,6,7,8-HpCDD	 1.3E-6/1.7E-4 1.0E-6/1.3E-4	 3.4E-6/3.0E-4 2.6E-6/2.4E-4	 2.9E-5/1.3E-4 2.2E-5/1.0E-4

Table 7. Summary of Pollutants Projected to Cause Human Health Impacts for Direct Nonhazardous Landfill Dischargers (continued)
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Anglers	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Anglers
Current (continued):			
Stream No. 7			
OCDD	0/NA	0/NA	1.6E-6/7.4E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.2E-6/5.7E-6
Stream No. 8			
OCDD	0/NA	0/NA	2.3E-6/1.1E-5
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.8E-6/8.5E-6
Stream No. 9			
OCDD	0/NA	0/NA	3.8E-6/1.8E-5
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	2.9E-6/1.4E-5
BAT:			
Stream No. 1			
OCDD	0/NA	0/NA	3.9E-7/1.2E-8
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.0E-6/3.1E-8
Stream No. 2			
OCDD	0/NA	0/NA	3.7E-7/7.9E-7
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.7E-7/2.1E-6
Stream No. 3			
OCDD	0/NA	0/NA	4.6E-7/2.5E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.2E-6/6.5E-6
Stream No. 4			
OCDD	0/NA	0/NA	2.9E-7/4.9E-7
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	7.6E-7/1.3E-6

Table 7. Summary of Pollutants Projected to Cause Human Health Impacts for Direct Nonhazardous Landfill Dischargers (continued)
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Anglers	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Anglers
BAT (continued):			
Stream No. 5			
OCDD	0/NA	0/NA	3.9E-7/8.4E-7
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.0E-6/2.2E-6
Stream No. 6			
OCDD	4.9E-7/6.0E-5	1.2E-6/1.1E-4	1.1E-5/4.9E-5
1,2,3,4,6,7,8-HpCDD	1.3E-6/1.6E-4	3.3E-6/2.9E-4	2.8E-5/1.3E-4
Stream No. 8			
OCDD	0/NA	0/NA	1.1E-6/5.1E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	2.9E-6/1.3E-5
Stream No. 9			
OCDD	0/NA	0/NA	7.9E-7/3.7E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	2.1E-6/9.8E-6

NOTE: Total number of streams evaluated = 35 (35 rivers), number of landfills = 37 and total number of pollutants = 26. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.
NA = Not Applicable

Table 8. Summary of Potential Systemic Human Health Impacts for Direct Nonhazardous Landfill Dischargers
(Fish Tissue and Drinking Water Consumption)
(Sample Set)

	Fish Tissue Hazard Indices > 1	Drinking Water Hazard Indices >1
Current		
Streams (No.)/Facilities (No.)	1/1	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Anglers	0	0
Subsistence Anglers	1 (2.2)	0
Affected Population	328	NA
BAT		
Streams (No.)/Facilities (No.)	1/1	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Anglers	0	0
Subsistence Anglers	1 (2.2)	0
Affected Population	328	NA

NOTE: Total number of streams evaluated = 35 (35 rivers), number of landfills = 37, and number of pollutants = 26.
Table presents results for those streams/landfills for which the projected hazard index for any pollutant exceeds 1.0.
Number in parentheses represents the range of hazard indices for each stream(s) with index >1.
* Disulfoton

Table 9. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Drinking Water Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Streams (No.) / Facilities (No.)	0/0	NA/NA
Carcinogens (No.)	0	NA
With Drinking Water Utility # 50 miles	0	NA
Carcinogens (No.)	0	**NA**
TOTAL		
BAT		
Streams (No.) / Facilities (No.)	0/0	NA/NA
Carcinogens (No.)	0	NA
With Drinking Water Utility # 50 miles	0	NA
Carcinogens (No.)	0	NA
TOTAL		**NA**

NOTE: Total number of streams evaluated = 35 (35 rivers), number of landfills = 37, and number of pollutants = 26. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}.
NA = Not Applicable

Table 10. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Fish Tissue Consumption)
(National Level)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Streams (No.)/Facilities (No.)	45/45	NA/NA
Carcinogens (No.)	2	NA
General Population	2 (2.3E-6)	5.9E-4
Sport Anglers	2 (6.0E-6)	1.1E-3
Subsistence Anglers	45 (1.6E-6 to 5.1E-5)	1.4E-3
TOTAL		**3.1E-3**
BAT		
Stream (No.)/Facilities (No.)	43/43	NA/NA
Carcinogens (No.)	2	NA
General Population	2 (1.8E-6)	4.3E-4
Sport Anglers	2 (4.5E-6)	7.8E-4
Subsistence Anglers	43 (1.0E-6 to 3.9E-5)	8.5E-4
TOTAL		**2.1E-3**

NOTE: Total number of streams = 139, number of landfills = 143, and number of pollutants = 26. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.

Number in parentheses represents the range of total cancer risks for stream(s) with risk $>10^{-6}$.

NA = Not Applicable

Table 11. Summary of Potential Systemic Human Health Impacts for Direct Nonhazardous Landfill Dischargers
(Fish Tissue and Drinking Water Consumption)
(National Level)

	Fish Tissue Hazard Indices > 1	Drinking Water Hazard Indices >1
<u>Current</u>		
Streams (No.)/Facilities (No.)	2/2	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Anglers	0	0
Subsistence Anglers	2 (2.2)	0
Affected Population	643	NA
<u>BAT</u>		
Streams (No.)/Facilities (No.)	2/2	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Anglers	0	0
Subsistence Anglers	2 (2.2)	0
Affected Population	643	NA

NOTE: Total number of streams = 139, number of landfills = 143, and number of pollutants = 26.
Table presents results for those streams/landfills for which the projected hazard index for any pollutant exceeds 1.0.
Number in parentheses represents the range of hazard indices for each stream(s) with index >1.
* Disulfoton

Table 12. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Drinking Water Consumption) (National Level)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Streams (No.) / Facilities (No.)	0/0	NA/NA
Carcinogens (No.)	0	NA
With Drinking Water Utility # 50 miles	0	NA
Carcinogens (No.)	0	NA
TOTAL		
BAT		
Streams (No.) / Facilities (No.)	0/0	NA/NA
Carcinogens (No.)	0	NA
With Drinking Water Utility # 50 miles	0	NA
Carcinogens (No.)	0	NA
TOTAL		

NOTE: Total number of streams = 139, number of landfills = 143, and number of pollutants = 26. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}.

NA = Not Applicable

Table 13. Potential Fate and Toxicity of Pollutants of Concern (Nonhazardous Landfills)

	Chemical Name	CAS Number	Aquatic Toxicity Category	Volatility Category	Sediment Adsorption Category	Bioaccumulation Category	Biodegradation	Carcinogenic Effect	Systemic Health Effect	Drinking Water Value	Priority Pollutant
1	1234678-HPCDD	35822469	Unknown	Moderate	Unknown	Unknown	Unknown	X	X		
2	1,4-Dioxane	123911	Slight	Slight	Slight	Nonbioaccumulative	Slow	X			
3	2-Butonone	78933	Slight	Moderate	Nonadsorptive	Nonbioaccumulative	Fast		X		
4	2-Propanone	67641	Slight	Moderate	Slight	Nonbioaccumulative	Fast		X		
5	4-Methyl-2-Pentanone	108101	Slight	Moderate	Slight	Nonbioaccumulative	Fast		X		
6	Alpha-Terpineol	98555	Slight	Moderate	Slight	Slight	Moderate				
7	Ammonia (As N)	7664417	Slight	Moderate	Nonadsorptive	Unknown	Moderate				
8	Barium	7440393	Slight	Unknown	Unknown	Unknown	Unknown		X	M	
9	Benzoic Acid	65850	Slight	Slight	Slight	Slight	Moderate		X		
10	BOD	C-002	Unknown	Unknown	Unknown	Unknown	Unknown				
11	Chromium	7440473	Moderate	Unknown	Unknown	Slight	Unknown		X	M	X
12	COD	C-004	Unknown	Unknown	Unknown	Unknown	Unknown				
13	Dichlorprop	120365	Moderate	Nonvolatile	Slight	Slight	Slow				
14	Disulfoton	298044	High	Slight	Moderate	Moderate	Moderate		X		
15	Hexanoic Acid	142621	Slight	Moderate	Slight	Slight	Moderate				
16	Hexavalent Chromium	18540299	High	Unknown	Unknown	Slight	Unknown	X	X	M	X
17	Methylene Chloride	75092	Slight	High	Slight	Nonbioaccumulative	Moderate	X	X	M	X
18	Nitrate/Nitrite	C-005	Unknown	Unknown	Unknown	Unknown	Unknown		X	M	
19	N,N-Dimethylformamide	68122	Slight	Nonvolatile	Nonadsorptive	Nonbioaccumulative	Moderate		X		
20	OCDD	3268879	Unknown	Slight	High	Unknown	Unknown	X	X		
21	O-Cresol	95487	Slight	Slight	Slight	Slight	Fast	X	X		
22	P-Cresol	106445	Slight	Slight	Slight	Slight	Fast	X	X		
23	Phenol	108952	Slight	Slight	Slight	Nonbioaccumulative	Fast		X		X
24	Strontium	7440246	Unknown	Unknown	Unknown	Slight	Unknown		X		
25	TDS	C-010	Unknown	Unknown	Unknown	Unknown	Unknown				
26	Titanium	7440326	Unknown	Unknown	Unknown	Unknown	Unknown		X		
27	TOC	C-012	Unknown	Unknown	Unknown	Unknown	Unknown				
28	Toluene	108883	Slight	High	Slight	Slight	Moderate		X	M	X
29	Total Phenols	C-020	Unknown	Unknown	Unknown	Unknown	Unknown				
30	Tripropyleneglycol Methyl Ether	20324338	Slight	Nonvolatile	Slight	Nonbioaccumulative	Moderate				
31	TSS	C-009	Unknown	Unknown	Unknown	Unknown	Unknown				
32	Zinc	7440666	Moderate	Unknown	Unknown	Slight	Unknown		X	SM	X

Note: M = Maximum Contaminant Level established for health-based effect.
SM = Secondary Maximum Contaminant Level (SMCL) established for taste or aesthetic effect.

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Table 14. Toxicants Exhibiting Systemic and Other Adverse Effects (Nonhazardous Landfills)*

	Toxicant	Reference Dose Target Organ and Effects
1	1234678-HpCDD	Reproductive and developmental effects, immunotoxicity, chloracne
2	2-Butanone	Decreased fetal birth weight
3	2-Propanone	Increased liver and kidney weights and nephrotoxicity
4	4-Methyl-2-Pentanone	Lethargy, increased relative and absolute weight in liver and kidney
5	Barium	Increased blood pressure
6	Benzoic Acid	No adverse effects observed**
7	Chromium	No adverse effects observed**
8	Disulfoton	ChE inhibition, optic nerve degeneration
9	Hexavalent Chromium	No adverse effects observed**
10	Methylene Chloride	Liver toxicity
11	N,N-Dimethylformamide	Hepatotoxic
12	Nitrate/Nitrite	Methemoglobinemia
13	O-Cresol	Decreased body weights and neurotoxicity
14	OCDD	Reproductive and developmental effects, immunotoxicity, chloracne
15	P-Cresol	Hypoactivity, distress, and maternal death
16	Phenol	Reduced fetal body weight in rats
17	Strontium	Rachitic bone
18	Titanium	***
19	Toluene	Changes in liver and kidney weights
20	Zinc	Anemia

* Chemicals with EPA verified or provisional human health-based reference doses, referred to as "systemic toxicants".

** Reference dose based on no observed adverse effect level (NOEL).

*** RfD is an EPA-NCEA provisional value; Contact EPA-NCEA Superfund Technical Support Center for supporting documentation.

Table 15. Human Carcinogens Evaluated, Weight-of-Evidence Classifications, and Target Organs (Nonhazardous Landfills)

	Carcinogen	Weight-of-Evidence Classification	Target Organs
1	1,4-Dioxane	B2	Liver and Gall Bladder
2	1234678-HpCDD	B2*	Liver
3	Hexavalent Chromium	A	Lung
4	Methylene Chloride	B2	Liver and Lung
5	O-Cresol	C	Skin
6	OCDD	B2*	Liver
7	P-Cresol	C	Bladder

A = Human Carcinogen
B2 = Probably Human Carcinogen (animal data only)
C = Possible Human Carcinogen

* **-** Classified as carcinogen based on TEF of dioxin.

Table 16. Landfills Included on State 304(L) Short Lists

Subcategory	SIC Code	Landfill NPDES	Landfill Name	City	Waterbody	REACH Number	Listed Pollutants
Municipal*	4953	MD0061093	Reich's Ford Road Landfill	Frederick	Bush Creek	02070009005	Cyanide, silver
Unknown	4953	MD0061646	Round Glade Landfill	Oakland	Round Glade Run	05020006-	Selenium, silver

Source: Compiled from OW files dated April/May 1991.
* Included in water quality modeling analysis.

Table 17. Modeled Landfill Facilities Located on Waterbodies With State-Issued Fish Consumption Advisories

Subcategory	Discharge Type	Advisory Date	REACH Number	State	Waterbody	Pollutant	Species	Population
Municipal	Direct	February 1992	02040105004	PA	Delaware River	Chlordane, PCBs	American Eel, Channel Catfish, White Perch	NCGP
Municipal	Direct	February 1992	01040002001	ME	Androscoggin River	Dioxins	Fish	NCSP, RGP

Source: The National Listing of Fish Consumption Advisories (NLFCA) - December 1995

NCSP - Advises against consumption of fish and shellfish by subpopulations potentially at greater risk (e.g., pregnant or nursing women or small children).
RGP - Advises the general population to restrict size and frequency of meals of fish and shellfish.
NCGP - Advises against consumption of fish and shellfish by general population.

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